Chapter 11 Pump Stations

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Chapter 11 PUMP STATIONS

This chapter of the Design Standards and Guidelines (DSG) presents guidance for Seattle Public Utilities (SPU) pump stations for potable water, stormwater, and wastewater. The primary audience for this chapter is SPU engineering staff and consulting engineers working on SPU projects. Required standards are shown as underlined text.

The information in this chapter should be used in conjunction with other DSG standards, including *Chapter 7, DWW System Modeling*; *Chapter 9, Electrical Design*; and *Chapter 10, Instrumentation & Control (I&C) Supervisory Control and Data Acquisition (SCADA)*.

> ***Note:*** *This chapter of the DSG does not replace the experienced engineering judgment of a registered professional engineer. All pump station designs for both upgrades and new stations should be done under the supervision of an experienced, licensed engineer.*

11.1 KEY TERMS

The abbreviations and definitions given here are used throughout this Chapter and follow either common American usage or regulatory guidance.

11.1.1 Abbreviations

Abbreviation	Term
AASHTO	formerly American Association of State Highway and Transportation Officials now just AASHTO
ac, AC	alternating current
ACI	American Concrete Institute
ADA	Americans with Disabilities Act
AISC	American Institute of Steel Construction
AMC	Asset Management Committee
AMCA	Air Movement and Control Association
ANSI	American National Standards Institute
AOR	acceptable operating range
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	formerly American Society of Testing and Materials; now known as ASTM International

Abbreviation	Term
BEP	best efficiency point
CIP	Capital Improvement Program
Critical Services	Major users of SPU's services, typically: Emergency services, public safety facilities, medical facilities, schools, educational facilities, transportation infrastructure, and vulnerable populations. See the Drainage System Analysis, Appendix C, Figure 2. Contact SPU for GIS data set
CSI	Construction Specifications Institute
CSO	combined sewer overflow
DOH	Washington State Department of Health
DWW	drainage and wastewater
Ecology	Washington State Department of Ecology
EGL	energy grade line
FRP	fiberglass-reinforced plastic
ft	Feet
gpm	gallons per minute
HGL	hydraulic grade line
HI	Hydraulic Institute
HMI	Human-Machine Interface
HP	Horsepower
HVAC	heating, ventilation, and air conditioning
I&C	Instrumentation and Control
IEEE	formerly Institute of Electrical and Electronics Engineers; now known as IEEE
LOB	line of business
MCC	motor control center
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NPSH	net positive suction head
NSF International	NSF International: a not-for-profit, non-governmental standards organization also trademarked as The Public Health and Safety Company
ODP	open drip proof
OI	Operator Interface
O&M	operations and maintenance
P&ID	process and instrumentation diagram
PLC	programmable logic controller

Abbreviation	Term
POR	preferred operating range
psi	pounds per square inch
RCM	reliability centered maintenance
SBC	Seattle Building Code
SCADA	supervisory control and data acquisition
SDCI	Seattle Department of Construction and Inspections
SDOT	Seattle Department of Transportation
TEFC	totally enclosed fan cooled
V	Volt
VFD	variable frequency drive

11.1.2 Definitions

Term	Definition
backflow preventer	A device installed in potable water piping to prevent the flow of non-potable water into a potable system.
Best efficiency point (BEP)	The discharge rate at which an impeller of a given diameter rotating at a given speed operates at maximum efficiency.
Booster	A pump that takes suction from a pressurized piping system and discharges, at a higher pressure, to a second, isolated piping system.
Cavitation	Vapor bubbles formed on a solid surface (often an impeller) in contact with a liquid. The vapor bubbles occur when the pressure in the liquid falls below the vapor pressure.
Centrifugal pump	A rotodynamic pump in which the fluid is displaced radially by the impeller. Commonly, any rotodynamic pump in which the fluid is displaced radially, axially, or by a combination of both.
Dry well	The below-grade structure of a pump station which houses piping, valves, pumps, and electrical equipment.
Dynamic head	Head (energy) losses associated with friction and minor (fitting) losses.
Engineering	Generic term for SPU engineering staff.
Firm pumping capacity	Capacity of the pumping station with the largest pump out of service or on standby.
Force main	Piping, external to the station and filled with liquid under pressure, through which the station discharges.
Guidelines	Advice for preparing an engineering design. Guidelines document suggested minimum requirements and analysis of design elements to produce a coordinated set of design drawings, specifications, or lifecycle cost estimates. Guidelines answer what, why, when, and how to apply design standards and the level of quality assurance required.
Impeller	A circular casting mounted on a rotating shaft with vanes to accelerate the fluid.
Intake	A structure from which the pumps take suction.

Term	Definition
Net positive suction head (NPSH)	Absolute dynamic head of the pumped liquid at the suction eye of the pump.
Net positive suction head available (NPSH$_a$)	The NPSH at which the pump in each system operates at a given discharge rate.
Net positive suction head required (NPSH$_r$)	The minimum NPSH at which a pump can properly operate for a given discharge rate.
Packing	Semi-plastic material installed in a stuffing box to seal the shaft opening in the casing to restrict the leakage of liquid from the casing along the shaft.
Peak pumping capacity	Capacity of the pumping station with the maximum allowed number of pumps operating.
Pump	A machine that imparts kinetic and potential energy (from an external energy source) to a liquid to force a discharge from the machine.
Pump station	A structure housing pumps, piping, valves, and auxiliary equipment.
Runout	The maximum possible discharge for a pump.
soft start	Motor starting in which the inrush current is reduced.
Standard	Drawings, technical or material specifications, and minimum requirements needed to design a particular improvement. A design standard is adopted by the department and generally meets the functional and operational requirements at the lowest lifecycle cost. It serves as a reference for evaluating proposals from developers and contractors. For a standard, the word must refer to a mandatory requirement. The word should is used to denote a flexible requirement that is mandatory only under certain conditions. Standards are underlined throughout the DSG.
Submersible pump	A pump or pump and motor designed to operate while partially or fully submerged in a suitable for fully submerged operation.
total dynamic head	The sum of static and dynamic heads. Also, the total head at which a pump will operate at any given discharge rate.
total static head	The difference in elevation between the surface of the pond from which the pump draws water and the surface of the pool into which the outlet discharges.
water hammer	Rapid, severe, and often destructive changes in pressure in a piping system caused by a sudden change of liquid velocity.
wet well pump	A pump designed to be directly immersed in the liquid.
wet well	The below-grade compartment of a pump station into which liquid flows and from which pumps draw suction.

11.2 GENERAL INFORMATION

11.2.1 Pump Stations in SPU's Systems

SPU owns and operates approximately 104 pump stations of various types including water, wastewater, drainage, and CSO storage.

11.2.1.1 Water Pump Stations

SPU currently operates 31 potable water pump stations. SPU water pump stations have a minimum of one to a maximum of four pumps each. The stations' capacities range from 110 to 38,200 gallons per minute (gpm). The primary function of a water pump station is to transport water to storage facilities to meet peak demand each day and to ensure that proper pressure is maintained while meeting fire flow requirements. In general, the SPU water pumping system is robust and meets service levels.

Most existing SPU water pump stations use intermittently operated constant speed pumps to fill elevated tanks and reservoirs. Two stations pump water from well fields, while the remaining pump stations are in-line booster pumps that deliver water directly to the customer at the appropriate pressure. All SPU pump stations are electrically powered except for four—one pump station has a diesel motor and electric motors, the other three are hydraulically powered by turbines.

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Name	Head	Pump 1	Pump 2	Pump 3	Pump 4	Type
Volunteer Park	108	4,000	4,000			Distrib
Warren Ave N	265	4,000	4,000			Distrib
West Seattle Reservoir	62	4,500	4,500			Distrib

Acronyms and Abbreviations
Distrib: distribution
gpm: gallons per minute
Trans: transmission
Flow rates and head shown are approximate and for reference only. Do not use for design purposes.

11.2.1.2 Wastewater Pump Stations

SPU currently owns and operates 68 wastewater pump stations and five CSO/SSO storage facilities with drain pumps. The SPU wastewater collection system consists of various types of stations and pumping equipment, including wet well/dry well stations, stations with wet wells only (submersible), and pneumatic-ejector-type stations.

SPU stations are typically equipped with two pumps. Currently, SPU operates a single three-pump station (Pump Station 35, scheduled to be changed to two-pump system by 2026). Older stations may not have 100% firm capacity and regularly use both pumps to meet demand. Station firm capacities generally range from 50 gpm to 2,700 gpm, with most stations under 400 gpm.

The primary purpose of a pump station is to receive wastewater or drainage from a service area or drainage basin and convey that flow to a discharge point outside of the basin. A network of SPU-owned and maintained gravity pipes feeds the basin. Wastewater is pumped from a pump station via a pressurized force main pipe into either SPU’s downstream collection infrastructure or the King County regional trunk collection system.

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11.2.1.3 Drainage Pump Stations

Currently, SPU operates one drainage pump station (Table 11-3). Typically, drainage pump stations are installed as a flood control measure within a drainage basin to alleviate any flooding by a severe rainstorm. Removed for Security

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11.2.2 System Maps

SPU storm drainage, wastewater, and combined sewer system maps are available from the following sources:

- Base Maps
- SPU Engineering Records Center and GIS Mapping Counter (SMT 47th floor)
- CSO Control Facilities O&M folders (DWW Facility Manual SharePoint Site – SPU Internal Access Only)
- SPU/King County Wastewater Sewer/Drainage Topography maps (SMT 45th floor)
- Seattle Department of Construction and Inspections (SDCI) Side Sewer and Storm Drainage Information desk (SMT 20th floor)
- City of Seattle Open Data Portal
- Seattle Digital Infrastructure Records (SeaDIR)

11.2.3 DSG Design Resources

DSG design resources include example technical and material specifications, example calculations, and checklists. For cost estimating guidance, refer to the SPU Cost Estimating Guide. The following design resources are discussed in this chapter and its appendices:

- **Example Technical Specifications.** Example technical specifications for drainage and wastewater pump stations are presented in Construction Specifications Institute (CSI) format (see **Appendix 11A - Example Pump Station CSI Specifications**). The example specification sections listed below include only those that are typically unique to pump stations. This is not a comprehensive set of specifications for pump station projects. Notes to the design engineer may be embedded within these specifications. Each specification section must be tailored for each contract. The design engineer must determine the full set of specifications necessary for each project and review each example specification for applicability.
  - Section 01 35 05 Sewer Bypass Plan
  - Section 05 50 05 Metal Gratings
  - Section 08 31 00 Access Hatches
  - Section 09 90 00 Painting and Coating
  - Section 23 00 00 Ventilation
  - Section 23 80 00 Odor Control Equipment
  - Section 26 24 19 Motor Control Centers
  - Section 26 29 13 Combination Motor Starter
  - Section 26 29 23 Variable Frequency Drive Motor Controllers

- Section 40 07 00 Mechanical Identification
- Section 40 23 00 Pipe, Fittings, and Accessories
- Section 40 23 01 Pump Station Valves
- Section 40 90 05 Control Loop Descriptions
- Section 40 91 10 Primary Elements and Transmitters
- Section 40 91 16 Magnetic Flow Meters
- Section 40 91 23 Staff Gage
- Section 40 21 13 Constant Speed Vertical Centrifugal Pumps
- Section 43 21 13 Variable Speed Vertical Centrifugal Pumps
- Section 43 21 13 Constant Speed Vertical Centrifugal Chopper Pumps
- Section 43 21 14 Reinstallation of Salvaged Vertical Centrifugal Pumps
- Section 43 21 29 Sump Pumps

- **Example Calculations.** Example calculations are available for sizing pump station elements and selecting pump equipment (**Appendix 11B - Pump Station Design Calculator [Constant Speed]**, **Appendix 11C - Pump Station Design Calculator [Variable Speed]**, and **Appendix 11D - Example Calculations - Wet Well Sizing**). These calculations are for reference only and not intended as standards. It is at the discretion of the engineer to select a calculation methodology. The example calculations provided in Appendix 11B-D are for a duplex wet well/dry well wastewater station. Separate examples are provided for constant speed and variable speed applications. All calculations must be reviewed by a qualified Professional Engineer.
- **Equipment Data Sheet Template.** An equipment data sheet template is provided as an example only (**Appendix 11E - Equipment Data Sheet Template**). It can also be tailored for instruments. Projects may use other formats for data sheets as needed.

11.2.4 Level of Service

Pump station modifications and development must meet the defined SPU level of service for the appropriate line of business (LOB).

If an existing system does not meet the specified level of service, it should be modified to do so. If an existing system does meet the level of service, asset management principles should be used to determine whether updating or adding new stations is justified. New stations may be justified if a new station can significantly reduce costs.

11.2.4.1 Water

For water pump stations, the 2019 Water System Plan identifies these level-of-service objectives:

- Provide agreed-upon pressure and flow in the water transmission system for wholesale customers.
- Provide adequate pressures for drinking water supplies in the water distribution system. This includes delivering peak hour demands at a minimum of 30 pounds per square inch (psi) at utility meters and not drop below 20 psi during normal operations for delivery to retail customers.

- Meet efficiency goals in the water distribution system. This includes maintaining system leakage losses of no more than 10% of that supplied to the retail service area, as defined by Washington State Department of Health (DOH) guidelines.

To confirm these objectives, the designer should determine the actual pressure and flow for the existing facilities (review SCADA data) and the required pressure and flow at the locations serviced by the pump station (utilize water system model).

11.2.4.2 Wastewater

For wastewater pump stations, consider the following performance criteria when providing a recommendation on firm pumping capacity and design scope for a station being overhauled as part of the combined sewer overflow (CSO) Program or the Pump Station Program:

- Pump stations should have minimal sewer backups with specific guidelines based on interim drainage and wastewater (DWW) LOB sizing guidance for the Capital Improvement Program (CIP):
  - **Pump stations serving non-critical services:** No more than one sewer backup in 10 years (10% annual probability) at the wet well (through the wet well hatch or into an unpermitted point of overflow) or within the connected upstream or downstream combined or sanitary sewer lines caused by insufficient pump station capacity.
  - **Pump stations serving critical services:** No more than one sewer backup in 25 years (4% annual probability) at the wet well (through the wet well hatch or into an unpermitted point of overflow) or within the affected upstream or downstream combined or sanitary sewer lines caused by insufficient pump station capacity.
- CSOs should be limited to an average of one untreated discharge per permitted outfall per year. This limit is based on eliminating the basin's control volume. Control volume is a highly uncertain, climatic horizon dependent value that should be determined based on site context, infrastructure context, and financial context. The control volume associated with the modeled 50th percentile 2035 climate horizon may be used for initial planning purposes. Consult the LOB for further guidance.
- The facility should be designed to produce zero dry-weather overflows into permitted outfalls.
- Zero overflows at unpermitted points of overflow, regardless of weather conditions.

For pump stations with known wet weather influence, the effects of climate change on future rainfall should be considered when calculating potential inflow rates and firm capacity. SPU does not currently have a set policy on the climate horizon to be used for this calculation. Consult the DWW Line of Business Representative for current guidance.

The SPU wastewater system discharges to King County's regional wastewater collection system. The design engineer must consider the potential effects on King County's system when making a pump capacity and design recommendation. Any effects on King County must be negotiated with King County by the DWW LOB representative. Increases in firm pumping capacities typically require compensation for the effects on the regional system. The design engineer should identify ways to achieve the performance criteria described in the bullets above without affecting King County's system. The DWW LOB representative can provide regional and basin hydraulic and hydrologic models to assist in this analysis. For information on permitting and environmental review requirements with King County, see *DSG Chapter 2, Design for Permitting and Environmental Review*.

11.2.4.3 Drainage

Drainage pump stations can be constructed as part of the regular conveyance system but may also be used for special purposes such as flood mitigation, drainage of closed areas, or management in runoff of areas with tidally influenced outfalls. SPU does not have a currently adopted design level of service for drainage pump stations in each of these scenarios. As such, the appropriate design level of service may vary based on the project's intent and must be coordinated with the Line of Business Representative.

In general, the design capacity should be sufficient to allow connected storm drain pipes to comply with requirements set out in SPU Directors Rule DWW-210 (Public Drainage System Requirements) as well as *DSG Chapter 8, Drainage and Wastewater Infrastructure*.

11.2.5 Design Life

Design life refers to a service period in which about 50% of a group of assets has a high probability of failure, as recognized by the manufacturer and/or SPU planners. Neither equipment nor structures will necessarily fail if left in service beyond their design life. However, design life is an important benchmark for indicating when SPU should consider rehabilitation or replacement. It is also used when conducting lifecycle cost analyses.

SPU does not have a formally adopted policy on pump station elements and design life. Until a policy is available, refer to the basic understanding described below. The intended design life of new pump stations and upgrade/rehabilitation projects should be coordinated with the Line of Business Representative at the start of design.

SPU pump stations are structures that house mechanical and electrical equipment. The structure itself has an anticipated design life, as does each piece of equipment inside it (Table 11-4).

Table 11-4
Typical Design Life for SPU Pump Station Elements

Component	Type	Design Life (years)
Structural	Buildings (aboveground) and most structural elements	100
	Below grade concrete structures	150
	Roof (water pump stations only): Composite Metal	20-25 35+
Mechanical	Valves Piping (within pump station) Backflow preventers HVAC	25
Electrical	Motors (time period between each rewinding)	15

Component	Type	Design Life (years)
Pumps	Starter and motor control systems)[1]	20
Water	Dry well pumps (horizontal axial split pumps, single or dual stage)	35+
Drainage and Wastewater	Dry well/wet well pumps (centrifugal)	25
	Submersible pumps < 5 hp	10
	Submersible pumps >25 hp[2]	15-25

Notes
[1] Electrical elements other than motor windings may last over 35 years. Many electrical elements are replaced sooner when more efficient systems are developed or when code compliance is triggered by other work. Motor repair or replacement may require new starters or control systems in some circumstances.

[2] Typically small submersible pumps (<25 hp) are replaced rather than repaired given their low cost versus the repair cost. Dry well pumps will likely need rebuilding of subcomponents such as bearings, couplings, seals, or impellers.

Acronyms and Abbreviations
hp: horsepower
HVAC: heating, ventilation, and air conditioning

Existing SPU pump stations are generally between 40 and 100 years old. Some pump stations have been rehabilitated, while others may still operate original equipment. In many cases, equipment replacements, upgrades, and minor facility modifications are not well documented in the Seattle Digital Infrastructure Records. Existing conditions must be evaluated thoroughly at each facility before beginning design work.

The design engineer should refer to any available maintenance records and existing operations and maintenance manuals when determining the remaining life of existing equipment. Maintenance records for the past ten years are generally available via SPU's Maximo Work Management System. Operations and maintenance manuals for recently retrofitted sites may be found on the DWW Facility Manual SharePoint Site, although manuals for older equipment may only exist in hardcopy format. External consultants must contact SPU to arrange access to this information.

11.3 GENERAL REQUIREMENTS

The design engineer should be familiar with water, wastewater, and drainage industry standards and code requirements for pump station design. If industry standards and City requirements or regulations conflict, the design engineer should discuss the discrepancy with the LOB owner, operations manager, and SPU project engineer before resolving the issue (see contacts in DSG section 11.11). In general, the more stringent requirement should govern.

11.3.1 Industry Standards

All pump station designs should consider the standards and guidelines provided by the Hydraulic Institute (HI), ASTM International (formerly known as American Society for Testing and Materials Standards), *Pumping Station Design* edited by Robert L. Sanks (also known as the Sanks book), DOH, the Washington State Department of Ecology (Ecology), and other applicable industry standards. All new SPU facilities should conform to all requirements cited in this section.

11.3.1.1 Water Pump Stations

Water pump stations must be designed to meet American Water Works Association (AWWA) and DOH standards.

11.3.1.2 Wastewater and Drainage Pump Stations

Wastewater and drainage pump stations must be designed to meet local and HI standards, as well as other industry-accepted standards for solids-bearing water.

Newly designed wastewater pump stations must, at a minimum, meet Ecology's Criteria for Sewage Works Design, in addition to other requirements stated throughout this chapter.

All wastewater facilities, including pump stations, must meet DOH requirements for cross-connection control between potable water supplies and wastewater systems.

Table 11-5 lists industry standards and relevant international and national codes that frequently apply to pump station projects. This is not an exhaustive list. Other industry standards may apply to particular facilities. It is the design engineer's responsibility to determine applicable standards and use the latest version of each.

Table 11-5
Common Industry Standards and International and National Codes for Pump Stations

Organization	Standard	Description
Industry standards		
ANSI	B73.1	Horizontal, end-suction centrifugal pumps
ANSI/AWWA	E101	Vertical turbine and submersible pumps
ASHRAE	Standard 90.1	Energy conservation in new buildings
ASME	8.2	Displacement and centrifugal pumps
ASTM International	Various	Forging and coating of mechanical piping
AWS	D – 1.1	Structural welding code
AWWA	Various	Disinfection, piping, and other elements of drinking water systems
IEEE	Standard 446	Emergency and Standby Power
Hydraulic Institute	Various	All applicable standards for design, installation, operation, and maintenance of rotodynamic pumps and design of wet wells and pump intakes
International and National Codes		
ACI	318	Building code requirements for reinforced concrete
ACI	350	Recommended practice for design of concrete sanitary structures
ADA	28 CFR Part 36	Americans with Disabilities Act Guidelines for Buildings and Facilities
AISC		Handbook of Steel Construction
AMCA	300	Test Code for sound rating

Organization	Standard	Description
ASCE	7	Minimum Design Loads and Associated Criteria for Buildings and Other Structures
IBC		International Building Code
NEC	Section 501 -8	National Electrical Code
NEMA		National Electrical Manufacturers Association
NFPA	37	Installation and use of stationary combustion engines and gas turbines
NFPA	58	Storage and handling of liquefied petroleum gases
NFPA	Standard 90A	Installation of air conditioners and ventilation systems
NFPA	820	Standard for Fire Protection in Wastewater Treatment and Collection Facilities
NSF International	60	Purity of chemicals for drinking water
NSF International	61	Purity of products for drinking water
UBC		Uniform Building Code
UFC		Uniform Fire Code
UL	1004	Electrical Motors
UMC		Uniform Mechanical Code
Local Codes		
Seattle Building Code		
Seattle Fire Code		
Seattle Mechanical Code		
Seattle Electrical Code		
Seattle Energy Code		
Washington State Energy Code		

Acronyms and Abbreviations

ACI: American Concrete Institute
ADA: Americans with Disabilities Act
AMCA: Air Movement and Control Association
ANSI: American National Standards Institute
ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers
AWS: American Welding Society
AWWA: American Water Works Association
IBC: International Building Code
IEEE: Institute of Electrical and Electronics Engineers
NEC: National Electrical Code
NEMA: National Electrical Manufacturers Association
NFPA: National Fire Protection Association
UBC: Uniform Building
UFC: Uniform Fire Code
UMC: Uniform Mechanical Code

11.3.2 Regulations

All pump stations must be built to the currently adopted version of applicable City of Seattle, Washington State, and federal codes and requirements including local building, fire, safety, and electrical codes. SDCI and Seattle Department of Transportation (SDOT) maintain current lists of City construction codes. Table 11-6 shows City and Washington State regulations that commonly apply to pump stations. This is not an exhaustive list.

Table 11-6
City and State Standards and Codes for Pump Stations

Code	Document
City of Seattle	
Seattle Streets Illustrated	SDOT Director's Rule/SDCI DR 31-2017/SDOT Rule 04-2017
Stormwater Code	City of Seattle Stormwater Code (SMC 22.800 – 22.808) City of Seattle 2021 Stormwater Manual
Side Sewer Code	Side Sewer Code (SMC 21.16) SDCI/SPU Requirements for Design and Construction of Side Sewers Directors' Rule 4-2011 (Drainage and Wastewater Discharges)
Right-of-Way Opening and Restoration Rules	SDOT Right-of-Way Opening and Restoration Rules (SDOT DR 01-2017)
Right of Way Improvement Manual	SDOT Right of Way Improvement Manual (Streets Illustrated)
City Standard Plans and Specifications	City of Seattle Standard Specifications for Road, Bridge, and Municipal Construction and Standard Plans for Municipal Construction
Noise Ordinance	Noise Abatement, SMC 25.08
Seattle Land Use Code	Seattle Land Use and Zoning Code, SMC 23
Seattle Plumbing Code	Washington State Plumbing Code with Seattle amendments, 2018
Seattle Building Code	International Building Code w/ Seattle amendments, 2018
Seattle Electrical Code	National Electrical Code w/ Seattle amendments, 2020
Seattle Mechanical Code	International Mechanical Code with Seattle amendments, 2018
Street Use Code	Street Use Code, SMC 15
Seattle Fire Code	Seattle Fire Code, 2015

Source: www.seattle.gov

Acronyms and Abbreviations
DWW: drainage and wastewater
SDCI: Seattle Department of Construction and Inspections
SDOT: Seattle Department of Transportation
SMC: Seattle Municipal Code
WAC: Washington Administrative Code

11.4 BASIS OF DESIGN

Basis of Design documentation communicates design intent to plan reviewers and future users of a constructed facility. Documenting the Basis of Design and archiving it with the project record drawings provides future staff access to historical design decisions. For pump stations, assumptions and design criteria for capacity, level of service, and future conditions are particularly important to document.

The design engineer must prepare a basis of design memorandum for each pump station project, including minor modifications. See *DSG Chapter 1, Design Process* for general requirements of documenting the Basis of Design.

11.4.1 Basis of Design Plan Sheet

In addition to the basis of design memorandum, a basis of design plan sheet must be prepared as part of the design package. See *DSG Chapter 1, Design Process*. The basis of design plan sheet is a general sheet that shows an overview of key operating information and lists significant design assumptions and requirements for major design elements.

- The design engineer must include a basis of design plan sheet in the plan set.
- The sheet must be archived with the record drawings.

The basis of design plan sheet is not intended for construction and should **not** be included with the bid set. The sheet is inserted after completion of bidding for the project and archived with the record drawings.

In general, the Basis of Design Plan Sheet should address design parameters and assumptions for Civil, Mechanical (pumping system and HVAC), Electrical, and Structural disciplines. The sheet need not address existing systems that are not part of the project scope.

An example Basis of Design Plan Sheet is shown in Appendix F. This example is not exhaustive. The designer may modify the content of the sheet to suit individual projects.

11.5 DESIGN PROCESS

For a general discussion of the SPU design process, see *DSG Chapter 1, Design Process.* This section describes additional items for pump station design.

11.5.1 Planning

Long range planning for system upgrades and rehabilitation is managed by the Line of Business Representative for each type of station (water, wastewater, drainage). Two planning mechanisms are used, depending on the needs.

11.5.1.1 Non-Programmatic Projects

Non-programmatic projects are meant to address a specific need at a specific location. Examples of these projects could include building new ground-up facilities, significantly expanding the capacity of existing facilities, or altering the function or operation of an existing facility in a significant way. These projects are typically complex and may be funded from a variety of sources outside of normal pump station lines of business depending on the changes planned. These projects will generally go through Stage Gates 1 and 2 individually for budgeting and authorization.

11.5.1.2 Programmatic Projects

Programmatic projects serve an ongoing need system-wide and are typically used to rehabilitate existing stations. While these projects may make substantial alterations, they chiefly serve to extend the useful lives of the stations more or less within the existing footprint. Programmatic projects are usually prioritized according to an asset management strategy. For example, SPU uses a combined criticality and failure risk score to prioritize wastewater projects. This method considers the condition of existing assets, probability of failure, as well as consequences of failure to determine the most acute needs.

Programmatic spending and projects are generally laid out for at least six years and updated every three years along with SPU's spending and rate path. Programmatic projects are authorized at the program level and do not need to go through Stage Gates 1 and 2 individually.

11.5.2 Project Scoping

Scoping for pump station projects, especially retrofits, must be developed in a team setting with engineers, Operations crews, and the LOB representative. The team should review existing conditions in the field with Operations staff to identify operational needs and existing difficulties that could be improved through the project.

Retrofit projects should strive to comprehensively address existing performance issues, deficiencies in operability and maintainability, and code compliance issues. Completed projects should leave the facility in like-new condition, ready to serve for the next major lifecycle. Piecemeal projects are not efficient and are strongly discouraged. SPU has had poor experience with partial projects generating costly rework during subsequent upgrades.

11.5.3 Design Review

Design documents should be circulated at each milestone as required in *DSG Chapter 1, Design Process.* The standard circulation list for pump station projects is included in Appendix 11H.

In addition to the normal circulation process, the design team must review all designs with SPU Operations staff just before each major design milestone (30%, 60%, 90%). Operations reviews should take place in a workshop setting with the design team and representatives of each operations discipline. Workshops should cover proposed equipment, layouts, access, maintenance procedures, and any potential deviations from design standards. Use visual aids such as 3D CAD models, marked up photographs, or other exhibits to clearly illustrate each discussion topic. All feedback received must be documented clearly in the project record. Work with the Line of Business Representative for review and approval of any requested scope changes.

11.5.4 Design Process Documents

This section describes design process deliverables for a typical pump station retrofit or new facility.

11.5.4.1 Preliminary Engineering Report

Typically, the preliminary engineering report for a pump station is submitted to DOH (water pump station) or Ecology (wastewater and drainage pump station) for approval before final design. The report may be used to develop environmental documentation. It should focus on alternative analysis and development of design criteria and details for the selected alternative (Table 11-7).

Table 11-7
Typical Content of a Preliminary Engineering Report for Pump Station Design

Section	Description
Section 1: Introduction	Project background info and objective: desired level of service, need for project, and facilities to be constructed.
Section 2: Business Case Documentation	Standalone document (summary) submitted to Asset Management Committee (AMC) for business case approval, which includes background, objective, options, benefit/cost analysis, and recommendations.
Section 3: Facility Selection	Alternatives (if any) for site locations, facility configurations and layouts. Must discuss geotechnical characteristics. Should include alternative analysis and risk/value modeling and site plans of most viable alternatives.
Section 4: Pump Selection	Discussion of number of pumps and their capacities, design discharge pressures, and motor sizing. Includes a process flow diagram.
Section 5: Facility Operation & Control	Discussion of upstream and downstream system elements (e.g., tanks, other stations, and plants), process mechanical for pump station piping and valves, and pumping unit controls and instrumentation.
Section 6: Electrical	Description of potential service supply, proposed electrical loads, voltages, motor starting, and lighting.
Section 7: Structural and Architectural	Description of structural and building codes and assumptions for pump station design. Presents criteria facilities are expected to comply with (e.g., exterior building shell types). For above-grade, includes an architectural rendering.
Section 8: Building Mechanical	Description of the building mechanical codes and assumptions for pump station design. Presents criteria that the facilities are expected to comply with (e.g., required air changes per hour).
Section 9: Cost and Schedule	Planning level cost estimate and detailed project schedule.
Appendix	The following items included (as appropriate): • Business case and cost estimate • Draft specs for major equipment • Equipment data sheets for major equipment • Geotechnical Report • Hydraulic calculations and pump selection analysis • Key project meeting minutes or decision documents • Memo on Project Delivery Analysis (design build or conventional procurement) • PE drawings: cover sheet, location map, Basis of Design Plan Sheet, code compliance sheet, site plan (buildings, staging, roads, major drainage features and sensitive areas), architectural rendering, facility floorplan and facility roof plan, process flow, major equipment layout, key building sections, electrical one-line diagram, prelim P&ID, control architecture, sheet &spec list finished design • Preliminary design calculations • State Environmental Policy Act (SEPA) Checklist

11.5.4.2 Design Calculations

Pumping station projects require many calculations from each design discipline. Applicable assumptions and design criteria should be included on each calculation sheet and also documented in the Basis of Design memorandum. Calculations must be reviewed by the Checker at each design milestone. See *DSG Chapter 1, Design Process.*

Typical calculations required for a pump station upgrade or new design project are shown in Table 11-8. Some calculations may not be applicable, especially for retrofit projects. Additional project-specific calculations may be required.

Table 11-8
Typical Pump Station Design Calculations

Process/Mechanical	Structural	Electrical/ I&C	Geotechnical	HVAC/Plumbing
Hydraulic profiles and energy grade line	Sizing base slab, walls, and roofs	Light and various load calculations	Soil borings and bearing pressures	Air exchanges per hour with sizing of ductwork and ventilation fans
System curves and pump selection	Reinforcement sizing and schedule	Generator, transformer, and MCC sizing	Soil classification and design parameters	Potable water and gas demands
Wet well volume	Loadings for cranes	Voltage drops	Soil loadings	
Fuel storage demands	Equipment pad design	Utility/grid connection/protection	Seismic design coefficients	
Surge analysis and air/vacuum needs	Loadings for gratings and framing	PLC integration with existing SCADA	Potential ground settlement analysis	
Pipe sizing	Piping support	Arc flash hazard analysis		

Acronyms and Abbreviations
HVAC: heating, ventilation, and air conditioning
I&C: Instrumentation and Control
MCC: motor control center
PLC: programmable logic controller
SCADA: supervisory control and data acquisition

11.5.4.3 Design Documents

Design packages for pump station projects must comply with the standard design package deliverable checklists for all projects shown in *DSG Chapter 1, Design Process*.

The following additional deliverables are specific to pump station projects and are required at certain milestones as shown in Table 11-9 below.

Table 11-9
Additional Design Deliverables for Pump Station Projects

Requirements	30%	60%	90%	Final	Commissioning
Deliverable					
Facility Bypass Plan	D	F			
Recommended Preventative Maintenance Schedules			D	D	F
Standard Operating Procedures				D	F
Facility Operations and Maintenance Manual			D	D	F
Protective Device Coordination Study and Arc Flash Hazard Analysis					F
Process and Instrumentation Diagrams (P&IDs)	D	F			
Control Loop Descriptions		D	D	F	F
Calculations (All disciplines)	D	D	D	F	
Equipment Data Sheets	D	D	D	D	F
Asset Onboarding Tasks		D	D	D	F

D: Draft
F: Final

11.5.4.4 Project Manual

This section provides specifics on project manuals for pump stations.

A. Technical Specifications

SPU has adopted CSI as its standard for construction specifications on pump station and electrical projects. Unless the pump station is part of a large project formatted in APWA style, it must use CSI format. APWA specifications are generally written for roadway projects. Pump stations contain a great deal of electrical and mechanical equipment. Specialized subcontractors are needed on large electrical/mechanical projects. For each specialty, specifications are generally presented in more detail than is typical in APWA format.

B. Standard Specifications

City and SPU Standard Specifications govern many specific work items for construction contracts. However, not all SPU Standard Specifications have been converted to CSI. Design teams should work with their assigned Public Works Contracting engineer to determine how to incorporate City and SPU standard specifications that have no CSI equivalents.

For example technical specifications for pump station installations, see **Appendix 11A - Example Pump Station CSI Specifications**.

11.5.4.5 Equipment Data Sheets

During preliminary design, the design engineer should develop equipment data sheets for major pieces of equipment. At a minimum, an equipment data sheet must be developed for all equipment, instruments, and items that require power (including heating, ventilation, and air conditioning [HVAC], plumbing, SCADA, security, and architectural items).

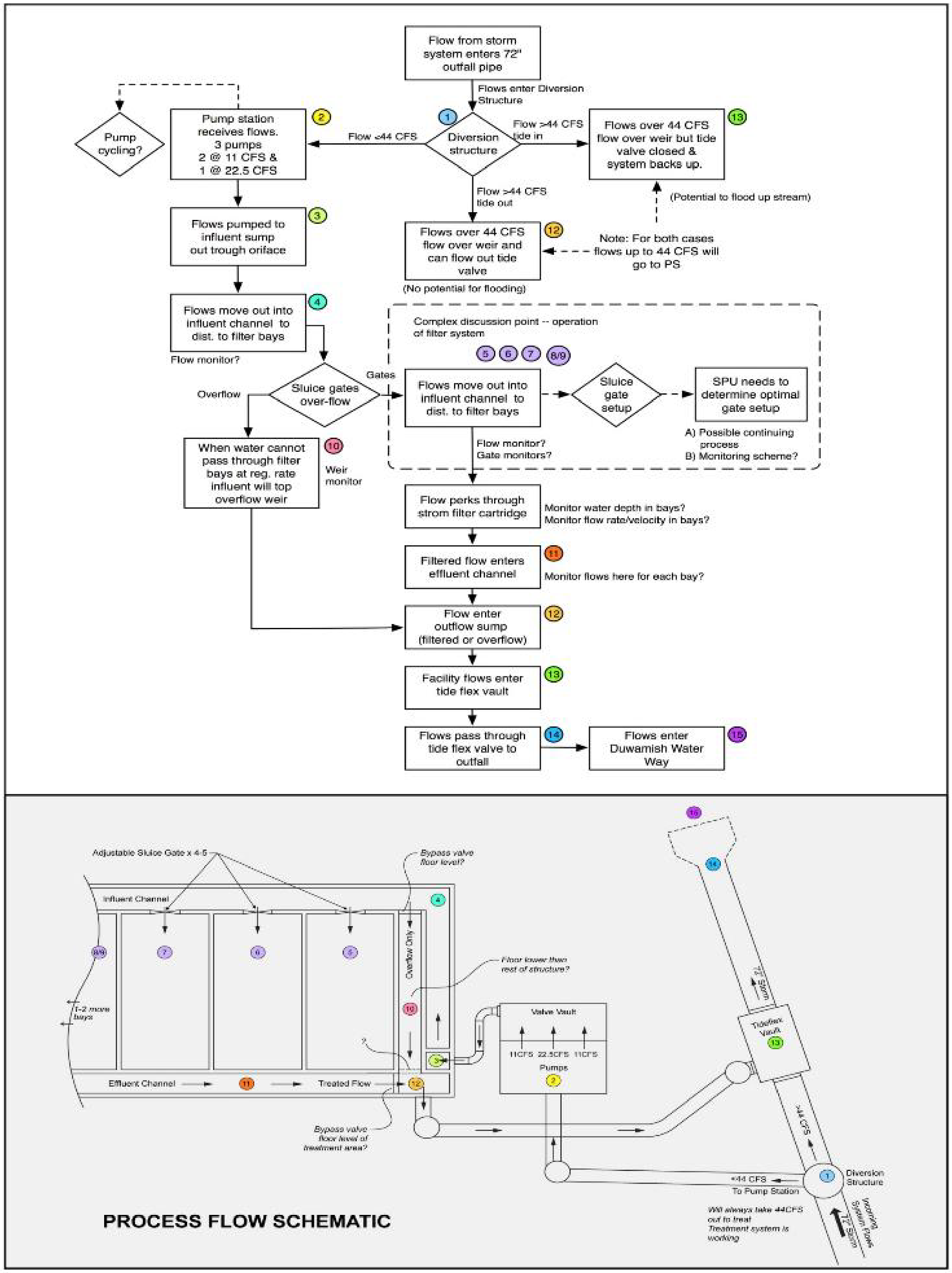
For an example for equipment data sheets, see **Appendix 11E - Equipment Data Sheet Template**.

11.5.4.6 Process Flow Diagrams

Process flow diagrams are simplified drawings that clarify a process. For pump station design, the diagrams should demonstrate the intended flow paths, hydraulic controls and monitoring points. Figure 11-3 shows an example of a typical process flow diagram.

If I&C is associated with the process, the technical specifications must include a description of each process control loop in Section 40 90 05.

Figure 11-3
Example Process Flow Schematic: South Park Pump Station and Water Quality Facilities



Acronyms and Abbreviations

CFS: cubic feet of water per second
PS: pump station

11.6 DISCIPLINE-SPECIFIC DESIGN CONSIDERATIONS

This section presents design considerations specific to individual disciplines within the pump station design team, including civil; mechanical; structural; electrical; and instrumentation, monitoring, and controls. See *DSG Chapter 4, General Design Considerations* for general design considerations that apply to all SPU projects.

11.6.1 Civil

Additional civil engineering design considerations for pump stations include access, parking, electrical vehicle charging stations, pipeline corridors, bypass pumping, flood protection, water supply backflow prevention, future expansion, physical security elements, hydrants, and influent screening.

11.6.1.1 Access

Refer to *DSG Chapter 4, General Design Considerations* for general considerations for access, hatch sizing and layouts. The additional guidance presented in this section is specific to pump stations and must be considered in conjunction with the requirements of Chapter 4.

Table 11-10 shows SPU's preferred access types for pumping stations.

Table 11-10
Preferred Equipment Access

Item	Most Desirable	Acceptable
Access to Pumps at Grade (if applicable)	Pump station to be located on grade and a rollup door provided to move equipment in and out	7-ft-high, 6-ft-wide double door
Access to Pump not at Grade	Internal stairwell	Ladder access
Large Access Hatch for Lifting Equipment and Cleaning	Equipment dimension plus 10-inch minimum on all sides; overall minimum of 36 inches x 42 inches	Equipment dimension plus 6-inch minimum on all sides, overall minimum of 36 inches x 36 inches Hatches 6-ft wide and greater must be a double door
Lifting Mechanism for Removal	Boom truck access preferred, then crane hoist. If roll up door is provided on grade, boom truck access not required	Crane hoist or overhead traveling crane. Lifting points must be centered over equipment, and accessible from working surfaces (gratings). Gratings under lifting points must have removable panels.
Clearance	8-ft minimum under lifting hoist, subject to overall equipment size	Largest equipment dimension in hoisting orientation, plus 2 ft between bottom of equipment and any other equipment in the station that must be crossed over, plus rigging height

Item	Most Desirable	Acceptable
Internal Lifting for Maintenance Inside Station	Internal crane access (jib crane or bridge crane typical)	Eyebolts or similar overhead lifting points located over the center of mass of each piece of equipment (pumps, valves, etc). Gratings under lifting points must have removable panels.

Acronyms and Abbreviations
ft: feet/foot

A. Vehicle Access

Pump stations must be arranged to allow a boom truck to lift major equipment, such as pumps, motors, and valves, completely out of the pump station. Verify that adequate flat, firm ground is available for boom trucks to park sufficiently close to access hatchways within the appropriate maximum lifting radius for equipment to be accessed. If site constraints prohibit equipment lifting by boom truck, fixed equipment lifting hoists and conveyance systems must be provided.

Wastewater stations must allow for vacuum truck access to the wet well. This includes a clear path from the wet well access hatch to the lowest point of the well. Working platforms located directly below the hatch must include hinged or removable grating panels that allow vacuum tubes to pass through the platform.

B. Doors and Hatches

Coordinate access hatch locations, sizes, and features with SPU Operations. Hatches for personnel access must provide enough space for a retrieval tripod to be set up over the opening or be equipped with a removable davit arm. Hatches must include a padlock hasp that can accommodate SPU's standard padlocks.

Both wet and dry wells at drainage and wastewater stations must be equipped with one or more hatches sufficient to allow installation and removal of pumps and other large equipment.

C. Lifting

Cranes, eyebolts, and other internal lifting fixtures must be sized with adequate capacity to allow use of manual or electric hoists when lifting the largest piece of equipment within their working area. Load ratings must be clearly stenciled or placarded on or adjacent to each fixture.

11.6.1.2 Parking

Refer to section 4.3.1.1 of *DSG Chapter 4, General Design Considerations* for general parking requirements. A minimum of two parking spaces must be provided for all pump stations. Additional requirements in the Land Use Code (Seattle Municipal Code Title 23) may apply. Where sites are not secured, sign all dedicated parking as 'Exempt Vehicles (D) Only'.

Dedicated space must be provided for a portable generator at all pump stations. This space must be located adjacent to the generator plug.

11.6.1.3 Electric Vehicle Charging Stations

Pump stations must include level 2 Electric Vehicle Service Equipment capable of charging at least two vehicles concurrently. Stations must comply with the City of Seattle standards for charging stations currently in place at the time the project is designed.

For sites without fencing or where electric vehicle charging stations cannot be practically secured, charging stations may be omitted with the consent of SPU Operations.

11.6.1.4 Physical Security

Refer to *DSG Chapter 15, Physical Security* for security requirements at SPU pump stations.

11.6.1.5 Signage

Refer to section 4.14 of *DSG Chapter 4, General Design Considerations* for typical minimum signage requirements at SPU facilities. Pump station facility identification signage must be provided in addition to these minimum requirements. Facility identification signs must be 18 inches by 24 inches and retroreflective following the standard design shown in Figure 11-4 below.

Figure 11-4
Typical Pump Station Identification Signage

11.6.1.6 Pipeline Corridor

For conduit, force main, and other pipeline corridor design elements, including easement requirements, see *DSG Chapter 4, General Design Considerations*.

The following additional guidance is specific to pump stations:

- Pipes should enter and exit structures perpendicular to the structure wall whenever possible.
- Parking over the pipeline corridor is acceptable for normal vehicles and portable equipment. Non-permanent or non-critical features such as landscaping may also be located over the pipeline.
- If the corridor is under a crane setup area, extra pipeline protection, such as concrete encasement or additional cover, must be incorporated to protect buried utilities from heavy loads.

11.6.1.7 Fire Hydrants

Depending on facility size and operations, a protective fire loop may be needed around the facility. For hydrant requirements, see Seattle Fire Department and SDCI requirements, in addition to *DSG Chapter 5, Water Infrastructure*.

11.6.1.8 Water Service and Backflow Prevention

Water services for pump stations are provided for a number of uses. The requirements differ depending on the type of facility.

A. Water Pump Stations

Provide a domestic water service (minimum 1-inch diameter) on the premises for maintenance and washdown needs. Backflow prevention is not typically required for water pump stations, unless a site-specific hazard exists, such as an irrigation system or fire suppression system. In general, water services for water pump stations should be designed to avoid the need for backflow prevention.

B. Wastewater and Drainage Pump Stations

All SPU wastewater and drainage pump stations must have a domestic water service (minimum 1-inch diameter) on the premises for maintenance and washdown needs. Cross-connection control must be provided in accordance with DOH requirements (WAC 246-290-490). Water services should be terminated outside the station with a hose bibb with an adjacent shutoff valve buried in a standard valve box.

11.6.1.9 Flood Protection

A. All Grades

To reduce flooding risk and facilitate easy cleanup, the floors of buildings and outdoor equipment pads at all grades must be built at least 6 inches above the surrounding finished grade. Sites must be graded to ensure that surface waters drain away from hatches, doors, and other openings.

B. 100-Year Flood Zone

All pump stations must remain in operation during a 100-year flood event in accordance with Ecology's *Washington Criteria for Sewer Works Design*. The 100-year flood levels are shown on FEMA flood maps. These maps are available from the FEMA Map Service Center or as hardcopy FEMA maps from SPU or SDCI GIS. Where there is a risk of site flooding, SPU recommends site grading as the method for elevating the structures above the 100-year flood level.

When a water or drainage and wastewater facility requires installation within the 100-year flood zone, special provisions must be incorporated into site and facility design to allow the facility to operate when flooded. These special provisions may include one or more of the following:

- Provide equipment that can be operated while submerged, e.g., submersible pumps, motors, power cables, and connections. For wet well/dry well stations, use immersible motor pumps with integrated closed-loop cooling systems.
- Raise building floors and equipment pads above the 100-year flood elevation.

- Raise access and equipment hatches above the 100-year flood elevation line and/or install watertight access hatches.
- Provide an earthen embankment around the site to a height above the 100-year flood elevation, with a small pump station for removal of stormwater collected within the earthen embankment; this method may result in higher operating cost.
- Consider over-sized or redundant sump pumps in dry wells and equipment rooms.

Protection of water supply pump stations from 100-year flood waters is critical to protecting public health during a flood. Extra care should be taken during design and construction to prevent contamination of the water supply by flood water.

<u>In all facility types, the electrical equipment including motor control centers (MCCs), variable frequency drives (VFDs), main panels, and backup power supplies must be protected from 100-year flood waters</u>.

C. Seal Level Rise, Coastal Flooding, and Climate Change Resiliency

SPU does not have a currently adopted policy for design of facilities in areas subject to future inundation as a result of climate change induced sea level rise. Many of SPU's waterfront stations are vulnerable to this.

It is often not practical to elevate structure entrances and hatchways above future flood elevations. In these cases, consider other mitigation measures such as watertight hatchways, redundant sump pumps, facility relocation, site regrading, and others. Work with the LOB Representative and SPU Operations to determine the most appropriate flood-proofing measures for each project.

11.6.1.10 Future Expansion Considerations

For general future expansion planning requirements, see *DSG Chapter 4, General Design Considerations*. The following additional guidance is specific to pump stations:

Expansion planning requirements for pump stations should be determined by the LOB representative during project scoping. Future elements for pumping stations could include:

- Permanent backup power supply
- Additional pumping equipment and associated motor controls
- Additional storage capacity
- Force main replacement
- Odor control

Clearly identify planned future improvements on the design drawings so that design intent can be documented for future designers. When possible, design and install provisions for future equipment in a way that allows installation to be completed with minimal disruption to ongoing facility operations. This can include routing empty conduits and ducts to future equipment locations and providing empty pump bays and empty MCC sections or buckets. Where future pumps are planned, provide piping connection points with isolation valves.

11.6.1.11 Utilities

All pumping facilities require one or more utility services (e.g., electrical, water, sewer, natural gas, and communications). The availability and capacity of existing utilities should be investigated and compared with the estimated demands of a new facility.

Power lines at or near the site do not guarantee that ample electrical capacity or the appropriate type of service will be available. New services or additional capacity may be required. One common example of additional capacity need is a small pump station for a residential area. While the residential power lines may have excess capacity, they may only provide 240V, 1-phase service. Most pumps require 480V, 3-phase. In such cases, new power lines must be brought to the site from a 480V transformer, which the local utility must design and install. See Section 11.6.4 for more information about electrical utility service requirements. See also DSG Chapter 9, Electrical Design.

Typical utilities required for water supply and wastewater pump stations are shown below (Table 11-11). This list should be verified for each project.

Table 11-11
Typical Utility Requirements for Pump Stations

Utility	Primary Uses	Wastewater Pump Stations		Water Pump Stations
		Small Facilities	Large Facilities	
		Small Facilities	Large Facilities	
Electrical	Pumps	480V (3-phase)	480V (3-phase) Medium voltage may be required for large facilities	480V (3-phase) Medium voltage (4,160 V) is used at several existing larger facilities
Communications	SCADA/Telemetry	CenturyLink phone connection, as directed by SPU SCADA		
Natural Gas	Space heating and standby power	None	As needed Minimum ¾ inch connection	As needed Minimum ¾ inch connection
Potable Water Supply	Restrooms, drinking fountains and fire protection	Backflow prevention provisions required. See *DSG Chapter 17, Water Service Connections*		
Washdown Water[1]	Cleaning	Minimum 1-in service required		Recommended
Sewage	Internal plumbing External side sewer	Floor drains		Floor drains Bathrooms recommended
Storm Drain	External Service Drain	4 inch if required	6 inch or larger per site requirements	6 inch or larger per site requirements
Flushing Water[2]	Pump seal flushing	3/4 inch to 1 inch if required		Recommended

Notes

[1] Washdown water system connected to a potable water supply or a reclaimed water source must have step-down pressure valve and backflow protection as required by the DOH and the Uniform Plumbing Code.

[2] Flushing water systems, if supplied by a potable water source, must have an air-gap separation from the potable supply system. In-line pressure reduction and backflow preventions are not allowed for this application.

Acronyms and Abbreviations
DOH: Washington State Department of Health
SCADA: supervisory control and data acquisition
V: volt

Natural gas and other fossil fuel sources are being phased out of use at City facilities. Newly constructed facilities must use electrical power for building and water heating. Retrofit projects must replace existing fossil fuel equipment with electrically powered equipment. Refer to resources from the City's Office of Sustainable Energy when determining energy code requirements for new and retrofitted facilities.

11.6.1.12 Painting and Coatings

Painting should be used to protect the integrity of structures, piping, and equipment and to indicate the process of exposed piping and equipment (Table 11-12). In general, paints should be a heavy-duty, abrasion-resistant coating system suitable for the environment to which it is exposed. For piping, the flow direction of the fluid or gas conveyed must be shown on the exterior of the pipe to help facilitate O&M activities. Manufactured process labels may be used in lieu of painting.

Table 11-12
Pump Station Standard Paint Coloring Scheme

Piping System or Equipment	Solid Color	Color Band	Letter Code	Letter Color
Buildings				
Buildings (Inside)	White			
Wastewater Dry Wells (Walls and Ceiling)	Light Green (Fed Std Color 24583)			
Wastewater Dry Wells (Floors)	Burgundy (Fed Std Color 30152)			
Ceiling Panels & Structural Steel	White			
Drain – Gravity (Sewage)	Black		Drain	White
Drain – Suction or Pressure (Process)	White		Drain	Black
Equipment – General				
Exit Doors – Industrial			Exit	
Fire Hydrants – Potable: Barrel & Dome Nozzle Cap, Top Nut & Shield	 Silver Green	Dk Blue/ White	PW	White
Fire Hydrants – Plant Water Chlorinated Barrel & Dome Nozzle Cap, Top Nut & Shield	 Silver Green	Lt Blue/ Yellow	PWC	White
Gates & Operators	Black			

Piping System or Equipment	Solid Color	Color Band	Letter Code	Letter Color
HVAC Unit	Dark Gray			
Hydraulic Fluid	Orange		Hyd Fluid	White
Meter Station Cabinets	Russet			
Natural Gas	Red		NG	White
Oil	Orange		Oil	White
Overflow – Emergency	Gray	Brown	Overflow	White
Pumps, Motors, Gear Drives	Green			
Safety Equipment Storage	Green			
Sample – Sewage or Sludge	White	Brown	Sample	Black
Sewage – Raw	Black		Sewage	White
Structural Steel	Black			
Valve Heads & Operators (Inside)	Red			White
Valve Heads & Operators (Outside)	Red			
Vent (Odor Control)	White		Vent	Black
Vent (Sewage)	Black		Vent	White
Ventilation Units – Inside	Gray or Alum			
Ventilation Units – Outside	White			
Water – Fire	Dk Blue		Fire	White
Water – Hot Potable	Dk Blue	White	HW	White
Water – Hot Service	Lt Blue	Red	HW	White
Water – Non Potable, Non Chlorinated	Lt Blue	Brown	Sec Effluent	White
Water – Plant Water Chlorinated	Lt Blue	Yellow	PWC	White
Water – Potable	Dk Blue	White	PW	White
Water – Service	Lt Blue	Red	SW	White
Water – Service, Return	Lt Blue	Red	SW Ret	White

Floor coatings for areas subject to water and washdown must include a non-skid aggregate treatment unless otherwise requested by SPU Operations.

11.6.2 Mechanical (Ventilation and Ancillary Systems)

Mechanical engineering design considerations include HVAC, plumbing, sump pumps, and fire suppression.

Pumping system design is discussed in Section 11.7.

11.6.2.1 Heating, Ventilation, and Air Conditioning (HVAC)

A. Applicable Codes and Standards

Commonly referenced codes and standards for HVAC design include the Seattle Mechanical Code, American Society of Heating, Refrigerating, and Air Conditioning (ASHRAE) Standards, and NFPA 820 (Standard for Fire Protection in Wastewater Treatment and Collection Facilities). Additional codes and standards may apply. It is the responsibility of the designer to determine which codes and standards apply to a particular project.

B. SPU Design Requirements

<u>The following design requirements for ventilation systems must be met for retrofit and new construction of all wastewater and drainage pump stations.</u> Where these requirements are in conflict with other applicable codes, the more stringent criteria will apply.

- Dry well ventilation systems must be designed such that dry wells receive an unclassified hazard classification as described in the National Electrical Code (NEC) and NFPA 820.
- Wet well ventilation systems may be designed such that wet wells receive a Class I Division I hazard classification as described in the NEC and NFPA 820. Downgrading of this space is not typically required.
- Ventilation system for electrical spaces and equipment rooms (both above and belowground) must be designed to allow these spaces to receive an "unclassified" hazard classification as described in the NEC and NFPA 820. Electrical spaces must be provided with ventilation systems similar to those required for dry wells.
- All piping/conduit penetrations must be gas-tight.
- All conduits going to and from wet wells must have code-approved seal-offs.
- Dry wells must be physically separated from adjacent wet wells.
- General duct criteria:
  - Sizing and airflow velocity: Minimum 6-inches in diameter, recommended airflow velocity of 1,500 feet per minute (ft/min); velocities up to 2,000 ft/min maximum are acceptable. See Table 11-14 for capacities of various duct sizes based on the recommended and maximum velocities.
  - Duct Material:
    - Dry well: Galvanized steel or aluminum. Anchors and supports should be either galvanized or stainless steel.
    - Wet well: Stainless steel or plastic (polyvinyl chloride [PVC], fiberglass-reinforced plastic [FRP]) ducts. Anchors should also be stainless steel. Supports should be stainless steel or FRP.
- Balancing dampers: Materials to match the duct and should be provided on all ducts so the ventilation system can be balanced to maintain required space pressurizations relative to ambient.
- Discharge:

  - Dry well: Spaces within typical SPU pump stations tend to be small and air draw-off or discharge within the space is typically not a primary concern since adequate mixing will occur in the spaces due to duct discharge and intake velocities. Where possible, the supply air should discharge into the upper level of each dry well "floor" or "level" and the exhaust draw-off location should be located near the bottom of these spaces.
  - Wet well: The supply air should be discharged at a level above any grating/landing level or High Alarm level, whichever is highest. Exhaust systems in wet wells should be located above the overflow level and pull air from under the roof deck as close as possible.
  - Egg-crate type registers are recommended for exhaust air inlets on all pump stations and may be used on supply air discharges for small to mid-size pump stations. Large pump stations (greater than 15 ft across) should use a supply diffuser with air throw distance and directionality as appropriate for the installation.
- Exterior exhaust outlet locations:
  - Dry well: <u>A dry well discharge vent pipe must be at least 10 ft away from the supply air intake and any doors or hatches into the dry well, wet well, or electrical vault</u>.
  - Wet well: <u>A wet well discharge vent pipe must be at least 10 ft away from the supply air intake and any doors or hatches into the dry well, wet well, or electrical vault</u>. Untreated air outlets should generally be at least 8 feet above finished grade.
- Dry well supply and exhaust fans:
  - General: Supply and exhaust fans should have the same capacity to allow for easier balancing.
  - Type: In-line, direct drive centrifugal with speed control. Speed control must be located within the fan housing (not readily accessible to tampering).
  - Material: Aluminum with corrosion-resistant coating.
  - Motor enclosure and voltage: totally enclosed fan cooled (TEFC) or open drip proof (ODP), minimum 120-volt (V) single phase.
- Wet well exhaust fans:
  - Type: In-line centrifugal.
  - Material: FRP, where available, aluminum with corrosion-resistant coating elsewhere.
- Motor enclosure and voltage: Air Movement and Control Association (AMCA) Type A or Type B, minimum 120-V single phase. Explosion-proof rated motors (EXP) are required for fans located within classified spaces.
- Physical separation of wet wells and dry wells:
  - <u>Any existing leaking piping/conduit penetrations must be sealed with non-shrink epoxy grout or similar type material</u>.
  - <u>All conduits going to and from wet wells must have code-approved seal-offs if not already installed</u>. <u>Seal-offs must be installed if not included on an</u>

existing conduit. All existing seal-off fittings should be inspected for adequate sealing compound.

- Existing access doors between dry wells and wet wells must be removed and the openings sealed. Alternate means of access to wet wells may need to be constructed for retrofitted stations.
- Existing ventilation openings between wet wells and dry wells must be permanently sealed with non-shrink epoxy grout or a similar material. Separate ventilation systems for wet and dry wells must be provided.

- Dry well ventilation monitoring and alarm requirements for unclassified space:
  - Operation of the ventilation equipment is required to be continuously monitored per NFPA 820. A flow detection device that is connected to the SCADA building data monitoring system must be provided for each fan. Thermal dispersion flow switches are SPU's preferred flow detection device.
  - As required by code, non-audible signals consisting of a dual light (green light/red light) alarm system must be provided at the entrance of the dry well. This device should be located just inside each dry well access hatch or door, such that it is easily visible from outside.
  - Fire extinguishers must be provided in dry wells per NFPA 820.

- Filtration: Depending on the specific location and design of each pump station, filtration may be required on dry well and/or wet well ventilation systems.
- Dry well and wet well supply air filtration is required where stations are exposed to salt-bearing marine air (typical for stations located along the waterfront). If left unfiltered, corrosive salt air can accelerate deterioration of sensitive electrical and mechanical equipment, as well as the facility as a whole.
  - Wet well exhaust filtration is required for stations with fats, oils, and grease in the influent. This is especially important at stations with turbulent wet wells or large plunges from the inflow pipe to the wet well surface. Filtration should be placed on the suction side of exhaust fans. If left unfiltered, aerosolized grease in the airstream can build up on fan impeller blades, throwing them out of balance and destroying bearings far ahead of their life expectancy.

SPU is piloting filter systems on several stations but does not have a standardized filter system at this time. In general, mist elimination filters, such as those commonly specified with odor control systems, should be used. Filter housings should drain to the dry well sump, or wet well. Contact the Line of Business Representative for current guidance on filtration systems.

C. Air Exchange and Duct Velocity Requirements

Air change standards determine, in part, the electrical classification, and thus design requirements, for each space in a wastewater pump station. Table 11-13 lists the required air exchanges for commonly used spaces. Table 11-14 shows recommended duct sizing and maximum velocities that are typically associated with acceptable noise levels.

Table 11-13
Standard Air Exchanges per Hour

Location or Area	Minimum Air Changes/Hour
Equipment Rooms	15
Underground Vaults	12
Emergency Ventilation for Wastewater Head Space	15-60
Wastewater Pump Station Wet Well, where Odor is not a Concern – Design as Class 1, Div 1 per NFPA 820	12
Wastewater Pump Station Wet Well, where Odor is a Concern – Design as Class 1, Div. 1 per NFPA 820	Greater of 4 ACH or maximum influent rate
CSO Facility Storage Tank	Greater of 2 ACH or maximum influent rate
Wastewater Pump Station Dry Well – Unclassified (NFPA 820)	>8[1]

Notes: 1.) NFPA 820 requires minimum 6 air changes per hour in this space to obtain an unclassified space rating. SPU prefers a higher ventilation rate as shown.

Acronyms and Abbreviations
ACH: air changes per hour
NFPA: National Fire Protection Association

Table 11-14
Recommended Duct Sizing

Duct Diameter (inches)	Recommended Velocity (ft/min)	Airflow Quantity (cfm)	Maximum Velocity (ft/min)	Airflow Quantity (cfm)
6	1,500	290	2,000	390
8	1,500	520	2,000	690
10	1,500	810	2,000	1,090
12	1,500	1,170	2,000	1,570

Acronyms and Abbreviations
cfm: cubic feet per minute
ft/min: feet per minute

For water pump stations, including below-grade spaces, follow applicable building and mechanical codes and standard practices for industrial buildings when determining the required number of air exchanges. For facilities with water chemical addition (e.g., chlorine), the design engineer must research applicable codes and requirements.

D. Insect and Pest Screening

Screening must be provided on all louvers for equipment cabinets and enclosures, as well as vent intakes and outlets. Screening must be a combination of heavy-duty stainless steel mesh (suitable for bird and small animals) as well as fine mesh suitable for insects.

E. Temperature Management

The design engineer should account for the effect of outside temperature with the design of the drywell ventilation system. Ventilating the dry well at six air exchanges per hour (ACH) and higher will heat the space if the outdoor temperature is higher than the indoor temperature. This can be problematic in spaces with temperature-sensitive electrical equipment and periods of extreme outdoor air temperatures.

The design engineer should account for the effect of low outside temperatures on the design of the dry well ventilation system. Ventilating the dry well at six ACH and higher can potentially create temperatures below freezing in the ventilated space. Supplemental space heating or cooling may be advisable in some locations depending on the process equipment and piping installed.

The recommended temperature for pump stations is between 50 °F and 90 °F to prevent equipment and process lines from freezing or overheating. Heat tracing can be used to supplement ambient heating. Increased ventilation and air exchanges can be used to supplement cooling if temperature is a concern. See *DSG Chapter 10, I&C (SCADA)* for more information on motor temperature monitoring.

F. Odor Control

SPU's requirements for odor control at drainage and wastewater pump stations are outlined in the Appendix 11I. This document provides guidance on how to evaluate existing odors and risks for complaints, along with thresholds for when different levels of odor mitigation or control should be installed.

An Odor Monitoring Study is required during scoping for all pump station projects (retrofits and new construction). This study will inform the odor mitigation requirements for the project. See Appendix 11I for study requirements. Contact SPU for examples of past odor monitoring studies.

SPU prefers to address odor concerns with reduced air exchanges in the wet well (refer to Table 11-13) as a first step. Where reduced ventilation is not sufficient to mitigate concerns, media filtration, typically with some form of carbon, should be included in the project scope. SPU is currently piloting several different types of odor control systems at various pump stations. Work with the LOB representative and SPU Operations to determine the type of odor control system most appropriate for each project.

G. Wet Well Corrosion Control

Wastewater pump stations can experience high levels of hydrogen sulfide (H2S), a by-product of decomposing waste. Large wet wells can amplify the problem because quiescent flow conditions allow solids to settle. Longer detention time in the wet well increases H2S production.

H_2S exists in two forms: dissolved and atmospheric. The latter is the primary concern for corrosion. The following measures should be incorporated in wet well design to combat corrosion:

- Ventilation should be designed per Sections 11.1.1.1 and 11.1.1.1A of this Chapter. Installing odor control equipment should be considered.
- Gratings, ladders, structural beams, anchors, railings, and other miscellaneous metals in wet wells must be constructed of galvanized or stainless steel. SPU Operations prefers to avoid use of FRP gratings and ladders.
- All control panels located in wet wells or other hazardous environments must be designed for a minimum of NEMA 4X rating. See *DSG Chapter 10, I&C (SCADA)* for more detail on control panels.

Larger mechanical equipment, including pumps and combination air valves located in wet wells or vaults, must be specifically designed to operate in corrosive environments. The manufacturer of each piece of equipment should be consulted to verify the equipment is suited for operation in the intended location.

Wet well linings should be considered when designing new pump stations. Typical linings for wet wells at SPU stations are high-build epoxy coatings on all concrete surfaces. For retrofit projects, wet well coatings should be evaluated on a case-by-case basis in coordination with SPU Operations. Wet well linings must be installed at existing pump stations that show visible evidence of concrete deterioration or water infiltration/exfiltration.

Epoxy coatings should also be considered for force main discharge structures, which typically have high H_2S exposure due to flow turbulence. Where epoxy coatings are used in areas that may have foot traffic during maintenance (e.g., wet well floors), a non-skid aggregate surface treatment should be included.

H. Noise Control

Table 11-15 shows sound level limits for pump station design. These requirements were established for the hours of 7 AM to 10 PM on weekdays and 9 AM to 10 PM on weekends. However, as part of community engagement, SPU recommends additional noise reduction measures for equipment that will run frequently. Nighttime noise reduction of stationary equipment used to convey water by a utility is considered exempt. Refer to the City's Noise Ordinance, SMC 25.08 for the most current requirements. If the requirements of SMC 25.08 and this standard differ, the more stringent requirements will govern.

On-site standby generators installed in residential areas must be equipped with a sound-attenuating enclosure, including exhaust silencer. SPU has successfully used Cummins Power Generation's Level III sound enclosures at many existing facilities.

Table 11-15
Noise Requirements

Location of Sound Source	Noise Limits at Receiving Property (in decibels)		
	Residential	Commercial	Industrial
Rural	52	55	57
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

Source: Seattle Municipal Code SMC 25.08

11.6.2.2 Plumbing

Most pump stations require little plumbing. Detailed plumbing design is beyond the scope of the DSG. For additional guidance on plumbing, consult the Seattle-King County Department of Health.

11.6.2.3 Sump Pumps

Select municipal/heavy-duty sump pumps capable of handling solids and debris, with a minimum 2-inch threaded outlet. Sump pump piping systems must include a shutoff (gate) valve, a check valve, and unions as needed to remove the valves and pump for maintenance. Use full bodied valves wherever possible. Sump pumps must use an adjustable float trigger.

Select 120V, single-phase sump pumps wherever possible. All 120V sump pumps must plug into a standard wall receptacle. Higher voltage sump pumps may be hard wired.

Select sump pumps with appropriate electrical hazard classification ratings for the space they will operate in. Vaults containing wastewater process piping may be considered classified spaces requiring explosion-proof sump pumps. These pumps have limited availability and may require long lead times.

For spaces subject to high risk of flood or high consequence in case of flood, consider redundant sump pumps.

11.6.2.4 Fire Suppression Systems

Pump stations with above-ground facility or control buildings may require fire suppression systems. Consult the Seattle Fire Code and Seattle Building Code for guidance.

11.6.3 Structural

DSG Chapter 4, General Design Considerations provides structural engineering requirements for all SPU structures and buried vaults. This Section provides supplemental guidance for structural components and considerations that are unique to pump stations. Consult both Chapter 4 and Chapter 11 when working on structural elements of pump stations.

11.6.3.1 Applicable Codes and Standards

Table 11-16 lists typical structural codes and manuals that govern the design elements for pump stations. Pump stations are typically within Occupancy Group “U” in the Seattle Building Code

(SBC). Additional codes and standards beyond those listed may apply for some projects. It is the designer's responsibility to research and determine all applicable code requirements.

Table 11-16
Typical Structural Codes

Code	Name
ASCE 7	Minimum Design Loads for Buildings and Other Structures
ACI 318	Building Code Requirements for Structural Concrete
ACI 350	Code Requirements for Environmental Engineering Concrete Structures
ACI 350.3	Seismic Design of Liquid-Containing Concrete Structures
AISC 360	Specification for Structural Steel Buildings -
ANSI/NAAMM	Metal Bar Grating Manual

Acronyms and Abbreviations
ACI: American Concrete Institute
AISC: American Institute of Steel Construction
ANSI: American National Standards Institute
ASCE: American Society of Civil Engineers
NAAMM: National Association of Architectural Metal Manufacturers

11.6.3.2 Analysis of Existing Structures

When upgrading internal mechanical, electrical, and minor structural components of an existing pump station (e.g., ladders, landings, and stairs), upgrading the primary structure to current code requirements for structural loads is generally not required. Unless there is indication of structural distress, the pump station's primary structural components (e.g., top slab, walls, and base slab) can be assumed to provide adequate structural capacity.

If modifications are made to the primary structure or new loads are applied to the structure, the capacity of the existing structure must be considered. The design engineer can use available design plans for the existing structure to determine the existing load capacity. If no plans are available, the design engineer must use best judgement based on experience.

Common modifications that affect the capacity of the existing structure are new openings in the walls or top slab or demolition of portions of walls or beams that support the wall or top slab. When such modifications to the existing structure occur, the structure typically must be strengthened.

11.6.3.3 Design Loads

Refer to *DSG Chapter 4, General Design Considerations*, 4.4.1 for typical design loads on exterior walls, top slabs, bottom slabs, gratings, guardrails, ladders, and slide gate operators. Load combinations should be per ASCE 7, Chapter 2, and must be verified by the design engineer.

A. Interior Walls

Interior walls in SPU pump stations are generally located between the wet well and dry well. Interior walls are typically required to handle hydrostatic and seismic lateral loads. Hydrostatic loads are calculated based on water surface elevations in the wet well. The maximum possible water surface elevation should be considered. Seismic loads are calculated based on lateral accelerations generally determined through geotechnical analysis. If no analysis is available, acceleration coefficients can be obtained using the online U.S. Geological Survey (USGS) ground motion calculator. If using the USGS calculator and the soil type is unknown, input soil type based on a conservative assessment. After determining an acceleration coefficient, the structural engineer can determine the seismic loads applied to the interior wall using guidance provided by ASCE 7, Chapter 12. Because of the typical wet well size in SPU pump stations, sloshing waves need not be considered. If the wet well size requires that sloshing waves be considered, American Concrete Institute (ACI) 350.3 can serve as a design guide.

B. Suspended Platforms

Suspended platforms and associated framing at SPU pump stations should be designed to handle the following live loads:

- 100 psf over entire surface area.
- 350 pounds (lbs) pedestrian point load (at controlling location) plus 40 psf distributed load.
- Equipment loads, if equipment maintenance could result in placing heavy loads (such as pumps or motors) on the platform. Combine any equipment loads with 20 psf distributed load.
- Dynamic loads do not need to be considered if all of the above loads are considered.

C. Grating

Many of the suspended platforms at SPU pump stations are constructed with grating supported by beams. The grating should be designed to handle the same loads as the associated suspended floor design. At minimum, the grating should be designed for a load of 100 psf with a maximum deflection of ¼ inch. The NAAMA Metal Bar Grating Manual provides grating design guidance. Hot-dip galvanized grating, which allows for future field modifications, should be used in most cases. Grating design and support systems must consider and allow for future penetrations for piping and conduit. Often framing is required to support the grating edges around such penetrations. Grating should be fully banded along all edges and openings. SPU generally does not prefer use of FRP gratings at this time.

11.6.3.4 Load Cases

A. Stability and Buoyancy

Generally, the design of buried pump stations does not need to consider overturning stability. However, overturning stability should be considered if the pump station is partly buried, with one side more exposed than the opposite side. In this situation these uneven soil loads need to be considered when calculating overall stability and foundation reactions. The pump station should be designed to ensure that resultant of the stability reactions is within the mid-1/3 of the base, resulting in bearing pressure over the entire foundation. Stability cases should consider static, dynamic, and buoyancy loads.

See *DSG Chapter 4, General Design Considerations* for design of buried structures against buoyancy.

11.6.4 Electrical

DSG Chapter 9, Electrical Design, provides overall code compliance and general guidelines. This section describes electrical items specific to pump station operation and control. There are no pump station-specific requirements for conduits and receptacles, grounding, and lighting. For requirements on these electrical considerations, refer to *DSG Chapter 9, Electrical Design.*

11.6.4.1 Project Electrical Design Documents

The following are project (contract) drawings typically required to properly detail the electrical design of pump stations:

- Control schematics
- Duct bank sections
- Facility system block diagrams
- Panel and lighting schedules
- Power distribution one-line diagram
- Pump station lighting plan
- Pump station power wiring and grounding plan
- Site plan: lighting and communications
- Site plan: power distribution and grounding
- Switchgear, MCC, panelboard, and equipment elevations
- System P&ID schematics
- Symbols and abbreviations
- Typical electrical construction details

11.6.4.2 Energy Considerations

Most of the energy consumption at pump stations is that required to run the primary pumps. The ability to include equipment that meets system requirements at the highest possible efficiencies will minimize overall energy consumption.

The design engineer should follow SPU asset management requirements to develop a full lifecycle analysis of the existing condition and all proposed alternatives. The analysis should consider the benefit of high-efficiency motors and VFDs where appropriate to reduce energy costs associated with the pump station.

11.6.4.3 Area Classifications

Wastewater pump stations and associated vaults and equipment spaces must be classified according to NFPA 820. Electrical equipment, enclosures, and installation must comply with NEC. See *DSG Chapter 9, Electrical Design*.

11.6.4.4 Utility Power Source

New SPU pump stations must have 480V, 3-phase, and 60Hz electrical power. When a large horsepower (hp) motor, such as 400 hp or above, is required, a medium voltage (4,160V) system must be considered. Alternative voltage services may be considered on a case-by-case basis in locations where it is not economically feasible to bring 480V to the site.

Existing SPU pump stations use a range of power configurations, including 240/120V, 1-phase; 240/120V 3-phase; 208/120V, 3-phase; 480/277V, 3-phase; and 4,160/2,400V, 3-phase (water pump stations only). Where additional substations, transformers, or switchgear are required, sizing and installations should conform to the requirements of *DSG Chapter 9, Electrical Design*.

11.6.4.5 Standby Power Source

Permanent on-site standby generators must be included in the scope of work for new pump station construction and pump station retrofit when at least one of the following conditions is met:

- Wastewater stations with less than one hour of emergency storage volume (see 11.8.1).
- Stations (all types) serving critical services or stations where a power failure would endanger public health or safety.
- Stations (all types) with known power reliability issues or otherwise subject to frequent outages.

Additional circumstances may warrant standby generator installation and should be evaluated with the Line of Business Representative as needed.

All permanent generator installations must be equipped with an automatic transfer switch to automatically start the generator in the event of power loss.

All SPU pump stations, regardless of type, size, or storage time must be equipped with generator power plugs and manual transfer switches connected to the main electrical service. The plug is used to connect a portable generator that provides emergency power to the pump station. Camlock plugs must be used for all portable generator connections.

Generator fuel tanks must be sized for minimum 24 hours of operations between refuelings.

Currently SPU uses Cummins diesel generators and transfer switches for permanent standby power.

SCADA control power for all sites must be backed up by a dedicated DC Uninterruptible Power Supply (UPS) to allow pump station monitoring during a utility power outage. The DC UPS must be sized to power the SCADA equipment and all critical instruments for a minimum four hours of utility power outage. The DC UPS must not power environmental controls (HVAC), including those in the SCADA control panel, due to the large power needs required by such devices.

11.6.4.6 Pump Motor Selection

A. Minimum Requirements

The following standard requirements must be met when selecting pump motors:

- Premium efficiency motors with a 1.15 service factor, Class F insulation with Class B temperature rise limitation must be specified per NEMA standards, except for valve actuators and submersible motors.
- Motors must be sized to not run the connected load within the service factor.
- All 480V motors and motors used in VFD applications must be inverter duty ready.
- Motors must be capable of operating continuously.
- Motors rated 50 hp and larger, especially those used in continuous duty or critical load applications must be equipped with over-temperature sensors embedded in the motor windings.
- Include power factor correction capacitors for motors 50 hp and greater, but do not implement in VFD applications.
- All motors used in VFD applications must be equipped with a shaft grounding device.
- All 3-phase submersible motors must be included with over-temperature and seal leak/moisture sensors.
- Constant speed motors less than ¾ hp should be specified for 120V, 1-phase power (typical for most sump pumps and some ventilation fans).

B. Additional Considerations

The following additional guidance may apply in special or severe duty applications:

- Consider specifying winding space heaters for 3-phase motors located in damp, wet, hose-down, or process areas. This is an especially important consideration for motors that may operate infrequently. Heaters should switch off when motors are running.
- Select an appropriate and cost-effective winding protection device (RTD, thermistor, thermocouple sensor) for the motor size.
- All motors driving equipment associated with the treatment process should be located in an area that is easily accessible for O&M. If required, large motors should be provided with ladders and platforms for maintenance.
- Ensure that doors, hatches, cranes, and lifting eyes can accommodate the specified motors.
- Consider immersible type motors in dry wells that have potential for flooding. These motors can remain operational even if submerged. The motors should be mounted integral to the pumps. Immersible motors must have cooling characteristics suitable to permit continuous variable speed operation in air.

11.6.4.7 Motor Control Centers

Motor control centers (MCCs) house all motor starters, distribution transformers, lighting panels, and main protection for the pump station. The following are SPU standards for MCCs:

1. Process control equipment (PLCs, PACs, etc.) must be installed in a separate SCADA panel.
2. MCCs must be rated 600V, NEMA 1G or 12 and consist of a series of metal enclosed, freestanding, dead front vertical sections bolted together.
3. Individual vertical sections must be 90 inches high, 20 inches wide, and 20 inches deep unless special space requirements are identified.
4. Bottom channel sills should be mounted on both the front and rear of the vertical sections extending the full width of each shipping split. The top of each section should have removable plates with lifting angles.

Removable units should connect to the vertical bus in each section with tin-plated, self-aligning, pressure type copper plug connectors. Removable units should be aligned in the structure on guide rails or shelves and secured with a cam latch mechanism or racking screw.

11.6.4.8 Motor Starting and Controls

SPU uses a variety of control starters and controls. Project teams should work with SPU Operations and Maintenance and the Line of Business Representative to select an appropriate type of control for the pump size that also meets the process needs of the facility.

A. Combination Starters

Constant speed motors sized up to 15 hp may use a combination starter with a motor circuit protector (MCP) and across-the-line full voltage starter sized according to NEMA. The MCP is a means of short circuit protection. Motor starters are magnetic line voltage type with individual control power transformer, 120V secondary fuses and 3-phase bimetallic overload protection. Primary side fuse overcurrent protection should be provided on all control power transformers. This method of motor starting is commonly used on smaller pump stations with relatively consistent demand.

B. Reduced Voltage Soft Starters

Constant speed motors sized 15 hp and larger must use a reduced voltage starter (RVSS) or other means to minimize the instantaneous high-power draw from the utility at pump start-up (inrush current). Soft starters must be solid-state design with isolation and bypass contactors.

When the pump reaches full speed, and after a short time delay, the soft starter electronics will be bypassed and isolated. The pump will run through a bypass contactor. Taking the electronics out of the circuit creates less wear and tear on the starter and provides operation that is more efficient.

C. Variable Frequency Drives

Variable frequency drives (VFD)s allow enhanced control of inverter-duty motors across a wide range of speeds. Some brands include other various advanced features such as anti-jam, torque limiting, and others. VFDs satisfy the soft-start requirement for motors 15 hp and larger but may be used on any size motor.

Consider using VFDs where facilities must accommodate a wide variety of flows or otherwise need or would benefit from additional operational flexibility. For motors up to 400 hp, 460V alternating current (AC) VFDs should be used. Higher voltage and hp ratings should be considered on a case-by-case basis.

1) Requirements

The following are design guidelines for VFDs:

- **Manufacturer.** If possible, VFDs should be designed and specified to be the product of a single manufacturer. Drives up to 200 hp may be mounted in an MCC. Larger drives should be furnished by the pump or equipment supplier.
- **Power Factor Correction.** SPU does not recommend using individual power factor correction capacitors or banks of capacitors on distribution systems with VFDs or other nonlinear loads. Capacitors with tuned filters may be required to eliminate the potential of a resonant frequency developing on the distribution bus. On large distribution systems capacitor banks with automatic controls, tuning filters may be considered. Unfiltered power factor correction capacitors should never be added to any bus directly connected to VFDs.
- **VFDs for Existing Motors.** Restrictions on motor lead length and winding insulation class due to reflected voltages can be a problem when applying VFDs to existing motors. The VFD manufacturer should be consulted to determine if a problem potentially exists. Output reactors or cable terminators may be necessary. SPU recommends replacing the motor with a new inverter duty motor if possible.
- **6-Pulse Systems.** When 6-pulse VFD systems with line reactors do not meet the harmonic limitations imposed by the Institute of Electrical and Electronic Engineers (IEEE 519), or where standby generators are used as a power source, specify low harmonic multi-pulse or “clean power” VFDs with system active harmonic filters for facilities with 100hp or greater motors.
- **Location/Enclosure.** Investigate all potential VFD manufacturers and provide adequate space inside the pump station for a worst-case scenario.

When possible, equipment should be installed in environmentally conditioned electrical rooms. Environmental conditioning should include temperature and humidity control as well as the removal of dust and corrosive vapors from the supply air.

Supply air should not be taken from process areas. Alternatively, equipment cabinets may be furnished with self-contained cooling equipment, with rejected heat vented outdoors.

VFD enclosures should be rated NEMA 1A. Such enclosures are completely metal enclosed and sectionalized to isolate and minimize the effects of internal short circuit currents. The structures should consist of framework of preformed steel channels or angles covered with bolted steel sheets.

2) Harmonics

VFDs are non-linear devices that develop harmonics. Harmonics are integer multiples of the fundamental frequency. When summed to the fundamental frequency, the result is a distorted waveform that can create adverse conditions in a distribution system.

IEEE has set the only recognized standard addressing harmonic limits: IEEE 519-2022, the Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems. This standard stipulates specific limits for current and voltage distortion at a point of common coupling; traditionally for pump stations, this is the point where the utility connects to multiple customers (i.e. line side of the utility transformer). Table 11-17 shows possible methods for mitigating harmonics.

Table 11-17
Harmonic Mitigation Methods for VFDs

Method	Description
6-Pulse Drive	• Common, cost-effective. • Typically, reactor per unit impedance is 3% to 5%. • Providing drive with a line reactor can eliminate the most severe effects. • Increasing impedance of line reactor does not reduce harmonics linearly. A practical minimum can be reached simply by adding inductance. • Cost and size vs. the theoretical minimum comparison and optimization lead typically to 3% to 5% line reactors.
Multiple Pulse Rectifiers	• In 12-, 18- or 24-pulse drives the two, three, or four rectifiers are parallel-connected and fed by a phase shifting transformer. • Harmonic compensation is effective at the primary side of the transformer. • 18- and 24-pulse systems are not economical for floor space, losses, and power factor when compared with other low harmonic solutions. In an 18-pulse drive, the efficiency is typically 96%. • Multi-pulsed systems always require a dedicated transformer for the drives because the cancellation is reached on the primary side. • Power factor in 18-pulse systems is poor (typically 0.95). Current distortion when these phase shifting transformers are used is total harmonic distortion (THD) = 3% to 15% depending on parameters such as pulse number, line imbalance, and balancing of windings.
Passive Filter Designs	• Trap or shunt filters are tuned to a certain frequency component. For example, connecting several traps (multiple arm filters) can be effective for filtering out the fifth and seventh harmonic component. • This type of solution may be sensitive to resonance phenomena with other network components and may introduce a high leading power factor. • Can cause voltage drop and thus reduce the drive capacity.
Active Filters	• Actively compensates for harmonic components in a network by generating the same harmonic components in an opposite phase. This technology is realized with modern power electronic devices. • Cost is relatively high, compared to passive filters.
Insulated Gate Bipolar Transistor (IGBT)	• Typically used when regenerating is required. • Generates low harmonic voltage and current distortion levels. • Cost is higher than a passive filter.

11.6.5 Instrumentation, Monitoring, and Control

DSG Chapter 10, I&C (SCADA) describes overall code compliance, standards, and general guidelines for I&C systems. This section describes instrumentation specific to pumping station monitoring, operation, and control.

11.6.5.1 Instrumentation for Drainage and Wastewater

Pump instrumentation will allow for control and monitoring of the pump and station equipment. Monitoring will also include all trending and alarm functions. The following is the minimum pumping control instrumentation.

A. Magnetic Flow Meters at Discharge of Pump

The programmable logic controller (PLC) should be programmed to calculate the flow totalizing function. The flow meters should be specified with reverse flow sensing capability to detect a check valve malfunction for systems that will not have motor operated discharge valves. Magnetic flow meters with remotely mounted transmitters should be used. Magnetic flow meters should be in-line type. For wastewater pump stations, a single flow meter should be provided on the discharge header for smaller stations. For stations with firm capacities exceeding 2,500 gpm, consider providing a flow meter for each pump. Totalizing functions should be performed through the SCADA system or directly in the corresponding PLC.

Wastewater pump stations may use meters by Krohne, Toshiba, Siemens, or Endress + Hauser. Flow meters must be installed in accordance with the manufacturer's recommendations for upstream and downstream straight runs of pipe. Specify 'mount-anywhere' style meters specifically designed for minimum straight approach pipe

Isolation valves and dismantling fittings must be provided to allow flow meters to be removed. Provide a corporation stop and ball valve adjacent to the flow meter for installation of a temporary pressure gauge and pressure relief petcock.

Flow meters must be protected against continuous submergence with a minimum rating of IP68. Cable terminations at the coil must be fully factory potted.

B. Low-Pressure Pump Suction Pressure Gauges, Transmitters, and Mechanical Switches on Suction Side of Each Pump

Permanent pressure gauges or instruments are not required at wastewater pump stations. A tap and ball valve must be included on the suction side of each pump for installation of a temporary pressure gauges for testing as needed.

C. Pressure Gauges

Permanent pressure gauges or instruments are typically not installed wastewater pump stations as they tend to clog over time. A tap and ball valve must be included on the suction and discharge sides of each pump for temporary pressure gauges to be installed as-needed for testing. As discussed above, similar taps must be provided adjacent to flow meters to permit measurement of pressure and flow at a common point in the system.

D. Open/Close Limit Switches for all Pump Isolation Valves

Limit switches are not required for isolation valves in wastewater pump stations.

E. Pump and Motor Vibration Switches

The motor for each pump above 50 hp should be monitored for vibration. The vibration monitors should be specified to be as manufactured by PMC/BETA Corporation, or equal. Each vibration monitor must have the following features:

- Two limit switches for each pump: one for alarm and one for pump shutdown; each limit should be independently adjustable
- A display to show the current status of the velocity level
- Manual reset button to reset the monitor and relays to the non-alarm state
- Test button for each channel to trip the alarm for testing with and without pump shutdown
- Time delay for each limit to be independently adjustable from two to 15 seconds
- An illuminated indicator per channel and limit to light after the time delay when any set point is exceeded
- A trip light to illuminate immediately when any set point is exceeded and before alarm or shutdown is initiated
- A circuit checker with illuminated indicator to continuously light when the pickup circuit is working properly

F. Wet Well Level Transmitters and Sensors

SPU's current standard for level sensing is the KPSI 750 pressure transducer. Select an appropriate pressure range for each facility's wet well (e.g., 5 psi, 10 psi, or 15 psi).

G. Wet Well Manual Staff Gauge

Staff gauges are installed in wet wells adjacent to pressure transducers to provide a manual verification of proper function. Gauges should be prominently visible and constructed of materials suitable for wastewater immersion. Where possible, ensure gauges are easily visible without entering the wet well.

H. Pump Station Flood Alarm Switch

The pump station flood alarm switch detects a high-water level or flood condition in the dry well or other equipment spaces. Flood switches must be readily accessible for testing without special tools or equipment. SPU prefers the GEMS LS-1900 for this application. Locate flood switches adjacent to sumps.

I. Pump Station Electrical Power Fail Alarm

The pump station electrical (AC) power fail alarm detects power conditions through a power fail relay or a more sensitive phase failure relay that monitors the incoming power at the pump station.

J. Pump Run Contact

Pump run status is monitored by a run contact in each pump motor starter. The run status signal is sent to the PLC and then to the SCADA operator workstation.

K. Motor Connected Contact

The motor connection status is monitored via a dry contact in the motor disconnect plug for each pump and should be interlocked with pump run operation

L. Pump Hand-Off-Auto Switch

Each pump in the pump station must be equipped with an analog hand-off-auto (HOA) switch. The status of each pump must be monitored by the SCADA PLC.

When the switch is in the Hand position, a run signal is sent to the pump and it will no longer accept remote commands. When the switch is in the Off position, the pump will not accept any run command from any source. When this switch is in the Auto position, the signal is a permissive for a pump remote start command to the respective pump. All SPU pump stations currently include this status signal.

The HOA position status signals must be added as basic data inputs to the PLC and monitored by the SCADA system.

M. Pump Jog Switch

Each pump in the pump station must be equipped with a local jog (momentary) switch. Jog switches must be located physically adjacent (within arm's reach) to the associated pump.

Jog switches provide a means for operators to manually start the pump momentarily for maintenance and troubleshooting purposes. Jog switches should be wired to send the same run command to the motor starter equipment regardless of HOA operator switch position. For VFD pumps, the jog switch is generally configured to run the pump with a 100% speed via the VFD jog input, although this may be configured to any lower speed depending on the specific needs of the site.

N. Pump Start and Stop Commands

The PLC sends a pump start or stop command to each pump motor starter when the pump is required to run or stop. The PLC outputs the pump start/stop command only when the pump HOA switch is in the Hand position and the operator inputs a command in the Human Machine Interface (HMI).

O. Pump Available Status – Calculated

The PLC calculates the pump's status as available when the LOR switch is in the Remote position and there are no pump alarms. Include this status signal in the SCADA system to allow the remote operator and automatic control applications to prepare for pump start.

P. Pump and Motor Bearing High Temperature Alarms

Bearing inboard and outboard high temperature switches must be interfaced with the PLC. An additional relay may be required to add a dry contact for PLC input.

Q. Motor Overload Alarm

Motor overload relays must be interfaced with the PLC. An additional relay may be required to add a dry contact for PLC input.

R. Shaft Speed Monitoring

For pumps operating on variable frequency drives, shaft speed sensors should be considered on a case-by-case basis as speed calculated by the VFD may be inaccurate in cases where the motor is slipping or stalled. This can be useful troubleshooting and optimizing pump operation. SPU does not have a standard instrument for shaft speed monitoring at this time.

S. Torque Monitoring

For pumps subject to heavy ragging, consider a separate torque monitoring sensor on a case-by-case basis. This can be useful for troubleshooting and optimizing pump operation. SPU does not have a standard instrument for shaft speed monitoring at this time.

11.6.5.2 Instrumentation and Monitoring for Drinking Water Pump Stations

The pump station data/instrumentation standard includes all SPU drinking water pump stations for the distribution system. Typical pump station standard equipment and signals are described is this section.

A. SCADA Control Panel

The equipment that controls a pump station must be housed in a SCADA PLC panel. The panel contains a pump station PLC, supporting instrumentation, and accessories and appurtenances required to control and monitor the pumps. Additional control interfaces may be needed to monitor buildings auxiliary HVAC, fire alarm, and security systems.

A local Operator Interface (OI) or HMI can be provided as an option on the SCADA panel for local control and indication. The OI has the capability to display, store, and reset alarm conditions and trends.

For detailed information on SCADA panel requirements, see *DSG Chapter 10, I&C (SCADA)*.

At most SPU sites, standard control panel signals are provided on the existing SCADA. Additional signals should be added at any sites that do not include all standard signals. Standard control panel signals include the following:

- Control Panel AC Power Failure Alarm
- Control Panel PLC Battery Voltage Alarm
- Control Panel PLC Battery Charger Alarm
- Control Panel Door Open Alarm
- PLC Key State (PROGRAM-REMOTE-RUN)
- PLC Communication Fail Alarm

- Batteries Voltage – Analog Signal

B. Pump Station Suction Pressure

The suction pressure monitoring at a pump station measures the pressure at the upstream side of the pump suction connections and downstream of the station inlet or storage facility connection.

<u>All SPU pressure transmitters for pump stations must be Rosemount 2088</u>.

Low-suction pressure alarms, typically below 15 psi, must be installed as a basic instrument at all pump stations.

C. Pump Station Discharge Pressure

A pump station discharge pressure transmitter measures the pump station discharge pressure and sends the signal to the PLC, then to the SCADA operator.

<u>The discharge pressure transmitter Rosemount 2088 must be installed as a basic instrument at all pump stations</u>.

D. Pump Station Discharge Flow

Pump station discharge flow rate is measured by a flow meter between the pump discharge header and the discharge zone. A corporation stop and ball valve should be included near the flow meter for installation of a temporary pressure gauge.

<u>All flow meters for SPU water pump stations must be Krohne mag meters. Flow meters must be installed in accordance with the manufacturer's recommendations for upstream and downstream straight runs of pipe. Isolation valves and dismantling fittings must be provided to allow flow meters to be removed for maintenance purposes.</u>

E. Pump Station Discharge Pressure High Alarm

The discharge pressure high alarm signal is provided either by a pressure switch connected to the pump station discharge line or by PLC logic, which monitors the analog signal from the discharge pressure transmitter. The alarm can be used either to provide an alarm only to the SCADA operator or to stop the pumps with either PLC logic or a hardwired interlock. An alarm is sent to the SCADA operator.

<u>Discharge pressure high switches must be added at all pump stations as a basic instrument</u>.

F. Pump Station Flood Alarm

The pump station flood float switch detects a high-water level or flood condition in the pump station building.

G. Pump Station Fire Alarm

The pump station high heat sensor detects a possible fire in the pump station building and a fire alarm signal is registered in the SCADA PLC.

H. Pump Station Electrical Power Fail Alarm

The pump station AC power fail condition is detected with a power fail relay or a more sensitive phase failure relay that monitors the incoming power at the pump station.

I. Pump Running

Pump running status is monitored by a run contact in each pump motor starter. The run status signal is sent to the PLC, then to the SCADA operator workstation.

J. Pump Hand-Off-Auto Switch

Each pump in the pump station must be equipped with an analog hand-off-auto (HOA) switch. The status of each switch must be monitored by the SCADA PLC.

When the switch is in the Hand position, a run signal is sent to the pump and it will no longer accept remote commands. When the switch is in the Off position, the pump will not accept any run command from any source. When this switch is in the Auto position, the signal is a permissive for a pump remote start command to the respective pump. All SPU pump stations currently include this status signal.

The HOA position status signals must be added as basic data inputs to the PLC and monitored by the SCADA system.

K. Pump Jog Switch

Each pump in the pump station must be equipped with a local jog (momentary) switch. Jog switches must be located physically adjacent (within arm's reach) to the associated pump.

Jog switches provide a means for operators to manually start the pump momentarily for maintenance and troubleshooting purposes. Jog switches should be wired to send the same run command to the motor starter equipment regardless of HOA operator switch position. For VFD pumps, the jog switch is generally configured to run the pump with a 100% speed via the VFD jog input, although this may be configured to any lower speed depending on the specific needs of the site.

L. Pump Start and Stop Commands

The PLC sends a pump start (or stop) command to each pump motor starter when the pump is required to run (or to stop). The PLC outputs the pump start/stop command only when the pump LOR switch is in the Remote position, and a command is received from the operator HMI.

M. Pump Available Status – Calculated

The pump available status is calculated by the PLC and is true when the LOR switch is in the Remote position and there are no pump alarms. SPU should add this status signal to allow the SCADA operator and automatic control applications to prepare for pump start.

N. Pump and Motor Bearing High Temperature Alarms

Bearing inboard and outboard high temperature switches must be interfaced with the PLC. An additional relay may be required to add a dry contact for PLC input.

O. Motor Overload Alarm

Motor overload relays must be interfaced with the PLC. An additional relay may be required to add a dry contact for PLC input.

P. Pump Discharge Valve Status

Where pump discharge valves are installed, the open and closed status must be monitored by the SCADA system PLC to provide an alarm if the valve is not open when the pump is running. The pump discharge valve position status switches must be added as a basic data requirement.

Q. Intrusion or Security

Intrusion switches and vault security alarms should be added as basic data for water quality security and site security purposes at pump station sites.

R. Pump Station Electrical Power Consumption (optional)

Electrical power total consumption in kilowatt (kW) and energy consumption rate in kilowatt hour (kWh) should be measured at the station, input to the PLC and sent to the SCADA system and operator at less than 15-minute intervals. SPU does not currently monitor electrical power consumption at its pump stations.

Power monitoring should be added at SPU pump stations as advanced data.

Electrical power consumption data can be used to check the power company billing information on a monthly interval and is required at one to five-minute intervals to calculate pump efficiency.

One of the three alternatives for electrical power consumption monitoring should be installed as advanced data at all pump stations (Table 11-18).

Table 11-18
Alternatives for Monitoring Electrical Power Consumption

Name	Description	Advantage/Cost
Alternative 1 Interface to Existing Power Company Meter	• Power consumption can be monitored by SCADA system by having the power company install an interface between the PLC and the electric power company billing meter. This interface provides a contact closure pulse output to the PLC discrete input with a specific number of kWh per pulse. PLC logic totalizes the pulses and converts the value to kW.	• Lowest cost of the three alternatives for power monitoring.
Alternative 2 New Power Monitor in Electrical Switchgear for Pump Station	• An additional electrical power monitor that must be installed between the electrical service entrance meter and the MCCs with the motor starters for the pumps. • Requires installation of current and potential transformers to monitor and calculate power consumption.	• More accurate power consumption total and rate information. • Electrical variables (e.g., kW, kWh, voltage, and power factor) and alarms (e.g., high- and low-voltage and power failure) can be monitored and data stored to provide more information on electrical problems.

Name	Description	Advantage/Cost
	• Provides additional benefit of monitoring and storing electrical power variables and alarms that can be used for maintenance and troubleshooting.	• Cost is more than Alt 1 due to additional equipment and installation cost. • Alt 2 has additional electrical data that can be used to troubleshoot electrical supply and load induced problems.
Alternative 3 New Power Monitors in MCC for each Pump Motor	• Same power monitor described for Alternative 2 can be installed in the MCC for each pump motor.	• Much more accurate power consumption total and rate information. • Additional electrical information is available for each pump motor that can be used to resolve station and motor electrical problems. • Cost is higher than Alts 1 and 2 because of additional new equipment and modifications to each starter. • New power monitors for each pump not recommended. Additional cost not justified by benefits.

Acronyms and Abbreviations
kW: kilowatt
kWh: kilowatt hours
MCC: motor control center
PLC: programmable logic controller
SCADA: supervisory control and data acquisition

11.6.5.3 Control Functional Requirements

A. Programmable Logic Controller

The pump station PLC collects operational data that will be available to the operators in the Utility Operations Center via the SPU SCADA system.

The PLC should consist of the necessary CPU, communication, and I/O modules to support the control and monitoring functions. These functions should provide communications with the Utility Operations Center, onsite Operator Terminals (optional), analog and discrete digital I/O for pump control, and I/O sufficient for the additional monitoring of auxiliary systems where required.

The PLC control panel should have environmental controls if necessary to heat or cool the control panel. The use of room HVAC may mitigate the need for this.

For more detail on PLC requirements, see *DSG Chapter 10, I&C (SCADA)*.

B. Control Narratives (Control Loop Descriptions)

A control narrative must be developed for each pump station to facilitate programming and operation of the system, both locally and remotely, with equipment and staff safety as primary considerations.

11.6.5.4 Project Instrumentation and Control Design Documents

The following are typical contract drawings for I&C for pump stations:

- P&ID for each process (pumping, HVAC, etc.)
- Control system architecture/block diagram
- Control panel front view and layout
- Instrument loop diagram
- Instrument schedule
- PLC input/output schedule
- Construction details

11.6.5.5 Vibration Monitoring

The motor for each pump above 50 hp should be monitored for vibration. The vibration monitors should be specified to be as manufactured by PMC/BETA Corporation, or equal. Each vibration monitor must have the following features:

- Two limit switches for each pump: one for alarm and one for pump shutdown. Each limit should be independently adjustable.
- A display to show the current status of the velocity level.
- Manual reset button to reset the monitor and relays to the non-alarm state.
- Test button for each channel to trip the alarm for testing with and without pump shutdown.
- Time delay for each limit to be independently adjustable from two to 15 seconds.
- An illuminated indicator per channel and limit to light after the time delay when any set point is exceeded.
- A trip light to illuminate immediately when any set point is exceeded and before alarm or shutdown is initiated.
- A circuit checker with illuminated indicator to continuously light when the pickup circuit is working properly.

11.7 PUMP STATION DESIGN

This section describes hydraulic calculations, pump selection, facility layout, and piping design.

11.7.1 Hydraulic Design

This section describes system curve development, pump hydraulics, and pump selection.

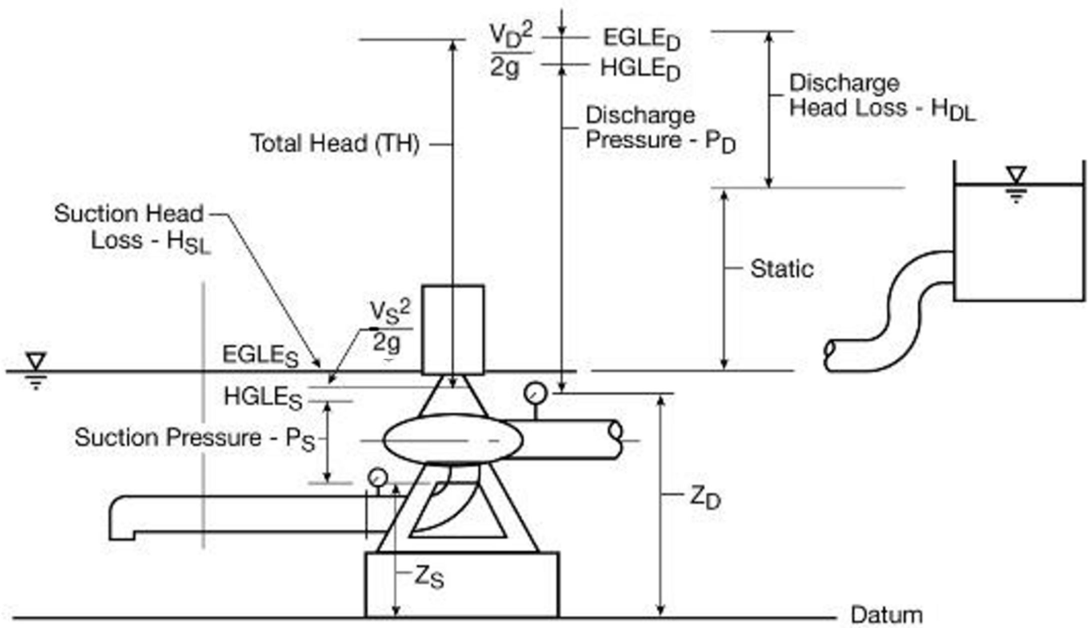
11.7.1.1 System Curve Development

System curves represent the variation in total dynamic head with pumping rate through the pumping system. At zero flow, total dynamic head is equal to total static head. As the pumping rate increases, the velocity head, friction losses, and pump losses increase. Thus, total dynamic head increases with pumping rate. This section describes design considerations associated with system curves.

A. Basic Hydraulic Considerations

Both under-sizing and over-sizing pumping systems can result in inefficient operation. A key parameter needed to select a pump is the pressures it has overcome to convey flow. Head is defined as the distance above or below a base elevation (datum) that a free water surface would reach if it were not confined (e.g., in a pipe). If the distance is below datum, the distance is negative. If the distance is above the datum, the distance is positive. Figure 11-5 shows common hydraulic terminology.

Figure 11-5
Common Pump and Piping System Terms



$$TH = Static + H_{DL} + H_{SL}$$

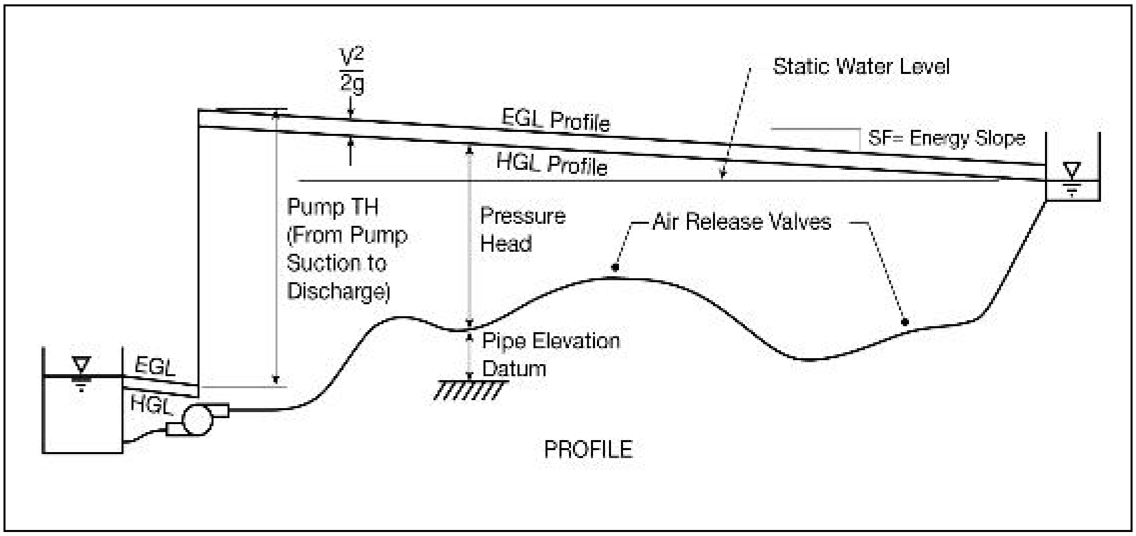
$$TH = \left(Z_D + P_D + \frac{V_D^2}{2g}\right) - \left(Z_S + P_S + \frac{V_S^2}{2g}\right)$$

Note: Example represents a flooded suction condition.

B. Hydraulic Grade Line and Energy Grade Line Profiles

Hydraulic grade line (HGL) and energy grade line (EGL) profiles plot the energy and head along a pipe route. HGL elevation at any point along a pressurized discharge pipe is the water surface that would be attained in a conveyance connected to a piezometer tap oriented perpendicular to the direction of flow. The HGL elevation consists of the pipe's elevation (relative to a datum), plus the pressure head. The EGL elevation at any point consists of the HGL elevation plus the velocity head ($V^2/2g$) at that point along the pipe. shows a typical HGL and EGL. Figure 11-6 depicts HGLs and EGLs graphically.

Figure 11-6
Typical HGL and EGL



Acronyms and Abbreviations
EGL: energy grade line
HGL: hydraulic grade line
TH: total head

C. Total Static Head

Total static head is the difference in elevation between water level on the suction side and water level on the discharge. Because water elevations or pressures vary, a minimum and maximum static head should be computed.

D. Suction Static Head

Suction static head is the elevation difference between the centerline of the pump impeller and the water surface. This static head may be either a suction lift (wet well level below the pump) or a flooded suction (wet well level above the pump). Whenever possible, a flooded suction configuration is desirable. A suction lift configuration requires close coordination with the pump manufacturer.

E. Discharge Static Head

Discharge static head is the elevation difference between the centerline of the pump impeller and the water or energy elevation at the discharge point.

F. Dynamic Head Losses

Head losses associated with pumping systems are largely caused by pipe wall friction and turbulence through pipe fittings (elbows or valves). These head losses are referred to as friction losses and fittings losses, respectively. Friction and fitting loss (minor) equations provide only approximate results, not exact values. It is important to strive for accuracy when considering appropriate head loss ranges to avoid being overly conservative or liberal.

1) Friction Losses

Friction losses in closed conduit flow are commonly estimated by one of the following equations:

- **Hazen-Williams Equation**
- **Darcy-Weisbach Equation**

The Hazen-Williams equation must be used to calculate friction losses for pumped flow for all pipes less than 2,000 ft in length or less than 18 inches in diameter (EQN 11.1):

$$h_L = \left(\frac{V}{1.318 \times C \times R^{0.63}}\right)^{1.85} \times L$$

Where:

h_L = head loss (ft)

V = pipe velocity (ft/sec)

C = Hazen-Williams C coefficient of friction

R = hydraulic radius (ft)

L = pipe length (ft)

Ensure that the above units are consistent with project information. Ranges of Hazen-Williams C coefficients for various pipe materials, diameters, and ages are available from manufacturers and various sources in technical literature. Such information should be obtained for the specific pipes being considered in addition to the anticipated design life of the pipes. Table 11-19 lists the typical Hazen-Williams coefficient values.

<u>When new pumps are installed on existing pipe the actual C coefficient must be determined through field testing.</u> For water stations, use a minimum of two hydrant flow tests for each size and material of piping. For wastewater pump stations, use a minimum of two closely agreed (preferably more) pressure and drawdown tests at the station to determine coefficients for the force main. Note that depending on service life, conditions, and wear and tear, actual 'C' values may be substantially lower than those shown. When testing reveals low 'C' values (below 90) visual inspection and cleaning of the force main may also be warranted.

The Hazen-Williams equation should be cautiously used for pipes of either significant length (>2,000 ft) or large diameter (>18 inches). In these cases, the Darcy-Weisbach equation is a more accurate estimation of friction loss. It should be used to verify the results obtained using the Hazen-Williams equation.

For most SPU installations, the Hazen-Williams Equation can be readily used because the piping is typically less than 18 inches in diameter and less than 2,000 ft in length.

Table 11-19
Typical C Coefficients for Pipe Types used in SPU Pump Stations

Material	Hazen-Williams C
New Pipe	
Ductile or cast iron, uncoated	130
Ductile or cast iron, cement-mortar lined	145
Steel, epoxy or cement mortar lined	140
PVC	150
Moderate service, 20+ years	
Ductile, cast iron or steel, uncoated	100
Ductile, cast iron or steel, cement-mortar lined	100
Long-Term Service, 50+ years	
Ductile, cast iron, or steel	80–90

Acronyms and Abbreviations
PVC: polyvinyl chloride

2) Fittings (Minor) Losses

The head losses caused by flow separation and turbulence through pipe fittings are expressed by stating the head loss as a multiplier (K) of the velocity head ($V^2/2g$) through the fitting (EQ 11.2). The discussion here concerns evaluation of force mains to develop system curves. The same principles, however, apply when station losses are considered. shows the limits of the force main.

The following is the Fittings Losses Equation (EQ 11.2):

$$h_L = \frac{KV^2}{2g}$$

Where:

h_L = head loss (ft)

K = friction factors (see)

V = pipe velocity (ft/sec)

g = gravitational constant (32.2 ft/sec2)

Minor loss coefficient (K) values for various fittings may scale with diameter, joint type, flow velocity, geometry, or other factors. The designer should take care to select the K value that most nearly represents the situation being analyzed, especially in systems where dynamic head is dominated by minor losses.

Use coefficients provided by the valve or fitting manufacturer where available. Where manufacturer data are not available, the designer may refer to other available resources such as the Hydraulic Institute Engineering Data Library or *Pumping Station Design* (Sanks, et al).

Typical K values for a limited number of common fittings are listed in Table 11-20 below.

Table 11-20
Typical K Values/ Fittings (Minor) Loss Coefficients

Type of Transition or Fitting	Typical K Value
Pipe entrance, where upstream velocity equals zero:	
a. Pipe projecting into tank (re-entrant)	0.8
b. End of pipe flush with tank (square-edged)	0.5
c. Slightly rounded entrance	0.25
d. Bell-mouthed entrance (flush or re-entrant)	0.05
Pipe exit, where downstream velocity equals zero:	
a. Abrupt transition	1.0
b. Bell-mouthed transition	0.8
Reducers/increasers:	
Gradual reducers (pipe wall flare <40°):	0.1
Smooth bends:	
Regular radius 90° (10-inch diameter or less)	0.3
Regular radius 90° (>10-inch diameter)	0.2
Long radius 90° (10-inch diameter or less)	0.1-0.2
Long radius 90° (>10-inch diameter)	0.1
45°	0.1
22.5°	0.05
Valves: (see manufacturer's literature for actual values):	
a. Angle	2
b. Butterfly	0.3 to 1
c. Swing check (if spring-loaded, head loss may increase by 2 psi or more)	2 to 2.5[1]
d. Rubber flapper check	1 to 2
e. Slanting disc check valve	1.1
f. Foot	0.8
g. Gate	0.1
h. Globe	5.5 to 6.0
i. Plug (port area 85% of pipe area)	0.7
h. Ball or cone	0 (for full flow through area)

Source: Hydraulic Institute Engineering Data Book

Notes
[1] K values for check valves will vary widely with the brand of valve and flow velocity. Consult with valve manufacturers for actual K values at the design flow rates for use in design calculations. Take care in this process as check valves are typically the largest single contributor of minor losses in a given piping system. K values for fittings are typical reference values only and may vary with size.

Acronyms and Abbreviations
psi: pounds per square inch

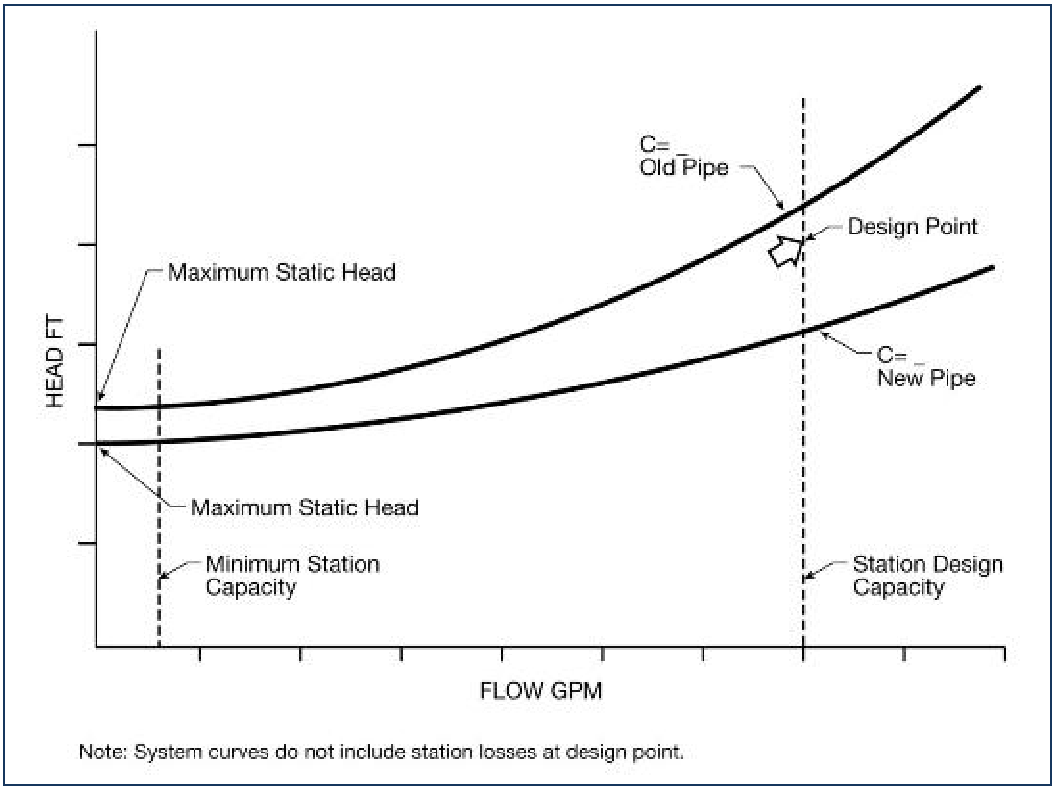
G. System Curves

The system curve is a graphical representation of total dynamic head versus discharge flow. The total head equals the system static head plus the dynamic head losses. System curves should be plotted across the range of possible water levels (static heads) and possible friction coefficients for the design life of the facility. Other critical points of operation should also be identified.

The boundary defined by the minimum and maximum system curves provides the range of operation for system head requirements. One curve should show the maximum static head with loss. The other should show the minimum static head with loss (Figure 11-7). Except for systems where flow is to be externally controlled, system curves of the range of conditions the pump will encounter should be provided to the manufacturer.

Tip: *Provide pump manufacturers with a reasonable estimate of what station losses are likely to be. Pump selection should always strive for highest efficiency at the most frequent pumping rate(s).*

Figure 11-7
System Curve



Acronyms and Abbreviations
gpm: gallons per minute

H. Net Positive Suction Head

Net positive suction head (NPSH) is a measure of the total energy head on the suction side of the pump, relative to the centerline of the pump impeller (Figure 11-8). A pump's required net positive suction head ($NPSH_r$) varies with discharge, type of impeller, and pump speed. The $NPSH_r$ is provided by the pump manufacturer. The available net positive suction head ($NPSH_a$) indicates the actual total energy available on the suction side of the pump as shown in the equation below. SPU recommends that the $NPSH_a$ be at least two times the manufacturer's required value. In no case may $NPSH_a$ be less than five feet above the $NPSH_r$.

$NPSH_a$ is calculated using the formula (EQN 11.3):

$$NPSH_a = H_{bar} + H_{sub} - H_{Vp} - H_L$$

Where:

H_{bar} = head, in feet of water, corresponding to the total barometric pressure on the surface of the liquid being pumped. This includes atmospheric pressure plus any pressure in the enclosed tank or space the pumped liquid is contained in.

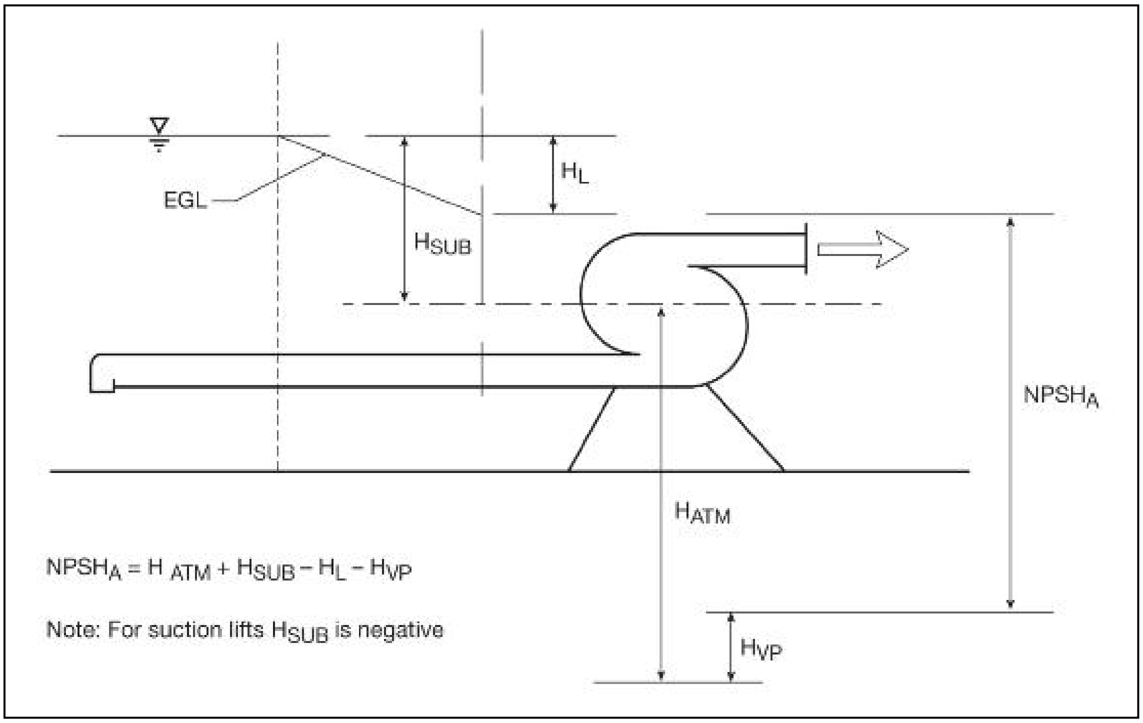
H_{sub} = difference between centerline of pump impeller and liquid level above the suction pipe, feet

H_{vp} = vapor pressure of liquids, dependent on type and temperature of liquids, in feet of water

H_L = head losses in suction pipe (friction and fitting losses), calculate with Equations 11-1 and 11-2.

Note that the calculation must include H_{atm} at actual altitude elevation of the pump.

Figure 11-8
Net Positive Suction Head



11.7.1.2 Pressure Transient ('water hammer') Surge Analysis

Pressure transients, commonly known as 'water hammer', are changes in pressure brought about by abrupt changes in flow within a pipeline. Any change in flow will produce a change in pressure. The most common abrupt change in pipeline flow occurs from a power failure to a pump station, or the abrupt stopping of pumps. Constant speed pumps that do not have soft start/stop controls can be especially problematic in some circumstances.

Any significant abrupt or rapid change in flow will produce an abrupt change in pressure.

For most small pump stations, pressure surges caused by water hammer are not severe and no water hammer control equipment is needed. All pumping and pressure pipeline systems should be investigated for water hammer where flow can be rapidly accelerated and/or decelerated.

A comprehensive computer modeling study must be completed to fully understand the potential effects of pressure surges on force main operation. For wastewater pump stations, SPU recommends considering a comprehensive modeling study when the force main meets at least one of the following criteria:

- Crosses under a river, water body, or other obstruction requiring a siphon or inverted siphon configuration
- Has local high and low points or significant knees along the vertical alignment that may require air, vacuum, or combination release valves
- Is longer than 500 ft and larger than 6 inches in diameter
- Has other unusual or unique operating conditions prone to abrupt changes in velocity, siphoning effects, air pockets, or flow separation (vacuum effects).

A completed modeling study will inform the need for, and location of, any required surge mitigation devices. Modelling studies should be started at the 30% design milestone and finalized by the 90% design milestone.

Required devices based on modeling could include standpipes, air/vacuum relief valves, surge tanks, and pump flywheels. <u>Force mains should be designed to avoid the need for surge mitigation devices wherever possible.</u> Where mitigation cannot be avoided, emphasis should be placed on reliability and minimization of required maintenance. Passive devices, such as standpipes, should be considered where practical.

When air/vacuum relief valves are required for wastewater service, SPU recommends the Vent-O-Mat RGX B valve with piped outlet (that is, an outlet routed to nearby gravity sewer). Depending on the specific configuration, some air relief valves may require odor control mitigation.

11.7.1.3 Pump Hydraulics

This section describes design elements of pump hydraulics.

A. Pump Characteristic Curve

The pump characteristic curve is a graphical representation of the discharge that a pump can supply against a particular head or total head (TH). In general, the pump's head capacity curve should be selected and specified to be of the type that is "constantly rising" towards the shut-off head. Operation of pumps at dips (reverse slopes) or flat spots in the pump curve is not permitted. Pump characteristic curves are unique and therefore are provided by the pump manufacturer or their representative.

When two or more pumps are operated in parallel, the station losses should not be added to the system curve. Instead, subtract the losses from the manufacturers' individual pump characteristic curve (Figure 11-9). This correction prevents compounding of station losses when evaluating overall pump station operation. Modifying the pump curve from the manufacturer results in a more accurate understanding of how each pump will operate. The resulting curve is called a modified pump characteristic curve or modified pump curve for short. Figure 11-10 shows an example modified pump curve. SPU typically operates wastewater pumps in parallel setting.

Figure 11-9
Boundary of Station Losses Associated with Modified Pump Curve

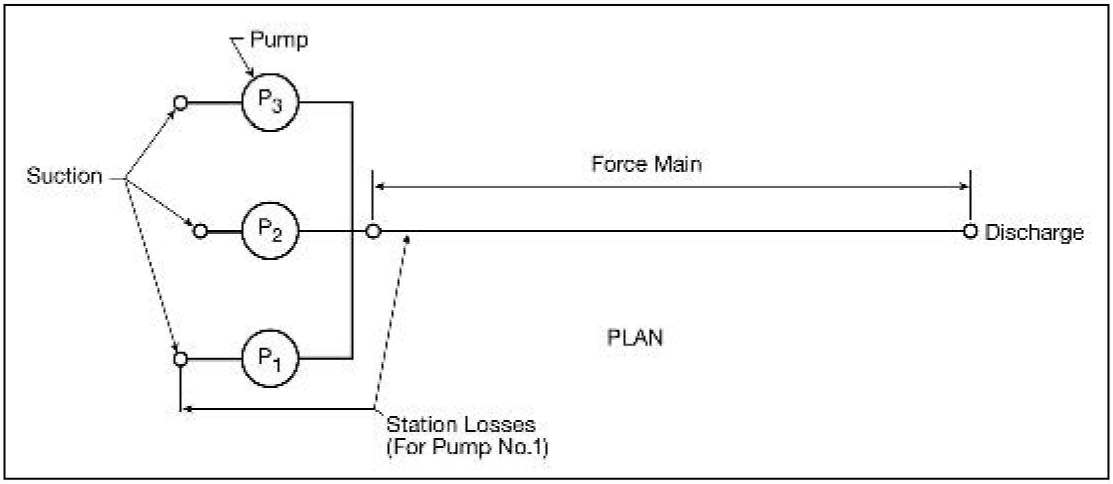
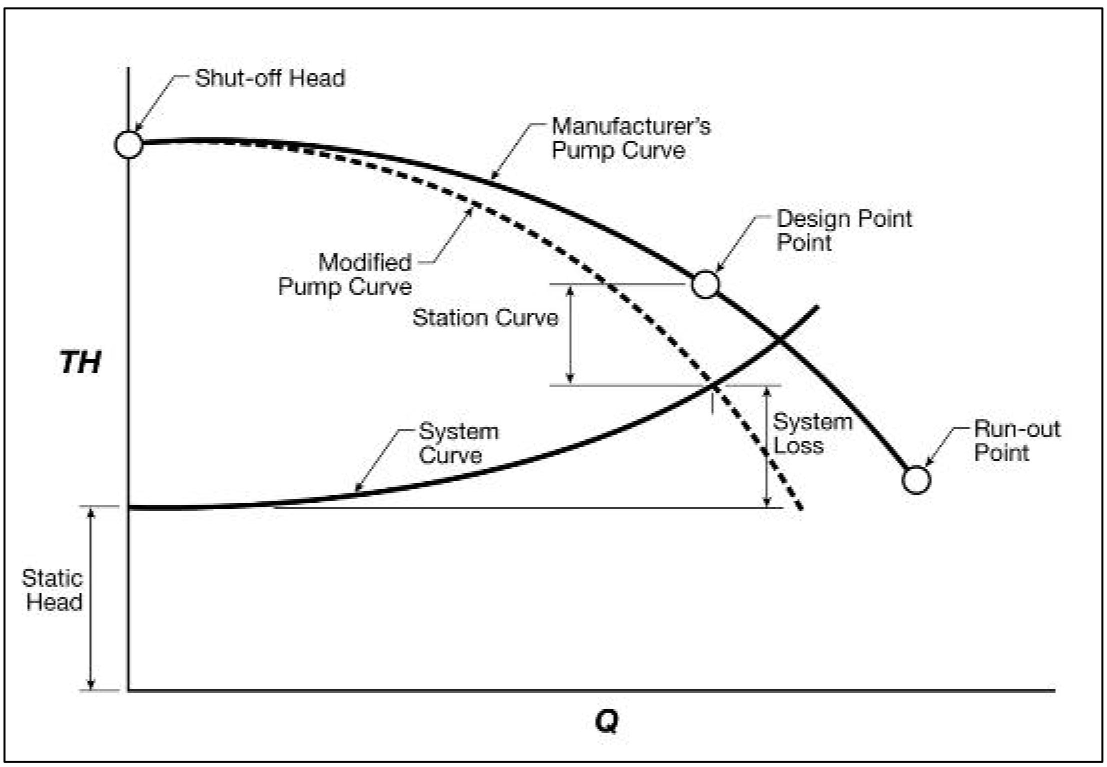


Figure 11-10
Typical Modified Pump Curve



Acronyms and Abbreviations
Q: flow
TH: total head

B. Shut-Off Head

The head produced by a pump at zero discharge is called the shut-off head. SPU does not recommend operating pumps continuously at or near the shut-off head. For large pumps, even operation for a few minutes at shut-off head may damage the pump. Adverse effects of operation at shut-off head are heat build-up, excessive vibration, and shaft deflection.

C. Pump Runout

The last or maximum discharge point shown on the manufacturer's pump curve is referred to as the pump runout point. Runout implies “close to running away,” which refers to operating against little head and pushing enough flow that the pump operating on the extreme right of, or beyond, the end of the manufacturer’s published performance curve. Operation on this part of the curve is outside the manufacturer’s recommended operating region and is a region of low efficiency and high-power consumption and causes vibration and cavitation damage. This condition is often made worse by the fact that conservative engineering can overestimate pipe friction. Pumps should primarily be selected for where and how they will operate most frequently. To help avoid this condition, the design engineer should evaluate proposed pumps across the entire range of possible pipe friction losses.

D. Acceptable Operating Range

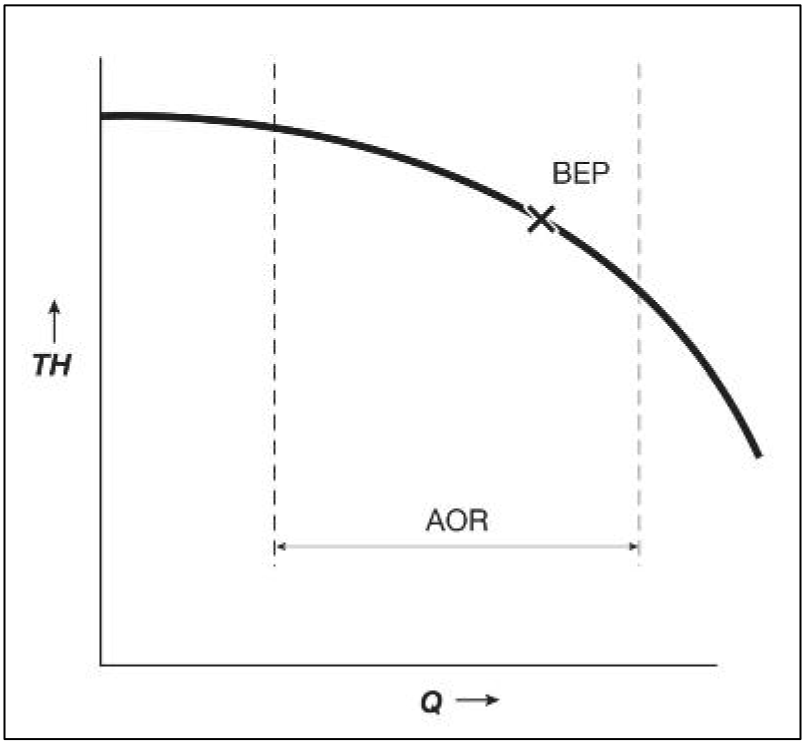
Acceptable operating range (AOR) is the range of flows over which the service life of the pump will not be seriously compromised. If run outside of this range, bearing life may be reduced, and noise, vibration, and component stresses may be increased. Pump manufacturers will typically provide the AOR, which is best shown directly on the pump characteristic curve. See American National Standards Institute (ANSI)/HI 9.6.3.

The far-right side of the published pump characteristic curve is generally considered to be the maximum flow limit of the AOR. However, the minimum flow is designated separately. Operation outside the AOR may cause cavitation, excessive vibrations, and larger than usual radial forces on the impeller shaft. Maximum allowable pump discharge may also be limited by the NPSH and motor hp may be exceeded.

11.7.1.4 Best Efficiency Point

Best Efficiency Point (BEP) is the point on a pump curve where the pump achieves maximum hydraulic efficiency. Typically, pump BEP is shown on a pump characteristic curve that the manufacturer provides. Figure 11-11 shows a typical pump characteristic curve with the BEP and AOR from a manufacturer.

Figure 11-11
Typical Pump Characteristic Curve



Acronyms and Abbreviations
AOR: acceptable operating range
BEP: best efficiency point
Q: flow
TH: total head

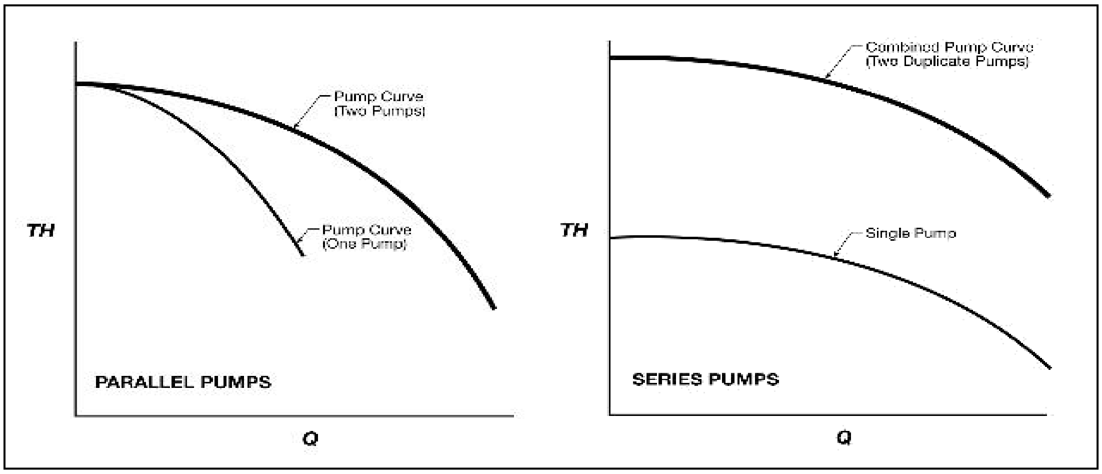
A. Preferred Operating Range

Preferred operating range (POR) is the range of flows over which the pumped flow is highly controllable. Within this range, the service life of the pump is not significantly affected by hydraulic loads, vibration, or flow separation. The POR for most centrifugal pumps is from 70% to 120% of BEP. For smaller pumps (0.5 hp), the manufacturer may recommend wider POR. See ANSI/HI 9.6.3.

B. Multiple-Pump Operation

When pumps are operating in parallel, pump head stays the same but the amount of flow increases (Figure 11-12). When pumps are operating in series, the TH increases but the flow remains the same. SPU does not currently operate pumps in series, but owns some multistage pumps that work in a similar fashion.

Figure 11-12
Pump Curves for Parallel Pumps and Series Pumps

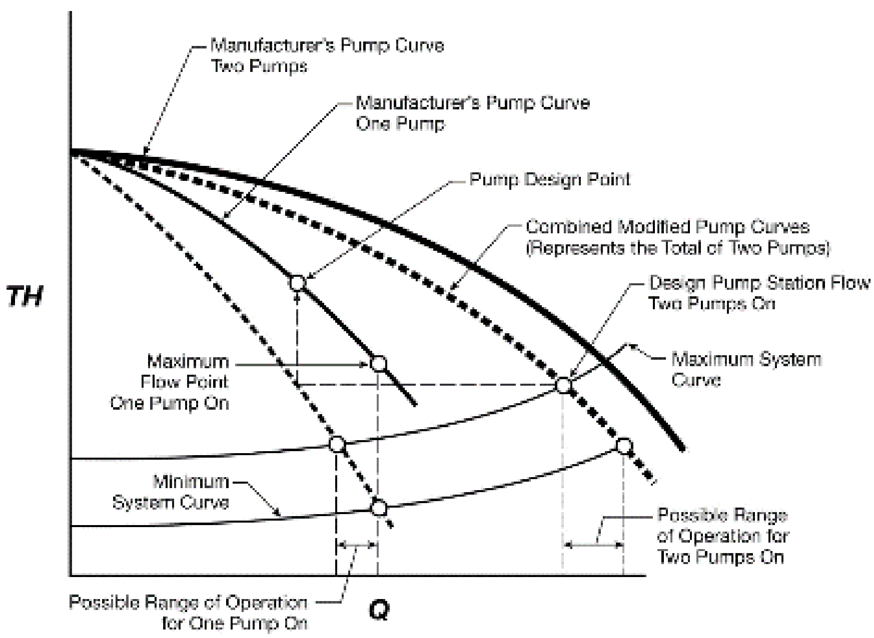


Acronyms and Abbreviations
Q: flow
TH: total head

11.7.1.5 Comparison of Pump Curves and System Curves

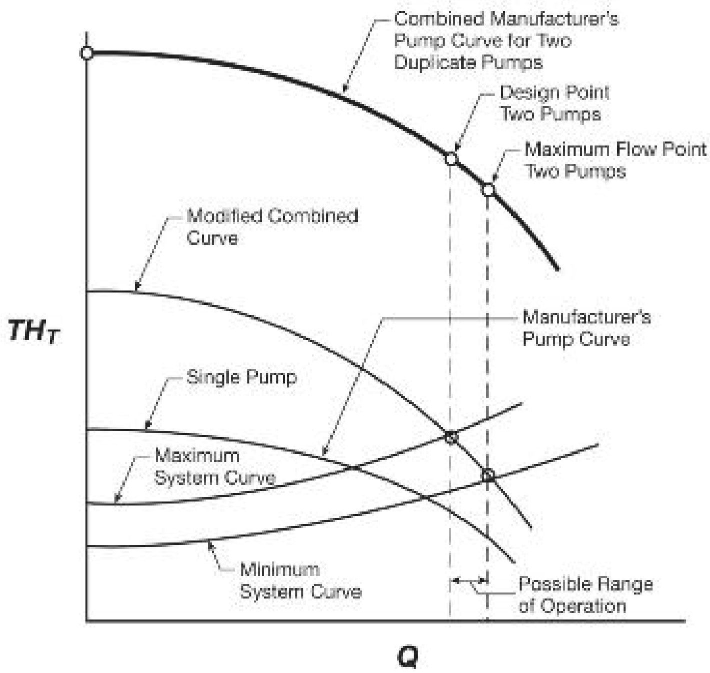
The design engineer should select a pump characteristic curve that, when modified to account for station losses, will intersect the maximum system curve at the design discharge. If possible, the pump should operate at or near BEP during typical conditions (Figure 11-13 and Figure 11-14).

Figure 11-13
Typical Modified Pump and System Curve (Parallel Pumping)



Acronyms and Abbreviations
Q: flow
TH: total head

Figure 11-14
Typical Modified Pump and System Curve (Series Pumping)



Acronyms and Abbreviations
Q: flow
TH: total head

11.7.2 Pump Selection

11.7.2.1 General

Pump selection must consider the full range of operating speeds and conditions expected. In most systems, pumps will operate outside the POR for certain conditions. However, most system operating conditions can typically be met within the POR through careful pump selection and station design.

For SPU, the typical operating conditions are dual pump in lead-standby or dual pump in lead-lag (parallel) configuration.

SPU recommends a strategy of selecting pumps where the most common operating condition on the system curve intersects the pump curve to the right of the pump's BEP, but to the left of the maximum limit of the POR when operating at 100% speed. This approach facilitates the maximum range of pump speeds and flows within the POR along the system curve.

Systems with relatively low static heads compared with friction losses can operate within the POR over greater design speed ranges than those systems with higher relative static head.

The following are basic principles that govern overall pump selection in order of importance:

- Pumps must be capable of meeting all design operating conditions.
- Pumps should operate within the POR for the most frequent operating conditions.

- Designers are cautioned that variable speed pumps will usually run at minimum flows the vast majority of the time and may only see maximum flows a few times in a typical year. This is especially true in basins with large wet weather peaking factors (typical for most combined sewer basins). In these cases, pump and piping configurations should be optimized around the lower flow rate to the maximum extent feasible. Continued operation at minimum speeds and pipe velocities can exacerbate maintenance issues like ragging and plugging.
- Unless approved by all acceptable manufacturers for a particular project, pumps must operate within the AOR, even for less frequent operating conditions such as minimum and maximum pumping rates.

11.7.2.2 Manufacturer Preferences

Table 11-21 shows the manufacturer preference for SPU water and drainage and wastewater pumps in order of preference. When possible, select manufacturers with local service centers and parts warehouses. If pumps with long-lead or unique spares must be used, consult with SPU Operations to identify which spare parts should be procured and stored with the pumps.

Table 11-21
Preferred Manufacturers for Water and Wastewater Pumps

Pump	Company
Water	Aurora
	Fairbanks & Morse (now Fairbanks Nijhuis)
	Worthington
Drainage/Wastewater	Cornell
	Vaughan
	Fairbanks Nijhuis
	Aurora

11.7.2.3 General Pump Selection Criteria

Pump selection must be based on the following standards unless otherwise authorized by SPU:

- Impeller diameter: Not to exceed 90% of maximum impeller size
- Minimum pump efficiency: 80% for water and 60% for wastewater and drainage
- Minimum speed – wastewater: 885 revolutions per minute (rpm) (900 rpm nominal)
- Maximum speed – wastewater: 1770 rpm (1800 rpm nominal)
- Solids handling – 3-inch sphere minimum for wastewater pumps
- Rag handling – Wastewater pumps must incorporate rag handling features unless explicitly exempted by SPU. See 11.7.4.3 (Impeller Selection).

Exceptions for minimum efficiency requirements may be considered in some cases where a pump with lower efficiency has a much lower maintenance burden and a corresponding lower net lifecycle cost. If impeller sizing requirements cannot be met, contact the SPU project engineer.

A. Constant Speed Pump Selection

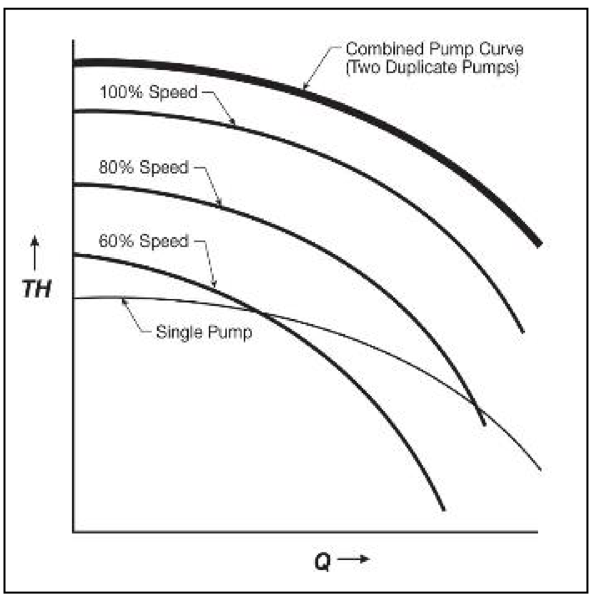
For constant speed pumping applications, pump selection is relatively straightforward. Pumps should be selected that most closely match the pump BEP with the most frequent operating point from the system curves.

B. Variable Speed Pump Selection

Pump affinity laws govern pump operation at multiple speeds. shows how pump characteristic curves are translated at different pump speeds. For a detailed explanation, SPU recommends referring to *Pumping Station Design* (Sanks, et al).

Variable speed pump selection introduces an additional dynamic to pump selection. Proper hydraulic selection will allow the pumps to operate through a maximum range of speeds and flows within the POR. Efforts should be made to maximize the time that the typical operating conditions fall within the POR, while ensuring that other extremes (e.g., maximum and minimum flows) can be met with the selected pumps. Figure 11-15 shows how pump curves vary with speed.

Figure 11-15
Variable Speed Pump Curves



Acronyms and Abbreviations
Q: flow
TH: total head

1) Water Pump Stations

For potable water pump stations, selection of variable speed pumps should be carefully considered. Because of successful water conservation, SPU water pump stations may have ample, or even excess, capacity. On these pump stations, pumps with variable speeds may provide a relatively simple way to significantly reduce power costs, improve operational control, and add flexibility. Modern variable speed pumps are cost effective and reliable. When modifying or upgrading existing pump stations, the design engineer should evaluate using variable speed pumps.

2) Wastewater Pumps Stations

For wastewater pump stations, the use of variable speed pumping may increase pump clogging if not properly implemented. The source of the problem is often operating the pump in a range below the POR. When the pump operates below the POR, suction recirculation can occur. Recirculation tends to wrap debris around the pump impeller blades and generates additional debris in the suction piping. The debris can eventually accumulate on the impellers. When operating within the POR, suction recirculation is limited and debris passes through the pump more easily. Low suction and force main velocities at minimum flow rates can also contribute to clogging. Proper selection and operation of pumps is critical to minimize pump clogging. Where possible, pumps and process piping should be selected to optimize performance and maintain required velocities at the minimum flow rate to reduce the potential for these issues. Additionally, the design engineer should be aware of the following:

- **Multiple Pump Operation with BEP at Peak Flow Rate.** This can result in single pump operation intersecting the system curve outside the AOR throughout most of the pumps operating range. It also causes the pump to operate frequently at or near runout conditions, resulting in increased maintenance and hydraulic inefficiencies.
- **Variable Speed Operation at or left of BEP at Full Speed.** For pumps intended to operate at multiple speeds, this approach can severely limit the range of speeds over which system performance will fall within the POR or AOR. As pump speed is decreased, the POR and AOR effectively move to the left relative to the system curve. That means less of the total POR or AOR will overlap with the system curve(s) at all other speeds.

11.7.2.4 Multiple Pump Operation

Multiple pumps may be required for pump stations that have frequent operation at two or more required flows/pressures that are significantly different from one another. The further apart the most frequent operating points are from each other on a system curve, the more difficult it becomes to identify a pump that can operate efficiently across all system demands. Multiple pumps may also be required when a local utility cannot deliver the service required to operate larger, single pumps. Local utilities may limit the maximum power or other such parameter of any single piece of equipment in certain areas to protect their service base.

For stations with multiple pumps, the effect of multiple pumps being out of service should be considered when determining the level of redundancy that should be provided. Facilities must meet the required firm capacity with the largest unit out of service.

The following are the most important factors for multiple pump operation:

- For pumps operating in series, pump discharge pressures are additive while total flow remains constant. The discharge of Pump 1 is connected to the suction of Pump 2 with no other (normally open) process connections.
- For pumps in parallel, pump discharge flows are additive while pressures remain constant. The discharges of Pumps 1 and 2 are normally open and connected to a common discharge header and both pumps are in operation.

11.7.2.5 Pump Redundancy

A. Water Pump Stations

Redundancy and flexibility are extremely important for the water transmission system. The overall system must be designed to remain fully functional when any one major component is out of service.

The following are guidelines for water pump station redundancy:

- For critical water pump stations, it may be justified to provide three pumping units each sized at 50% capacity. In this scenario, even if two pumps are not operational, the station can still accommodate 50% capacity.
- A business case and risk analysis should be performed before selecting this method.
- Consult with utility operations staff about redundancy needs early in the planning process.

B. Drainage and Wastewater Pump Stations

SPU requires a minimum of two pumps for drainage and wastewater pump stations. When two pumps are used, one must be a 100% duty unit and one must be for 100% standby. Pumps must alternate duty and standby roles with each pumping cycle.

If configurations with more than two pumps are selected, the firm capacity must be met with the largest unit out of service.

11.7.2.6 Impeller Selection for Drainage and Wastewater Pumping

Several types of impellers are available for drainage and wastewater pumping. Each impeller type is designed for a specific type of product and operating condition. SPU uses all impeller types throughout the system. The design engineer must coordinate with SPU Operations and the pump manufacturer to select the impeller type and material of construction most appropriate for the hydraulic conditions and the amount of solids/rag loading of the expected influent at a pump station. Designers must expect and plan for rag loading in the influent unless definitively proven otherwise. Contact SPU Operations and SPU Source Control for information on existing ragging issues at particular stations. The available impeller types and the associated uses for application at SPU pump stations are described in detail below.

A. Enclosed ('non-clog') Impellers

Enclosed, or non-clog, impellers have long been industry standard recommendation for wastewater pump stations. These impellers offer excellent efficiency, smooth operation, and minimal NPSH requirements. However, enclosed impellers are prone to ragging and clogging. Operating costs saved in efficiency are easily outweighed by excessive maintenance and cleaning costs when more than a token number of rags are present. Consider these impellers only when the influent is known to have minimal rags.

B. Semi-Open Impellers

Semi-open impellers generally omit the bottom shroud found on enclosed impellers. Delta impellers sacrifice efficiency and increase potential for noise and vibration in exchange for improved rag handling capability and reduced clogging. SPU operates this impeller in several older legacy stations, but generally does not prefer it for new projects.

C. Cutting Impellers

Cutting impellers feature a fixed blade on the pump suction plate that acts against rotating blades on the bottom of the impeller. This design generates a scissoring effect that reduces the size of rags and directs rags through the pump. These impellers offer excellent performance in stations with mild or moderate ragging, usually with a minimal penalty in efficiency. However, they may not perform well in stations with severe ragging. Several manufacturers offer some sort of cutting solution, some of which can be retrofitted into existing pumps in some cases. Cutting impellers are SPU's preferred solution for mild to moderate ragging.

D. Chopper Impellers

Chopper impellers are unique to specific types of pumps. Hydraulic efficiency is often poor, especially at lower flow rates, but may be adequate or excellent at higher flows. These impellers chop anything in the influent into small pieces that are easily pumped, and can successfully operate under the most severe ragging conditions with very little cleaning and maintenance. Consider this impeller type when heavy or severe ragging conditions are present.

E. Screw-Centrifugal

Screw-centrifugal impellers are a unique hybrid type that offer excellent hydraulic efficiency and excellent rag-handling capabilities. Pumps with screw-centrifugal impellers typically require more vertical space than traditional pumps of the same flow rate. These pumps must be serviced and cleaned by SPU's machinist crew due to the tight tolerances needed for proper operation. Select this pump and impeller only with the consent of SPU Operations. SPU operates screw-centrifugal pumps at only a small number of stations that are subject to extreme ragging conditions.

11.7.2.7 Impeller Material Selection

Impellers are available in a wide range of materials and coatings. Cast iron impellers are appropriate in most situations. The design engineer should consult with the pump manufacturer to select the most appropriate impeller material and coating (if applicable) for each situation. Stations with corrosive or rock and grit-laden influent, especially stations fed from beach lines, may require impellers constructed of high chrome ductile iron, stainless steel or other exotic metal alloys.

11.7.2.8 Seals

<u>Flush-free mechanical seals must be used on all wastewater and drainage pump stations</u>. Availability of flush-free mechanical seals, and their performance at the anticipated system pressures, should be verified with the pump manufacturer. When possible, use locally and readily available flush-free mechanical seal components. Avoid use of proprietary seals.

<u>Submersible pumps must use tandem mechanical seals with a moisture sensor in the space between seals.</u>

11.7.2.9 Bearings

Bearings for pumps must have a minimum ANSI B-10 bearing life of 40,000 hours when pump operates at 25% of BEP capacity for impeller diameter supplied at maximum speed of operation. Project specifications should require pump manufacturers to submit a shaft stress and bearing life analysis with the submittal package.

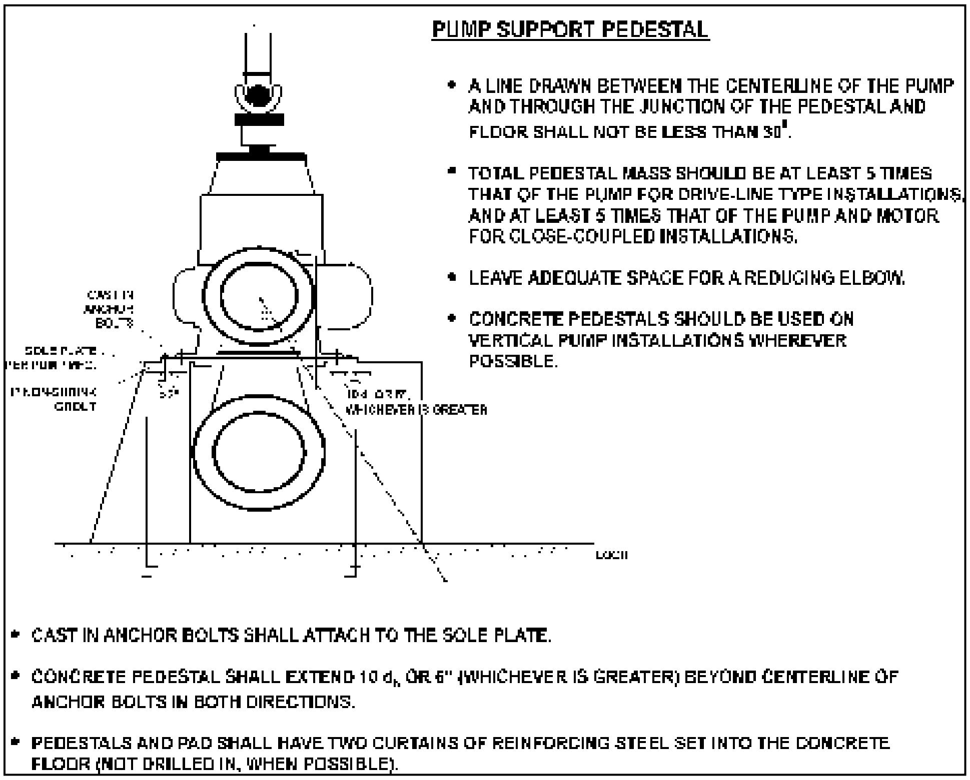
11.7.3 Pump Base Design

A proper base support is essential to minimize vibration on all rotating equipment. Pumps that are 50 hp or smaller may successfully use manufacturer-provided mounting bases. To minimize potential pump base problems, SPU recommends using concrete bases over steel frames for larger pumps.

Concrete pump pedestals should be used for pump supports and designed for easy maintenance access (Figure 11-16). The pedestals can be designed with vertical sides to maximize the amount of concrete mass beneath the pumps. Tapered sides can be used to improve access between pumps. Incorporation of a sole plate on top of the pump pedestal allows the pump to be accurately leveled and eases pump removal and maintenance. It is critical that the sole plate be properly grouted into place to provide firm contact between the pump and the pedestal. Cast-in-place J or headed anchor bolts should be provided to affix the sole plate to the pump pedestal. The pump pedestal should be anchored to the pump station floor using cast-in rebar curtains wherever possible, although epoxy grouted connections are acceptable for retrofits.

Pump bases are unique for submersible pumps installed in a wet well. Their geometry can significantly affect the pump intake hydraulics. Sufficient exposure is required to the wet well volume or pump suction appurtenances.

Figure 11-16
Pump Base Support



11.7.4 Station Layout

11.7.4.1 General

All pump stations must be equipped with a permanent space dedicated for a portable standby generator unless a complete permanent standby power system is provided.

The space should be completely isolated from the rest of the pump station. Isolation allows a less stringent area classification to be maintained for electrical facilities and lower capital costs for electrical equipment. Electrical equipment will also have a longer life if kept in a dry area.

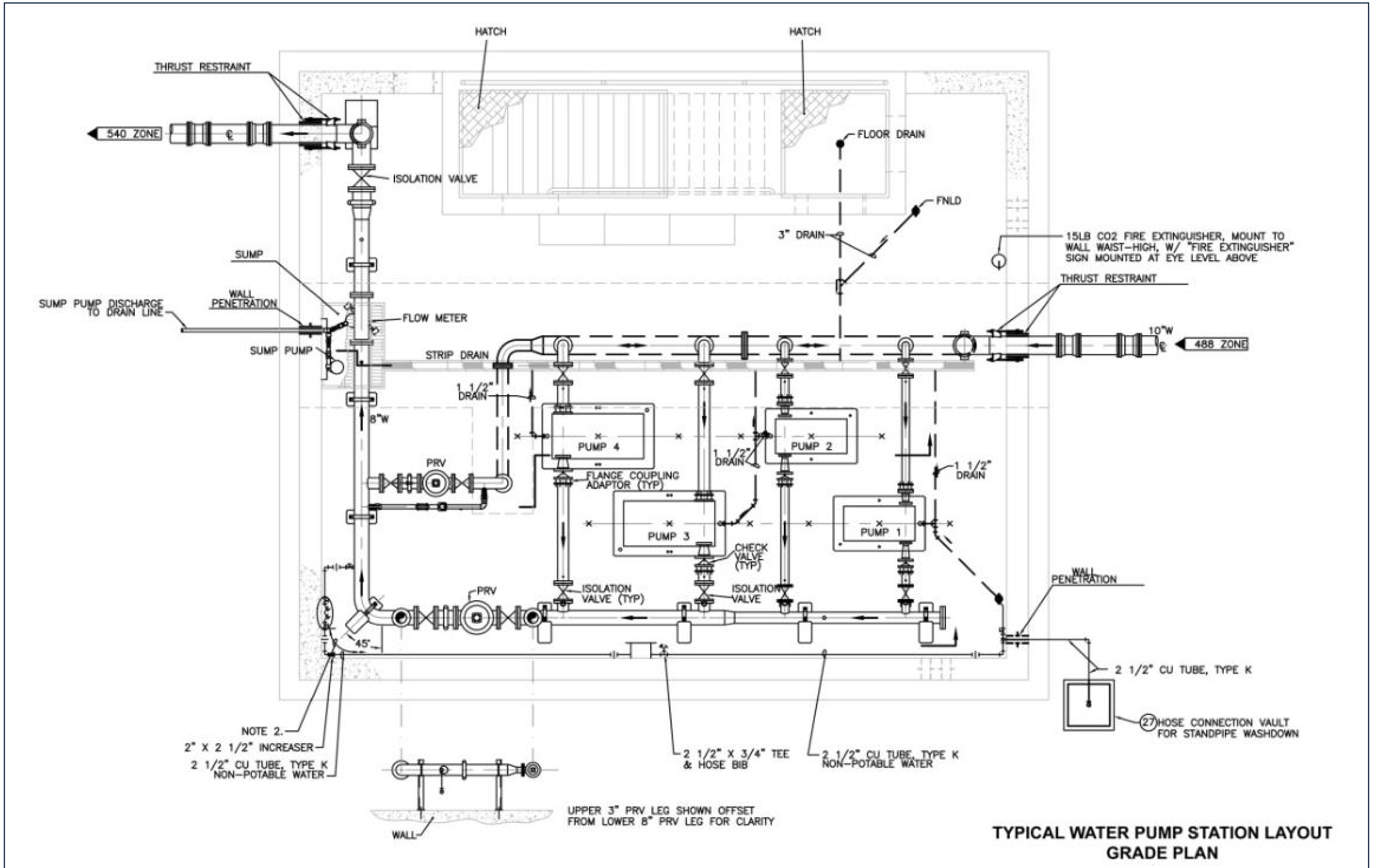
11.7.4.2 Water Pump Stations

A water pump station typically consists of a concrete structure with hatches or doors, pumps and pump foundations, isolation valves, check valves, pressure regulating and sustaining valves, pipes, pipe supports, flow meter, couplings, sump, sump pump, floor drain, HVAC, MCC, and I&C.

Potable water pumps are typically horizontal centrifugal pumps at grade. They are not connected to a wet well. Potable water systems must be certified NSF International 60/61 for use with potable water and the system must be completely disinfected to AWWA standards. Cross-connection control measures need to be carefully considered. Potable water pumping stations tend to be cleaner and drier than wastewater stations and are not classified areas. Therefore, it is not as critical to place electrical equipment (e.g., controllers and MCCs) in a separate room from the pumps. It is, however, desirable if space allows. Electrical equipment separated from the rest of the process is more cost effectively temperature controlled and can require less stringent NEMA classifications.

Figure 11-17 shows a typical layout of an SPU water pump station.

Figure 11-17
Typical Water Pump Station Layout



11.7.4.3 Wastewater and Drainage Pump Stations

Wastewater and drainage pump stations can be of two different configurations: dry well/wet well or submersible (wet well). These facilities include submersible pumps, pump foundations, isolation valves, check valves, inflow sluice valves and combination air release valves, sumps, sump pumps, force main, pipes, pipe supports, ventilation system, MCC, e-plug, generator, and I&C. Not all pump station types are appropriate for all flow rates and locations. When conducting options analyses, be sure to consider all technically viable station types. Work with SPU Operations and the Line of Business Representative to select a solution that is technically feasible, operable, and maintainable.

A. Dry Well/Wet Well Layout

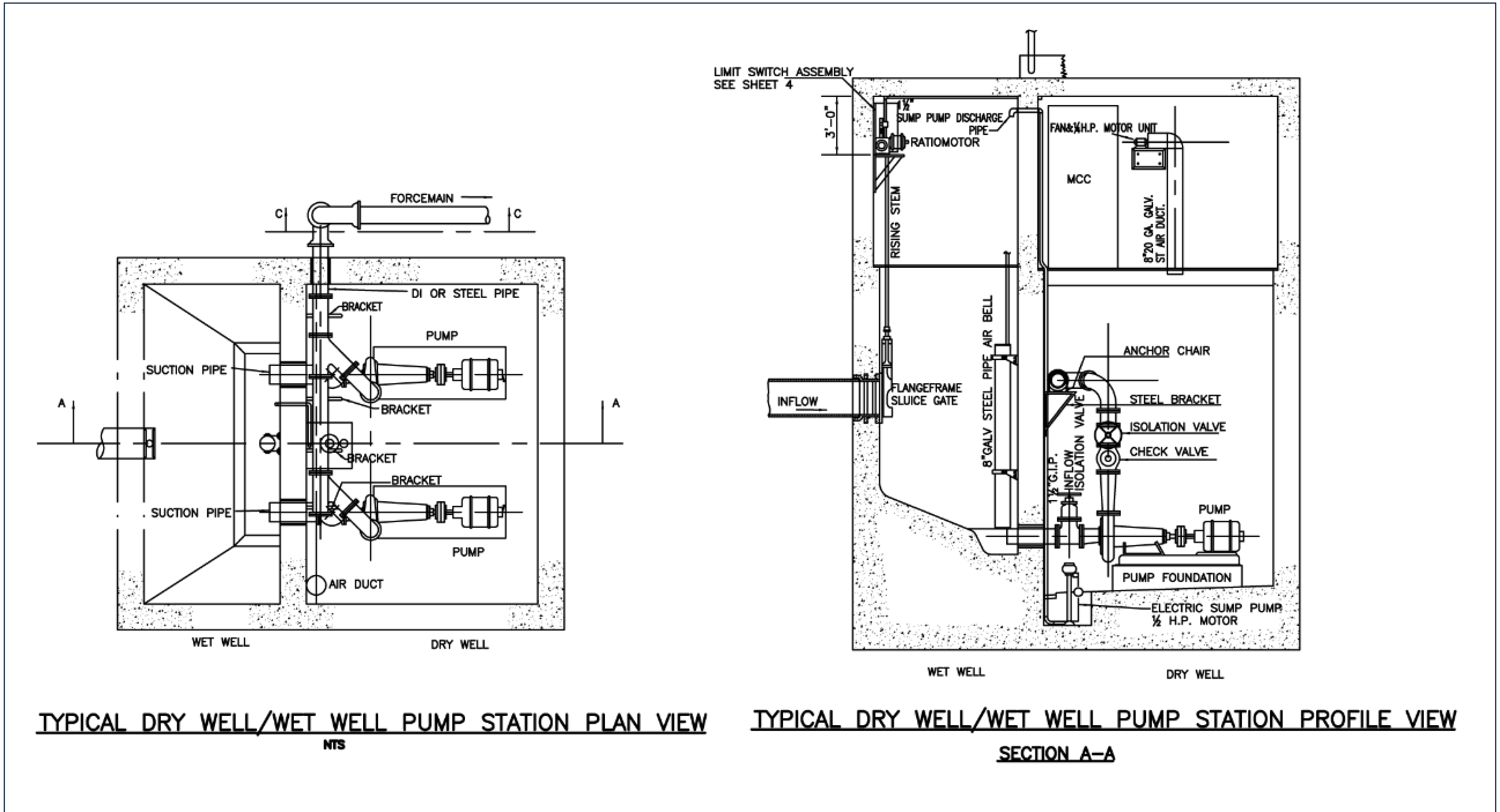
A dry well/wet well configuration typically consists of separate spaces, usually below grade, that may or may not share a common wall. The wet well space receives wastewater from the upstream collection system and functions as a temporary reservoir for pumping. The dry well houses pumps, piping, valves, process equipment, and usually electrical equipment. Intake pipes convey wastewater from the wet well to the suction side of the pumps. Some existing facilities may still have doors allowing direct access between dry wells and wet wells. These doors are no longer allowed by NFPA 820. Removal of these doors and creation of separate access is required for retrofit projects.

Dry well/wet well stations generally provide good access and working space for maintenance of equipment and have the longest life of SPU pump stations (some existing stations have structures that are nearly 100 years old).

While this configuration is preferred, it is also generally the most expensive and is not always viable, especially at lower flow rates. In areas subject to flooding or inundation, below grade dry well/wet well stations are at higher risk of damage and outage. This station type requires major excavation and construction in the right of way that may not always be feasible.

The majority of SPU's existing facilities use the dry well/wet well configuration and it is generally SPU's preferred configuration for new facilities. Figure 11-18 shows a typical layout for a dry well/wet well station.

Figure 11-18
Typical Dry Well/Wet Well and Wet Well Layout



B. Submersible (Wet Well) Layout

A submersible pump station configuration consists of a single wet well which receives incoming wastewater and houses pumps with integrated motors capable of operating while submerged. Depending on the size of the station valves and appurtenances may be housed in the wet well or in a separate valve vault. Electrical and SCADA equipment may be housed in a separate vault or in above grade cabinets. Submersible stations require boom truck access for removal and service of pumps in the wet well. See Figure 11-19 for a typical submersible pump station layout.

When space allows, valves and appurtenances must be installed above the maximum water surface elevation in a separate dry vault to allow better access for maintenance.

Submersible stations are often a good choice for very small basins and low flow rates, but are generally suitable for a wide range of flows. Facility layouts are generally more flexible versus other pump station types.

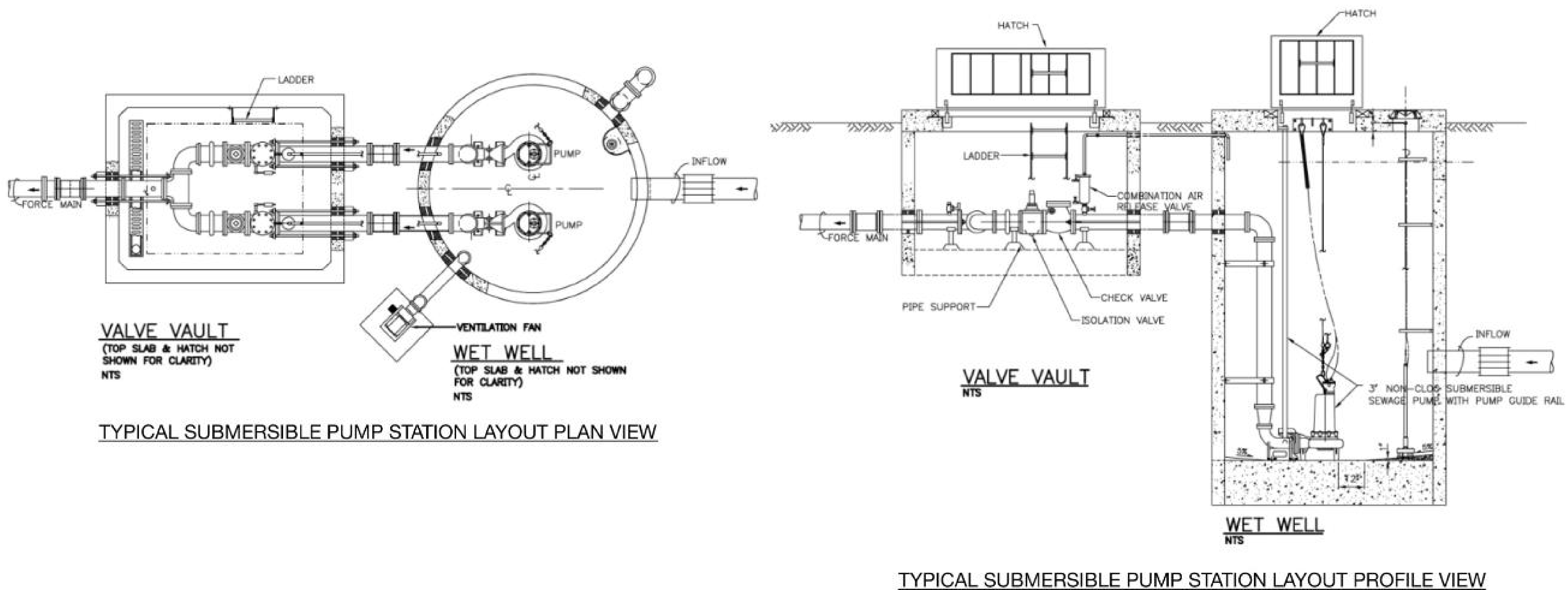
SPU operates many submersible stations, which are generally amongst the newest stations. The smallest submersible stations generally use grinder pumps, while larger stations use traditional solids handling pumps.

C. Pneumatic Ejector Stations

SPU's wastewater system includes several legacy pneumatic ejector pump stations. These stations generally serve small, low-flow basins with low static heads. Ejector stations generally consist of one or more pressure vessels (receivers) that collect incoming sewage. When receivers fill to a pre-set level, air compressors pressurize the receiver and force sewage out through the connected force main.

Due to aging equipment and growing maintenance requirements, SPU plans to decommission all existing ejector stations and provide service to these basins with new pump stations or other alternative means. New pneumatic ejector stations will not be built going forward.

Figure 11-19
Typical Submersible (Wet Well) Layout



11.7.5 Process Piping Design

Pipe design for pump stations includes process and force main piping. Process piping refers to all piping inside the pump station.

11.7.5.1 Pipe Sizing, Materials, and Jointing

A. Wastewater Force Main Sizing

Force mains must be 4 inches or greater to allow for inspection and cleaning. Pipe size should not compromise minimum and maximum velocity requirements.

When installing a new force main or rehabilitating an existing force main, consider alternative installation methods to reduce cost. For information on trenchless technology, see *DSG Chapter 8, Drainage and Wastewater Infrastructure*.

Wastewater force mains must be tested according to Standard Specification 7-17.3(4)F.

B. Materials

The following are SPU standards for pump station pipe materials. Other materials may be acceptable if approved by SPU:

- All piping within the pump station structure must be either ductile iron or carbon steel and must be designed with restrained joints.
- At a minimum, ductile iron piping must be service Class 52. Flanged, grooved, or otherwise fabricated ductile iron pipe must be service Class 53 minimum. All ductile iron piping must follow Standard Specification 9-30.1(1).
- Steel piping design must follow AWWA M11. All steel piping must follow Standard Specification 9-30.1(4).
- Wastewater force mains beyond the pump station structure may be constructed of restrained joint ductile iron pipe service Class 52 or thicker, or of high-density polyethylene (HDPE) (thickness as required, not to exceed a dimension ratio (DR) of 17).
- Metallic wastewater piping and fittings, both within and outside of pump stations, must be epoxy lined.

Material selection should be as consistent as is practical throughout all pump station piping to minimize the need for transitional appurtenances (e.g., dielectric flange insulation kits).

Material selection and pressure classes, or pipe wall thicknesses, may significantly affect hydraulics. For example, ductile iron piping is controlled by the inside diameter (ID) while (depending on size) carbon steel piping may be controlled by the outside diameter (OD). As a result, 20-inch ductile iron piping will have a fixed inside diameter of almost exactly 20 inches. A 20-inch carbon steel piping could have a significantly reduced inside diameter depending largely on the selected pipe schedule (a metric associated with pipe thickness).

The following are other important factors to consider for pump station pipes:

- Exposed piping may require insulation and/or heat tracing provisions to protect against the elements.
- Buried piping may be subject to depth of cover requirements or special provisions related to local geotechnical conditions. Buried steel piping should conform to the requirements of AWWA M11.
- Buried metallic piping should be evaluated for cathodic protection needs (see *DSG Chapter 6, Cathodic Protection*).

C. Joints and Couplings

Typically, ductile iron piping uses flanged connections, and carbon steel piping uses either flanged or welded connections for piping inside a pump station. Flanged pipe should not be used in buried applications.

Where in-line equipment (e.g., pumps, valves, or flow meters) is installed, jointing must be provided on either side of the equipment, to allow for disassembly and removal. For this application, SPU generally recommends dismantling joint fittings, grooved couplings, or other fittings that allow length adjustment and disassembly clearance. In most cases, flanged joints are not appropriate for equipment removal. Flexible, rubberized couplings should not be used to connect equipment to the piping system as these are easily assembled with improper alignment.

Force mains, ventilation ducts, and other pipe penetrations must include a flexible joint at the entrance to, or exit from, a structure. Joints must be located a distance from the outside wall of the structure of 12-inches or one pipe diameter, whichever is greater. Where the project geotechnical report predicts differential settlement of six-inches or greater during the design seismic event, the flexible joint should be a telescoping double ball joint fitting.

11.7.5.2 Drainage and Wastewater Pump Piping Velocities

For drainage and wastewater pump stations, the minimum and maximum velocities allowed through pump inlet (suction) and discharge pipes must meet those shown in Table 11-22 .

Table 11-22
Velocities for Pump Inlet (Suction) and Discharge Piping for Individual Pumps

Location	Minimum Velocity (fps)	Maximum Velocity (fps)
Inlet Piping	2	8
Inlet Piping (High Rag influent)	5	8
Discharge Piping	2	10
Discharge Piping (High Rag effluent)	5	10

Acronyms and Abbreviations
fps: feet per second

A. Minimum Velocities

Certain technical constraints affect pipe size selection. For force mains conveying sewage, minimum velocity must be 2 ft per second (fps) for wastewater and 2 fps for drainage pump stations during initial operation. For stations subject to ragging or above-average solids in the influent, higher minimum velocities (at least 5 fps) are strongly required. Insufficient velocity can lead to build up and plugging in process or force main piping.

B. Maximum Velocities

To maintain head losses at reasonable values, the maximum velocity in wastewater force mains must be 8 fps. For short (< 100 ft) force mains, SPU allows higher velocities (up to 10 fps) on a case-by-case basis. Pipe wall erosion from grit is a concern when velocities exceed 10 fps.

C. Velocities for Variable Speed Pumping

Additional caution is warranted when sizing piping that will accommodate a wide range of velocities, especially where variable speed pumping is used. See Section 11.1.

11.7.5.3 Piping Support Design

Proper installation of piping, supports, and restraint fixtures is required for optimum pump performance and reliability. The installed piping must be supported by pipe supports connected to the surrounding structure and not by the pump itself. Extra loads on the pump nozzles can be created by lack of adequate pipe support systems, leading to misalignment of the pump shaft with the driver shaft, binding or rubbing of the pump rotor, and in extreme cases, the breaking of pump nozzles or feet. Another piping problem is natural frequencies of the piping system causing the pump to operate out of range. A properly designed pipe support system holds the weight of the pipe rather than imparting such loads on the pump nozzles, while restraints and guides are used to redirect the forces generated by thermal effects and thrust away from the pump nozzle. Pipe supports must be designed to handle vertical, horizontal, axial, thermal, and seismic forces. See *DSG Chapter 4, General Design Considerations*. Do not connect piping to pump nozzles with flexible rubberized couplings, as these may inadvertently allow pipe misalignment when improperly installed.

11.7.5.4 Valves

Valve selection is critical to properly control flow and pressure through a pipe system. SPU generally provides a check valve immediately downstream of the pump. Isolation valves should be included on either side of any piece of equipment that will be routinely isolated and removed from service. At a minimum, isolation valves should be incorporated on both the suction and discharge side of each installed pump, check valve or other major piece of equipment.

A. Water Pump Stations

Water system piping should use resilient seated gate or butterfly valves for piping greater than 4 inches in diameter and ball or globe valves for smaller lines. Drain valves must include an air gap and be directed to a floor drain. All connections to the potable water system must provide backflow preventers.

Table 11-23 lists appropriate valve types for the SPU water pump stations.

Table 11-23
Valves for SPU Water Pump Stations

Function	Acceptable Types	Comment
Isolation	Butterfly Gate (12 inches) Ball (<4 inches) Globe (<4 inches)	• Required on all pump discharges. • If on piped suction, should be at least five pipe diameters upstream of the pump suction.
Check Valves	Swing check Double disk	• Required on all pump discharges upstream of isolation valve. • Must be installed horizontally. Consult manufacturer for other installations.
Pressure Relief Valves		• Commonly included on downstream side of pump to maintain upstream pressure. Should be connected to floor drain.
Combination Air/Vacuum		• Air/vacuum valves should be provided on piping at high points on sections to be drained.
Air Release Valve		• Likely be required on discharge side of pump and at all high points in the line. • Will sometimes "spit" water. Should be piped to a floor drain with an air gap.
Pump Control Valve	Ball valve Globe valve	• Minimizes pump surge from starting and stopping pumps (motor or hydraulic operated).

Other valves associated with ancillary systems for pump stations include those for a potable water source for hose bibs, fire protection, or drain and flushing valves for the system. Smaller valves for these connections should be ball valves for isolation and globe valves for draining.

B. Drainage and Wastewater Pump Stations

Valves used on drainage and wastewater system piping should be fully ported valves that are compatible with liquid-bearing solids fluid. Fully ported valves are especially important when the valve is located within four pipe diameters of a pump inlet. Flow acceleration and non-uniform flow distribution caused by reduced port valves can propagate downstream from the valve. This condition can cause non-uniform flow distribution at the pump inlet or flow rotation in conjunction with the pump suction elbow.

Table 11-24 lists recommended valve types for SPU drainage and wastewater pump stations.

Table 11-24
Valves for SPU Drainage or Wastewater Pump Stations

Function	Acceptable Type	Comment
Isolation	Gate valves	• Required on all pump discharges • If on piped suction, should be at least five pipe diameters upstream of the pump suction

Function	Acceptable Type	Comment
		• Double-disc gate valves generally preferred by SPU Operations
Check Valves	Swing check	• Required on all pump discharges upstream of isolation valve • Must be installed horizontally • Consult manufacturer for other installations • Must include outside weight or spring and level (rubber on bronze seat)
Combination Air/Vacuum[1]		• Must be rated for wastewater applications. • Must only be used with overall water hammer control scheme • Should be provided with back flushing capabilities and threaded or flanged outlets piped to sewer • SPU recommends Vent-O-Mat RGX B
Air Release		• Required on most pump discharges. • Must be rated for wastewater applications • Must be piped to wet well or sewer
Wet Well Installation	Slide gate	• Used to isolate wet well from inflow to station (stainless steel)

Notes [1] Air release valves (or some other device by which air can be released from a discharge pipe) should be placed at all significant high points along the discharge pipe. If these locations are not vented, air that comes out of solution will accumulate in high points of the pipe and create additional head in the system and can accelerate corrosion due to the accumulation of hydrogen sulfide.

11.7.5.5 Valve Operators and Actuators

Valves may be either manually or automatically operated, depending on their function in a particular process.

A. Manually Operated Valves and Gates

Manually operated valves and gates are typically used to block flow and isolate a particular space or portion of a pipeline for maintenance purposes. These valves and gates are typically equipped with handwheels or operating nuts.

Handwheels should be used for valves which are located within dry wells, vaults, or other secure areas not easily accessible to the public. Where valves are located more than 7 feet above the floor or grating deck, provide a chainwheel operator.

Valves that are buried or located in wet wells and confined spaces should be configured to allow operation from the ground surface without entry into the confined space. Such valves should be equipped with AWWA standard 2-inch square operating nuts, oriented vertically, within 12 inches of finished grade. In some cases, stem extensions or bevel gear operators may need to be used to achieve this. Ensure a minimum 2-foot (preferably three foot) radius clear space is available around the nut to allow the valve to be operated using a standard T-wrench or portable handheld actuator.

B. Automatically Operated Valve and Gates

Automatically operated valves and gates are typically used to modulate flow for process control. These valves and gates are equipped with an actuator that controls valve position according to commands given by an external controller connected to the SCADA system. Actuators may also be used on isolation valves or gates that are too large or heavy to be operated manually. Actuators may be electric or hydraulic depending on the application.

All actuators must be equipped with an Uninterruptible Power Supply (UPS) and configured to move to a preset safe position in the event of power failure. See *DSG Chapter 9, Electrical Design* and *DSG Chapter 10 (I&C, SCADA* (I&C, SCADA).

Electric actuators use an electric motor to drive a geared system that opens and closes the valve. These actuators can operate valves with a threaded stem and can also operate quarter-turn valves equipped with a worm gear operator. All electric actuators must be furnished with a handwheel for backup manual operation. For design guidance on electric operators, see DSG Chapter 10 (I&C, SCADA, Section 10.10.6.

Hydraulic actuators use pressurized fluid to extend or retract a piston coupled to an arm or cam on a valve to change the valve's position. These actuators are suitable for operating quarter turn valves, such as ball or plug valves. Pressurized fluid is routed through the piston using solenoid valves controlled by an external PLC. For water pump stations only, hydraulic actuators can use a bleed line from the pressurized water pipeline as a source of operating pressure.

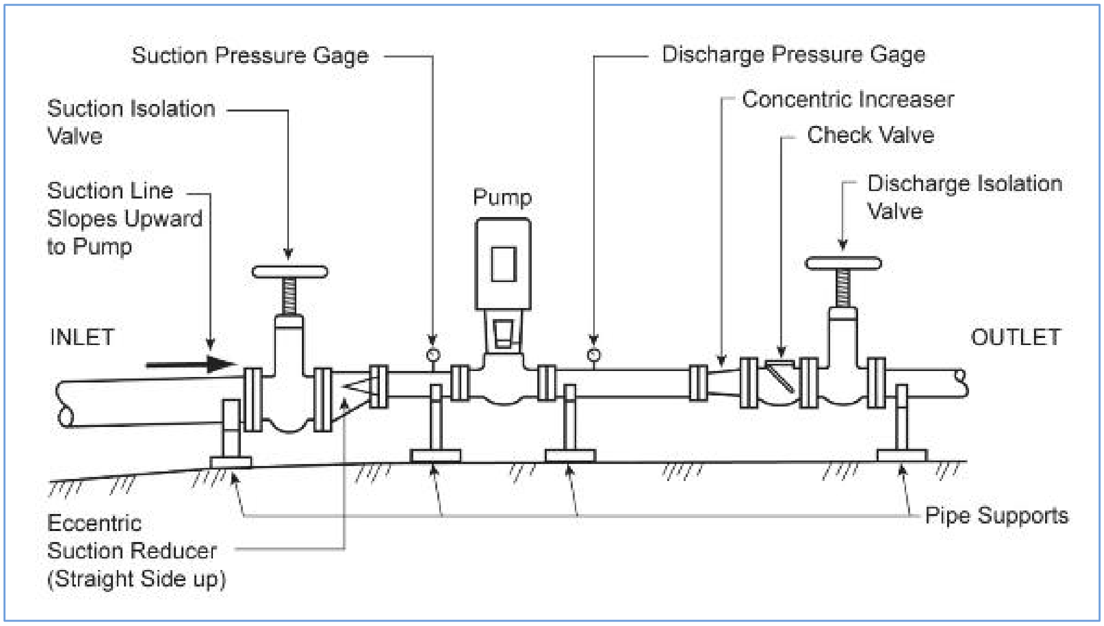
11.7.5.6 Inlet Piping

Pump intake design must follow HI section 9.8. The pump intake configuration is critical to delivery of acceptable hydraulics to the pump intake. Subtle differences in piping configuration can greatly determine whether a pump inlet receives well-distributed or severely skewed flow.

A. Typical Inlet and Outlet Configurations

The inlet (suction) side of the pump typically includes an isolation valve, a pressure tap, and a reducer to match the piping to the size of the pump inlet (Figure 11-20). The outlet side of the pump typically includes an increaser, an air relief valve (at the high point), a pressure gauge or transmitter, a check valve, and isolation valve and a flow meter. Occasionally, sample taps may need to be provided on the discharge piping. To prevent accumulation of air pockets, all points along an outlet pipe should be made lower than the static water level at the end of the pipe, with a consistent upward slope. This arrangement allows air to be released when the pump idles. Air buildup in pipelines can cause air binding, reduce pump performance, and accelerate corrosion. Potential for air entrapment must be avoided.

Figure 11-20
Typical Inlet and Outlet Configuration



B. Wet Well Piping and Pump Intakes (Drainage and Wastewater)

Wastewater and drainage pumps are connected by pipe to wet wells and piped through a force main to SPU systems. The flow configuration through a wet well can result in a separation of solids from liquid, head loss, and a vortex effect. To reduce flow separation and unnecessary head loss, it is beneficial to provide a flared inlet (turned-down elbow with a flared inlet or a horizontal flared inlet) that can create smooth acceleration of flow as it enters the inlet pipe.

1) Turned-down Inlet

Generally, a turned-down elbow is more effective than a horizontal inlet when there is low velocity in the wet well.

2) Horizontal Inlet

SPU prefers a horizontal inlet. It is less prone to generation of pre-swirl in the suction piping than is a turned-down elbow. Pre-swirl is flow rotation approaching the pump inlet, which is a common source of impeller cavitation damage and vibration. SPU recommends horizontal inlets for turbulent wet wells that have higher velocity flows and circulation patterns. Horizontal inlets do, however, require greater submergence than turned-down elbows to prevent surface vortex formation. Flared inlets should be flush with the partition wall.

C. Header Piping to Water Pumps

Unlike wastewater pump stations, typically, water pump stations are not connected to a wet well or reservoir but are hard piped in the transmission system. In this case, a larger header is brought into the station and each individual pump pulls suction from the header. The main feeder header may be located under the pump station slab (which will require access vaults) or may come in overhead depending on hydraulics. The piping from the feeder to the pumps should be straight and short runs when possible.

D. Pipe Reducers

Reducers are frequently required in pump inlet piping to match the suction pipe diameter with the pump size. When placed in horizontal piping, suction reducers should be eccentric type, oriented with the flat side on top to prevent air from accumulating in the intake piping.

The angle of convergence of an eccentric reducer increases for each pipe size reduction. As the reducer convergence angle increases, the flow disturbance generated becomes more severe. This flow disturbance requires additional lengths of equivalent straight pipe between the reducer and the pump inlet or pump suction elbow to reduce the disturbance to the pump.

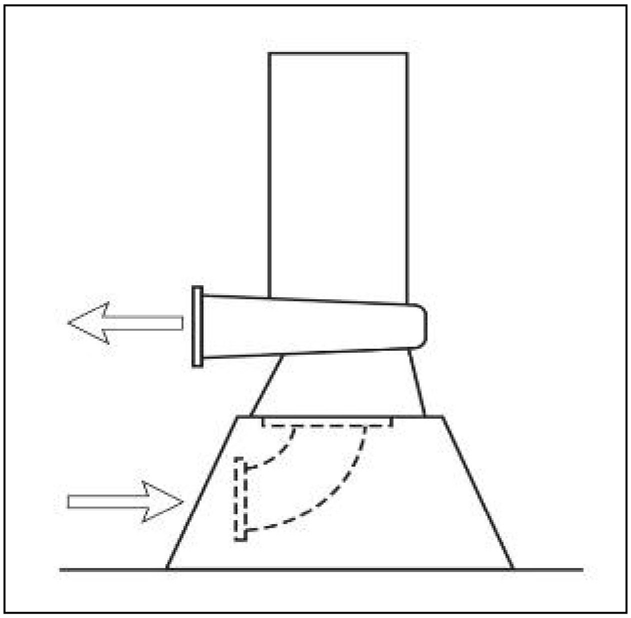
The following are guidelines for pipe reducers:

- Eccentric reducers should be located at least one pipe diameter away from the pump inlet or pump suction elbow for every nominal pipe size reduction.
- As an example, a standard 16-by-12-inch reducer should be located at least two pipe diameters (24 inches) away from the pump inlet because it provides a reduction of two standard nominal pipe sizes. Generally, standard pipe sizes in this range are increments of even whole number nominal diameters.

E. Pump Inlet and Discharge Elbows

Vertically mounted wastewater pumps require a 90-degree elbow upstream of the pump. The elbow is typically attached directly to the pump inlet (Figure 11-21) and is usually furnished by the pump manufacturer as a part of the mounting base. The dashed line in represents the pump suction elbow of a submersible pump mounted in a wet well. For large pumps with cast-in-place bases, the elbow resides between concrete walls on either side.

Figure 11-21
Pump Suction Elbow Leading to Pump Body



In some circumstances, the pump suction elbow has been cited as a major concern associated with pump vibration and increased maintenance. Physical modeling shows that pump suction elbow geometry affects hydraulics at the pump inlet. It is critical to use a reducing elbow because a standard (non-reducing) elbow will deliver a severely skewed velocity profile to the pump inlet.

<u>To deliver a flow that meets HI velocity distribution criteria, the ratio between the inlet and outlet sides of the elbow must be a ratio of 1:1.5</u>. The inside diameter of the pump throat is typically a smaller diameter than the pump inlet flange and can be used for this calculation in lieu of the downstream diameter of the pump suction elbow. Use of long radius elbow is preferred in this configuration. However, short radius reducing elbows can also be effective. Work with the pump manufacturer to determine the most appropriate inlet piping and suction elbow design for each situation.

For most submersible pumps, the fitting immediately downstream of the pump discharge is typically a 90-degree elbow required to orient the pumped discharge flow vertically and route it through the balance of the downstream mechanical equipment. These fittings can experience significant and highly variable thrust forces, especially at startup. SPU recommends that the pump manufacturer be closely consulted to determine what, if any, additional reinforcement may be required for fittings attached to the pump nozzle. Such provisions may affect the final dimensions and should be considered when designing concrete bases and supports to accommodate this equipment.

11.7.5.7 Bypass Capabilities for Drainage and Wastewater Pump Stations

Bypass pumping capabilities must be included at all pump stations to allow critical flows to be maintained with temporary equipment while the pump station is out of service.

Temporary portable pumps connected to the existing process piping are ideal for bypass pumping and typically are used for smaller capacity pump stations. To accommodate bypass pumping operations, additional tee fittings with isolation valves and blind flanges or cam lock couplings must be installed on the force main or discharge process piping system for wastewater stations. Drains must be included on the bypass tee to allow for temporary hoses to be drained prior to disconnection.

Bypass connections should be installed immediately outside of the pump station in a separate vault, when possible. Tees for temporary connections must be sized for the full design flow of the facility. In no case may a tee be more than one diameter smaller than the force main itself. Tees with branches larger than 4-inches must be equipped reducers to allow connection to 4-inch temporary hoses. These reducers provide compatibility with SPU's portable bypass pumps for short-term or emergency response. The bypass gate valve must be sized to the branch of the tee and placed ahead of any reducers. For long-term, full-capacity bypassing, reducers and camlock fittings may be removed to allow additional flow. SPU's standard connection for bypass tees is a male camlock fitting with a dust cap. An example bypass vault for wastewater stations is shown in **Appendix 11F - Example Bypass Vault Layout.** Lighting should be provided in bypass vaults that are intended for personnel entry.

When possible, pump stations should be equipped with a nearby upstream maintenance hole, overflow chamber, or secondary wet well that can serve as a reservoir for bypass pumping during maintenance of primary wet wells. In all cases, provide an isolation gate on the inflow line to isolate the wet well from incoming flow. For more information on bypassing, see *DSG Chapter 3, Design for Construction.*

11.7.5.8 Inspection and Cleaning Access for Wastewater Force Mains

SPU does not currently have established standards and practices for wastewater force main maintenance and inspection. Project teams should work with SPU Operations to determine inspection and cleaning access requirements for force mains on a project-by-project basis. Consider providing cleanout wyes, pig ports, or similar access when force mains pass through unstable soils, private property, under water bodies or structures, or otherwise may be difficult to excavate for emergency repairs.

11.8 WET WELL DESIGN

Wet wells are required for wastewater and drainage pump stations. The design engineer should follow the HI American National Standard for Pump Intake Design (ANSI/HI 9.8-1998). Critical design considerations for solids-bearing fluids include:

- Flow should not decelerate between the wet well and the pump inlet
- The wet well should incorporate minimal horizontal surfaces and should be free from low-velocity zones where solids are most likely to accumulate
- Wet well geometry should discourage large-scale flow circulation patterns

- Provisions should be included to periodically create turbulence in the wet well to re-entrain settled solids, floating grease, and debris
- Wet wells must have sufficient working volume to meet motor cycling requirements defined in Section 11.8.1.3.
- Wet wells must be sized to provide adequate storage for pump operation and emergency response.

Designers must evaluate each of these requirements when determining the required wet well volume and geometry.

11.8.1 Required Wet Well Volume

Required wet well volume is typically governed by storage for emergency response, as well as required working volume to support adequate motor cycle times. Project teams must evaluate both requirements. The larger requirement will govern.

Projects which have passed 60% design by January 1, 2024 may elect to utilize storage time requirements stated in the 2020 edition of SPU Design Standards and Guidelines.

11.8.1.1 Storage Volume for Emergency Response

Storage volume allows adequate time for SPU Crews to respond to station alarms and resolve any issues before overflows occur. These could be pump clogging, mechanical breakdown, power loss, failure of critical components, etc. Depending on the circumstances, multiple crews may be required to resolve the issue. This requirement may not apply to drainage pump stations depending on the specific nature of system.

Designers should note that SPU does not currently staff pump station crews on duty 24/7 and may only have standby operators available after hours. Standby operators have a minimum call-out response time of two hours to arrive on site. Response times may be longer during severe weather events or regional emergencies, as first response resources are limited and prioritized across all of SPU’s assets based on immediate risks to the health and safety of the public.

- <u>For new pump stations, provide minimum four hours of storage.</u>
- <u>For pump station retrofits, expand existing storage to not less than two hours.</u>

In cases where the defined storage criteria cannot be met, project teams must work with the SPU Shared Services Operations and Maintenance Manager, DWW Line of Business Representative, and SOPA Wastewater Operations Manager to determine a storage volume that balances response time, risk to the Utility, and the governing design constraints. The Project Team must document the storage volume analysis along with written approval of all three parties in the project Basis of Design Memorandum. Objections to the final design storage volume by any party must also be documented.

<u>If final design volume provides less than one hour of storage, requirements for standby power apply.</u> See Section 11.6.4.5.

A. Calculation of Required Emergency Storage Volume

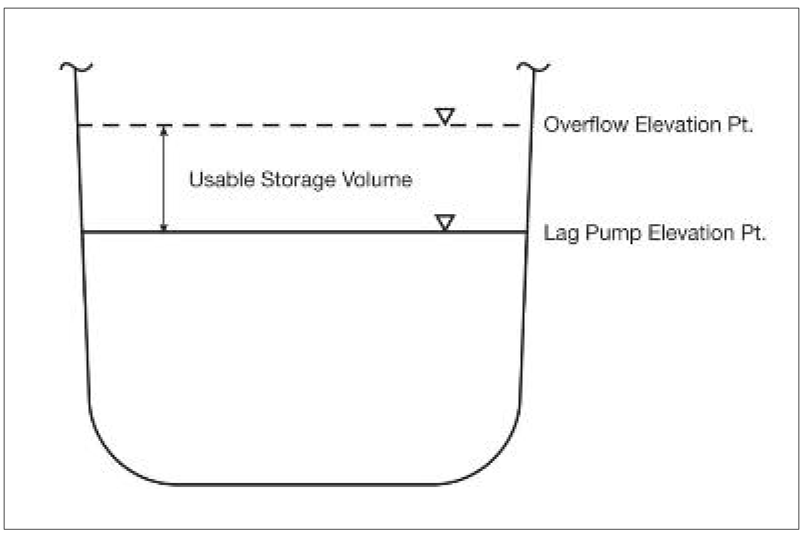
- For new or existing combined sewer stations, or stations with known wet weather influence, calculate the required emergency storage volume based on the 95th percentile inflow rate determined by hydraulic modeling for the selected climate horizon (see Section 11.2.4.2). Where hydraulic modeling is not available the calculation may be based on not less than two years of existing flow data.

- For existing sanitary sewer stations, calculate the required emergency storage volume based on the 95th percentile inflow rate based on not less than two years of existing flow data.
- For new sanitary sewer stations, calculate the required emergency storage volume based on peak and average flows as recommended by the orange book (to be revised)

B. Calculation of Available Emergency Storage Volume

Storage volume for emergency response is defined as shown in Figure 11-22 below:

Figure 11-22
Usable Wet Well Emergency Storage Volume



Wet well storage volume can consist of any combination of the following:

- Pump station usable wet well storage volume (lag pump elevation to overflow elevation).
- Capacity in gravity pipelines upstream of the pump station (lag pump elevation to overflow elevation).
- On-line storage pipes installed upstream of the pump station (lag pump elevation to overflow elevation).
- Off-line detention basin that is normally dry but connected to the pump station specifically to provide additional storage volume (least preferred).

Exercise caution when determining how much, if any, capacity in the collection system can be used for wet well storage volume. Typically, a water surface elevation in the upstream gravity pipelines will correspond to an overflow or similar condition (e.g., the invert of a connected pipeline). The available volume of a collection system that can be used for emergency storage should be determined case by case depending on system geometry, pipe routing(s), backwater effects, and criticality of operation. The balance of the storage requirement must be met using one of the four methods discussed above.

Choosing the condition at which wet well storage is evaluated has a significant effect on the required wet well storage volume. SPU evaluates response time based on analysis of historical inflow data under four different conditions:

- Average spring-summer inflow (April to September)
- Average winter inflow (October to March)
- Average wet weather inflow (SCADA wet weather tag for the active facility based on nearby rain gauge data)
- 95th percentile inflow

As available, at least two years of inflow data should be used in calculating storage time. Storage time for all four conditions must be reported in the Basis of Design regardless of which value is used for calculating response time. This information is used to plan and guide future maintenance work at the facility. When estimating the available storage time, the design engineer should select the condition based on the nature of the inflow at a facility. Spring-summer inflow may not be used for this calculation. For new facilities, the anticipated maximum daily inflow indicated by hydraulic modeling should be used for calculating required storage volumes if flow monitoring data are not available.

11.8.1.2 Required Wet Well Volume for Motor Cycling

Pump motors and starters need to cool a sufficient time between starts or they will overheat causing thermal overload protectors to trip out and stop the motors. The time needed between pump starts—called cycle time—increases with motor size. Recommended maximum values for across-the-line (from idle to full operation) motor starts per hour are provided in Table 11-25. The corresponding required cycle times must always be verified with the motor manufacturer, especially if the number of starts per hour will exceed the values shown below. Submersible motor manufacturers may allow additional starts per hour depending on the installed conditions.

Table 11-25
Recommended Motor Starts per Hour

Type	Size (hp)	Maximum Starts (per hour)
Horizontal Split Case Pumps	< 20	6
	20 to 50	4
	60 to 200	2
	> 200	1
Non-Submersible Motors Installed in Dry Well	< 20	6
	20 to 50	4

	60 to 200	2
	> 200	1
Submersible Motors Installed Submerged in Wet Well	100 or less	8
	> 100	6
Submersible Motors Installed in Dry Well	100 or less	6
	> 100	4

Acronyms and Abbreviations
hp: horsepower

The following is the formula for the required wet well volume based on desired pump cycle time:

$$V = \left(\frac{t \times Q}{30}\right)$$

Where:

V = wet well volume (ft^3)

t = motor cycle time (minutes)

Q = pump flow rate (gpm)

The pump station wet well sizing example (**Appendix 11D - Example Calculations - Wet Well Sizing**) shows how to calculate wet well volume. One method for reducing the required wet well volume is incorporating control strategies that stagger pump operation in multiple pump installations. In a two-pump installation, alternating the pumps will result in an effective overall motor cycle time for each pump. That time will be only half as long as it would have been if one pump served as the sole duty pump and the other as standby. As motor cycle time decreases, so does required wet well volume.

11.8.2 Influent Screening

SPU does not typically provide screening (e.g., bar screens) on wastewater pump stations. However, design engineers may consider adding screening on select drainage and wastewater pump stations to prevent large debris build-up in the wet well and to reduce cleaning requirements. Screening should be designed to keep debris larger than 3 inches from entering the wet well. Screening requirements should be reviewed with SPU Operations and the LOB representative on a case-by-case basis.

11.8.3 Influent Conditioning

At drainage and wastewater stations subject to extreme rag and solids loading, adding conditioning pumps or macerators in the wet well may be effective means of reducing pump clogging. This should only be considered as a last resort if rag-handling pumps do not offer sufficient performance. SPU does not currently operate any influent conditioning equipment. Consult with SPU Operations and the LOB representative before considering influent conditioning.

11.8.4 Typical Wet Well Arrangements

Three typical configurations of wet wells are (1) self-cleaning trench, (2) rectangular style, and (3) circular. The following discussion focuses on wet well arrangements. Table 11-26 summarizes important characteristics of each style of wet well.

Table 11-26
Wet Well Self-Cleaning Trench vs. Rectangular Style

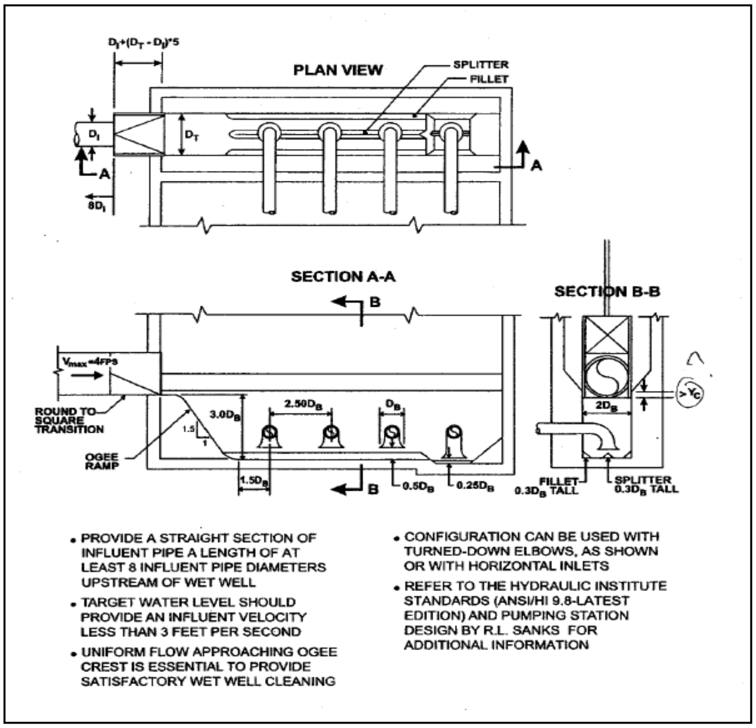
	Self-Cleaning Trench	Rectangular
Usable Wet Well Volume Relative to Total Size	Small	Large
Required Pump Inlet Submergence	High	Average
Most Beneficial Application	Variable speed pumping with minimal motor cycling time	Constant speed pumping with highly variable wet well operating volumes
Maximum Recommended Capacity	None	About 8 mgd

Acronyms and Abbreviations
mgd: million of gallons per day

11.8.4.1 Self-Cleaning Trench Wet Well

SPU recommends the self-cleaning, trench-style wet well for solids bearing water (Figure 11-23) when constructing new facilities. SPU does not currently operate this design in any existing facilities. The HI pump intake standard provides guidance for design of the self-cleaning wet well. The following supplemental guidance should be used when designing trench-style wet wells.

Figure 11-23
Self-Cleaning Wet Well Configuration



Acronyms and Abbreviations
Vmax: maximum influent velocity
Di: inflow pipe diameter
DT: width of trench
Db: diameter of intake bell

The following are design criteria for a self-cleaning, trench-style wet well:

- These wells are sensitive to the uniformity of wet well approach flow. To ensure proper influent hydraulics, a minimum of eight equivalent diameters of straight influent conduit are recommended upstream of the wet well.
- A smooth and uniform transition between the influent pipe and the ogee ramp is required to clean the wet well. To facilitate this transition, the narrow portion of the trench should extend above the invert of the transition section by a distance greater than the critical depth of the maximum influent flow during the cleaning cycle. The narrow portion of the trench should be the same width as the transition section unless a sluice gate is installed at the wet well entrance. For installations with sluice gates, space should be provided to allow the gate frame to fit within the narrow portion of the trench.
- <u>The top radius of the ogee ramp must be designed so that flow does not separate during the cleaning cycle</u>.
- Trenches can develop air-entraining surface vortices that can enter the pump inlet. For this reason, these trench designs require more pump inlet submergence than other wet well designs. The minimum submergence for this trench-style wet well should be 2.5 times the diameter of the inlet bell. It is generally good practice to provide a vertical distance of 2.5 inlet bell diameters between the invert of the influent sewer and the bottom of the turned-down flared inlet. For flared horizontal inlets (not unflared

horizontal pipes), 2.5 inlet diameters are required between the invert of the influent sewer and the centerline of the intake. Additional submergence may be required based on the NPSH requirements of the selected pump. Close coordination with the pump manufacturer is required.

- Fillets and a center splitter are required to suppress subsurface vortex formation for the turned-down type inlet. Fillets and the center splitter should terminate into the ogee ramp, providing a smooth transition of the high velocity flow from the ogee ramp to the wet well floor during the cleaning cycle. The height of the fillets and center splitter should be equal to about 2/3 the bell to floor clearance.
- Because it has a small working volume, this trench-style wet well is most useful in variable speed pumping applications where influent flow can be matched by the pumping rate, thereby minimizing pump cycling and required storage.
- Where the influent sewer is used to increase either wet well working volume or storage volume, the slope of the surcharged portion of the influent sewer should be increased to facilitate scouring velocities during wet well cleaning. <u>The influent configuration must be designed to prevent high-velocity influent flow from separating from the ogee ramp</u>.

11.8.4.2 Rectangular/Circular Wet Well Design

Most existing SPU facilities employ rectangular, semicircular, or round wet wells. The rectangular/circular design has been widely used and extensively tested through hydraulic modeling. It is a compact design more suited for constant speed pumping applications than the trench design. This style will, however, provide reasonable performance for some variable speed pumping applications.

The design engineer should exercise caution when working on retrofits of existing stations that retain the existing wet well, as many of these wells do not meet current HI standards for storage, intake submergence, or flow patterns. Some wells may experience air entrainment issues due to the large vertical drops from inflow pipes at low water levels. Retrofit scopes may need to include baffle plates, revised channeling, or vortex suppression devices to mitigate air entrainment and flow patterns that may negatively impact pump performance. Consider these items on a case-by-case basis.

11.9 CONSTRUCTION

This section describes construction design elements for pump stations. See also *DSG Chapter 3, Design for Construction.*

11.9.1 Submittals

Submittals are required for all equipment and materials provided by the Contractor as defined in the technical specifications. For pump stations, the following items should be given special attention during the review and approval process:

- Materials. Verify that proposed equipment meets all requirements of the specifications, paying particular attention to pumps, motors, motor starters and MCCs, SCADA equipment, and HVAC equipment
- Layout shop drawings for process piping

- Layout shop drawings for electrical equipment and conduit routing
- Shop drawings for hatches, ladders, and gratings
- Testing and startup plan
- O&M instructions and requirements
- Certifications of compliance and completion of testing

Submittals are reviewed in detail against the Project Manual. Pumps should be reviewed against the equipment data sheets developed in design and included in the specifications. Particularly careful review is required when a manufacturer and or model number other than the first named product is submitted.

Layout shop drawings in particular must be held to and reviewed at the highest standard. These plans are key to preventing conflicts during construction. A thorough review can greatly reduce delays and costly rework.

11.9.2 Pump Station Testing and Startup

A well-defined plan is critical to successful testing and startup. This process begins with factory performance testing of the equipment (where applicable) and is completed with final approval of all checklist items and successful operation of the pump station through the test period.

11.9.2.1 Factory Performance Testing of Pumps and Equipment

Factory performance testing must be conducted for all water and wastewater pumps that have motors larger than 5 HP. For pumps 5 HP and smaller, the pump manufacturer may provide equipment based on previously performed tests for the specified pump design and similarly sized impellers to determine the operating characteristics. Such pumping equipment may be accepted based on the manufacturer’s normal quality assurance/quality control (QA/QC) testing.

The following are typical SPU requirements for factory pump performance tests:

- Testing setup should conform to the requirements and (HI standards (ANSI/HI 1.6 – latest edition). <u>Tolerance for acceptance testing must meet the following:</u>
    - 8” and larger pumps – Grade 1U
    - 6” pumps – Grade 1E
    - 4” pumps – Grade 2B

  Grades given are minimums. The design engineer may specify more stringent testing for critical equipment or equipment with unusual performance requirements on a project specific basis.
- Witness of factory testing is generally not required. For large pumping equipment with motors that exceed 200 hp or that have a capacity of more than 5,000 gpm, witnessed testing is preferred. The witnessed test should be observed by a representative of SPU that is familiar with the project and is qualified to understand the technical aspects of the factory test.
- Pump manufacturer should guarantee pump performance at the flow, head, brake horsepower, and efficiency specified.

- Factory performance test should include at least five data points evenly spaced from minimum to maximum flow to define the shape of the pump curve.
- For variable speed pumps, testing should be conducted at full speed, as well as the speed required to meet the design operating point.
- Pump curves developed during the factory test must be certified to guarantee performance.
- It is preferable to test equipment with the job motors if possible. However, supply chain issues and procurement schedules may prohibit this. It is acceptable to test performance with a factory calibrated motor as opposed to the job motor. However, for large equipment SPU may decide it is more appropriate to use the job motor for the testing. Submersible and immersible pumps must be tested with the job motors as a complete unit.

Factory performance testing is also required for motors. See typical testing requirements in the example specifications (**Appendix 11A – Example Pump Station CSI Specifications**, within the pumping equipment specifications).

If the equipment does not meet the specified operating conditions during the factory performance test, the pump manufacturer must make the necessary modifications to the pumps until the specified operating conditions are met. Do not allow shipment of pumps until the contract requirements are met.

In general, it is not recommended that VFDs or motor controls be transported to the pump manufacturer's factory for performance testing. Although testing the VFD at the factory with the pump could turn up operational problems, this testing approach is costly. It also presents unnecessary risk that the equipment could be damaged in transport.

11.9.2.2 Field Operational Testing

Field operational testing tests pump performance and the hydraulic design of the entire pumping facility. Field testing allows evaluation of pump intake design, force main hydraulics, pump and piping installation, and pump field performance.

The initial field test of a pump system should be done with the manufacturer's representative present. All acceptance criteria must be demonstrated under the full range of design flow and head conditions specified. Testing should be documented and signed off by the Contractor, vendor, engineer, and owner. The test will require that test equipment similar to that used for the factory testing be available. Much of the test equipment may be installed as part of the pump station design and should include:

- Flow meter
- Pressure gages on the pump suction and discharge piping
- Tachometer
- Power analyzer

Because the level of environmental controls is lower in field testing as opposed to factory testing, care must be taken to obtain a reasonable level of accuracy during field testing. Field data should be compared to factory testing data to confirm pump performance. Minor changes from factory performance should not cause alarm. Many factors affect performance, including data collection inconsistencies and differences in pump intake hydraulics. Significant differences between field tests and factory tests would be a more than 5% change in head and should be evaluated further. Field testing results should be used as a baseline condition to determine change in performance during future testing.

On large installations, specifications may require an independent company to do vibration testing. These tests document that equipment vibration does not exceed limits outlined in the equipment specifications. Many factors can cause excessive vibration: misalignment or imbalance of rotating equipment, improper pump support, or natural frequency of the pump and piping that is coincident with the pump rotating speed or a multiple of the rotating speed. If vibration levels exceed specified values, the root cause of the vibration should be identified and corrected promptly before it can cause long-term damage to the equipment.

11.9.2.3 Training

Project specifications must require factory or vendor-led training on proper O&M of pumps, motor starters, drives, odor control units, and other major pieces of equipment. A minimum of two 8-hour sessions for small equipment and up to five 8-hour sessions for more complex equipment should be included to allow all crew members to be trained. Trainers must be well qualified with complete knowledge of the equipment for which they are providing training.

Training should be provided to representatives of the owner's O&M and engineering staff. The content of the training should include proper O&M of the equipment with both classroom and hands-on experience. Coordinate project-specific training requirements with SPU Operations during design.

11.9.2.4 Asset Onboarding

Asset Onboarding refers to the practice of documenting new assets and asset attributes, creating entries for these assets in SPU's Maximo Work Management System and attaching appropriate preventative maintenance plans to these assets. Asset onboarding tasks begin at 60% design and carry on throughout construction, with several intermediate milestones. Refer to SPU's Asset Onboarding Guide for direction on the Asset Onboarding process.

11.9.3 Commissioning

Commissioning of pump stations and other facilities is handled by SPU's Commissioning Authority using the SPU's standard commissioning process. Please refer to the Infrastructure Commissioning Sharepoint Site for detailed information on commissioning plans, procedures, checklists, testing, and acceptance criteria. External users must contact SPU for access to this Sharepoint site.

11.10 OPERATIONS AND MAINTENANCE

SPU Operations and Maintenance Crews are responsible for maintaining pump stations. If equipment fails, crews must be able to respond quickly and safely to make repairs and prevent or minimize negative environmental impacts. A well-defined O&M plan and procedure is essential to this goal.

11.10.1 Operations and Maintenance Manuals

All pump station design packages must include a comprehensive facility operations and maintenance manual that explains the operating context of the facility, key parameters, locations of key equipment, as well as equipment manuals, standard operating procedures, recommended maintenance intervals, and associated job plans determined by the Reliability Centered Maintenance process defined in Section 11.10.3. A recommended Table of Contents is included in Appendix 11J.

11.10.1.1 Equipment Manuals

Specifications must require that the Contractor submit equipment O&M manuals in both printed (three copies) and electronic format (PDF format). Manuals, including electronic copies, must be indexed by system and piece of equipment. Electronic copies of manuals are stored on the SOPA DWW Facilities SharePoint site. These manuals typically consist of manufacturers' standard information, repair procedures, spare parts lists, warranty certificates, etc., for each piece of equipment installed with the contract.

11.10.1.2 Standard Operating Procedures

As part of the design package, facility-specific standard operating procedures (SOPs) must be developed by the design team for the following activities, at minimum:

- Bypass pumping
- Pump cleaning
- Removal of pumps and major equipment from the station
- Connection of portable generators
- Any other major maintenance activities unique to the site

Each SOP should include a detailed list of required special tools, equipment, and vehicles, along with a recommended step-by-step procedure for the task. Include simple visual aids such as diagrams, marked up drawings, or renders that show equipment parking and staging locations, lift sequences, and working ranges of cranes or other lifting equipment. SOPs will be maintained on site at each facility for use by SPU crews during regular maintenance activities and emergency responses.

11.10.2 Routine Maintenance

Typically, preventative maintenance activities for pump stations include routine inspection of the following:

- Air release valves
- Bearings
- Couplings
- Drives
- Generators
- HVAC equipment
- Impellers
- Motors
- Other ancillary equipment
- Pumps
- Seals
- Wear clearances
- Wet wells
- Grounds and landscaping

- Gratings, ladders, and structural elements
- Buildings and concrete structures

Periodic service and calibration of all instrumentation such as level sensors, alarms, flow meters, and SCADA equipment should also be conducted as a part of routine maintenance activities. SPU uses the Reliability Centered Maintenance methodology to determine the required maintenance intervals for each piece of equipment.

11.10.3 Reliability Centered Maintenance

RCM is an engineered process used to determine what must be done to ensure that any physical asset continues to do what its user wants it to do in its present operating context. The RCM process identifies all of the functions and performance standards of the asset being evaluated and then determines all of the ways that asset can fail. The RCM process also defines what risks are associated with the asset in terms of safety and environmental integrity, customer service and so on. RCM identifies a suitable failure management policy for each failure mode in the light of its consequences and technical characteristics. Failure management policies may include predictive or preventive maintenance, training, or redesign of existing systems. Some assets may be allowed to run to failure.

RCM offers the following:

- Greater safety and environmental integrity
- Improved operating performance (output, product quality, and customer service)
- Greater maintenance cost-effectiveness
- Longer useful life of expensive assets
- Comprehensive database of maintenance requirements
- Greater motivation of individuals from improved knowledge of equipment
- Better teamwork through common language and understanding of what must be done

For each new or existing facility, RCM workshops are held with the design team, SPU Operations and Maintenance, and the SPU Work Management Systems team late in the design process. These meetings are typically facilitated by specialty consultant experienced in the RCM methodology. Each operable component is reviewed and assigned a criticality based on its function and role in the system process (ventilation, water pumping, etc). Based on the criticality score, a maintenance strategy is selected that maintains an appropriate level of equipment reliability while minimizing O&M burden.

<u>All new pump station facilities must have an RCM analysis done before startup and testing</u>. The analysis will include a detailed operating context for the station, failure modes and effects analysis, and preventive maintenance tasks. <u>Results of the analysis must be implemented through MAXIMO</u> prior to acceptance of the facility.

11.10.4 Performance Testing/Energy Audits

To maintain acceptable pump station capacity, annual performance testing is conducted on all wastewater and drainage pump stations and on water pump stations that are near design capacity.

Pump station performance testing consists of collecting flow and head data for each of the pumps and comparing the data to the certified pump curves provided by the pump manufacturer. The performance testing is similar to that done at startup. The performance data collected at startup should be the baseline performance to which subsequent performance testing data are compared. The amount of acceptable degradation of pump performance can vary depending on design requirements and size of the pumping equipment. Generally, if pump performance has degraded by 5% from baseline, equipment maintenance should be considered. Minimum acceptable performance levels before maintenance overhauls are performed should be established for each pumping station.

Equipment wear can also reduce pumping efficiency. During evaluation of performance testing data, the efficiency of the pumping equipment should also be evaluated. The wire-to-water pumping efficiency can be determined during performance testing and can be converted to determine the energy consumption of the pumping station. Evaluation of energy consumption and amount of maintenance required for each pumping station will reveal where system upgrades would be most beneficial.

11.11 RESOURCES

Documents

1. ANSI:
    a. ANSI/AWWA D100, Welded Steel Tanks for Water Storage, and NACE Standard PRO 178
    b. ANSI/AWS D1.1, Structural Welding Code
    c. 73.1, Horizontal end-suction centrifugal pumps
    d. E101, Vertical turbine and submersible pumps
2. American Society of Civil Engineers (ASCE): Seismic Design (ASCE 7-02)
3. American Society of Mechanical Engineers (ASME): Boiler and Pressure Vessel Code, Section VIII, Pressure Vessels and 7.1, 8.2, Displacement and centrifugal pumps
4. ASTM International
5. American Water Works Association (AWWA): ANSI/AWWA D100, Welded Steel Tanks for Water Storage, and NACE Standard PRO 178, Item No. 53041 and E101, Vertical turbine and submersible pumps
6. City of Seattle (most current versions):
    a. Seattle Plumbing Code
    b. SDOT Streets Illustrated
    c. Seattle Energy Code
    d. Seattle Municipal Code
    e. Seattle Parking Requirement Code
    f. Sign Code (Seattle Land Use Code Ch. 23.55)
    g. Stormwater, Grading and Drainage Control Code (SMC 22.800-22.808)
    h. Environmentally Critical Areas (ECA) Ordinance (SMC 25.09)
    i. SBC
    j. SDOT
    k. SPU: Interim CIP Guidance
7. HI:
    a. Pump Intake Design (ANSI/HI 9.8)
    b. Rotodynamic Pumps for Pump Piping (ANSI/HI 9.6.6)
    c. Pump Intake Design Standard
    d. Standards (ANSI/HI 1.6 – latest edition)
    e. ANSI/HI 9.6.3
8. National Highway Institute: “Highway Stormwater Pump Station Design” Hydraulic Engineering Circular No. 24, USDOT Federal Highway Administration, Publication No. FHWA-NHI-01-007, February 2001
9. NEC: Section 501-8
10. NFPA 820, Recommended Practices for Wastewater and transmission facilities

11. NSF International: Standard 61
12. *Pump Station Design 3rd Ed.*, Editor-in-Chief Robert L. Sanks (the Sanks Book)

Websites

Hydraulic Institute
http://www.pumps.org/

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