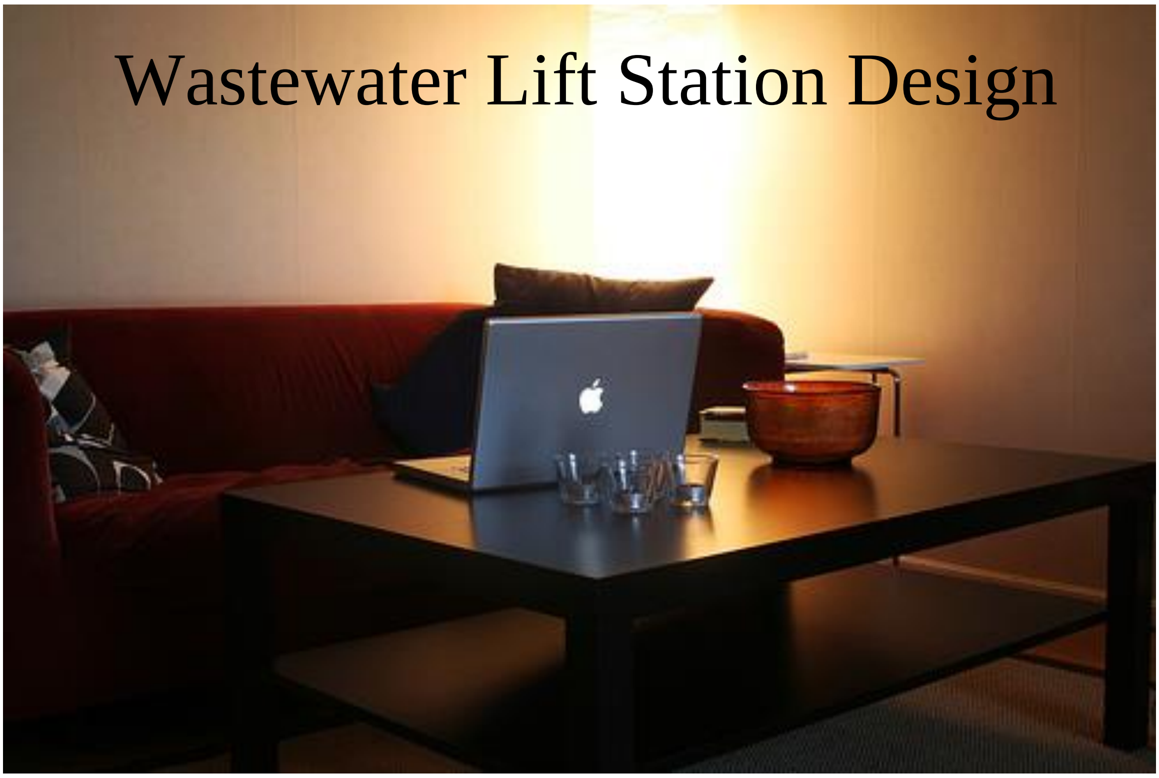

Wastewater Lift Station Design

By

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WASTEWATER LIFT STATION DESIGN

COURSE DESCRIPTION:

Wastewater lift stations are a necessity in many communities. In areas with limited elevation differences, many lift stations may be required, varying from quite small to very large. Even in communities with adequate overall slope, there are frequently areas that won't drain by gravity to the rest of the system. Lift stations are also very common near the end of the collection system, to lift the wastewater into a treatment facility. This course provides a comprehensive overview of all of the components of a lift station. It provides design guidance for these components, including the wet well, pumps, force mains, odor control, electrical systems, instrumentation and controls and site layout.

COURSE OUTLINE:

Flow Analysis
Hydraulics
Mechanical Systems
Odor Control
Electrical System
Instrumentation and Controls
Site Layout

LEARNING OBJECTIVES:

At the conclusion of this course, the user will:
Understand how design flows for a wastewater lift station are determined
Understand the hydraulic concepts of a lift station, including the wet well and pumping system
Become familiar with the mechanical systems in a lift station, including the pumps, force main, valves, flow meters, gages, yard piping, HVAC and noise control and abatement.
Understand the basics of odor generation in a wastewater lift station and how to control those odors.
Understand what electrical system components are necessary and how to determine the need for standby power.
Understand the concepts behind the necessary instrumentation and controls for a lift station and the site layout concepts.

INTENDED AUDIENCE:

This course is intended as a general guide to design of wastewater lift stations therefore the intended audience includes all engineers involved in design of these facilities, regardless of discipline. It is useful to all disciplines to understand the various components of a lift station to see how their specialty impacts the overall station performance. It also includes those engineers and managers responsible for reviewing lift stations.

COURSE SUMMARY:

This course provides a comprehensive overview of the components of a lift station. It includes design guidance for most of these components, including the wet well, pumps, force mains, odor control, electrical systems, instrumentation and controls and site layout. This course provides a good checklist of items that need to be included in the design to help eliminate the potential for a key component to be overlooked until late in the design process.

Flow Analysis

The first step in design of a wastewater lift station is to evaluate the design flows. Design and sizing must consider flows expected at startup, the flows expected at ultimate build-out (if applicable), as well as the flows expected during the years between startup and build-out. Initial and ultimate contributory flow areas to the facility must be identified., Once the contributory area is established, the land use and zoning for that area need to be considered. Different land uses generate different flows.

If an approved Master Plan exists for the service area, it must be incorporated into the analysis of design flows. The Master Plan should be re-evaluated for current conditions to ensure that changes in zoning, design parameters, future land use, etc. are addressed properly.

Flow Generation

To determine the design flows when only land use data is available, flows can be estimated based on the anticipated land use and the current flows from similar land uses within the community. Table 1 shows an example of land use and estimated flows.

Table 1 – Example Wastewater Flows based on Land Use

Land Use	Unit	Wastewater Average Daily flow/Unit (gal)
Single Family Residential	Dwelling	240
Multi-family	Dwelling	180
Commercial (retail)	1000 sq.ft.	75
Commercial (office)	1000 sq.ft.	90
Warehouse/Big Box Retail	1000 sq.ft.	25
Industrial	1000 sq.ft.	50
Schools	Student	20
Hotel (no restaurant)	Room	100
Hotel (with restaurant)	Room	150
Resort	Room	210
Hospital (all flows)	Bed	300

Once the contributory land uses are established, the zoning determined, and any large facilities identified, an estimation of the number of residences, and the total area of commercially/industrially zoned land use can be used to determine the total average daily flow expected to be generated by the contributory area. This flow rate is expressed in gallons per day (gpd). However, if the area under consideration will be developed in phases, the flows for each phase will also need to be determined. This may mean the lift station will need to be constructed in phases, or at least designed to allow for future expansion.

Project Phasing

Project phasing must be established at the conceptual design level. The lift station design must take into account initial flow volumes as well as build-out flows and attempt to optimize performance for both. Major elements such as the wet well, electrical service, panels, odor control, etc. shall be sized for the ultimate condition, but serious thought needs to be given as to the expandability of all site components in order to allow the capacity of the station to grow as the demand grows. For example, pumps rated at 1800 gpm to service build-out flows will not provide acceptable operating conditions when initial flow demand only requires 120 gpm.

Peaking Factors

The peaking factor is used to determine the dry weather design flows to size the collection system and pumping facility. It does not take into account wet weather flows, or those flows caused by inflow and infiltration (I&I) during storm events. Design wet weather flows should be addressed by evaluating the difference between dry weather flows and wet weather flows in other parts of the system. Lift stations should have sufficient capacity to convey peak wet weather flows up to some storm event, such as the peak wet weather flows produced by a 10-year, 24-hour storm event without causing any overflows.

For existing sites with average daily flows less than or equal to 2.0 MGD, a peaking factor of 4.0 is recommended, while for average daily flows greater than 2.0 MGD, a peaking factor of 2.5 is recommeded. To determine the maximum dry (peak) daily flow, the peaking factor is multiplied by the average daily flow. For example, if the average dry daily flow for an area is determined to be 10,000 gpd, the daily peak dry flow is considered to be 40,000 gpd.

Design Flows

There are several flow rates required to size the pumping system, with the average daily flow being the basis. The daily maximum flow (peak hour flow) is determined as noted above by multiplying the average daily flow by a peaking factor. Peaking factors vary throughout the literature, with many municipalities applying peaking factors based on their own flow records.

The following outline can be used as a guide to determine the contributory flows.

- Determine area of contributory flow:
  - Present
  - Future Development Expansion (if applicable)
  - External Flow Contributors
- Master Wastewater Development Plan:
  - Review and re-evaluate existing Master Plan(s)
- Land Use map:
  - Zoning
    - Current
    - Future
  - Large Commercial Developments
  - Large Industrial Developments
- Related Populations
  - Current
  - Future
- Table of flows:
  - Residential (per capita)
  - Commercial (per acre or facility)
  - Industrial (per acre or facility)
- Calculate flows for each area
- If the area/facility will be phased, the above information will be required for each phase

Hydraulics

A hydraulic analysis should be performed on all new wastewater lift stations and any wastewater lift stations that are being upgraded or otherwise modified. The analysis is used to determine the type and size of equipment necessary for efficient pump operation and to alleviate hydraulic surges during normal operation and during electrical power failures.

For the purpose of this course, the *firm* capacity is defined as the capacity of the lift station with the largest pump out of service. The *design* capacity is the capacity required to meet the peak daily flow of the wastewater from the service area served by the station. The *firm* and *design* capacities are often the same but can vary when more than two pumps are installed. Finally, the *emergency* capacity is defined as the capacity of the lift station with all pumps running (at full speed for VFD installations). Some municipalities prefer constant speed pumps for small lift stations and consider using variable speed pumps only for larger lift stations. Variable speed pumps are common in potable water systems since they provide significant operational flexibility. In lift station applications, the storage in the wet well usually provides enough flexibility that variable speed pumps may not be necessary.

Wet Well

Several flow conditions must be considered when sizing the wet well. The wet well must be sized to provide efficient operation at the ultimate build-out capacity, but must also be able to function with startup flows and during all planned phases of expansion. The storage volume required in the wet well depends on the method of pump operation, i.e. constant or variable speed, but in all cases should limit the detention time of wastewater under average flow conditions to no more than 30 minutes. Longer detention times result in formation of excess gases that can create odor problems. This means that, at a minimum, the pumps will have 2 cycles per hour. The pumps can cycle on more often in order to reduce the required wet well size, but the number of pump cycles in an hour should generally not exceed 6. This is somewhat depending on the size of the pump motors and the manufacturers recommended number of starts per hour. The computed volume of the wet well shall not include any capacity from upstream gravity sewer lines or manholes.

The minimum operating volume of the wet well, defined as the volume between the pump start and pump stop levels, can be determined using the following equation:

$$V = tq/4$$

Where:
V = required volume between start and stop elevations for a single pump, gallons
t = minimum time of one pumping cycle - time between successive pump starts, minutes
q = pumping capacity, or increment in capacity where one or more pumps are operating and an additional pump is started, gpm

The “pump off” level must be high enough to keep the pumps submerged per manufacturer’s recommendations. This information is specific to each pump and can be obtained from the pump manufacturer. It is sometimes (but not always) shown on the pump curve. The “pump on” level should be set no higher than 1 foot below the invert of the lowest influent pipe.

Pumping System

For the purpose of the hydraulic analysis, the pumping system consists of the pumps, force mains, and all associated valves and fittings.

Pumps
Pumps should be selected that provide at least 75% efficiency at the anticipated average flow during all phases of expansion. With raw sewage pumps which pumps which typically pass 3-inch solids, this efficiency can be difficult to achieve. In some instances, efficiencies of 55% are the maximum that can be provided by commercially available pumps. Pumps should be configured to operate in parallel. The minimum configuration is usually two pumps, each capable of handling the peak wet weather flow by itself. When more than two pumps are specified, the system should handle the peak wet weather flow with the largest capacity pump out of service. With three pumps, this is often accomplished by providing three identical pumps, each capable of providing at least 50% of the capacity. As noted above, this is defined as the station's *firm* capacity.

The design should include the ability to handle varying flows from initial startup to ultimate build-out. At each phase, the pumps must be sized to operate efficiently at average flows while providing enough capacity to handle anticipated wet weather peak flows. To account for wear on the impeller and volute from sand, grit, and other materials in the wastewater, it may be desirable to increase the peak capacity of the pumps slightly. Some standards recommend the peak capacity be increased by 5% to account for this wear.

Force Main
The force main(s) should be sized to achieve a velocity between 3 and 7 feet per second (fps) for all planned phases of expansion. Most standards require a minimum force main velocity of 2 fps. Either the Darcy-Weisbach or the Hazen-Williams equations can be used to determine the head loss versus length of pipe over a range of flow rates. Most designs use the Hazen-Williams equation due to its simplicity. Both friction and minor losses must be considered during the analysis.

The design should include an analysis for water hammer, especially if any of the following conditions exist.

- High points or rapid changes in slope in the force main
- Total dynamic head in the system is greater than 50 feet
- System velocities exceed 4 fps
- The force main is greater than 8-inches in diameter and longer than 1,000 feet

The change in pressure due to water hammer must be added to the normal operating pressure of the pipe. If the sum exceeds the rated working pressure of the pipe, steps must be taken to minimize the rate of change of velocity to limit the pressure changes within allowable ranges. An analysis of water hammer includes calculating the critical time, determining the maximum pressure increase, and selecting a method of control. Hand calculations usually suffice for simple systems, but large or complex systems may require computer modeling in order to fully understand and design for the effects of water hammer. One advantage of a computer model for a force main is the ability to identify locations where pressures can become negative during water hammer events. While most concerns with water hammer have been associated with high pressures, negative pressures can also occur, up to a full vacuum condition. This can also cause pipe failures. Simply placing vacuum release valves at high points in the system may not address all of the potential negative pressure issues.

The design engineer should make every effort to reduce the risk of water hammer by eliminating high points or rapid changes in slope in the force main. Some designers believe that providing backup power can eliminate the effects of a power failure. However, with backup power, when the time the main power source goes off line, the controls must sense this loss of power, determine it is not just a temporary power bump, start the backup generator, and then transfer service from the main source to the backup source. This process can take up to several minutes. The pump motor stops spinning almost immediately when power is lost, and the surge starts almost immediately, so the time it takes to transfer power to a backup source is not usually very effective at mitigating surge pressures. If the water hammer conditions cannot be eliminated, the recommendations need to be provided for surge control. Standard control measures include check valves, air/vacuum relief valves, automatic control valves, and surge relief valves and bypass piping.

System Head Curve

A family of system head curves are often developed to indicate the operating envelope of the pumps throughout the life of the facility. These curves can be constructed by using varying Hazen-Williams “C” or friction factors and wet well levels. The calculations to develop these curves can be completed by hand or with the aid of a computer model of the lift station and force main. At a minimum, curves should be established for both the “pump off” level and the “pump on” level using “C” values of 100 and 120 or equivalent friction factors. These values typically represent the friction factors for new pipe and for pipe that has been in service for many years. The design can be based shall be based on either value, depending on the material being used. A force main constructed with thermoplastic pipe (such as PVC or HDPE) will often have a friction value of 130 or 140 when new and over time this value will deteriorate to 120 or less. If ductile iron pipe is used, values of 120 for new pipe and 100 for old pipe are more reasonable.

Pump Curves

Once the system curve is developed, various pumps can be analyzed to determine which pump curves best fit the system curve. Most manufacturers provide pump curves with the TDH, efficiency, and power input plotted against the flow rate; this can be plotted on the system curve. Multiple pumps may be required to produce the necessary flow at the required head. This exercise should be completed for new designs as well as modifications to existing lift stations. With multiple pumps, the flow from two pumps will be less than the flow from a single pump, due to increased friction in the force main at higher flows. For example, If the design flow from one pump is 1000 gpm, when a second identical pump is turned on, the flow rate will be less than 2000 gpm. How much less is a function of the pump curve and the associated system curve.

When a pump has been selected, the motor rating (horsepower) and impeller size can be established, which corresponds to the required electrical load for the pumps. Pump curves for the *firm, design, and emergency* capacities plotted with the system head curves and calculations for each pump should be part of the design report for the lift station.

In the case where Variable Frequency Drives (VFDs) are used, the engineer should also evaluate the conditions when the VFD will be set to full speed (such as during peak flow at final buildout) and the conditions when the VFD will be set to lower values. The minimum flow rate at which the pump is capable of continuously pumping wastewater while achieving minimum velocity in the force main should also be identified.

Mechanical

A typical lift station consists of a wet well with submersible pumps, an above-ground force main header and valve gallery, an on-site odor control system, which may include both vapor and liquid phase aspects, electrical service and a backup generator.

Wet Well

Regardless of capacity, the wet well configuration and placement and spacing of the pumps should comply with the Hydraulic Institute guidelines to prevent turbulence and vortexing at the pump inlet. Wet wells are often designed for submersible pumps within the wet well. A wet well/dry well layout is also used in some areas and is more common with larger lift stations, where it is more desirable to have the mechanical equipment (pumps, motors and valves) in a dry enclosure.

The wet well is usually constructed using cast-in-place or pre-cast concrete sections and finished with an anti-corrosion coating system. Steel or fiberglass wet wells are sometimes used, but steel wet wells need very good protection against corrosion. In some situations, a packaged lift station is used, where all of the components are part of a package and installation involves excavation for the lift station and connection of piping and electrical components.

Shape and Configuration

Wet wells may be rectangular or circular depending on the capacity of the station and the hydraulic conditions. The bottom of the wet well must be sloped to the pumps in order to facilitate solids removal. This configuration is often referred to as a “hopper bottom.” The engineer must design the bottom to avoid the types of adverse hydraulic conditions mentioned above. In addition, the engineer must ensure that the fillets do not interfere with the operation of the level transmitters.

Depth

The depth of the wet well is determined by the lowest invert of the influent sewer(s) and the required storage capacity. The “pump on” control elevation should generally be no higher than 1 foot below the lowest influent pipe invert elevation. The “pump off” control elevation should be sufficient to provide the necessary cooling to the pumps as recommended by the pump manufacturer. Most manufacturers publish a minimum depth of submergence, measured from either the bottom of the wet well or from the top of the pump. In general, significant drops from the pipe invert to the wet well should be avoided. If they can’t be avoided, a drop manhole configuration should be included.

Other Wet Well Features

The following features should generally be incorporated into the wet well design:

- An access hatch with safety chains above the pumps in the top of the wet well. Hatch will generally be a two-leaf design with enough area to safely and easily remove the pumps.
- An additional hatch may be required, depending on the shape of the wet well, for the ultrasonic level transmitters and/or wet well maintenance.
- Removable aluminum safety railings should surround the perimeter of the wet well
- Guide rails (for pump removal of submersible pumps) should be constructed of Type 316 stainless steel.
- A sliding guide bracket and discharge connection elbow, which, when bolted to the floor of the wet well and to the discharge line, will receive the pump discharge connection flange without need of adjustment, fasteners, clamps, or similar devices.

Pump Systems

The use of constant speed pumps is generally preferred for smaller lift stations (generally those with a design capacity of 5 MGD or less). Larger lift stations (those designed for a capacity greater than 5 MGD) may utilize variable speed pumps if the hydraulic analysis shows them to be more efficient. The designer should consult the pump and/or motor manufacturer to determine the recommended number of starts per hour for the motor to ensure the design properly addresses this issue. A lift station where the design requires the motor to regularly exceed the recommended number of starts will likely see motor failure occur in a much shorter time frame. This information needs to be considered when sizing the wet well.

Pump Selection

The preferred pump is usually the pump with the highest efficiency at the design point. With systems that have multiple design points, and some lift stations might have multiple design points, depending on the system curve, it is sometimes necessary to select a pump that has reasonable efficiencies at all design points, rather than the one that has high efficiency at one design point and a much lower efficiency at another design point. It is also possible that efficiency has to be compromised to select a pump that will operate at all of the design points. It is also necessary to ensure the selected pumps have a Net Positive Suction Head required (NPSHr) that is less than the system's Net Positive Suction Head available (NPSHa) under the worst case scenario.

Motor speed will typically vary between 1155 (1200 nominal) and 1765 (1800 nominal) rpm. Pump motors should be explosion proof with watertight motor enclosures for dry well and wet well applications. Motor starting equipment should be suitable for the type of motor and required voltage. Motor starters will be designed for limiting the in-rush current where shocks or disruptions to the electrical supply are likely to occur as a result of pump start-up. Where low starting in-rush current is required for constant speed pumps, such as when using engine driven generator sets, or where the motor horsepower rating exceeds 50 hp, solid state soft starters should be used. A soft starter that reduces the in-rush current will lower the maximum demand (kw) for the lift station, which can significantly reduce the overall power bill.

Variable Speed Pumps

The main reason for using variable speed pumps as part of a wastewater lift station design is to match variable influent flow conditions as much as possible. Variable speed pumps are not usually used if constant speed pumps are capable of meeting the minimum to maximum flow range without exceeding the maximum allowable number of starts per hour or if the pump curve is relatively flat.

Variable speed systems are slightly more complicated than constant speed systems. In general, Variable frequency drives (VFDs) are more expensive to install but the extra cost can be recovered if the pump can routinely operate at lower speeds and the full speed is only necessary during unusual flow events. The additional complexity can require additional training of operations and maintenance staff.

If possible, VFDs should be provided by the motor manufacturer/supplier. This ensures the VFDs are properly matched for the operating ranges they will be subject to and ensures a unit responsibility for the pump motor and drive. The VFD specifications must include a complete description of the power system including any requirements for operation from standby generators.

Minimum flow conditions should also be considered in pump selection, especially where variable speed pumps are used. In general, pumps should not be operated at less than approximately 25% of design capacity, although some pumps cannot tolerate this large flow range. If low flow conditions require operation at less than 25% of design flow, pumps should be set for on-off control at these low flows; alternatively, smaller pumps could be used to pump low flows.

Other Pump Features
Additional features recommended for pumps and pumping systems are:
- Submersible pump motors should be submerged per manufacturer recommendations
- Motors (both constant and variable speed) should not be loaded to use more than 100 percent of the rated horsepower.
- Electrical motors should be matched to the power supply available.
- If smaller motors are operating in the same group as larger motors, the smaller motors can sometimes be rated at the same voltage as larger motors. This is desirable where possible.

Force main
Different municipalities have different requirements for force mains. In some places, only ductile iron pipe is approved for force mains. In other places, PVC or HDPE is acceptable. If ductile iron pipe is used, a special lining should be included. Standard cement-mortar lining should not be used for force mains, since the fluid being conveyed is corrosive to the cement mortar. Epoxy-lined ductile iron is more commonly used for force mains. The designer must also determine the necessity and extent of cathodic protection if ductile iron pipe is used.

Off-site
As noted above all effort should be made to ensure force mains are designed and constructed to maintain a positive slope. It is not a requirement to necessarily follow the contours of the land. High points or rapid changes in grade in the force main should be avoided as much as possible. If it is not possible to do so, air release valves should be placed at high points to prevent air locking and relieve negative pressures. An odor control system, such as a passive drum air scrubber, should be considered to remove odorous air discharged from air release valves installed on force mains. Air release valves and scrubber drums are generally housed in a vault. Any liquid collected in the vault should be drained to a contained sump, which must be emptied by maintenance personnel.

Thrust restraint needs to be analyzed at each change in pipeline direction, both horizontal and vertical. The bend angles should be minimized and generally only bends of 45-degrees and shallower are used.

All phases of development that require a force main need to have the force main installed. Some jurisdictions require a backup force main, but that is not common. The backup force main provides redundancy in case the primary needs to be taken offline for servicing and/or repair. The diameter of the force main lines may vary to account for phasing of the lift station. When multiple lines are installed, a minimum clearance of 5 feet, outside to outside, is recommended. Measures may be required to reduce the velocity before the wastewater is discharged to the gravity sewer system if the force main velocity exceeds 3 fps and the gravity sewer velocity is 2 fps or less. One way to reduce the velocity is to increase the size of the last 100 feet of the force main before it discharges into the gravity sewer system. Force mains should not discharge directly into a gravity sewer system without the use of a splitter box or a manhole. Force mains should generally enter the gravity sewer system such that the invert of the force main is within 1 foot of the crown of the highest influent sewer. If possible, the discharge shall be oriented to discharge into the flow line of the sewer in the downstream direction to reduce turbulence. Valves should not be installed on the discharge end of the force main.

On-site
The connection from each pump discharge line to the discharge manifold should be made at approximately 45-degree angles to the centerline of the manifold. Bends of 90 degrees and tees should generally not be used in this location. If wyes are used to connect the pump discharge to the manifold the wyes should be the same diameter as the manifold. However, depending on the site and its constraints, the use of reducing/increasing wyes or other reducing/increasing fittings may be necessary. Piping within the lift station should be supported with reinforced concrete saddles or fabricated steel pipe supports. The pipe should be set at a height of 24 to 36 inches for ease of valve adjustments and maintenance and should be equipped with steel hold-down straps. Exposed piping should include insulated flange gaskets as necessary to electrically isolate the lift station piping from the yard/system piping.

The piping design of the lift station needs to facilitate installation and removal of valves and accommodate slight alignment adjustments in the pump discharge piping. There are several ways to accomplish this task. One is to use sleeve-type flexible steel couplings restrained by tie-rods at each pump discharge connection. Couplings should be located between the pump and the discharge check valve. Because these couplings are not intended to provide significant longitudinal restraint, the piping must be anchored (restrained) to prevent movement and resist thrust. Another way to accomplish this task is to use flanged piping with flanged coupling adapters.

An emergency pump bypass connection assembly is often provided on the lift station discharge header, including an isolation plug valve. The discharge lines should connect to the discharge manifold in such a way to allow a portable pump to be connected to the manifold and pump into the force main as if it were a normal station pump. This arrangement allows the manifold to be bypassed. The isolation valves, check valves, and/or hydraulic/air operated plug valves located on the discharge lines should prevent any backflow to the permanent lift station pumps. When a lift station includes multiple pumps, the need for an emergency pump bypass is reduced. However, a major power failure, or failure of significant electrical equipment, would still require bypass pumping so these connections still have value.

<u>Valves</u>
The configuration of valves depends on the lift station's design capacity. Regardless of capacity, all discharge valves on the force main(s) should be installed in a location where they are readily accessible, but protected from freezing, when necessary. In colder climates, this is often accomplished by use of a vault.

The valves specified for use in wastewater lift stations need to be manufactured of materials appropriate for wastewater use. Typical valves used for clean water service are usually not appropriate.

All valves should be rated for the range of flows and pressures produced by the system pumps and all other internal pressures developed by the system.
Valves typically used in wastewater lift stations are divided into the following categories:
- Check/Control Valves
- Isolation Valves
- Air and Vacuum Valves
- Blowoff Valves

Check/Control Valves

An air-cushioned swing check valve is often used as a surge control valve. The check valve is usually installed horizontally in each pump discharge line between the pump discharge flange and the discharge manifold header. Even if a check valve is not required for surge control, each pump needs to have a check valve on the pump discharge.

For larger stations (generally those with flows greater than 3 to 5 MGD), automatic control valves may be considered. These valves can be either electrically or pneumatically controlled with electric control being preferred for larger lift stations. Normal operation of these valves upon pump shutdown is to slowly close the valve while the pump continues to run. When the valve is closed, a limit switch then stops the pump motor. Upon pump start-up these valves are closed and then are slowly opened to minimize the rate of velocity changes. On power failure, an emergency hydraulic or other type operator closes the valve slowly. The valve closure time should be based on the results of the surge analysis.

When electric valve operators are used, they should include manual handwheel operators and are generally designed for aboveground application. They need be provided with limit switches for valve position indication. Valve operators must be sized to ensure proper seating and unseating of the valve surfaces against the system and/or pumped head.

When pneumatic (compressed air) actuators are used, they need to include an air compressor, compressed air storage tank, and a compressed air drier. The compressed air drier is required to remove moisture from the compressed air prior to its delivery to the actuator. This helps reduce corrosion in the air lines. The air compressor and air drier also need to be connected to the station's standby power source.

Isolation Valves

The main function of an isolation valve is to provide positive isolation of the pump and its valving from the piping system for maintenance purposes. Isolation (shutoff) valves are required on the discharge side of all wastewater pumps. An isolation valve is also needed downstream of the main discharge flow meter. For wastewater service, isolation valves should be full-port eccentric plug valves.

Air and Vacuum Valves

Air release, vacuum release, or combination air vacuum/air release valves specifically designed for sewage applications need to be installed at high points at the station and throughout the length of force mains for the purpose of admitting and releasing air. Each valve must be specified with the appropriate orifice diameter suitable for the volume of air to be admitted or released. Sizing criteria for air release, vacuum release, or combination air vacuum/air release valves are generally provided in the applicable manufacturer design guidelines. To allow periodic maintenance on each valve, an additional isolation valve (¼-turn, resilient, rubber seated ball valve) and back- flushing connection is required for each air valve. These valve assemblies, including the isolation ball valve and associated piping, shall be rated for the maximum design pressure of the system piping. All valves installed underground need to be installed in a manhole or valve structure with adequate drainage.

A combination air valve is usually installed on the vertical leg of a T-fitting on the discharge piping prior to any other valve. Additionally, an air release valve should be installed downstream the check valves and upstream of the flow meter, again on the vertical leg of a T-fitting. The air release outlet should be piped back to the wet well for discharge. Air release valve outlet piping should include an air compressor type quick- release couplings.

Air release valves on force mains outside the lift station usually need to have odor control and a method of disposing of the moisture released with the air.

Flow Meters

Accurate measurement of flow discharged from a wastewater lift station is critical to the overall operation of the station. A flow meter is generally installed in the common discharge header of all wastewater lift stations to indicate and record the quantity of flow being pumped. In some instances, a flow meter is installed on the discharge of each pump. In wastewater applications, flow meters are usually in-line magnetic flow meters. Restrained flexible couplings or equipment dismantling joints are installed adjacent to the meter to allow for easy removal and replacement. The meter is typically installed inside the building, but in warm climates, it may be installed outside, but then it must be protected from direct exposure to the sun.

Flow meters typically require a straight section of pipe upstream and downstream from the meter, with no bends or reducers. The required length is typically expressed as a minimum number of pipe diameters on each side of the meter. The required length varies by manufacturer and type of meter but the design needs to provide for this minimum straight pipe length. Minimum velocities through the meter, as recommended by the meter manufacturer, must be maintained through the meter, not only at the design flow but also at the lowest anticipated pumping rate. It is not uncommon for the size of the meter to be smaller than the rest of the discharge piping, to maintain relatively high velocities. This often requires installation of reducers, which should be concentric reducers, rather than eccentric reducers, to reduce the turbulence caused by this fitting. The piping must be configured so that the meter is always filled with wastewater.

Some existing sites have strap-on, ultrasonic flow meters. Where practical, replacement of these meters should be considered, due to lower accuracy usually associated with these meters. However, due to site constraints and existing piping the meter application must be designed specifically for each wastewater lift station. Where possible, meters should be installed to meet the manufacturer's recommendations, and configured such that alternative metering methods are available to field verify the accuracy of the installed meters. The design of the flow measurement system shall consider the type of flow meter, its final layout configuration, and required controls based on available land, the station layout and the flow meter manufacturer. All discharge piping and fittings are typically ductile iron and should be epoxy-lined.

Pressure Gauges

Pressure gauges and transmitters should be installed on each pump discharge pipe prior to the check valve. The gauges should be graduated based on the anticipated pressures on the system. The pressure gauges should be provided with transmitters and be wired to the lift station's Computer Control System.

Yard Piping

A potable water supply is usually required at all pump stations to supply yard hydrants, hose bibs and emergency shower and eyewash systems. All combination eye wash and emergency shower stations should be installed with a concrete pad, drain and anti-scald valve.

Heating, Ventilation and Air Conditioning (HVAC)

HVAC system requirements vary significantly depending on the climate. In colder northern climates, heating equipment adequate to maintain reasonable operating temperatures is necessary. While the motors will generate some heat, they don't run very often at night, due to low flows, so the heat contribution from the motors is often ignored. While it is not necessary to heat the lift station to 70 degrees for continual human occupation, it is common to heat the lift station to something in the range of 45 to 55 degrees to eliminate the potential for freezing pipes or valves. At least some heating equipment should also be connected to the emergency generator.

In very hot southern climates, air conditioning equipment is often required. While the heat generated by the motors is not as much of a concern in colder climates, it can still overheat the building during hot summer conditions. In locations where high summer temperatures are common for extended periods and the motors are located inside the lift station, adequate air conditioning is necessary to maintain suitable operating temperatures with multiple pumps and motors running.

For designs that include a wet well, air exchange from the wet well should be both supplied and exhausted through ducts by powered blowers so a slight positive pressure is maintained. The remainder of the building should be well ventilated by means of roof and wall ventilators. All rooms, compartments, pits and other enclosures below grade for which access is provided, which may be entered and in which an unsafe atmosphere or excessive heat may develop, must have adequate forced ventilation. The HVAC equipment should generally be capable of producing at least six (6) complete room volume changes of air per hour. Rooms containing equipment or piping needs to be adequately heated, vented, and if necessary, de-humidified. Switches controlling forced ventilation shall be located outside such compartments. The building should be adequately insulated, suitable for local conditions.

Air conditioning must be provided for electrical control rooms. For wastewater lift stations with VFD units, two air conditioning (air handling) units are often provided, one to act as the primary and the other as a backup. Air handling units are usually designed to prevent maximum room or panel temperatures from exceeding 75 degrees F. Where applicable, the use of multiple, commercial grade, common-size air conditioning units to balance the air flow, is recommended rather than using one larger unit.

One of the main sources of lift station noise is anticipated to emanate from HVAC supply and exhaust systems and the use of standby emergency engine generators. Fan selection, duct sizing and configurations, and inlets and outlets should be carefully designed to ensure that noise emissions are minimized. This is especially important when lift stations are located in residential areas. Fans and blowers should be mounted within the building to reduce noise and discharges be equipped with appropriate sound traps.

The ventilation and air conditioning systems should be designed to satisfy the following codes and standards unless superseded by more stringent requirements:

- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- Clean Air Act Guidelines
- National Electric Code (NEC)
- National Fire Protection Association (NFPA) 90A
- Sheet Metal and Air Conditioning Contractors National Association (SMACNA) Standards
- NFPA
- Uniform Fire Code
- Uniform Mechanical Code
- Other local codes, ordinances, and regulations

Equipment Layout

HVAC ductwork and systems are typically the first mechanical items installed in a building once the structure frame has been constructed. The ventilation and air conditioning systems should be designed with adequate space for installation, operation, and maintenance accessibility and with regard for other trades. Air ducts to aboveground piping, louvers, and vents need to be adequately sized to reduce noise generation and transmission. The use of "sound traps", duct insulation and sound baffles should be used to reduce the transmission of station noise. All vents and louvers open to the outside need to be screened with heavy galvanized wire mesh (typically with a maximum ½-inchopening).

Electrical equipment associated with the ventilation system should be UL listed and conform to the National Electric Code and any local requirements.

Ventilation equipment is usually controlled by a thermostat and a hand-off-auto (HOA) entry switch. Failure alarms must be hardwired to the main station control panel and to the station's SCADA System.

<u>Noise Control and Abatement</u>

Noise levels from wastewater lift stations can have a negative effect on neighbors as well as plant personnel. Neighbors are affected by transmitted noise that extends beyond project boundaries, whereas station noise can have a negative effect on the health of plant personnel. Maximum noise levels in working environments are regulated under the federal Occupational Safety and Health Administration (OSHA) and sometimes local or state regulations. OSHA and local requirements and regulations need to be included in the design of all structures to establish the working environment's maximum noise levels.

Noise can come from a wide variety of sources but are mostly limited to noise generated from large equipment. These sources can include pump motors, HVAC systems, standby generator units, blowers, and fans. A significant contributor to noise can also come from operation and maintenance activities. Noise generated from these activities usually contains variations in tone or frequency. These variations typically have a greater annoyance impact on the surrounding community than simply the decibel level. Noise control measures at wastewater lift stations should focus on equipment selection, use of structure sound barriers and sound traps, acoustical shrouding and/or enclosures of equipment, wall batting, and acoustical architecture to attenuate the sound wave forms.

Construction of these facilities can also contribute significantly to noise levels resulting in human annoyance. Though construction is temporary, provisions should be included in the design specifications to ensure that the contractor obeys all local noise ordinances. One way to mitigate construction noise may be to restrict a contractor's work hours to specific times during the day/evening and/or require the use of temporary noise barriers.

Design Issues
In general, no noise, odor or vibration should be emitted so that it exceeds the general level of noise, odor or vibration emitted by uses outside of the site." Noise emitted from a wastewater lift station should generally not exceed a value of 50 dB at the project property line, when measured on an "A weighted" sound level meter according to the procedures of the Environmental Protection Agency (EPA). However, if the project is located in a light industrial or heavy industrial area, the acceptable average noise level is often 55 dB.

Table 2 has been provided for informational purposes only. It should be used as a frame of reference for comparing typical background noise levels for indoor and outdoor areas. This table has been reproduced from the WEF Manual of Practice No. 8, *Design of Municipal Wastewater Treatment Plants*.

Table 2 Typical Criteria for Background Noise

Space Type	Noise Level, dBA
Indoor	
Conference Room, Offices	42
Lobbies, Laboratory, Work Areas	47-56
Light Maintenance Shop	52-61
Work Spaces – communication required	56-66
Work Spaces – no communication required, but with no risk of hearing damage	66-80
Outdoor	
Quiet residential	40-50
Average residential	50-60
Commercial	55-65
Industrial	60-70

The emergency engine generator should be equipped with hospital grade exhaust silencers. If it is in a building, it should also have inlet and outlet louver appurtenances. If the generator is located outside of the station building or within a compound, the design should shroud the generator in its own soundproof enclosure. (Acoustical generator enclosures are readily available from a host of generator manufacturers). Depending on the required decibel level, multiple silencers may have to be arranged in series in order to achieve the desired decibel level. The generator may be located within a secondary containment area to lower the generator below the height of the station wall and reduce noise produced by the equipment. The containment should generally not be depressed more than three (3) feet below grade and four feet of clearance between the equipment and containment walls must be provided. A six-inch high curb should also be provided around the containment to prevent stormwater runoff from entering. Adequate flood protection measures shall be designed into the depressed generator design to ensure protection against flood hazard.

Standards

Some typical standards for noise levels and abatement include:

- Maximum Noise Level:
  - For industrial zones: 55 dB at the project property line.
  - For residential and commercial zones: 50 dB at the project property line.
- Station equipment should meet OSHA levels for 8 hours of continuous exposure without requiring hearing protection.
- Standby emergency generators should be provided with hospital grade exhaust silencers.
- Within station buildings and enclosures, the exhaust systems of standby emergency generators should be covered with high temperature insulation (inner layer shall be rated for 1,800 degrees Fahrenheit; outer layer for 1,000 degrees Fahrenheit).
- Vinyl coated, quilted, acoustically absorptive fiberglass batting (cloth) should be used to line the interior walls of the standby generator room and other high noise areas.
- As an alternative to batting, slotted acoustic concrete masonry units can be substituted for standard masonry units in the construction of a building. Factory-installed, sound absorbing elements are provided in masonry unit cores.
- Sound traps on ductwork systems, generator radiator and intake louvers should be constructed of Type 304 Stainless Steel sheets. Seams should be locked formed. Dividers should be fabricated of perforated 304 stainless steel sheets, cavities filled with an inert, moisture- and vermin-proof acoustical absorbent material.
- Acoustical equipment enclosures should be specified for individual pieces of equipment or pumps located in enclosure compounds. These enclosures should be constructed from acoustical quilts, modular acoustical screens, or as recommended by the equipment manufacturer.

Odor control

Odors from wastewater lift stations are typically the most significant issue for residents and/or businesses in the vicinity of the site. Therefore, all stations must have an odor control system. This system typically has two components: a component for treating foul air from the head space in the wet well and a component for preventing odors at the force main discharge and further downstream.

Downstream Odor Control

One preferred approach to control odors downstream of lift stations is by injecting a flow-paced, liquid calcium nitrate double salt solution (trade name “Bioxide”) directly into the force main (downstream of the flow meter) to reduce the formation of hydrogen sulfide. The injector and feed pumps must be capable of feeding Bioxide at the working pressures in the force main. It must also be installed in such a way as to allow easy maintenance of the injection nozzle. Other methods of odor control are available but this method provides a consistent means of odor control. Introduction of chemicals directly into the wet well is generally not acceptable.

Wet Well

Odor control needs to be provided at the wet well. This is typically accomplished using either a wet chemical scrubber or a biological system (biofilter). For existing sites, odor control systems shall be designed based on sampling of the air in the sewer headspace. For new sites, the system should be designed to treat a minimum concentration of 30 ppb H_2S and upwards of 100 ppm H_2S depending on the ultimate size of the lift station. All ductwork should be either FRP or schedule 80 CPVC and should extend into the wet well at a minimum depth of three (3) feet below the finished grade elevation. The ductwork should be designed to draw air uniformly from the wet well, minimizing short circuiting and stagnant areas.

Regardless of the type of odor control system employed it must be sized such that the concentration of H_2S remaining in the odor scrubber's discharge does not exceed the applicable air quality requirements. One example of these requirements limits the concentration of such emissions into the ambient air at any occupied place beyond the premises on which the source is located exceeds 0.03 parts per million (30 parts per billion) by volume for any averaging period of 30 minutes or more.

Individual odor control systems may require a local air quality permit. The permit may require installation of additional equipment, such as differential pressure gauges, so it must be reviewed carefully.

Wet Chemical Scrubbers
One common odor control technology is a wet chemical scrubber. This often consists of a three stage, skid mounted unit that uses sodium hydroxide (NaOH) and sodium hypochlorite (NaOCl) to oxidize the H_2S in the foul air. A fan draws odorous air continuously from the wet well through ductwork and into the scrubber. pH and Oxidation Reduction Potential (ORP) probes monitor the concentration of the chemicals and signal the feed pumps through a dedicated control panel when additional chemical is needed.

Biofilters
Another approach is the use of biofilters. Biofilters can have a larger footprint than a wet chemical system but provide a significant reduction in maintenance and do not require the use of chemicals. Biofilters should be installed as close to grade level as possible while still providing a gravity drain to the sewer. The blower, blower control panel, and irrigation control panel should all be installed above grade.

<u>Chemical Storage</u>

All chemicals at the lift stations must be stored and delivered by means appropriate to their hazard classification.

Regulations
There are several regulatory agencies and standards governing the storage and handling of chemicals. The following list identifies some of the more common requirements and agencies.

- Resource Conservation and Recovery Act (RCRA)
- Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA)
- Superfund Amendments and Reauthorization Act (SARA)
- Emergency Planning and Community Right-to-Know Act (EPCRA)
- International Fire Code (IFC) with COP Amendments
- National Fire Protection Act (NFPA)
- American National Standards Institute (ANSI)
- Local and state requirements

Tanks and Piping

Tanks, piping, valves, gaskets, etc. must be constructed of materials compatible with the chemical they contain and transport. All tanks and piping shall be labeled and marked according to the chemical they contain and its hazard classification. Table 3 identifies the acceptable materials of construction for various portions of the tank and piping system.

Table 3: Materials of Construction for Lift Station Chemical Systems

Chemical	Tank	Piping	Gaskets	O-Rings and Seals	Valve Seats	Valve Diaphragms
Bioxide	FRP HDPE	Schedule 80 CPVC HDPE FRP	EPDM	EPT	EPT	N/A
Sodium Hydroxide	FRP	Schedule 80 CPVC	Teflon EPDM (Steel-steel flanges)	EPDM	Teflon	Teflon & EPDM (dual diaphragms)
Sodium Hypochlorite	FRP	Schedule 80 CPVC	Viton	Viton	Teflon	Teflon & EPDM (dual diaphragms)

The tanks should be sized to store at least 30-days worth of their respective chemical. Each tank shall have a sight glass that indicates the level of the chemical inside the tank and that is visible from the chemical fill station. Sight glasses that contain chemical (as opposed to a float) must include isolation valves and a drain to facilitate replacement of the sight glass. In addition to a sight glass, each tank should have an ultrasonic level transducer installed to provide an independent measure of the liquid level in the tank. Level information should be sent to a transmitter located at the chemical fill station. The maximum full condition should be clearly labeled on the transmitter if the read-out is in any other unit than percent full.

A drain nozzle must be installed on each tank. This nozzle must be flush with the bottom of the tank to allow for complete drainage of the tank. The feed pump suction line must be separate from the drain line and include a basket strainer. The tank fill line should include, at an appropriate location, a strainer, tee, and quick connect to allow for transfer of chemical from the containment area back into the tank after a spill. Each tank must have a vent (with insect screen), which must be 2 pipe sizes larger than the fill line. Each tank shall also include an overflow, sized at least 1 pipe size larger than the fill line. When multiple tanks are used for the same chemical, the overflows should be tied together in a common overflow header to allow one tank to overflow into the other. The header needs to have an overflow piped to the containment area in the event both tanks are overfilled.

Containment

Containment areas need be provided for scrubber units, chemical storage tanks, and chemical feed facilities. The containment area for Bioxide must be located at least 20 feet away from the containment areas for both sodium hypochlorite and sodium hydroxide. Each chemical storage tank needs to be located in a separate, monolithically poured, concrete containment area with a protective (non-slip, non-porous) coating, resistant to the stored chemical and extreme heat and cold. This coating must be provided on both vertical and horizontal surfaces within the containment basin and extend across the top of the containment area wall to the outside face of the basin.

The containment volume should be designed to contain 100 percent of the total chemical storage tank volume plus 6-inches of freeboard. If the containment area is located outdoors (common in very warm climates but uncommon in colder climates), the containment area also needs to have adequate volume to contain the runoff from a major storm event. The magnitude of the vent will depend on the local regulations. The floor of each concrete containment area must be sloped to its own sump. The sump must be self- contained and must not drain to the sewer or wet well. The only pipe that can be connected directly to the containment area sump is the pipe coming from the sump located in the respective chemical unloading area. The sump shall be emptied as necessary by portable pumps. All materials, including pipe, concrete embeds, handrails, steps, hardware, nuts, bolts, etc., must be constructed of non-ferrous, non-corrosive materials and be suitable for exposure to the chemicals in question.

The following list provides additional design guidance for chemical containment areas.

- Depress bulk storage containment area sufficiently to allow for drainage from the truck unloading containment.
- Elevate all equipment pads and electrical/instrumentation conduits above the maximum liquid level.
- Route chemical lines from the chemical feed/dosing pumps and chemical storage tanks within the containment area or within chemically protected leak-proof pipe trenches; otherwise, chemical lines must be equipped with secondary containment.
- Provide FRP grating above all open areas of the containment basin to allow access to tanks, piping, pumps, etc. in the event of a tank rupture or spill.
- Provide a removable FRP panel above the containment area sump to allow for easy insertion of portable sump pump(s).
- Any piping that leaves the containment basin must be double contained. The containment piping must be open on both ends and be routed and sloped in such a way as to allow any chemical leaked from the carrier pipe to drain back to the respective containment basin.
- Penetrations of the containment basin must be kept to a minimum. Any penetrations that are necessary must include a water stop that is compatible with the respective chemical.

Chemical Unloading

Each tank should have an associated chemical unloading pad and fill station. The pad should be designed to contain a minor spill from the chemical delivery truck and route it to the proper containment basin. The fill station should also include a small containment sump that drains into the containment basin. Both of these areas should be coated with an appropriate coating, similar to that used in the containment basins.

Fill stations should be constructed adjacent to the chemical unloading pad. These stations provide for a centralized location to fill all the tanks in the associated containment basin. The stations should consist of a stand to support the tank fill lines and be of sufficient size and structural integrity to support the level transmitters for each tank. The transmitters should be mounted directly above or adjacent to the fill line for their respective tanks and be shaded from direct sunlight. Each tank fill line should consist of a threaded quick connect, isolation ball valves and a basket strainer. The fill station and all associated fill lines must be provided with appropriate secondary containment.

At a minimum, a combination eye wash and emergency shower station equipped with an anti-scald valve should be located immediately adjacent to each fill station. The path from the fill station to the eyewash station must be free of any obstacles or tripping hazards. Control panels and other electrical equipment should be located a safe distance from the eyewash station.

Electrical system

Coordination with the electric utility regarding the electric power supply voltage, transformer ownership, motor starting limitations, and metering requirements are crucial factors in the electrical design of a project and must be initiated very early in the design of the project. The motors specified for the pumps need to be compatible with the voltage available at the project site. While power lines may be close to the proposed site, the designer should not assume this means all motors are compatible with the available power.

General Design Guidelines

The electrical systems for wastewater lift station designs shall comply with the National Electrical Code (NEC) and all applicable local codes. The electrical equipment should be manufactured in accordance with the standards of the Institute of Electrical and Electronic Engineers (IEEE) and the National Electrical Manufacturers Association (NEMA) and be listed by the Underwriter's Laboratory (UL). The electrical equipment will require a "label" indicating compliance with the standards of the applicable codes.

The electrical design will include service entrance sections, switchgear sections, motor control sections, VFD cabinets (if required), standby and/or dual-power systems, control panels, conduit and wiring. In general, the electrical equipment specified must be suitable for the location of the installation, either indoors or outdoors. Outdoor equipment is typically mounted on concrete pads. VFD cabinets need to be housed in an air-conditioned building. If larger pumps are to be added in the future and/or the station is to otherwise be expanded, oversized conduits, cabinets, floor space, and additional conduits should be provided to meet the future needs.

Utility company equipment, namely the main site transformer, can be located either inside or outside of the site fence, depending on utility requirements and local preferences. The designer must coordinate the design with the servicing utility company to determine the most convenient way for the company to access their equipment and meters.

Standby Power Systems

Two separate independent sources of electrical power are generally always required for each wastewater lift station. The primary source is almost always commercial power from either utility substations or transmission lines. The standby power source should be from an on-site engine generator tied to the on-site distribution system. The fuel source can be diesel, gasoline, propane or natural gas. In general, natural gas is preferred where available, since this fuel source doesn't usually depend on a storage tank, which can be depleted during frequent or extended power outages. For phased facilities, the design must address the need to supply standby power for the ultimate pump station configuration along with the interim needs.

The standby power source is usually required to provide 100% of the capacity of the primary power source. For diesel-fueled, propane-fueled or gasoline fueled generators, adequate fuel supply must be provided to ensure operation of the lift station for an extended period of time. The period of time will be determined during design and will depend on the amount of fuel required and regulatory requirements. In addition, diesel and gasoline generators should have a double-contained, above ground fuel tank. The generator must meet the noise standards previously described.

It is recommended the generator installation be depressed to be below the height of the station perimeter wall, to reduce noise impacts. However, the generator should not be depressed more than three (3) feet. Adequate flood protection measures shall be designed into the depressed generator design to ensure protection against flood hazard.

Each generator must be designed with an Automatic Transfer Switch (ATS) rated for 100% of the full load power requirement of the station. This switch must be located downstream of the utility power meter and the main disconnect switch. The ATS shall conform to the requirements of NEMA and Underwriter's Laboratories. For sites deemed critical, a Manual Transfer Switch may also be required for connection of a portable generator.

Power System Protection

Wastewater lift stations will operate unattended. Therefore, their power systems need to be provided with protection against single phasing, improper phase rotation, ground faults, and power surges that may come in on the power lines such as from lightning strikes.

Fault studies analyzing the available fault currents may be required for each source of power. Faults should report to the Programmable Logic Controller (PLC) and alarm system.

A coordination study for selection of proper protective devices should be performed for each installation. If one of the sources is an engine generator, special care should be taken in selecting fault protective devices to ensure their operation when the station is being powered by its alternative power source (engine generator).

Uninterruptible Power Supply

An uninterruptible power supply needs to be provided for critical loads where failure of equipment to operate satisfactorily would jeopardize the health and safety of personnel or safety of station systems. Examples include the station's PLC, alarm system, and some instrumentation and control systems.

Equipment Sizing and Rating

Equipment and materials must be rated to withstand and/or interrupt the available fault current, with at least a 20% reserve margin for electrical load growth. Electrical power conduits shall be sized for ultimate design conditions. Electrical power conduits should not be installed in the same duct bank with instrumentation and control conduits.

For conduits installed in concrete or under base slabs, etc., the designer should provide and stub-up at all major equipment and panels at least two spare conduits for every 10 placed. The minimum size of the spare conduits should match the size of other conduits. These spares are not for anticipated future expansion but to permit installation of additional ancillary equipment if desired.

Motor Control Centers, Switchgear, and Electrical Panels

All motor control centers (MCC's), switchgear, and electrical panels should be provided with a solid state-monitoring device as a minimum.

Instrumentation and control

The entire Instrumentation and Control system for lift stations typically centers around a Programmable Logic Controller, or PLC. This device provides automatic control of various lift station systems, collects and transmits data about lift station processes, and identifies and communicates alarm conditions. The majority of stations will require one PLC. Redundant control is often required and this is often accomplished through the use of less sophisticated systems. However, lift stations deemed critical may require installation of a redundant PLC and associated hardware.

Control Systems

Lift Stations are nearly always intended to be unmanned sites. Therefore, automatic control systems are required to control standard functions at the lift station. The two main systems are pump control and security.

Pump Control

The Pump Control Panel (PCP) operates the lift station automatically, provides personnel with status indicators, data recorders, and control switches, and allows automatic or local control.

The pump control system is primarily controlled by wet well level transmitters. Each wet well should include two ultrasonic level transmitters: a primary and a backup. The primary indicator communicates level information to the PLC, which uses its programming to decide if the pumps need to turn on or off. The PLC then sends the appropriate signal to the PCP. The backup transmitter communicates level indication to the PLC and is used as a backup local controller for the PCP in the event the PLC is off-line.

Security

The main element of security at lift stations is access control. This can be accomplished by methods as simple as fences and locked gates in smaller communities. Where more security is desired or necessary, security control can be accomplished through the use of card readers and automated gates.

Instrumentation

A variety of instrumentation is used to identify potential process and control issues at a lift station.

Instruments

Table 4 identifies the instruments typically required, the location of the instruments and the equipment that instruments are connected to. All exterior mounted instruments must be protected from exposure to direct sunlight.

Table 4 Instrumentation

Instrument	Location	Equipment	Notes
Temperature Sensor	Field	Pump	
Moisture Sensor	Field	Pump	
Level Element	Field	Wet Well, Chemical Tanks	
Pressure Transmitter	Field	Force Main	One transmitter for each pump discharge pressure.
Pressure Gage	Field	Force Main	One gauge for each pump discharge pressure.
Flow Element	Field	Force Main	
Level Transmitter	Field/PCP	Tank Level Element/Wet Well Level Element	
Flow Totalizing Transmitter	PCP		
Transient Voltage Surge Suppressor	MCC	MCC	
Temperature Transmitter	PLC	PLC	PLC cabinet temperature indication

Process / Alarm Status Indication
Table 5 provides a list of the process / alarm status indications that are typically provided and their indication points.

Table 5 Process/Alarm Status Indicators

Status/Alarm Indicator	Indication	Notes
Pump Fault (Moisture, High Temperature, Overload)	Lamp on PCP, PLC, SCADA	For each pump. Overload or VFD fault should be utilized as applicable.
Pump Run Status	Lamp on PCP, PLC, SCADA	For each pump.
High Wet Well Level Alarm	Lamp on PCP, PLC, SCADA	
Wet Well Level Indication	PLC, SCADA	Two level transmitters should be installed in the wet well for redundancy purposes.
Force Main Pressure	PLC, SCADA	
Flow Rate Indication	PLC, SCADA	
Flow Rate Total	PLC, SCADA	
Generator Fault	Lamp on PCP, PLC, SCADA	
Station on Generator Power	Lamp on PCP, PLC, SCADA	
Station in Maintenance Mode	Lamp on PCP, PLC	
Station in Auto Mode	PLC	
Station in Local Control	PLC	
Odor System Control Failure	PLC, SCADA	
Odor Control Blower Run Status	PLC	
Odor Control Recirc Pump Run Status	PLC	

In addition, a Push to Test button should be installed on the PCP that tests the function of all indicating lamps within the panel.

All process related alarms at the site are typically reported through the SCADA system. Intrusion alarms may also be routed through the SCADA system depending on the sophistication of the security system. The following is a list of the common alarms.

- Control Power Failure
- Pump Failure (for each pump)
- Generator Failure
- High Wet Well Water Level
- Low Wet Well Water Level
- Station on Standby Power
- Odor Control System Failure
- Entrance Gate Intrusion (If electronically monitored)
- Electrical Panel Intrusion
- Generator Low Fuel
- Generator Fuel Leak

All process alarms, pump run time and flow totalizers should be resettable at the PCP. High Wet Well Level Alarm, pump run-time and flow totalizers should also be resettable remotely via the PLC.

Communications
Communications to and from the site can be accomplished via standard telephone lines, cell phone, wired internet or wireless internet.

Site layout

Storm water retention requirements, grading and drainage, set-backs, etc. are often governed by local codes and ordinances.

Facility Location
Generally, the property the lift station occupies should be large enough to provide at least a six (6) foot buffer around the station's perimeter wall and that the station should be somewhat centered in that property. This location separates the station from the nearest property owners and therefore reduces the likelihood of complaints from neighbors. The addition of low-maintenance landscaping surrounding the entire lift station will further blend the station into the neighborhood, although security concerns must be considered. The designer should initially consider this "centered location" for the orientation of the lift station and adjust or modify accordingly to satisfy project constraints, etc.

Setbacks
Setbacks from adjacent property and/or Right-of-Way lines will generally be governed by local codes and ordinances.

Ingress/Egress
Site layout should be designed to allow adequate access for an FHWA Class 9 delivery truck to the facility while providing minimal traffic disruption. Whenever possible, the entry/exit gate(s) should be positioned far enough from the right-of-way (out of traffic) to allow such a delivery truck to be parked while a worker opens the gate. A turning lane for ingress/egress to the facility may be required if a site is located on a heavily traveled roadway. Access to facilities on corner lots should be provided by the street with the lowest traffic volume.

Internal Layout

Wherever possible, a looped access road around the wet well should be provided. If size limitations do not allow this, the access road should provide the ability to enter and exit the site without having to back directly into a street. The access road should also include a driveway or similar paved area that allows personnel to access the pumps with a truck-mounted crane from a paved surface.

Bollards or other acceptable protection devices must be installed to protect all equipment, piping, electrical devices, etc. from vehicular traffic.

Chemical Storage and Containment

The chemical storage and containment areas should be directly adjacent to the looped access road to facilitate safe and easy delivery of chemicals.

Electrical Equipment

The electrical equipment should be arranged in a line and be located in close proximity to the wet well. For a typical layout, this will put the electrical lineup inside the access loop. Bollards or other protective structures must be installed around the lineup in sufficient number to protect it from potential damage caused by delivery trucks or maintenance vehicles.

The emergency generator can be placed anywhere within the site. However, if the generator is diesel powered, it must be located in such a way as to avoid a direct drainage path to any dry wells installed at the site. In addition, the designer must consider noise restrictions and ease of access when siting the generator.

Storage and Buildings

The designer shall provide space for a lockable storage container at all sites. This could include adequate storage space within the building. The size of this container will vary based on the capacity of the lift station and the equipment being utilized, but can be as large as 10 ft by 20 ft. In addition, a storage cabinet for Operations and Maintenance manuals and log books should be included in the building design.

For sites that utilize VFDs, an air conditioned building is typically required.

Architecture and landscaping

It is common for lift stations to be located either in or close to residential communities and commercial centers. Therefore, consideration must be given to the outward appearance of the site. Some communities have specific architectural and landscaping requirements for public facilities in all areas, but may be more restrictive in residential areas.

External Features

External criteria should generally incorporate the theme of the surrounding community into the aesthetic design of the station. Form, style, materials of construction, colors, and finishes should reflect that theme. The underlying intent of the external architectural treatment of a facility is to have it blend in with the surrounding community/neighborhoods while maintaining a level of security. In some cases, an artist may be commissioned to add elements of public art to the walls, gates, and/or landscaping. Established local standards, preferences, and guidelines for materials, building layout, site security, and appearance should also be discussed and integrated into the design.

Internal Features

The primary internal design features will focus on the location and configuration of the selected processes within the station footprint, size of major pieces of equipment and their interdependency on adjacent mechanical and electrical systems, and their operation and maintenance. The buildings on the site should incorporate design elements of surrounding buildings or development if they exist.

Lighting

The lighting design must satisfy the operational needs of the facility. Interior ambient light levels should be established for optimum safety and efficiency. Task lighting should be provided for the electrical components, odor control systems, and instrument panels and should be controlled via a toggle switch located at the entrance door. As a minimum, task lighting must provide adequate lighting for the safe and efficient maintenance and operation of equipment at night.

Site lighting will usually be provided using wall-mounted lights around the site perimeter. These lights should be controlled by a toggle switch located directly inside the gate. Exterior lighting criteria should be established to accommodate all necessary nighttime operations and assure a reasonable level of security for the facility. At the same time, exterior lighting criteria shall avoid illumination levels that are a nuisance to the surrounding community. Sites with continuous nighttime lighting in residential areas are generally not desirable.

Gates and Perimeter Wall

It is common to have just one gate for access to the lift station. This means that there must be enough room for a fire engine or chemical delivery truck to turn around within the station. In some areas, perimeter walls around the entire site are provided to be compatible with the surrounding environment. In other areas, a high chain link fence is all that is necessary to provide the necessary security.

The use of automatic rolling gates for lift station access gates is encouraged, when this makes sense. hall be automatic rolling gates. Swing gates are acceptable, but only where a rolling gate is not practical. In addition, the gates should sit 3-inches above finished grade and be 20 feet wide to allow for fire engine and chemical delivery truck entry.

Signage

Several different types of signage are required both inside and outside of the lift station. The following is a typical list:

- An identification sign shall be installed on the entry gate(s) and shall include the lift station number, address, and emergency contact phone number
- NO SMOKING signs shall be installed on each corner of the wet scrubber containment area and at each access point to the wet well
- NFPA 794 Information Diamonds shall be installed on each chemical tank along with a sign indicating the chemical being stored and its concentration
- DANGER EQUIPMENT STARTS AUTOMATICALLY signs shall be installed near any equipment that may be remotely started. At a minimum this includes:
    - Chemical recirculation pumps
    - Bioxide system
    - Emergency generator
    - Automatic Transfer Switch
- DANGER NON-POTABLE WATER signs shall be installed on or near all hose bibs
- Chemical metering pumps shall be identified with the chemical they pump.
- All piping connections to equipment shall be labeled with the fluid they contain

Landscaping

In projects where landscaping is required, the use of a registered landscape architect (RLA) is recommended. Landscaping materials, plantings, etc. should be provided in accordance with local codes and ordinances and be compatible with the local climate. Specific issues regarding landscaping and site security around the lift station should be addressed prior to submitting plans for permitting.

Plant Inventory and Re-Vegetation Design

The RLA should prepare an on-site inventory (vegetative plan and de-vegetative plan) of desired native plants within the wastewater lift station site, staging areas, storage areas, piping alignment, etc. for potential salvage and reuse. The RLA shall provide recommendations for the following:

- Plant inventory (by species, number, and location) and salvage plans.
- Specifications for site restoration.

Plantings and Ground Cover

Landscape planting should be plant species commonly used and appropriate for the region. All species should be selected for ease of maintenance, hardiness, and drought tolerance. Plant selections should serve as an example of aesthetically pleasing, yet reasonable techniques of resource management and water conservation wherever possible. In some area, landscaping rock can be employed in lieu of vegetation that will require regular irrigation, mowing and other maintenance.

The RLA must consider the safety and security of the lift station facility while specifying plant species and locations. Landscaping materials must not aid in gaining access into the lift station. Trees should not be planted in the proximity of the lift station perimeter, keeping in mind the mature height of the tree. Only low-growing or insubstantial shrubs may be planted near the lift station perimeter.

Irrigation System

Irrigation system design criteria should harmonize with the surrounding neighborhood. As such, irrigation water should not be visibly wasted to evaporation, but rather efficiently and unobtrusively delivered to the point of use through underground piping (i.e. drip system) and operated by a controller system.

Wastewater Lift Station Design - Quiz

Updated: 6/12/2023

1. What flows need to be considered when sizing a lift station?
   a. Only ultimate build out flows
   b. Only flows expected at startup
   c. Only flows expected until 50% of ultimate build out
   d. All of the above

2. What is the recommended peaking factor for existing sites with average daily flows less than 2.0 MGD?
   a. 2.5
   b. 3.0
   c. 4.0
   d. 5.0

3. The capacity of the lift station with the largest pump out of service is defined as?
   a. The firm capacity
   b. The design capacity
   c. The emergency capacity
   d. None of the above

4. What is the recommended minimum distance between the pump on level and the invert of the lowest influent pipe?
   a. 0 feet
   b. 1 foot
   c. 2 feet
   d. 3 feet

5. What is the recommended range of velocities in a force main?
   a. 2 to 4 feet per second
   b. 3 to 7 feet per second
   c. 5 to 10 feet per second
   d. 7 to 12 feet per second

6. Why should placement and spacing of the pumps in a wet well comply with the guidelines from the Hydraulic Institute?
   a. To prevent turbulence at the pump inlet
   b. To prevent vortexing at the pump inlet
   c. Both of the above
   d. None of the above

7. Which of the following is not a typical nominal motor speed for a wastewater pump?
    a. 1200 rpm
    b. 1800 rpm
    c. 3600 rpm
    d. None of the above

8. What is the recommended maximum bend angle in a force main?
    a. 90 degrees
    b. 45 degrees
    c. 30 degrees
    d. 22.5 degrees

9. Where should air release and air/vacuum valves be installed on a force main?
    a. Only at high points
    b. At high points and throughout the length of the force main
    c. At a maximum spacing of 100 feet
    d. These valves are not necessary on a force main

10. Heating of the lift station is required to maintain about what temperature in the building?
    a. 32 degrees
    b. 45 to 55 degrees
    c. 70 degrees
    d. Heating is never necessary.

11. What is the typical noise level in a quiet residential area?
    a. 40 to 50 dBA
    b. 50 to 60 dBA
    c. 55 to 65 dBA
    d. 60 to 70 dBA

12. Which of the following is typically used for odor control at a wet well?
    a. Wet chemical scrubber
    b. Biofilter
    c. Either of the above
    d. None of the above

13. What type of pipe is typically used for sodium hydroxide feed systems for odor control?
    a. CPVC
    b. HDPE
    c. FRP
    d. All of the above

14. Which of the following is a potential fuel source for an emergency generator?
    a. Diesel
    b. Natural gas
    c. Propane
    d. All of the above

15. Which of the following alarms should generally be reported through the SCADA system:
    a. Pump failure for each pump
    b. Generator failure
    c. High wet well water level
    d. All of the above