Appendix B*: Software Requirements for a Wastewater Pumping Station Wet Well Control System

1 Concept of Operations

A wastewater pumping station is a component of the sanitary sewage collection system that transfers domestic sewage to a wastewater treatment facility for processing. A typical pumping station includes three components: a sewage grinder, a wet well, and a valve vault (Figure B.1). Unprocessed sewage enters the sewage grinder unit so that solids suspended in the liquid can be reduced in size by a central cutting stack. The processed liquid then proceeds to the wet well, which serves as a reservoir for submersible pumps. These pumps then add the required energy/head to the liquid so that it can be conveyed to a wastewater treatment facility for primary and secondary treatment. The control system specification that follows describes the operation of the wet well.

1.1 Purpose

This specification describes the software design requirements for the wet well control system of a wastewater pumping station. It is intended that this specification provide the basis of the software development process and as preliminary documentation for end users.

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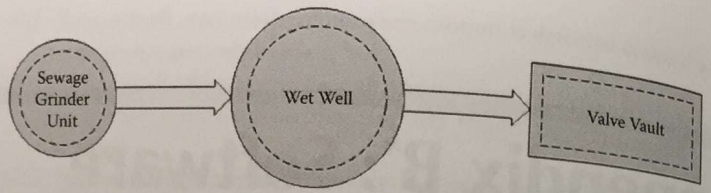

Figure B.1 Typical wastewater pumping station process.

1.2 Scope

The software system described in this specification is part of a control system for the wet well of a wastewater pumping station. The control system supports an array of sensors and switches that monitor and control the operation of the wet well. The design of the wet well control system shall provide for the safety and protection of pumping station operators, maintenance personnel, and the public from hazards that may result from its operation. The control system shall be responsible for the following operations:

1. Monitoring and reporting the level of liquid in the wet well.
2. Monitoring and reporting the level of hazardous methane gas.
3. Monitoring and reporting the state of each pump and whether it is currently running.
4. Activating a visual and audible alarm when a hazardous condition exists.
5. Switching each submersible pump on or off in a timely fashion depending on the level of liquid within the wet well.
6. Switching ventilation fans on or off in a timely fashion depending on the concentration of hazardous gas within the wet well.

Any requirements that are incomplete are annotated with "TBD" and will be completed in a later revision of this specification.

1.3 Definitions, Acronyms, and Abbreviations

The following is a list of definitions for terms used in this document.

Audible Alarm: The horn that sounds when an alarm condition occurs.
Controller: Equipment or a program within a control system that responds to changes in a measured value by initiating an action to affect that value.
DEP: Department of Environmental Protection.
Detention Basin: A storage site, such as a small unregulated reservoir, that delays the conveyance of wastewater.
Effluent: Any material that flows outward from something; examples include wastewater from treatment plants.
EPA: Environmental Protection Agency.

Influent: Any material that flows inward from something; examples include wastewater into treatment plants.
Imminent Threat: A situation with the potential immediately and adversely to affect or threaten public health or safety.
Manhole: Hole, with removable cover, through which a person can enter into a sewer, conduit, tunnel, and the like, to repair or inspect.
Methane: A gas formed naturally by the decomposition of organic matter.
Overflow: An occurrence by which a surplus of liquid exceeds the limit or capacity.
Precast: A concrete unit that is cast and cured in an area other than its final position or place.
Pump: A mechanical device that transports fluid by pressure or suction.
Remote Override: A software interface that allows remote administrative control of the pumping control system.
Seal: A device mounted in the pump housing and/or on the pump shaft, to prevent leakage of liquid from the pump.
Security: Means used to protect against the unauthorized access or dangerous conditions. A resultant visual and/or audible alarm is then triggered.
Sensor: The part of a measuring instrument that responds directly to changes in the environment.
Sewage Grinder: A mechanism that captures, grinds, and removes solids ensuring a uniform particle size to protect pumps from clogging.
Submersible Pump: A pump having a sealed motor that is submerged in the fluid to be pumped.
Thermal Overload: A state in which measured temperatures have exceeded a maximum allowable design value.
Valve: A control consisting of a mechanical device for controlling the flow of a fluid.
Ventilation: The process of supplying or removing air by natural or mechanical means to or from a space.
Visible Alarm: The strobe light that is enabled when an alarm condition occurs.
Voltage: Electrical potential or electromotive force expressed in volts.
Wet Well: A tank or separate compartment following the sewage grinder that serves as a reservoir for the submersible pump.

2 Overall Description

2.1 Wet Well Overview

The wet well for which this specification is intended is shown in Figure B.2.

The characteristics of the wet well described in this specification are as follows:

1. The wet well reservoir contains two submersible pumps sized to provide a fixed capacity.

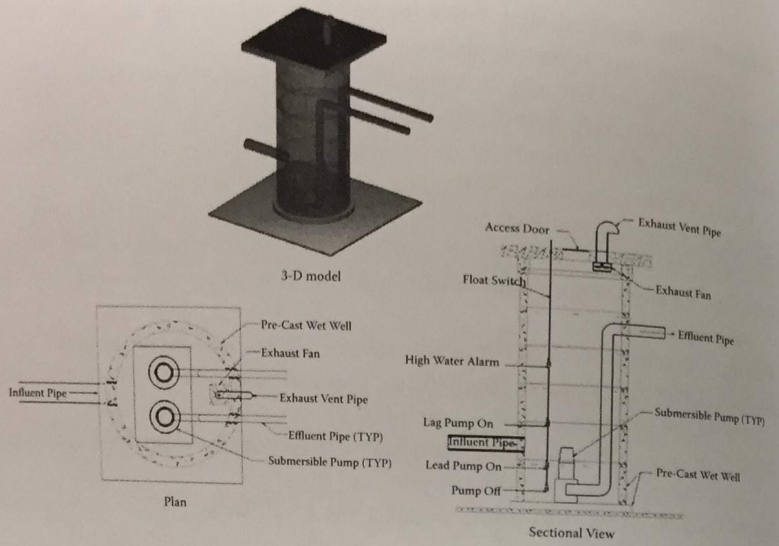

Figure B.2 Typical wet well (model, plan, and sectional diagram).

2. Hazardous concentrations of flammable gases and vapors can exist in the wet well.
3. The wet well has a ventilation fan that is oriented to direct fresh air into the wet well rather than just exhaust from the well.
4. An alarm and indicator light is located outside so that operators can determine if a hazardous condition exists. Hazardous conditions include but are not necessarily limited to a high gas level, a high water level, and pump malfunction.
5. A float switch is used to determine the depth of liquid currently in the wet well.

2.2 Product Perspective

2.2.1 System Interfaces

The system interfaces are described in subsequent subsections.

2.2.2 User Interfaces

2.2.2.1 Pumping Station Operator

The pumping station operators use the control and alarm display panels to control and observe the operation of the submersible pumps and wet well environmental

conditions. Manipulation of parameters and the state of the submersible pumps is possible when the system is running in manual mode.

2.2.2.2 Maintenance Personnel

The maintenance personnel use the control and alarm display panels to observe the current parameters and state of the submersible pumps and wet well and perform maintenance.

2.2.3 Hardware Interfaces

The wet well control system hardware interfaces are summarized in Figure B.3.

2.2.3.1 Major Hardware Components—Summary

The wet well control system hardware components are summarized in Table B.1.

2.2.3.2 Moisture Sensor

Each submersible pump shall be equipped with a moisture sensor that detects the occurrence of an external pump seal failure. Should a seal failure be detected, the pump shall be turned off and alarm state set.

2.2.3.3 Float Switch

The float switch is a mercury switch used to determine the depth of liquid within the wet well and set the on or off state for each pump. Three switch states have been identified as lead pump on/off, lag pump on/off, and high water alarm.

2.2.3.4 Access Door Sensor

The access door sensor is used to determine the state, either opened or closed, of the wet well access door.

2.2.4 Software Interfaces

2.2.4.1 Pump Control Unit

The wet well control system interfaces with the pump control system providing a pump station operator and maintenance personnel with the ability to observe the operation of the submersible pumps and wet well environmental conditions. The pump control unit provides the additional capability for pump station

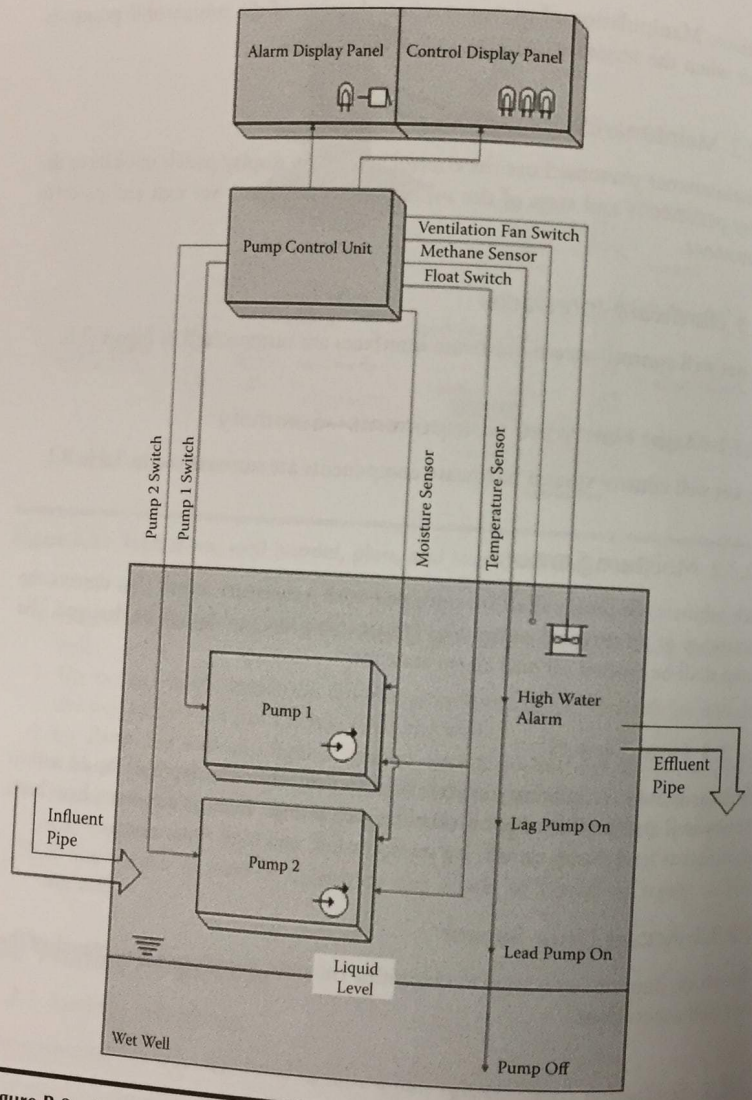

Figure B.3 Wet well control system hardware.

Table B.1 Major Wet Well Control System Hardware Components

Item	Description	Quantity
1	Pre-Cast Concrete Wet Well	1
2	Access Door	1
3	Ventilation Pipe	2
4	Axial Flow Fan	2
4.1	Fan Switch	2
5	Submersible Pump	2
6	Pump Control Unit	1
6.1	Temperature Sensor	2
6.2	Moisture Sensor	2
6.3	Float Switch	1
6.4	Access Door Sensor	1
7	Alarm Panel	1
7.1	Alarm Lamp	1
7.2	Alarm Buzzer	1
8	Control Panel	1
8.1	Panel Lamps	6 (3 per pump)

operators of manipulation of parameters and states of the submersible pumps when the system is running in manual mode.

2.2.4.2 Control Display Panel

The control display panel interfaces with the pump control unit providing visual information relating to the operation of the submersible pumps and environmental conditions within the wet well.

2.2.4.3 Alarm Display Panel

The alarm display panel interfaces with the pump control unit providing visual and audible information relating to the operation of the submersible pumps and the environmental conditions within the wet well.

2.2.5 Operations

The wet well control system shall provide the following operations:

1. Automated operation
2. Local manual override operation
3. Local observational operation

2.3 Product Functions

The wet well control system shall provide the following functionality:

2.3.1. Start the pump motors to prevent the wet well from running over and stop the pump motors before the wet well runs dry.
2.3.2. Keep track of whether each motor is running.
2.3.3. Monitoring the pumping site for unauthorized entry or trespass.
2.3.4. Monitor the environmental conditions within the wet well.
2.3.5. Monitor the physical condition of each pump for the existence of moisture and excessive temperatures.
2.3.6. Display real-time and historical operational parameters.
2.3.7. Provide an alarm feature.
2.3.8. Provide a manual override of the site.
2.3.9. Provide automated operation of the site.
2.3.10. Equalize the runtime between the pumps.

2.4 User Characteristics

2.4.1 Pumping Station Operator

Authorized personnel trained with the usage of the wet well control system when it is in manual mode.

2.4.2 Maintenance Personnel

Authorized personnel trained with the usage of the wet well control system.

2.5 Constraints

System constraints include the following items:

1. Regulatory agencies including but not limited to the EPA and DEP
2. Hardware limitations
3. Interfaces to other applications
4. Security considerations
5. Safety consideration

2.6 Assumptions and Dependencies

Assumptions and dependencies for the wet well control system include the following items:

1. The operation of the sewage grinder unit is within expected tolerances and constraints at all times.
2. A power backup system has been proved as a separate system external to the wet well control system.
3. The operation of the controls within the valve vault is within expected tolerances at all times.

3 Specific Requirements

The following section defines the basic functionality of the wet well control system.

3.1 External Interface Requirements

3.1.1 User Interfaces

The user interfaces are described in Figure B.4.

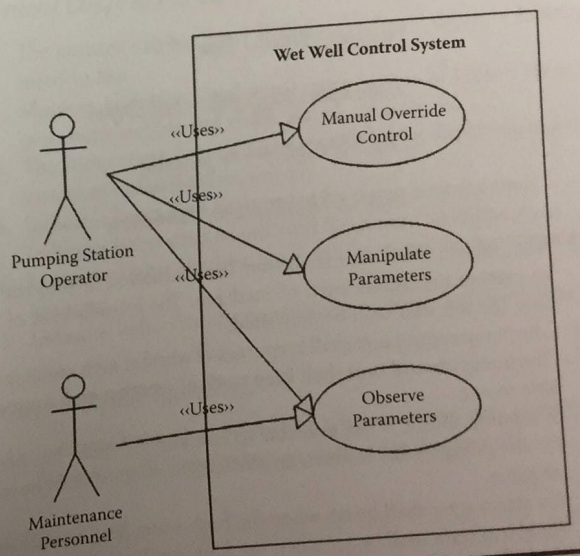

Figure B.4 Wet well user interfaces.

3.2 Classes/Objects

3.2.1 Pump Control Unit

3.2.1.1. The pump control unit shall start the submersible pump motors to prevent the wet well from running over and stop the pump motors before the wet well runs dry.

LeadDepth represents the depth of liquid when the first pump should be turned on.

LagDepth represents the depth of liquid when the second pump should be turned on.

HighDepth represents the depth of liquid that the wet well should be kept below. Should the depth of liquid be equal to or exceed HighDepth, the alarm state is set.

AlarmState represents a Boolean quantity such that at any time t, the audible and visual alarms are enabled.

Depth represents the amount of liquid in the wet well at any time t in units of length.

Pumping represents a Boolean quantity such that at any time t, the pumps are either running or not.

$$Depth : Time \rightarrow Length$$

$$pumping : Time \rightarrow Bool$$

$$HighDepth : LagDepth > LeadDepth$$

$$Depth \geq LagDepth \Rightarrow pumping$$

$$Depth \geq HighDepth \Rightarrow AlarmState$$

3.2.1.2. The pump control unit shall start the ventilation fans in the wet well to prevent hazardous levels of methane. The introduction of methane into the wet well shall be prevented.

3.2.1.3. The pump control unit shall keep track of whether each motor is running.

3.2.1.4. The pump control unit shall keep track of whether each motor is available to run.

3.2.1.5. If a pump motor is not available to run and a request has been made for the pump motor to start, an alternative motor should be started in its place.

3.2.1.6. An alarm state shall be set when the high water level is reached.

3.2.1.7. An alarm state shall be set when the high methane level is reached.

3.2.1.8. The starting and stopping of the pump motors shall be done in manner that equalizes the runtimes on the motors.

3.2.1.9. Level switches shall be used to indicate when pump motors should be started.

3.2.1.10. The pump control unit shall be notified if excess moisture is detected in a pump motor.

3.2.1.11. The pump control unit shall be notified if a pump motor overheats and shall shut down the overheated motor.

3.2.1.12. The pump control unit shall be responsible for monitoring the pumping site.

3.2.1.13. The pump control unit shall be responsible for recording real-time and historical operational parameters

3.2.1.14. The pump control unit shall be responsible for providing an alarm feature.

3.2.1.15. There shall be an automatic and manual mode for the pump control unit. Each pumping station shall either be in automatic mode or manual mode.

3.2.1.16. Monitor and detect prohibited entry to the wet well through the access door by way of a broken electrical circuit. Both audible and visible alarms are activated

3.2.1.17. Monitor and detect occurrence of a pump motor seal leak. If a leak has been detected both an audible and visible alarm should be activated.

3.2.2 Control Display Panel

3.2.2.1. The control display panel shall have a digital depth of influent measured in feet.

3.2.2.2. Monitor and detect prohibited entry by way of broken electrical circuit. Both audible and visible alarms are activated.

3.2.2.3. The pump control unit shall be responsible for displaying real-time and historical operational parameters.

3.2.2.4. Indicator lights shall be provided for pump running state.

3.2.2.5. Indicator lights shall be provided for pump seal failure state.

3.2.2.6. Indicator lights shall be provided for pump high-temperature failure state.

3.2.2.7. Indicator lights shall be provided for high wet well level alarm state.

3.2.3 Alarm Display Panel

3.2.3.1. Indicator lights shall be enabled when an alarm state is activated

3.2.3.2. A buzzer shall sound when an alarm state is activated.

3.2.4 Float Switch

3.2.4.1. When the depth of liquid is equal to or greater than the lead pump depth the float switch shall set a state that causes the first pump to turn on.

3.2.4.2. When the depth of liquid is equal to or greater than the lag pump depth the float switch shall set a state that causes the second pump to turn on.

3.2.4.3. When the depth of liquid is equal to or greater than the allowable high liquid depth the float switch shall set an alarm state.

3.2.5 Methane Sensor

3.2.5.1. When the volume of methane is equal to or greater than the high methane volume, the methane sensor shall set a state that causes the ventilation fans to turn on.

3.2.5.2. When the volume of methane is equal to or greater than the allowable maximum methane volume, the methane sensor shall set an alarm state.

HighMethane represents the volume of methane that should cause the exhaust fans to turn on.

MaxMethane represents the volume of methane that the wet well should be kept below. Should the volume of methane be equal to or exceed MaxMethane an alarm state is set.

ExhaustFan represents a Boolean quantity such that at any time t, the exhaust fan is either running or not running.

AlarmState represents a Boolean quantity such that at any time t, the audible and visual alarms are enabled.

A partial formalization of the methane sensor operation is given below.

$$MaxMethane > HighMethane$$

$$ExhaustFan : Time \Rightarrow Bool$$

$$AlarmState : Time \Rightarrow Bool$$

$$Methane \geq MaxMethane \Rightarrow ExhaustFan$$

$$Methane < MaxMethane \Rightarrow ExhaustFan$$

$$Methane \geq MaxMethane \Rightarrow AlarmState$$

4. Reference

IEEE Std 830-1993 (1993). *IEEE Recommended Practice for Software Requirements Specifications*. Piscataway, NJ: Institute for Electrical and Electronics Engineers.