Drainage System Condition Assessment

FINAL REPORT

For the Sewerage and Water Board of New Orleans, Louisiana

March 15, 2018

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The results of Veolia's condition assessment of the Sewerage & Water Board's (S&WB) storm water (drainage) system reveals widespread equipment condition deterioration and an urgent need to improve several aspects of the S&WB's organization and processes. Although the 'availability' status of pumps and generators have been accurately communicated to the public, the 'capability' of much of this equipment is in a degraded state, which compromises safety margin and escalates risk of failure. The current condition and management of the drainage system is at a critical crossroad requiring a new path to correct issues and reduce the high level of risk it imposes on the residents of the city. Furthermore, while Veolia did not investigate funding sources required for S&WB to address these risks, it is likely that significant increases in capital budgets will be required if existing allocations do not align with the recommendations from this report.

Background & Objectives

The City of New Orleans engaged Veolia in August to conduct an assessment of the New Orleans drainage system. The city, as well as the S&WB, should be applauded for demanding a comprehensive, transparent review of the system in the wake of flooding issues on August 5, 2017. The city, its leadership and the S&WB have recognized there is an urgent need to improve the system, and this review is a critical step forward. This assessment is intended to provide a road map for the city and the S&WB to address the infrastructure concerns in the city's drainage system.

The S&WB operates and maintains an extensive collection of drainage system assets which serve the City of New Orleans. This portfolio includes storm water collection system assets, power generation assets, power distribution assets, and numerous drainage pumping stations located throughout the city. The drainage pumping stations operate on a combination of 25 Hz and 60 Hz power supplies. Electrical power generated and distributed by the S&WB is primarily 25 Hz, while 60 Hz is primarily supplied by the local distributed electricity supplier, Entergy.

The objective of Veolia's engagement with the S&WB was to assist with determining: (1) The condition of the storm water collection, power generation, power distribution, drainage pumping, and associated ancillary systems and (2) a list of key actions required to first **restore** the functionality of the drainage system and then **sustain** this functionality in the future.

The results of the condition assessment will draw a firm distinction between **availability** and **capability** of drainage pumping equipment. S&WB has traditionally communicated the number of pumps and generators that are available. Availability strictly refers to whether or not a pump is able to be start and does not provide any indication as to how well a pump can pump. The results that are presented in this report will provide new insight into the ability of available equipment to perform its intended function. The difference between availability and capability is necessary to quantify in order to understand which equipment warrants attention and maintenance to mitigate unforeseen failures and unavailability.

Condition Assessment Approach

To achieve this objective, Veolia conducted a detailed **condition assessment**, which defines the condition of S&WB's drainage system assets for the period of August 25, 2017 through November 21, 2017. The tasks outlined below structured the condition assessment approach.

(1) **Develop an Asset Hierarchy** - This task entailed developing a comprehensive asset hierarchy, specifying every item of the plant which requires maintenance attention of any kind.

(2) **Conduct a Criticality Assessment** - The objective of this task was to facilitate the identification and prioritization of systems and their assets based on rankings from a standardized scale for consequence and likelihood of worst case failure scenarios. Critical spares were also addressed via determining the critical spares requirements of the S&WB's physical assets to fully support operations and maintenance.

(3) **Conduct a Condition Assessment with the most relevant predictive technologies** - The primary objective was to establish a baseline of the physical condition of the S&WB's drainage system assets. A wide range of non-invasive condition-based techniques from the asset-reliability industry were employed.

(4) **Pump Capacity Testing** - The goal of this task was to establish the actual available capacity and hydraulic capabilities of the drainage system pumping stations.

(5) **Assess a sample portion of the Drainage System** - The objective of this task was to determine the functional status of the drainage collection and conveyance system.

(6) **Build a Visibility and Analytics Platform** – This task involved (1) assessing existing drainage pumping station systems and communications infrastructure (2) designing a visibility platform in collaboration with the S&WB and (3) implementing instrumentation and software to provide remote visibility of the operational status of equipment at the drainage pumping stations.

(7) **Review the coordination of Drainage System Maintenance between S&WB and the City of New Orleans Department of Public Works** - The objectives of this task were to provide a high-level review of the impact of the multi-jurisdictional responsibility over the drainage system on the system's performance.

The underlying principle behind Veolia's condition assessment methodology is to utilize diagnostic testing to **better predict and manage a piece of equipment that is in the process of failing**. Monitoring such equipment is necessary to prevent the limitations it would bring to the pumping system's ability to convey water out of the city in the event of its failure. The results of this condition assessment, therefore, are a baseline of data and insights upon which S&WB can begin to take action. Specifically, S&WB can begin to prevent failures before they occur, which is critical for a system that is designed to protect the residents of the city from the effects of flooding. The drainage system must be maintained to the highest standard of reliability to respond at a moment's notice to a torrential downpour. Running equipment to failure is not an effective maintenance practice for a mission critical operation of this magnitude.

Veolia observed that the S&WB has historically operated in a reactive manner towards maintenance of outdated machinery that requires lengthy, complicated, and costly repairs. Furthermore, operating in a reactive mode results in detrimental operational risk and consequences than can be avoided if assets are repaired or replaced in a deliberate, planned manner prior to failing. The success of S&WB hinges upon their willingness to move towards a proactive maintenance mode to better manage maintenance costs, invest in aging infrastructure, management plans, and most importantly, improve the reliability of the drainage system. The results and associated data from this condition assessment have initiated this process for the S&WB and should be treated as the first trend point of a future proactive maintenance program.

Veolia assessed the system in a manner different than how the city entities have typically measured success. While S&WB and the City of New Orleans may be accustomed to reviewing the drainage system condition by individual pump and turbine **availability**, Veolia has established the current **capability** by conducting a holistic condition assessment, taking into consideration the core functions of the drainage system (see Figure 1), namely, (1) the **Collection System** to assess how efficiently water is being conveyed to the drainage pumping stations, (2) **Power Generation** to assess power availability to meet drainage pumping station demands, (3) **Power Distribution** to assess the ability to distribute available power to the drainage pumping stations and (4) the **Drainage Pumping Stations** themselves where pumps and core systems necessary to run the pumps were assessed.

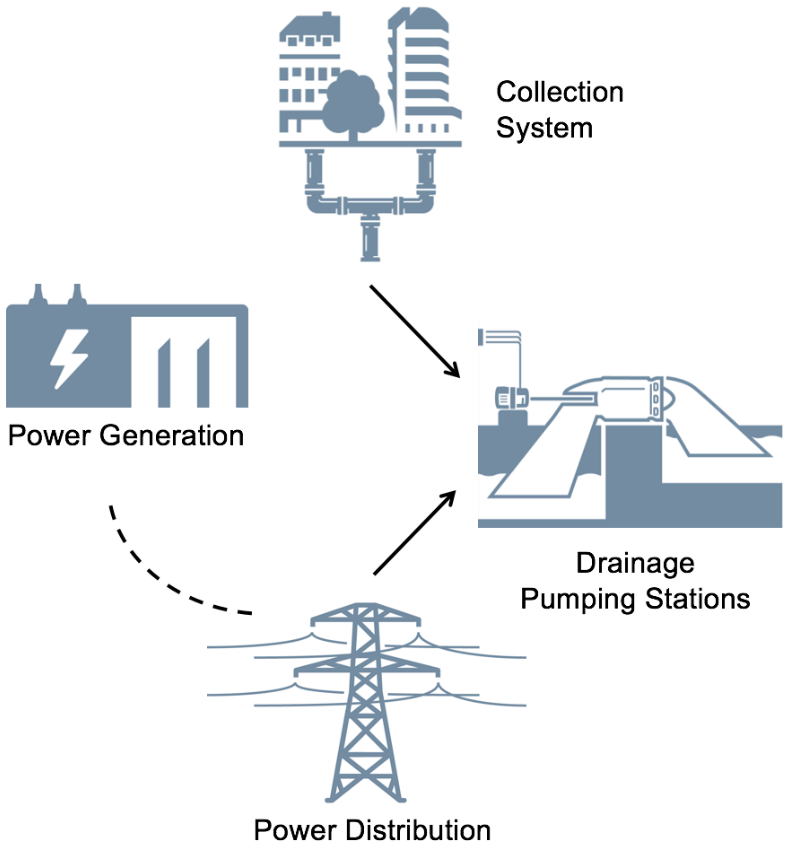


Figure 1: Drainage System Components

Drainage System Condition Assessment Results

(1) **Collection System**. Veolia assessed a 1% representative sample set to project the total diminished capacity of four different system asset categories. Diminished capacity refers to an estimated reduction in a cross-sectional area. This estimate was then extrapolated for each asset type. This task utilized acoustic and visual technologies to estimate such reductions. Findings indicate that catch basins, pipes, box canals and open canals reveal a diminished capacity of 16%, 27%, 22% and 14% respectively. Of note, the New Orleans Department of Public Works launched an aggressive catch basin cleaning campaign in 2017 which overlapped Veolia's condition assessment efforts. Catch basin diminished capacity was likely significantly higher prior to this campaign.

Catch Basins
16% Diminished Capacity

Box Canals
22% Diminished Capacity

Pipes
27% Diminished Capacity

Open Canals
14% Diminished Capacity

(2) **Power Generation.** Veolia conducted vibration, infrared, and sensory diagnostics on operational equipment to assess the condition of power generation for drainage pumping stations. These diagnostics indicate the level of deterioration. During the time of Veolia's assessment, extensive construction was in progress and therefore many systems were not able to be tested.

S&WB power generation systems include a combination of steam and combustion turbine generators. Steam is produced via local dual fuel fired boilers. Natural gas is supplied by the local distribution supplier, Entergy New Orleans, LLC (Entergy). Both the steam boilers and the combustion turbine units can operate on natural gas or diesel fuel. All units produce 25 Hz electrical power except one of the combustion turbines which produces 60 Hz electrical power. Power generation can be supplemented via frequency changer units which convert 60 Hz electrical power into 25 Hz.

Table 1 illustrates (1) equipment vibration issues, (2) motor circuit analysis (MCA) identified electrical issues, and (3) infrared identified issues that compromise the ability to generate adequate power.

Table 1: Summary Table of Power Generation Condition Assessment Findings

	Rated Power (MW)	Frequency (Hz)	Available Power (MW)	Vibration	Motor Circuit Analysis	Infrared	Comments
Power Systems				4 issues	Major issues		Boiler fans have electrical issues, rewind recommended
Turbine 1	6	25	6	2 issues		High temp	Lube oil cooler blocked
Turbine 3	15	25	0			High switchgear temperature	Equipment was operational for a brief period of time to obtain infrared data
Turbine 4	20	25	0				Equipment not operational at the time of Veolia's Assessment
Turbine 5	20	25	0				Equipment not operational at the time of Veolia's Assessment
Turbine 6	25	60	15	No issues			Vibration readings good
Plant Frequency Changer	3.75	25	3.75	2 issues	Issues		Electrically at risk, clean recommended
Carrollton Frequency Changer 1	6	25	6	2 issues	Issues		Electrically at risk, clean recommended
Carrollton Frequency Changer 2	2.5	25	2.5	2 issues	Issues		Electrically at risk, clean recommended
Station D Frequency Changer 3	6	25	6	2 issues	Major issues		Electrically at risk, rewind immediately
Station D Frequency Changer 4	6	25	6	2 issues	Issues		Electrically at risk, clean recommended

Note: Though out of scope, West bank frequency changers were tested during Veolia's efforts at the request of S&WB. All three of the units located in the West bank were found to have issues and unit #3 was identified as having high resistive imbalance. The resulting recommendations from the test specialist was to professionally clean units #1 and #2 and plan a rewind of unit #3 in the near future.

(1) **Power Distribution**. The assessment of the power distribution system focused on 35 of the S&WB's 25 Hz underground feeders. Veolia employed industry standard cable testing techniques to assess the feeders, including insulation resistance, polarization index, and Very Low Frequency (VLF) tests. The results of this work reveal that 30 of the 35 feeders failed these basic tests. A number of other key 25 Hz underground feeders were not able to be released by S&WB for testing and were subsequently not tested. Above ground feeders were also not tested because S&WB indicated that these cables were less critical than underground feeders.

Figure 2 below depicts the outcome of the assessment. Feeders shown in red failed the insulation resistance and polarization index tests. Incidentally, the age of these cables exceeds industry standard practice. Immediate cable replacement is recommended for these feeders. Feeders shown in orange presented low insulation resistance and/or polarization index and should be considered for replacement. Feeders shown in yellow failed the insulation resistance tests, but passed polarization index tests. For both orange and yellow feeders, S&WB should consider conducting additional online partial discharge testing and offline testing to refine replacement prioritization and timing. Feeders shown in green (5 of 35 feeders) passed insulation resistance and polarization index tests and follow on VLF testing. No immediate action is recommended for these feeders apart from repeating these tests periodically to monitor condition.

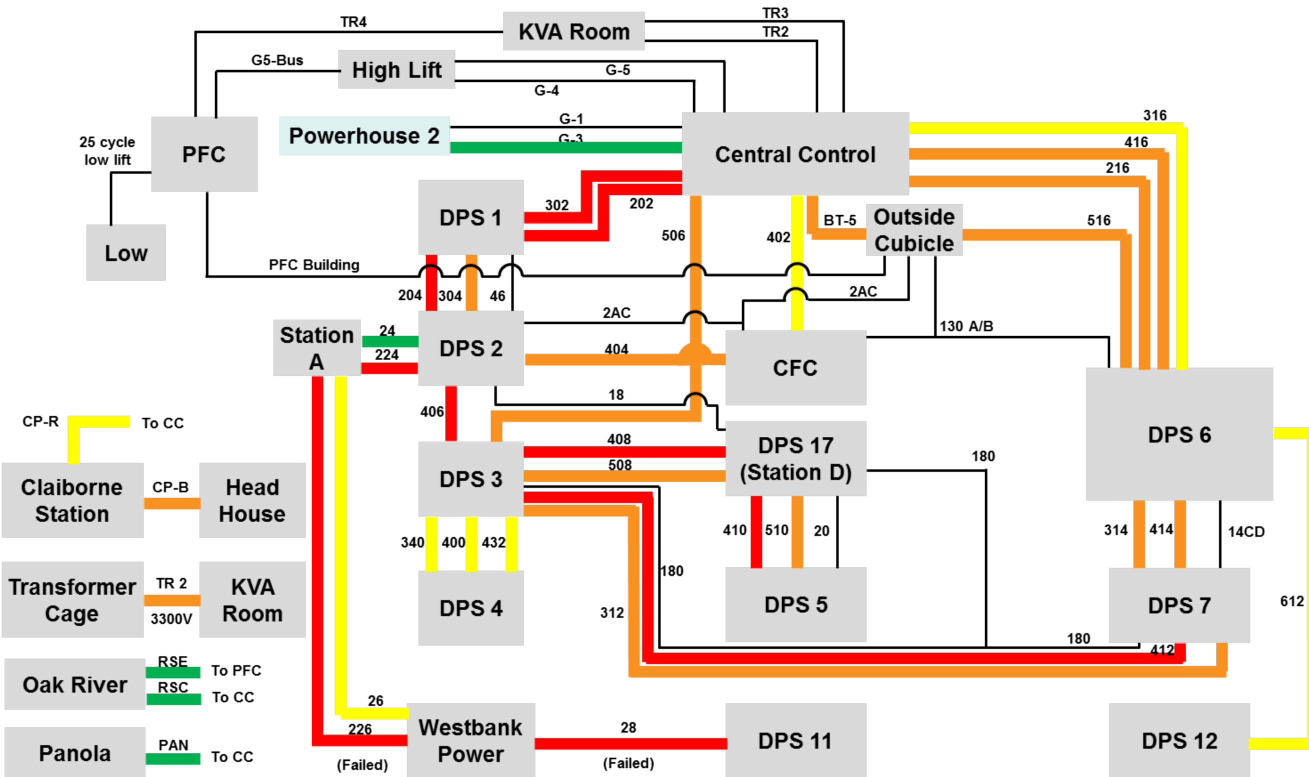


Figure 2: 25 Hz Feeder Test Results

Table 2: 25Hz Feeder Test Results Key

Figure 2 Key: Summary of Test Results			
Fail	30 of 35 cables tested	Red: Failed insulation resistance and polarization index tests, and cable age exceeds industry standard practice. Immediate cable replacement recommended.	8 of 35 cables tested
		Orange: Presented low insulation resistance and/or polarization index and should considered for replacement. Consider conducting additional online partial discharge testing and offline testing to refine replacement prioritization and timing.	14 of 35 cables tested
		Yellow: Failed insulation resistance tests, but passed polarization index tests. Consider conducting additional online partial discharge testing and offline testing to refine replacement prioritization and timing.	8 of 35 cables tested
Pass	5 of 35 cables tested	Green: Passed insulation resistance and polarization index tests and follow on VLF testing. No immediate action, repeat test periodically to monitor condition.	5 of 35 cables tested
Not Tested	10 cables	Black: Testing was not performed.	10 cables

(2) **Drainage Pumping Station Core Systems.** The following core systems are necessary components for a drainage pumping station to convey water out of the city.

a. **Drainage Pumps**. Assessments performed on the drainage pumps included:

   i. **Pump performance testing** to measure the ultimate pumping capacities of drainage pumps and drainage pumping stations.

   ii. **Vibration** assessment to identify abnormal or elevated vibration readings on rotating equipment component indicative of wear and other potential condition issues.

   iii. **Suction and discharge bell inspections** to identify if any significant pipe corrosion or interference of pump performance is present which warrants intervention.

   iv. **Pump piping metal thickness** assessments to determine if material loss of pipe is severe enough to warrant replacement.

   v. **Gearbox oil analysis** (where applicable) to determine if degradation, contamination or machine issues are present.

   vi. **Motor circuit analysis**, to determine if any motor circuits have insulation or other electrical issues

b. Vacuum Systems. Assessments performed on the vacuum pumps and systems included

   i. **Pump and system performance tests,** to determine the capabilities to effectively prime certain types of drainage pumps.

   ii. **Motor circuit analysis**, to determine if any motor circuits have insulation or other electrical issues.

   i. **Vibration** assessment to identify abnormal or elevated vibration readings on rotating equipment component indicative of wear and other potential condition issues.

c. Electrical Systems. Assessments included:

   i. **Electrical hardware and panel inspections**, to identify any major visible condition issues including signs of burning or corrosion.

   ii. **Infrared assessment**, to identify any condition issues with electrical connections and equipment with high temperature differentials.

   iii. **Transformer oil analysis**, to determine the condition of oil filled transformers and identify any indicators of potential failures.

   iv. **Motor circuit analysis**, to determine if any motor generator set circuits have insulation or other electrical issues.

   v. **Motor oil analysis** (where applicable) to determine if degradation, contamination or machine issues are present.

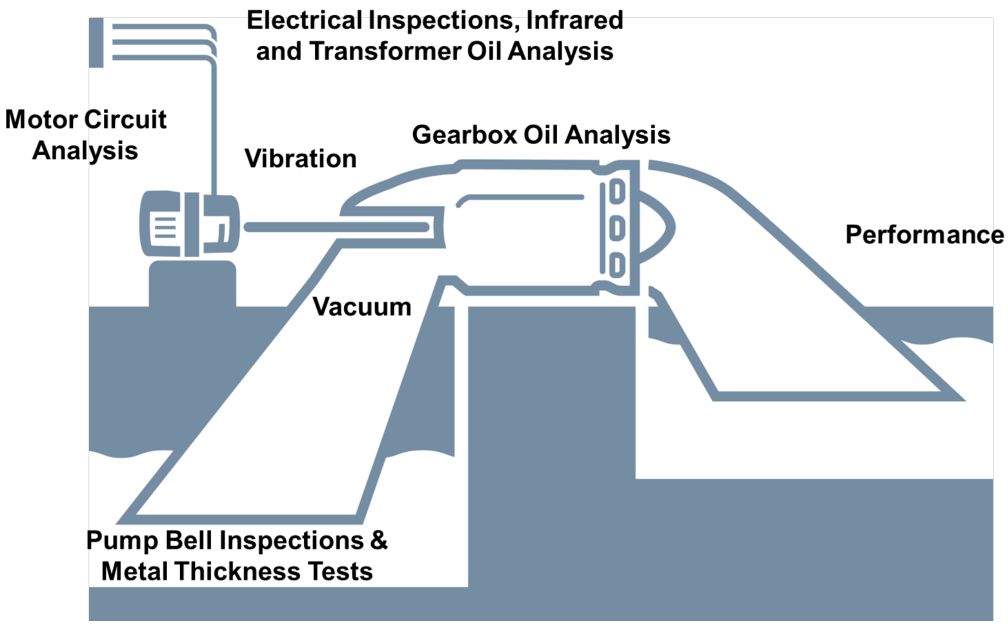


Figure 3: Drainage Pumping Station Tests Performed

The test results from the drainage pump, vacuum and electrical system assessments are summarized in Table 3 below. Specifically, the table summarizes the number of major issues, by pump station, which highlight that a piece of equipment is in the process of failing. Pump performance results are summarized in Section 1.5.

Table 3: Summary Table of Major Equipment Issues Identified with Diagnostic Testing

Test Type	Count of Major Issues	Locations
Electrical Hardware & Panel Assessment	11	DPS 1, 3, 6, 11, 13, 15, 17, Elaine
Infrared	7	DPS 1, 3, 17, 19, Powerhouse
Motor Circuit Analysis	6	DPS 4, 17, Westbank, Powerhouse
Metal Thickness	4	DPS 12, 13, 15, 17
Rotating Equipment Oil Testing	4	DPS 4, 6, 14
Suction and Discharge Bell Assessments	15	DPS 3, 6, 7, 12, 15, Elaine
Transformer Oil Testing	2	DPS 2, 7
Vacuum Pump Testing	32	DPS 1, 3, 4, 5, 6, 7, 11, 13, 17, 19, I-10
Vibration	8	DPS 4, 5, 15, 18, I-10

In summary, these test results indicate that the affected assets are in the process of failing. It will be critical to take corrective action as detailed in the table in Section 1.5 of this report as the failure of these assets could have a significant impact on the operation of the pumping station.

Focus Areas for Improvement

Before detailing the path forward for S&WB to address the issues with the drainage system, it is worth noting a few high-level themes that S&WB must address as part of its strategy to improve the reliability of its system:

- **Full transparency to the public on drainage system capacity and availability**. The August 5th flooding event caused significant credibility issues for the S&WB with its stakeholders. This event added to the long list of failures for the organization. The S&WB must guarantee full transparency with regard to the true capacity and uptime status of key S&WB assets preventing the City of New Orleans from being caught off guard in events like the August 5th flooding.

- **Investments in electrical supply and asset renewals**. There is a need to upgrade both electrical supply infrastructure and obsolete, degraded equipment. In terms of electrical supply, S&WB needs to (1) develop a plan to transition from 25 Hz to 60 Hz for all assets (2) work with Entergy to provide a robust energy feed to the S&WB and (3) invest in new power generation assets. This recommendation represents one of many possible power supply options for S&WB. Additional analysis would be required to fully vet all potential power supply options.

- **Executive leadership must drive performance**. While Veolia recognizes the difficulty of driving performance amidst frequent leadership change, there must be a focus on improving the condition, operation, and maintenance of the drainage system. Leadership should oversee and prioritize this effort, bringing together all functional groups that are critical to cross-organization implementation of an Asset Reliability Program for the drainage system: Purchasing, Finance, Engineering, Contract Managers, Maintenance Managers and Operations.

- **Culture change to improve the performance of operations and maintenance.** The S&WB operates in a reactive mode that is now ingrained the everyday behaviors and operating practices of staff. Veolia regularly experienced resistance to new ideas and processes by staff. Shifting to a proactive mode of operations and maintenance will require a significant change in behaviors and mindsets. This is a management problem that absolutely must be addressed for success.

- **Capital planning to address major asset condition deficiencies**. Veolia observed a number of asset condition deficiencies that are not addressed in short or medium-term capital plans. The capital planning process should be improved to refine: (1) project identification and prioritization processes (2) project design and specification processes to adequately vet alternatives, identify preferred options, specify the selected option, and define commissioning and performance requirements for acceptance (3) project management and construction management processes to ensure that projects are executed as designed and fully commissioned prior to acceptance.

- **Automation of systems and shift towards becoming a more data driven organization**. S&WB is currently heavily reliant on manual processes for operation, including limited monitoring capability throughout the drainage system. Veolia was contracted to develop a Visibility and Analytics platform to provide remote visibility of the operational status of equipment at the drainage pumping stations. This provides a powerful foundation for S&WB to build and optimize their drainage system operations. It is important to note that this design was an emergency set-up and further investment in staffing, skills, and upgrades are required to keep it operational expand it to its full capabilities.

- **Improve safety culture at S&WB facilities**. Management must be committed to provide the necessary resources and tools for success to ensure a safe and healthy work environment. It is essential that worker health and safety be a core value inherent within S&WB. It should be the responsibility of all S&WB employees to ensure that the health, safety and security of the general public, its customers, subcontractors and employees are protected.

- **Public awareness campaign to address the negative impact of littering and dumping on drainage system capacity and performance**. There is an opportunity to pursue a public awareness campaign to improve the public's understanding of the effects of littering on drainage system performance.

Implementing Recommendations: Requires a Holistic Change Management Approach

In order for S&WB to truly embrace and implement the recommendations outlined in this report, there are a number of key enablers that must be in place. The recommendations outlined in this report are made on the premise that the following improvements related to People and Communication, Operating Systems and Performance Management are addressed:

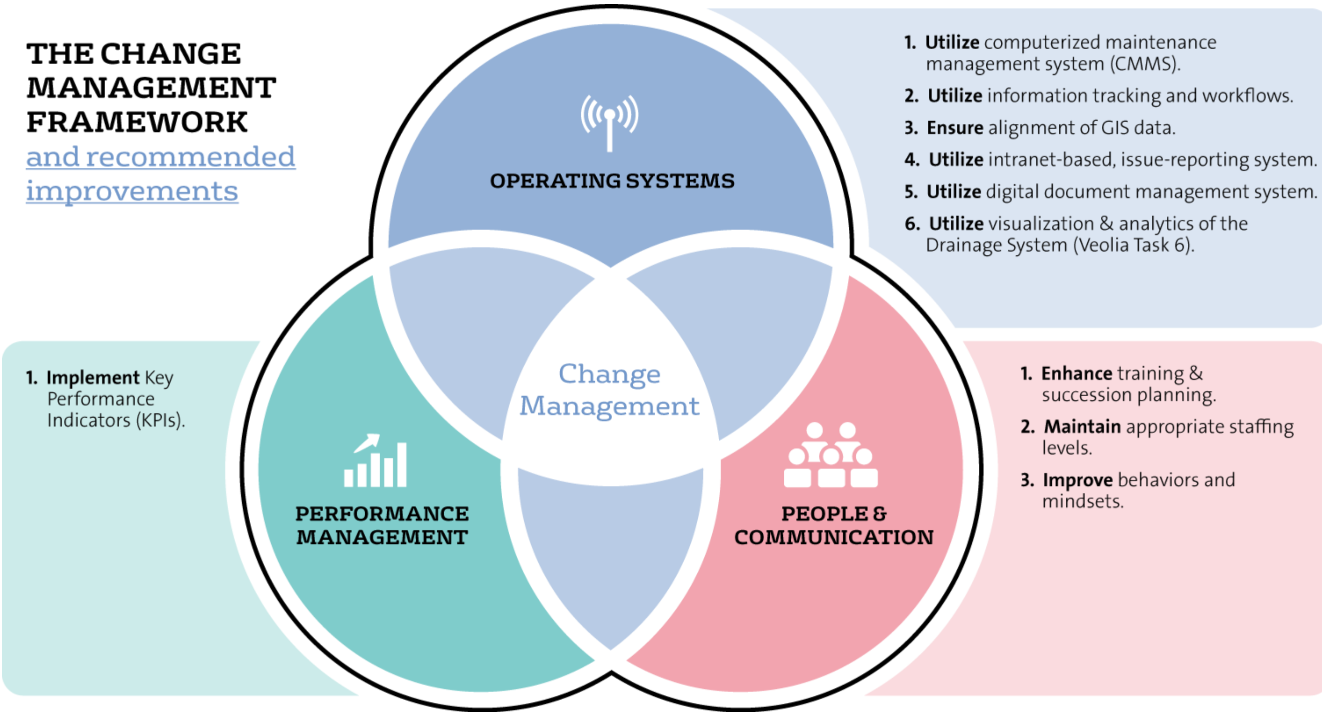


Figure 4: Change Management Framework

People and Communication

- **Training and succession planning**. The core knowledge of S&WB's drainage system is not documented and is held in the minds of relatively few individuals. An unprecedented effort will be required to ensure that knowledge sharing and training is provided to staff to protect the long-term functionality of the drainage system. System-wide observations of S&WB operators lacking the knowledge of the design and function of core assets, such as drainage pumps, suggests that incorrect operation is a contributing factor to premature equipment failure. A program should be developed where high-potential junior staff members are identified and given opportunities to mentor with senior staff members and incentivized to advance their careers with the S&WB. Addressing operator training and establishing Standard Operating Procedures (SOPs) will be a prerequisite to S&WB's ability to adopt the recommendations and maintenance plan outlined in this report. Similarly, Standard Maintenance Procedures (SMPs) and training should be developed and provided to maintenance staff.

- **Maintaining appropriate staffing levels**. Staffing has been a major challenge for S&WB in recent years. There are currently dozens of approved positions that have not been filled to date. Adding to this issue, additional staffing and skills will be required to manage Veolia's proposed Asset Reliability Program and the newly implemented Visibility and Analytics Platform developed by Veolia. The current and future needs for staff are critical and S&WB should explore various options to fill positions including procuring human resources firms that can assist with recruiting and retaining talent.

- **Behaviors and mindsets**. Shifting from a reactive to proactive mode of operation will require a significant change in mindset. Currently, staff members appear to be resistant to change and insistent on maintaining the status quo. An initiative to change this culture should be supported by management, focusing on proactive operations, innovation, recognition, incentives, ownership, accountability, and motivation. This is a leadership-driven initiative that must be rooted throughout the organization by way of a change management plan.

Operating Systems

- **Computerized Maintenance Management System (CMMS) and mobile CMMS**. While Veolia did not perform a detailed review of S&WB's CMMS (i.e. CASS WORKS), discussions with S&WB staff indicated that (1) the system had not been properly maintained in approximately 15+ years, (2) the system operates on outdated software that no longer has adequate manufacturer support, and (3) accessibility and functionality are limited compared to modern CMMS options. Having a well-developed and functional CMMS is imperative to support the recommendations that Veolia has made. The organization and tracking of maintenance is a crucial part of an effective Asset Reliability Program.

  To improve existing procedures, S&WB should migrate the current CMMS to a new platform and develop appropriate skillsets, processes, and practices to support the new platform moving forward. The renewed CMMS should be utilized as the core operating system for organizing maintenance and S&WB's overarching Asset Reliability Program. The CMMS must be used for all information collection (including via mobile interface to CMMS where appropriate), tracking and workflows including purchases, contractor work and costs of every interaction with assets. Purchasing and inventory must also be tied to the CMMS so that critical spares are available to complete any emergency work. The CMMS should be used to execute all corrective, preventive, and predictive maintenance tasks, as well as failure finding tasks. Each interaction with an asset should include updating of condition assessment grades such that ongoing trending and use of condition data supports repair and replacement decision making. Appropriate staffing must be allocated to enable the CMMS to function in this desired manner.

- **Information tracking and workflows**. Establishing workflows closely tied to the CMMS for maintenance and operations staff is vital for accurately tracking work requested and performed. This will reduce duplicate work orders, eliminate unnecessary maintenance, prioritize critical work for scheduling, validate completion of maintenance, and enable work order metrics to be tracked.

- **Ensure alignment of GIS data**. Veolia observed conflicting sets of GIS data maintained between S&WB and the Department of Public Works. Unifying these systems into a common GIS database will be required to support ongoing improvement in the operations and maintenance of the collection system assets associated with the collective drainage system.

- **Computerized intranet-based issue reporting system**. This system should be used by all personnel to report any equipment, personnel, or organizational issue or concern. The system should be developed on a secure intranet (internal network) framework to improve the speed and transparency of communication of industrial safety, environmental, equipment, programmatic, and administrative issues throughout the organization. The system should allow the originator to make the report anonymously or receive proper credit for their findings. The issue reporting system should work independently but together with the CMMS, as this system can be used to address issues that are beyond equipment issues.

- **A digital document management system.** The ability to access crucial documents allows operations and maintenance work to be performed efficiently and accurately. A digital document management system will allow all procedures, drawings, vendor manuals, and other active critical control documents to be available to all S&WB personnel immediately from their control room or work station. The CMMS equipment database can be linked to this digital document management system to instantly link reference documents to work orders and streamline the process of work planning. The document management system can also be used to store completed work orders, contracts, purchase orders, and other historical documents. A document management system requires adequate staffing to manage documentation, combined with strict document change management and control policies for organizational purposes.

- **System visibility.** Ensure that modern instrumentation and communications devices are implemented to improve visibility of the real-time operational status of remote systems. Task 6 of Veolia's effort to engineer and implement visibility systems provides the infrastructure and initial set of monitoring parameters for a long-term solution to address this need.

Performance Management

- **Key Performance Indicators (KPIs)**. Clear KPIs for each role within the S&WB needs to be developed, documented, and enforced. An organizational structure must also be developed that creates, disseminates, and monitors KPIs at appropriate levels. Some example KPIs include:

  (1) Number of purchases that are correlated to an asset (i.e. asset repair investment)

  (2) Work order backlog and age

  (3) Work order closing completeness (e.g. failure code, labor hours, comments, materials used, contractor costs, etc.)

  (4) Mean time between failures

  (5) Mean time to repair

  Managers must be able to easily access their respective KPIs (e.g. directly in their new CMMS, daily or weekly reports, and dashboard view of KPIs) in order to leverage them in managing their crews and reacting to deviations in performance, ultimately working towards a truly KPI-driven organization.

Summary Recommendations

The way forward for the S&WB is detailed in the Findings & Recommendations section. Twelve specific recommendations are categorized between (**1) Those actions required to first restore the functionality of the drainage system** and **(2) Those actions that allow S&WB to maintain this functionality in the future.** These categories can be further explained in the context of the below Asset Performance Reliability Framework. The framework begins with Customer Expectations.

Customer expectations are normally defined in terms of product quality, on-time delivery, competitive pricing, safety and compliance with environmental standards. Equipment performance parameters can be associated with quality, availability, cost/unit, safety and environmental integrity. To achieve this performance there are three inputs to be managed:

(1) **Process Technologies** provide capable equipment "by design" (inherent capability) to meet the equipment performance requirements.

(2) **Operating Practices** make use of the inherent capability of process equipment. The documentation of standard operating practices ensures the consistent and correct operation of equipment to maximize performance.

(3) **Maintenance Practices** maintain the inherent capability of the equipment. Deterioration begins to take place as soon as equipment is commissioned. In addition to normal wear and deterioration, other failures may also develop. This happens when equipment is pushed beyond its design limitations or when operational errors occur. Degradation of equipment condition results in reduced equipment **capability** and will result in loss of **availability** if the degradation is not detected, assessed, and addressed in a timely manner. Equipment downtime, customer service problems, and industrial safety and/or environmental incidents are some possible outcomes. All of these can negatively impact operating cost, damage public perception, and erode trust both internally and externally. The management of Physical Asset Performance is integral to the success of S&WB.

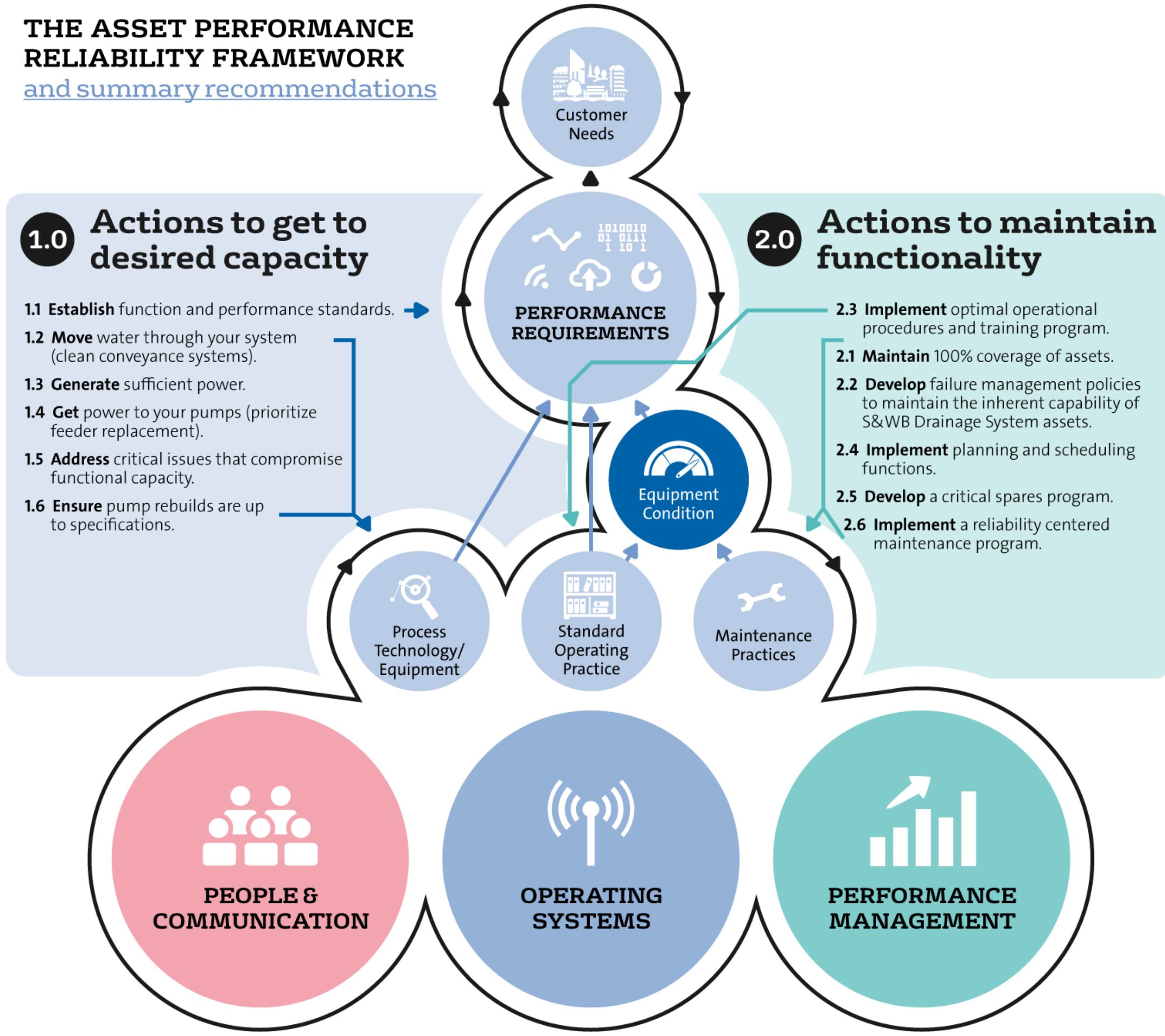


Figure 5: Summary Recommendations

Findings & Recommendations

Actions to Restore Drainage System Functionality

In the wake of the August 5th event, utmost importance was placed on immediately undertaking inspections of all of the S&WB's vital equipment to determine its condition, assess necessary repairs, and undertake such repairs in light of the vulnerability of New Orleans without the full functionality of these systems. This section details the present conditions that impact system performance and remedial actions necessary to restore system performance.

1.1 Establish System Functionality and Associated Performance Standards

Findings

Defining critical system functions with desired standards of performance is the first step in determining when normal equipment deterioration reaches an unacceptable level. There should be no doubt that physical assets are put into service because **someone wants them to do something**. This desired performance is known as the asset's **function**. The extent to which an organization wants an asset to perform its function can be defined by a minimum standard of performance.

The S&WB maintains many systems and assets that do not have such defined performance standards. For example, S&WB have not established minimum pump station flow rates required to prevent flooding during a design basis rain event. It is therefore likely that functional failure occurs long before an eventual catastrophic failure. Rather than evaluating performance against defined standards, S&WB runs systems and assets to complete physical failure before interventions are triggered. Failed equipment is then left out of service due to spare parts, contractual, and other issues, eliminating redundancy while the remaining pumps continue to be operated in a degraded state and beyond design operating limits.

The objective of maintenance can then be defined as keeping the performance of the asset (or system) **above** the minimum desired performance level. To achieve this, S&WB must check the asset or system for those failures that cause the failed states, total loss of function, and partial loss of function. The ways that a failure can occur are called **failure modes**.

Recommendation Detail

Systematically review the S&WB's vital systems and assets to determine the critical functions and assign minimum performance levels that can be tolerated prior to unacceptable consequences. Formalize and document the determined levels for use in periodic measurement of performance degradation and triggering of proactive intervention to restore performance.

Impact / Benefit for S&WB

Knowing the design basis for the collection, power generation, power distribution and drainage pumping systems is essential for modeling their ability to perform their intended design function and to evaluate operating margin as equipment begins to wear and performance decreases with use and age.

Implementation Outline

For power generation, modeling of all demands in worst case scenarios will yield required collective capacity, which in turn can be used to determine individual system and asset performance and functional failure thresholds. A similar approach could be used to determine the capacity of power distribution assets and the worst case demands that could be placed on them.

For drainage collection and pumping systems, a similar modeling approach will be needed with clear design goals in place to set the performance and functional failure thresholds (e.g. *Drainage Pumping Station X* has the primary function of removing storm water associated with rainfall of *2* inches per hour in the station's respective catchment area, which requires a pumping capability of *2,500* cubic feet per second at a flood stage suction level of *12* feet and a worst case discharge level of *24* feet).

1.2 Move Water through the System: Clean Conveyance Systems

Findings

The collective drainage system for the City of New Orleans was assessed to estimate the current reduction in system capacity due to debris accumulation, tree root ingress, failed assets, etc. The gravity collection system – including catch basins, pipes, box canals and open canals – was assessed visually with a pole camera and/or through the use of the Sewer Line Rapid Assessment Tool (SL-RAT). Detailed technology descriptions and inspection procedure can be found in Appendix 5.

Based on the condition assessment results for the sample of catch basins, pipes, box canals, and open canals, system diminished capacity by asset type is estimated below. Diminished capacity refers to an estimated reduction in cross sectional area extrapolated out for each asset type.

Catch Basins: Diminished Asset Capacity = **16%**

Pipes: Diminished Asset Capacity = **27%**

Box Canals: Diminished Asset Capacity = **22%**

Open Canals: Diminished Asset Capacity = **14%**


Collapsed Catch Basin


Catch Basin Debris


Catch Basin Debris

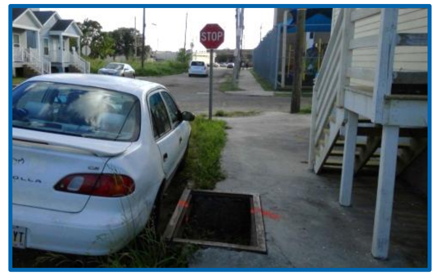

Obstructed Catch Basin


Obstructed Pipe


Obstructed Pipe

Obstructed Pipe

Open Canal Debris



Catch Basin Missing Cover

Figure 6: Collection System Issues

Recommendation Detail

Clean the entire drainage system once by the end of 2019. With the last full system cleaning program completed following Hurricane Katrina in 2005, debris has accumulated throughout the system impacting drainage pipe hydraulic performance. A preventive maintenance program would be difficult to prepare until the system has been cleaned once following a basin cleaning approach. A two-year storm sewer system cleaning program is recommended to restore the design capacity and serve as baseline for future cleaning program comparison and definition of preventive maintenance programs.

Another system-wide cleaning is recommended by 2021 to provide needed input to build a preventive maintenance program for the system. This preventive maintenance program would rely on data collected during the second full system pass with field crews documenting the quantity and types of debris removed. This type of documentation and associated analysis would be start of a continual effort to assess which portions of the system are seeing debris build-up and adjusting cleaning frequencies to match system demands.

Impact / Benefit for S&WB

Cleaning the gravity collection system from catch basins through to canals in a basin cleaning approach would improve hydraulic flow to the drainage system pumping stations, improve storage/transport capacity in the system, and allow for street drainage systems to meet their design intent.

By cleaning the system twice in four years, the S&WB will have a better idea of which pipes, areas, and drainage basins receive debris at a faster rate. These areas can be prioritized for cleaning as well as the rest of the system to optimize financial, staff and equipment resources.

This recommendation also provides an opportunity to interface with the City of New Orleans Department of Public Works (Public Works) for their prioritized pipe cleaning and street sweeping program. By working together, the S&WB and Public Works can better prevent debris from building up in the drainage system and over time will help reduce costs of cleaning which can be re-allocated to more pressing S&WB needs.

Implementation Outline

The S&WB and Public Works should work together to delineate and prioritize drainage basins for cleaning. The two entities should pool their respective cleaning resources so as to maximize cleaning production.

Catch basins and pipes less than thirty-six inches in width should be cleaned from the furthest extent of the drainage basin to the centralized point in which the drainage area empties downstream. This is critical as even the best silt traps used during pipe cleaning allows suspended debris to by-pass the silt trap and settle-out further downstream.

As sections are cleaned to the S&WB's box or open canals (pipe assets greater than or equal to thirty-six inches in width), cleaning of those larger pipe asset sections should then occur. This will aid in removing the debris from the system and provide improved hydraulic capacity over an entire drainage basin rather than following a piece-meal approach.

The second cleaning effort should be done in a similar fashion as the first with a specific focus on documenting debris accumulation and using this to design the preventative maintenance program.

1.3 Generate Sufficient Power

Findings

At the time of the August 5th event, power generation capacity at the Carrollton Water Purification Plant site was severely compromised due to multiple power generation unit failures. This ultimately limited the power supply to critical drainage pumping stations and was likely one of the primary contributors to the event. Many of these critical systems were not able to be assessed by Veolia as of the date of this report because the systems were still in a failed state and/or under construction during the assessment period.

Recommendation Detail

Ensure that remedial projects currently underway to restore generation capacity are continued and adequate generation capacity is restored and maintained, including sufficient redundancy to enable maintenance activities to be performed without compromising operations. Once systems are returned to operation, perform various condition assessments to obtain a baseline for rolling into the overall Asset Reliability Program. The S&WB needs to evaluate moving away from 25 Hz power as part of its overall capital investment plan. The S&WB should also look to work with Entergy to provide a reliable source of primary power from the **transmission grid** for its facilities and only self-generate power as a means to either balance utility feed reliability or function as an independent back-up. S&WB currently receives power from Entergy via the less-reliable **distribution grid.**

Impact / Benefit for S&WB

Reduce the risk of major flooding events caused by lack of power generation capacity. Purchasing transmission-grade utility power rather self-generating will improve reliability and reduce S&WB's overall energy costs.

Implementation Outline

Follow current construction / restoration plans and ultimately aim to have adequate generation capacity restored fully prior to the 2018 hurricane season. Condition assessment activities should be planned shortly after commissioning.

1.4 Get Power to the Pumps: Prioritize Feeder Replacements

Findings

The S&WB maintains an extensive network of underground and above ground power distribution equipment to supply power generated at the Carrollton Water Purification Plant and frequency changer sites to the required loads at the drainage pumping stations as well as other demands (sewerage, West bank water, etc.). The underground feeder assets were determined to be critical during early assessment and were the focus of extensive testing to determine their condition. A total of 35 sets of underground cables were tested across the different circuit lines of the S&WB. A number of underground feeders were not able to be tested as they were not able to be released to Veolia for testing. Above ground feeders were also not tested. Of the tested underground feeder lines, 30 failed the test. Those 30 were further broken into sub-categories to highlight the nuance within the different parameters of the test results. A summary of those test results is provided in Table 4 below.

Table 4: Summary of Power Feeder Test Results

From	To	Feeder Name	Test Result
Station 1	Central Control	302	Fail – replace immediately
Station 1	Central Control	202	Fail – replace immediately
Station 1	Station 2	204	Fail – replace immediately
Station 2	Station 3	406	Fail – replace immediately
Station 2	Station A	224	Fail – replace immediately
Station D	Station 3	408	Fail – replace immediately
Station D	Station 5	410	Fail – replace immediately
Station 7	Station 3	412	Fail – replace immediately
Station 1	Station 2	304	Fail – replace after prioritizing
Station 2	Carrolton Station	404	Fail – replace after prioritizing
Station D	Station 3	508	Fail – replace after prioritizing
Station D	Station 5	510	Fail – replace after prioritizing
Station 7	Station 6	314	Fail – replace after prioritizing
Station 7	Station 3	312	Fail – replace after prioritizing
Station 7	Station 6	414	Fail – replace after prioritizing
Station 6	Central Control	416	Fail – replace after prioritizing
Station 6	Outside Cubicle	516	Fail – replace after prioritizing
Station 6	Central Control	216	Fail – replace after prioritizing
Claiborne Station	Head House	CP-B	Fail – replace after prioritizing
Central Control	Outside Cubicle	BT-5	Fail – replace after prioritizing
Central Control	Station 3	506	Fail – replace after prioritizing
Transformer Cage	KVA Room (CC)	TR2 3330V	Fail – replace after prioritizing
Station A	West Bank Power Control	26	Fail – replace after prioritizing
Station 4	Station 3	340	Fail – replace after prioritizing
Station 4	Station 3	432	Fail – replace after prioritizing
Station 4	Station 3	400	Fail – replace after prioritizing
Station 6	Station 12	612	Fail – replace after prioritizing
Station 6	Central Control	316	Fail – replace after prioritizing
Claiborne Station	Central Control	CP-A	Fail – replace after prioritizing

From	To	Feeder Name	Test Result
Carrolton Station	Central Control	402	Fail – replace after prioritizing
Oak River Station	Plant-F.C.-Bldg.	RSE	Pass
Oak River Station	Central Control	RSC	Pass
Station 2	Station A	24	Pass
Panola Station	Central Control	PAN	Pass
Power House 2	Central Control	G3	Pass

Recommendation Detail

Veolia recommends that S&WB prioritize replacement of the 8 feeders recommended for immediate replacement and conduct further investigative testing (with feeders completely isolated) of the remaining 22 feeders found to fail testing to enable prioritization of their planned replacements.

S&WB is moving in the right direction in this regard and are in the process of fully or partially replacing, or have already fully or partially replaced, 8 feeders that they determined to be critical. Further analysis of the feeders can be found in the cable inspection report in Appendix 3D.

Impact / Benefit for S&WB

Focused capital spent to address the feeders which are in the worst condition and pose the greatest risk of failure to operations.

Implementation Outline

Adjust current capital program to incorporate as many of the 8 feeder cables recommended for immediate replacement which are not already planned for full replacement. Further adjust the short to medium term capital plan to address the remaining 22 feeders found to fail testing to enable appropriate prioritization and timing of their planned replacements.

1.5 Address Critical Drainage Pumping Station Equipment Issues Compromising Functional Capacity

Findings

The comprehensive condition assessments performed throughout the course of this effort on drainage pumping station assets revealed numerous cases of severely deteriorated asset condition, diminished asset functional performance, and inoperable assets, which negatively impact system performance and compromise capability. Focusing on immediate remedial actions for the worst performing assets will provide significant improvement. Once these current issues are addressed, actions to maintain desired performance can then be executed.

Drainage pump capacity performance test results are provided in Tables 5A through 5E. A comprehensive overview of the technology and methodology used to execute the pump capacity performance testing can be found in Appendix 4 as well as data and details for each pump. Supplemental recommendations to improve future pump performance have also been provided in Appendix 4.

Pumps have been identified in Table 5 by their Asset ID which includes the location (e.g. DPS01), prime mover identifier (e.g. Horizontal Pump A or HPA), and subcomponent identifier (e.g. Pump or PMP).

The following table presents all Curve Analyzed test statuses where performance testing was successful and pump performance curves were available to evaluate the test results. Retests are not required for pumps with Curve Analyzed status.

Table 5A: Summary of Drainage Pump Performance Capacity Test Results: Curve Analyzed

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Results (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority
DPS02-HPB-PMP	550	8.0	556	4.7	6.2%	640	87%	98%	79%	59
DPS03-HPC-PMP	1000	18.0	811	14.6	7.7%	1100	74%	80%	67%	27
DPS03-HPD-PMP	1000	18.0	953	11.1	7.2%	1190	80%	87%	73%	38
DPS03-HPE-PMP	1000	18.0	856	15.4	8.5%	1075	80%	88%	71%	34
DPS06-HPA-PMP	550	11.5	425	12.3	8.8%	520	82%	92%	69%	44
DPS06-HPC-PMP	1000	14.0	903	11.4	8.3%	1120	81%	89%	71%	39
DPS06-HPD-PMP	1000	14.0	757	13.8	8.4%	1130	67%	83%	64%	15
DPS06-HPE-PMP	1000	14.0	915	12.7	7.7%	1090	84%	98%	76%	53
DPS06-HPF-PMP	1000	14.0	903	12.9	13.1%	1050	86%	101%	71%	57
DPS06-HPG-PMP	1025	12.2	927	12.0	11.9%	1030	90%	105%	76%	61

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Results (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority
DPS06-VTP1-PMP	250	16.0	288	12.7	4.1%	277	104%	109%	99%	83
DPS06-VTP2-PMP	250	16.0	265	12.7	3.3%	277	96%	100%	92%	81
DPS06-VTP4-PMP	250	16.0	306	12.8	2.4%	276	111%	114%	108%	84
DPS07-HPC-PMP	1000	18.0	684	13.3	7.5%	1150	59%	67%	54%	10
DPS07-HPD-PMP	1000	18.0	782	13.3	7.9%	1140	69%	77%	63%	19
DPS10-VTP1-PMP	250	21.5	258	13.8	7.2%	300	86%	95%	79%	57
DPS10-VTP2-PMP	250	21.5	285	14.0	7.9%	300	95%	106%	86%	74
DPS10-VTP3-PMP	250	21.5	255	13.9	7.7%	305	84%	93%	76%	52
DPS10-VTP4-PMP	250	21.5	241	13.8	7.1%	295	82%	91%	73%	43
DPS11-CD3-PMP	56	8.0	28	10.7	2.7%	44	63%	75%	56%	68
DPS11-HPA-PMP	250	8.0	182	11.7	12.2%	165	110%	128%	80%	87
DPS11-HPB-PMP	250	8.0	184	9.7	12.5%	215	86%	106%	67%	63

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Results (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority
DPS11-HPD-PMP	570	12.0	462	11.4	8.9%	580	80%	89%	68%	35
DPS11-HPE-PMP	570	12.0	428	12.0	9.1%	575	74%	84%	65%	28
DPS13-HP7-PMP	1075	11.0	866	11.1	7.0%	1180	73%	84%	68%	26
DPS16-VTP1-PMP	290	17.0	252	13.9	8.0%	300	84%	91%	76%	54
DPS16-VTP2-PMP	290	17.0	242	14.0	7.5%	300	81%	87%	73%	40
DPS16-VTP3-PMP	290	17.0	240	14.9	7.6%	300	80%	88%	73%	37
DPS16-VTP4-PMP	290	17.0	226	14.3	8.0%	300	75%	83%	69%	30
DPS17-HPA-PMP	105	60.0	51	63.4	2.4%	105	49%	50%	47%	6
DPS17-HPD-PMP	105	60.0	48	63.4	2.3%	105	46%	47%	45%	4
DPS18-VTP1-PMP	65	17.0	46	12.2	2.1%	71	65%	68%	63%	13
DPS18-VTP2-PMP	65	17.0	44	12.2	2.4%	71	62%	64%	59%	11
DPS20-VTP1-PMP	250	11.0	152	7.8	3.2%	260	58%	62%	56%	9

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Results (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority
DPS20-VTP2-PMP	250	11.0	136	4.9	8.1%	275	49%	54%	45%	7
DPSDWY-VTP2-PMP	356	13.0	253	13.8	11.8%	359	70%	81%	62%	24
DPSELN-VTP1-PMP	50	18.0	43	13.9	2.1%	53	82%	85%	77%	69
DPSELN-VTP2-PMP	50	18.0	49	13.9	2.5%	53	92%	98%	86%	76
DPSI10-CD1-PMP	100	0.0	75	16.6	4.1%	106	71%	74%	67%	48
DPSI10-VTP1-PMP	250	0.0	150	18.4	2.4%	256	59%	61%	56%	29
DPSI10-VTP2-PMP	250	0.0	165	19.2	2.3%	253	65%	68%	63%	33
DPSI10-VTP3-PMP	250	0.0	142	16.7	2.0%	259	55%	57%	53%	25

The following table presents Raw Data Only status tests where only the test results and test head are available and no pump performance curves are available to evaluate this data. Nominal Comparison to Design has been calculated by dividing the test results by the nominal rated capacity to provide a rough order of magnitude evaluation of the results. Many of these pumps tested near or above their rated capacity except for DPS05-HPA-PMP, which should further researched to determine its rated head and retested at this rated head with plenty of suction head to ensure that the required NPSH is met, which is also unknown for this pump.

Table 5B: Summary of Drainage Pump Performance Capacity Test Results: Raw Data Only

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Result (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority
DPS02-CD2-PMP	25	Unknown	54	0.3	12.0%	N/A	216%	N/A	N/A	92
DPS02-CD3-PMP	25	Unknown	49	0.8	7.0%	N/A	196%	N/A	N/A	91
DPS04-HP1-PMP	320	Unknown	310	14.5	10.9%	N/A	97%	N/A	N/A	77
DPS04-HP2-PMP	320	Unknown	310	14.5	10.9%	N/A	97%	N/A	N/A	77
DPS05-CD1-PMP	80	Unknown	110	11.2	7.8%	N/A	138%	N/A	N/A	88
DPS05-HPA-PMP	550	Unknown	302	9.7	10.9%	N/A	55%	N/A	N/A	8
DPS05-VTP1-PMP	292	35.0	314	11.0	12.4%	N/A	108%	N/A	N/A	89
DPS05-VTP2-PMP	292	35.0	314	11.4	14.7%	N/A	108%	N/A	N/A	89
DPS13-CD3-PMP	50	Unknown	44	12.9	2.3%	N/A	88%	N/A	N/A	79
DPS13-HP4-PMP	1025	12.2	870	10.1	10.7%	N/A	85%	N/A	N/A	56
DPS13-HP5-PMP	1025	12.2	836	11.8	7.5%	N/A	82%	N/A	N/A	42
DPS13-VTP1-PMP	250	Unknown	236	12.6	2.9%	N/A	94%	N/A	N/A	75
DPS13-VTP2-PMP	250	Unknown	229	12.7	2.2%	N/A	92%	N/A	N/A	73

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Result (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority
DPS14-VTP1-PMP	300	Unknown	206	12.8	7.7%	N/A	69%	N/A	N/A	20
DPS14-VTP2-PMP	300	Unknown	266	12.5	7.1%	N/A	89%	N/A	N/A	60
DPS14-VTP3-PMP	300	Unknown	276	12.5	8.8%	N/A	92%	N/A	N/A	67
DPS14-VTP4-PMP	300	Unknown	252	12.9	7.3%	N/A	84%	N/A	N/A	54
DPS15-VTP3-PMP	250	Unknown	165	7.8	2.5%	N/A	66%	N/A	N/A	14
DPSGRT-VTP3-PMP	8	Unknown	5	6.8	4.8%	N/A	58%	N/A	N/A	50
DPSOLR-VTP1-PMP	33	Unknown	27	Unavailable	3.4%	N/A	82%	N/A	N/A	45
DPSOLR-VTP2-PMP	33	Unknown	33	Unavailable	7.3%	N/A	98%	N/A	N/A	80
DPSOLR-VTP3-PMP	33	Unknown	31	Unavailable	3.9%	N/A	93%	N/A	N/A	70
DPSPTC-CD1-PMP	3	29.0	3	Unavailable	2.9%	N/A	92%	N/A	N/A	64
DPSPTC-VTP1-PMP	125	22.7	131	Unavailable	11.3%	N/A	105%	N/A	N/A	85
DPSPTC-VTP2-PMP	125	22.7	132	Unavailable	9.4%	N/A	106%	N/A	N/A	86

The following table presents Bad Data tests statuses. Bad Data tests have been a point of contention due to differing opinions on the relevance of data that has been considered bad. To provide further clarification, a test can be given the status of Bad Data for the following reasons, which have been included as codes in Table 5C.

1. Failed CC Lynch QA/QC Analysis
2. Pump Operated Below Minimum Suction Level
3. Pump Operated Above Maximum Static Head
4. Data Derived from Integrated Flow Tests
5. Vacuum Leak, Level Indication, or Other Issue

The majority of tests classified as Bad Data should be considered the highest priority for further evaluation and retesting. The fact that a successful flow test was unable to be performed was due to an operational issue that warrants further evaluation due to the potential reliability implications. All data associated with these tests has been presented to ensure the highest level of communication and transparency. Where preliminary results and pump curves were available, performance analysis was performed and a weighted priority was provided to facilitate retest prioritization. Further details on the test history of each pump can be reviewed in Appendix 4-A.

Table 5C: Summary of Drainage Pump Performance Capacity Test Results: Bad Data

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Result (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority	Bad Data Code
DPS01-CD1-PMP	60	Unknown	41	3.9	14.8%	N/A	68%	N/A	N/A	72	1
DPS01-HPC-PMP	1000	Unknown	674	3.4	18.1%	N/A	67%	N/A	N/A	16	1
DPS02-HPA-PMP	550	8.0	N/A	0.5	N/A	N/A	N/A	N/A	N/A	N/A	1
DPS02-HPC-PMP	1000	Unknown	N/A	0.5	N/A	N/A	N/A	N/A	N/A	N/A	1
DPS07-CD2-PMP	70	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1
DPS07-HPA-PMP	550	11.5	341	12.4	13.6%	540	63%	79%	50%	12	1

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Result (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority	Bad Data Code
DPSDWY-VTP1-PMP	356	13.0	N/A	13.3	N/A	N/A	N/A	N/A	N/A	N/A	1
DPSDWY-VTP3-PMP	356	13.0	N/A	13.9	N/A	N/A	N/A	N/A	N/A	N/A	1
DPSGRT-VTP1-PMP	8	Unknown	2	6.8	51.3%	N/A	20%	N/A	N/A	17	1
DPS06-HPH-PMP	1100	12.0	1,020	13.6	7.4%	1110	92%	101%	82%	66	2
DPS06-HPI-PMP	1100	12.0	1,040	12.4	11.7%	1150	90%	106%	78%	62	2
DPS13-HP6-PMP	1075	11.0	821	13.0	8.9%	1000	82%	94%	71%	47	2
DPS19-HP1-PMP	1100	12.8	768	19.9	8.3%	920	84%	99%	74%	51	2
DPS19-HP3-PMP	1100	12.8	921	20.1	7.3%	920	100%	115%	86%	82	2
DPS19-VTP1-PMP	310	15.1	213	17.7	11.4%	305	70%	79%	61%	46	2
DPS19-VTP2-PMP	310	15.1	242	22.0	11.4%	280	86%	98%	75%	65	2
DPS03-HPA-PMP	550	11.5	379	12.7	7.3%	500	76%	88%	64%	31	3
DPS03-HPB-PMP	550	11.5	383	14.4	8.3%	410	93%	101%	91%	71	3
DPS04-HPC-PMP	1025	12.2	430	12.8	14.2%	1000	43%	52%	35%	2	4
DPS04-HPD-PMP	1000	Unknown	480	13.2	13.0%	N/A	48%	N/A	N/A	5	4

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Result (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario (%)	Worst Case Scenario (%)	Weighted Priority	Bad Data Code
DPS05-HPB-PMP	550	Unknown	250	11.1	8.3%	N/A	45%	N/A	N/A	3	5
DPS12-HPD-PMP	1000	12.0	443	11.1	9.8%	1060	42%	47%	36%	1	5
DPS01-HPA-PMP	550	8.0	470	2.4	7.3%	670	70%	78%	63%	21	5
DPS01-HPB-PMP	550	8.0	464	3.6	6.8%	660	70%	81%	63%	22	5
DPS01-HPF-PMP	1200	8.5	907	4.2	7.2%	1325	68%	75%	62%	18	5
DPS01-HPG-PMP	1215	7.5	967	0.5	9.0%	1375	70%	78%	63%	23	5
DPS01-VTP1-PMP	225	11.5	169	3.8	7.4%	248	68%	74%	62%	41	5
DPS01-VTP2-PMP	225	11.5	178	3.7	8.3%	249	71%	79%	65%	49	5
DPS01-HPD-PMP	1000	Unknown	797	4.1	6.9%	N/A	80%	N/A	N/A	36	5
DPS01-HPE-PMP	1000	Unknown	763	0.8	7.4%	N/A	76%	N/A	N/A	32	5

The following table presents Aborted test statuses, which represents tests that were attempted but had to be aborted due to an operational issue. Depending on the criticality of the pump, these tests should also be considered high priority for retesting to ensure operational capability and reliability of the pumps.

Table 5D: Summary of Drainage Pump Performance Capacity Test Results: Aborted

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Result (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario	Worst Case Scenario	Weighted Priority
DPS02-HPD-PMP	1000	Unknown	N/A	-2.2	N/A	N/A	N/A	N/A	N/A	N/A
DPS04-CD1-PMP	80	Unknown	N/A	13.3	N/A	N/A	N/A	N/A	N/A	N/A
DPS04-HPE-PMP	1000	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS06-HPB-PMP	550	11.5	N/A	11.9	N/A	N/A	N/A	N/A	N/A	N/A
DPS06-VTP3-PMP	250	16.0	N/A	11.9	N/A	N/A	N/A	N/A	N/A	N/A
DPS07-CD1-PMP	70	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS15-VTP1-PMP	250	Unknown	N/A	7.9	N/A	N/A	N/A	N/A	N/A	N/A
DPS15-VTP2-PMP	250	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS19-HP2-PMP	1100	12.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPSGRT-VTP5-PMP	80	Unknown	N/A	7.2	N/A	N/A	N/A	N/A	N/A	N/A
DPSGRT-VTP6-PMP	80	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

The following table presents tests that were not attempted due to equipment out of service and the cost-benefit of the complexity of measuring the discharge of the 15-CFS constant duty pump at DPS01.

Table 5E: Summary of Drainage Pump Performance Capacity Test Results: Not Attempted

Header Key:
Asset ID: Unique Identifier of Constant Duty (CD), Horizontal Pumps (HP), and Vertical Turbine Pumps (VTP)
Rated Capacity (CFS): The nominal design (nameplate) capacity of the pump at design static head conditions
Rated Head (ft): The nominal pool-to-pool head rating associated with the Rated Capacity per the pump performance curve
Test Results (CFS): The average volumetric flow measured by the test instrumentation
Test Head (ft): The average pool-to-pool static head during the period of flow data collection
Aggregated Test Result Uncertainty (%): The aggregation of instrumentation accuracy and coefficient of variation of collected flow measurements
Design Capacity at Test Head (CFS): Where flow curves are available, this value represents the design capacity of the pump at the test head conditions.
Nominal Comparison to Design (%): Test Results have been divided by the Design Capacity at Test Head. Where unavailable, Test Results have been divided by the Rated Capacity.
Best Case Scenario (%): Upper test result uncertainty limit divided by design capacity at lower uncertainty limit of static head
Worst Case Scenario (%): Lower uncertainty limit of test result divided by design capacity at upper uncertainty limit of static head
Weighted Priority: Comparison to Design and Pump Criticality from Task 2 have been combined and ranked with 1 being the highest priority for further action.

Asset ID	Rated Capacity (CFS)	Rated Head (ft)	Test Result (CFS)	Test Head (ft)	Aggregated Test Result Uncertainty (%)	Design Capacity at Test Head (CFS)	Nominal Comparison to Design (%)	Best Case Scenario	Worst Case Scenario	Weighted Priority
DPS01-CD2-PMP	15	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS03-CD1-PMP	80	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS03-CD2-PMP	80	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS05-CD2-PMP	80	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS06-CD1-PMP	90	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPS06-CD2-PMP	90	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPSGRT-VTP2-PMP	8	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
DPSGRT-VTP4-PMP	8	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Impact / Benefit for S&WB

Restoration of functional capacity associated with systems currently in a state of severely diminished capacity and/or poor condition.

Implementation Outline

Taking into account asset criticality and severity of the issues identified, the issues listed in Table 6 below by station and test type should be addressed in the short term.

To reiterate, these test results indicate that the affected assets are **in the process of failing or have already failed**. It will be critical to take corrective action as detailed in the table as the failure of these assets could have a significant impact on the operation of the pumping station.

Table 6: Equipment Issues Compromising Functional Capacity and Remedial Actions

Asset	Test Type	Issue Description	Remedial Action
DPS 01			
Horizontal Pump D	Infrared	Temperature rise of 35 degrees on the com ring when the DC lead screws into it	Check connection for proper torque when downtime allows
Battery Bank	Electrical Hardware & Panel Assessment	The discharge wire should not be tied to the hand rail. If insulation were to degrade, this could potentially cause a safety issue.	Relocate discharge wire
Vacuum Pump 1	Vacuum Pump Testing	Bad contactor. Had to hold finger on start button to run pump. Maintenance notified. Opened seal water bypass line, no change in vacuum.	Replace contactor
Vacuum System: VACUUM PUMP 2 -> #1 ISOLATION VLV	Vacuum Pump Testing	Isolation block valve (between VP2 and VP3) on main header not holding	Repair or replace valve as needed
Vacuum System: #4 &#3 ISOLATION VALVE <- VP3A -> #2 ISOLATION VLV	Vacuum Pump Testing	Could not perform dead head test due to placement of gauge (upstream of isolation valve). Performed system test from pump to #4 isolation block valve, #3 isolation valve not holding.	Repair or replace #3 isolation valve as needed
Vacuum System: VACUUM PUMP 3B -> #2 ISOLATION VLV	Vacuum Pump Testing	Performed system test from pump to 2nd isolation valve, through #1 isolation valve since it was not holding.	Repair or replace #1 isolation valve as needed

Asset	Test Type	Issue Description	Remedial Action
Vacuum Pump 4	Vacuum Pump Testing	Could not pull vacuum both during dead head and system test. Multiple trials. Bad solenoid, opened bypass. Added seal water booster pump to no effect.	Repair or replace pump as needed
Vacuum Pump 5	Vacuum Pump Testing	Bad solenoid, opened bypass	Replace solenoid valve on potable water supply
Horizontal Pump A	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Horizontal Pump B	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Horizontal Pump E	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump 1	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump 2	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump 6	Motor Circuit Analysis	Test indicated high inductive imbalance	Professionally Clean Windings
DPS 02			
Transformer 2	Transformer Oil Testing	Dissolved gas analysis indicated high Ethane levels due to mild overheating of the insulating liquid.	Perform DGA every month to trend ethane levels. If ethane levels increase, remove from service and replace oil.
Horizontal Pump A	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Horizontal Pump B	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Horizontal Pump D	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum #2	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 03			
Horizontal Pump C	Infrared	Delta T on the DC Rotor lead of 149 degrees F. There appears to be a loose/bad splice on the lead.	Recommend replacement of the lead when downtime allows

Asset	Test Type	Issue Description	Remedial Action
Vacuum Pump 3	Electrical Hardware & Panel Assessment	Both SCR are cracked inside the starter for vacuum pump 3. Both have leaked onto the floor and need to be replaced immediately.	Replace both SCRs immediately
Vacuum System: VACUUM PUMP 1 -> HPA	Vacuum Pump Testing	Portion of the vacuum system was unable to pull sufficient vacuum when tested: VACUUM PUMP 1 -> HPA. Initial test to MOV only held 12". Closed isolation valve, vacuum to 15".	Investigate further and perform remedial actions as needed
Vacuum System: VACUUM PUMP 1 -> HPB	Vacuum Pump Testing	Portion of the vacuum system was unable to pull sufficient vacuum when tested: VACUUM PUMP 1 -> HPB. Initial test to MOV only held 15". Closed manual isolation valve, no improvement.	Investigate further and perform remedial actions as needed
Vacuum System: VACUUM PUMP 2 -> HPC, D & E	Vacuum Pump Testing	Portion of the vacuum system was unable to pull sufficient vacuum when tested: VACUUM PUMP 2 -> HPC, D & E. Manually isolated HPD (no MOVs), lost 13" somewhere in system.	Investigate further and perform remedial actions as needed
Vacuum Pump 3	Vacuum Pump Testing	Opened seal water bypass, no improvement to vacuum.	Repair or replace pump as needed
Vacuum System: VACUUM PUMP 3 -> HPC, D & E	Vacuum Pump Testing	Lost vacuum. VP2 was not isolated, may have lost some through pump.	Investigate further and perform remedial actions as needed
Horizontal Pump B Discharge Bell	Suction and Discharge Bell Assessments	Heavy surface rust and corrosion observed above water. Large amount of biological encrustation below water.	Prepare and coat heavy surface rust and corrosion above water. Remove biological encrustation below water for further assessment.
Horizontal Pump C Discharge Bell	Suction and Discharge Bell Assessments	A crack was located approximately 2 feet long and 3 inches wide at mouth of bell on left side of the bell was identified. High corrosion was identified throughout the bell. The metal appears thin at the mouth of the bell. A deeper assessment of the bell and repairs recommended.	Further assessment and repairs as needed
Horizontal Pump A	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings

Asset	Test Type	Issue Description	Remedial Action
Horizontal Pump B	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Horizontal Pump C	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump 3	Motor Circuit Analysis	Test indicated high inductive imbalance	Professionally Clean Windings
DPS 04			
Vacuum Pump 1C	Vacuum Pump Testing	Pump would not start after 6 attempts. Kept tripping out. "Possible" cause may be too much water being introduced into pump cavity. Need to check electrical.	Investigate further and perform remedial actions as needed
Vacuum System: VACUUM PUMP 6A -> CD2	Vacuum Pump Testing	Pump could not pull vacuum	Repair or replace pump as needed
Vacuum Pump 6B	Vacuum Pump Testing	Pump was found to be failed and out of service	Repair or replace pump as needed
Horizontal Pump C	Vibration	Vibration analysis result indicates abnormal impeller and / or bearing condition	Inspect pump impeller and bearings for signs of wear / damage and remedy as needed
Horizontal Pump C	Rotating Equipment Oil Testing	Oil sample had very high moisture content, identified by visual inspection/color.	Replace oil and locate source of moisture contamination
Horizontal Pump E	Motor Circuit Analysis	Test indicated low insulation resistance	Monitor frequently/consider rewind, or clean
Constant Duty 1	Motor Circuit Analysis	Test indicated very high inductive imbalance	Rewind
Vacuum Pump #1A	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump #1B	Motor Circuit Analysis	Test indicated very low insulation resistance	Rewind
DPS 05			
Constant Duty Pump 2	Vibration	Vibration analysis result indicates excessive bearing wear	Replace pump bearings
Vertical Pump 3	Vacuum Pump Testing	Numerous issues noted with ancillary components that need to be addressed	Need to replace seal water pressure gauge. Check solenoid and pressure switch and remedy as needed.
Horizontal Pump A	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Horizontal Pump B	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings

Asset	Test Type	Issue Description	Remedial Action
CD 1&2 Rotor	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
CD 1&2	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
CD 3&4	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 06			
Horizontal Pump B Electrical Breaker	Electrical Hardware & Panel Assessment	Cable Insulation is only rated for 600V. Gray tape near termination point is beginning to peel off.	Replace with appropriately rated insulation
Horizontal Pump A Electrical Breaker	Electrical Hardware & Panel Assessment	Cable insulation is only rated for 600V	Replace with appropriately rated insulation
Horizontal Pump I	Rotating Equipment Oil Testing	The sample from this unit contained extreme water contamination. Due to the water content a DR Ferrography was performed instead of a particle count.	Change lube and thoroughly flush sump. Check for sources of water entry. Resample to track condition.
Vacuum Pump 1	Vacuum Pump Testing	Out of service. Seal water supply line has failed. Work order already in place with S&WB to repair line. Suction and or bypass isolation valves leaking by, noted during VP2 system test.	Complete outstanding work order addressing all issues
Vacuum Pump 4	Vacuum Pump Testing	Pump configured to pressurize system. When tried, cannot pull vacuum.	Repair or replace pump as needed
Vacuum System: VACUUM PUMP 8A -> INSIDE ISOLATION VLV	Vacuum Pump Testing	At 180sec, vacuum stopped at 12-14" then started to drop.	Investigate further and perform remedial actions as needed
Vacuum System: VACUUM PUMP - 8B -> INSIDE ISOLATION VLV	Vacuum Pump Testing	Started test with 8B. Peaked at -7.4psi, then started dropping? Started again then reached -8.4psi at 4 min, then started to drop. Replaced with second test gauge, reached 12 inHg, then started dropping. Opened water bypass, no effect.	Investigate further and perform remedial actions as needed
Vacuum System: VACUUM PUMP - 8A & 8B SYSTEM TEST	Vacuum Pump Testing	SOP is for both 8A & 8B to be used to start pump, can only start one at a time. Both pumps online pulled system to 14 inHg	Investigate further and perform remedial actions as needed

Asset	Test Type	Issue Description	Remedial Action
Horizontal Pump B Suction Bell	Suction and Discharge Bell Assessments	Hole found above mouth of pump B intake. Approximately 10-12 in above the mouth of the bell.	Repair as needed via patching hole
Motor Generator Set 4	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump #1	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump #6	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 07			
Transformer 5	Transformer Oil Testing	Tested with very high moisture content	Retest in one month recommended and planned oil replacement if / when verified
Vacuum Pump 1	Vacuum Pump Testing	Test 1 - Seal water bypass had to be open. Pulled down <10 sec after water was admitted.	Replace potable water solenoid valve
Vacuum Pump 3	Vacuum Pump Testing	Ops believes pump is problem not valves. Can only get 22" during dead head, 23" open during system test. Note - Preferred method is to operate 2 VPs to start a HP. Typically takes 4 min. No local seal water gauge at pump, assumed water pressure.	Repair or replace pump as needed
Horizontal Pump A Discharge Bell	Suction and Discharge Bell Assessments	Minor surface rust visible throughout metal exterior. Major corrosion at the mouth of the bell. Connect to vertical supports are compromised from corrosion. Vertical supports encrusted with biological growth.	Repair as needed
Horizontal Pump C Discharge Bell	Suction and Discharge Bell Assessments	Minor surface rust visible throughout metal exterior. Major corrosion at the mouth of the bell. Connect to vertical supports are compromised from corrosion. Vertical supports encrusted with biological growth.	Repair as needed
Horizontal Pump D Discharge Bell	Suction and Discharge Bell Assessments	Minor surface rust visible throughout metal exterior. Major corrosion at the mouth of the bell. Connect to vertical supports are compromised from corrosion. Vertical supports encrusted with biological growth.	Repair as needed

Asset	Test Type	Issue Description	Remedial Action
Horizontal Pump A	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Motor Generator Set 2	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Motor Generator Set 3	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump #1	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 11			
Horizontal Pump A Electrical Breaker	Electrical Hardware & Panel Assessment	Very old equipment for the breakers. There is visible charring inside the cabinet for this pump. Potentially occurring now.	Repair or replace equipment as needed
Vacuum System: VP3 -> HPD & E	Vacuum Pump Testing	System test was poor at 4inHg	Investigate further and perform remedial actions as needed
Vacuum Pump 3	Vacuum Pump Testing	Test 1 was with installed gauge - 13inHg @ 102sec. Test 2 was with test gauge - 72sec, 16.5 inHg.	Repair or replace pump as needed
Vacuum Pump 4	Vacuum Pump Testing	Pump tested poor	Repair or replace pump as needed
DPS 12			
Pump Pipework	Metal Thickness	Concern for pipe separating at expansion joint next to building wall. Reported water spraying during operation from area where piping penetrates concrete wall.	Investigate further and perform remedial actions as needed
Horizontal Pump D Suction Bell	Suction and Discharge Bell Assessments	Heavy corrosion observed at bell bottom and vertical supports. Many rust pin holes observed below water.	Investigate further and perform remedial actions as needed
Horizontal Pump D	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vacuum Pump #2	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 13			
Pump Pipework	Metal Thickness	Large areas of major thickness loss on piping for Pumps 1 and 2. Leaks in expansion joint for Pump 5 piping.	Investigate further and perform remedial actions as needed
Constant Duty Pump 3	Electrical Hardware & Panel Assessment	White residue on the lower part of the fuse	Repair or replace equipment as needed

Asset	Test Type	Issue Description	Remedial Action
Vacuum Pump 4	Vacuum Pump Testing	Diesel driven. Out of service, no clutch pad in place to drive the pump. Original was asbestos.	Replace clutch pad with suitable modern non-asbestos type
Vacuum Pump 5	Vacuum Pump Testing	Diesel driven. Out of service, no clutch pad in place to drive the pump. Original was asbestos.	Replace clutch pad with suitable modern non-asbestos type
Vacuum System: #4 ISOLATION <-VACUUM PUMP 6 -> #3 ISOLATION & HP6	Vacuum Pump Testing	Portion of the vacuum system was unable to pull sufficient vacuum when tested: #4 ISOLATION <-VACUUM PUMP 6 -> #3 ISOLATION & HP6	Investigate further and perform remedial actions as needed
Constant Duty 1	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 14			
Drainage Pump 3 Gearbox	Rotating Equipment Oil Testing	The iron and lead content have been flagged for observation. Certain particle count values are higher than desired and have been flagged for observation.	Inspect this unit for abnormal wear modes and remedy as needed
Drainage Pump 4 Gearbox	Rotating Equipment Oil Testing	The iron, copper, and lead content have been flagged for observation. This sample contained visible debris. Certain particle count values are higher than desired and have been flagged for observation.	Inspect this unit for abnormal wear modes and remedy as needed
Vertical Pump 1	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vertical Pump 3	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 15			
Pump Pipework	Metal Thickness	Severe corrosion and holes in pipe at canal; additional assessment required for Pump V-1 discharge pipe just outside building wall.	Investigate further and perform remedial actions as needed
Vertical Pump 1	Vibration	Vibration analysis result indicates abnormal gearbox condition	Take unit offline and Inspect gearbox, repair as needed
Vertical Pump 3	Electrical Hardware & Panel Assessment	Bridge rectifier is cracked and leaking fluid	Replace bridge rectifier immediately

Asset	Test Type	Issue Description	Remedial Action
Vertical Pump 1 Suction Bell	Suction and Discharge Bell Assessments	Medium to high corrosion identified but no breaches were detected.	It is highly recommended that a more thorough inspection is conducted due to the condition of the discharge bells
Vertical Pump 2 Suction Bell	Suction and Discharge Bell Assessments	Medium to high corrosion identified but no breaches were detected.	It is highly recommended that a more thorough inspection is conducted due to the condition of the discharge bells and the corrosion identified on the pump 1 intake bell.
Vertical Pump 3 Suction Bell	Suction and Discharge Bell Assessments	Medium to high corrosion identified but no breaches were detected.	It is highly recommended that a more thorough inspection is conducted due to the condition of the discharge bells and the corrosion identified on the pump 1 intake bell.
Vertical Pump 1 Discharge Bell	Suction and Discharge Bell Assessments	Heavy surface rust observed.	Investigate further and perform remedial actions as needed
Vertical Pump 2 Discharge Bell	Suction and Discharge Bell Assessments	Heavy surface rust observed.	Investigate further and perform remedial actions as needed
Vertical Pump 3 Discharge Bell	Suction and Discharge Bell Assessments	Heavy surface rust and holes observed.	Investigate further and perform remedial actions as needed
Vertical Pump 1	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Vertical Pump 2	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 17			
Frequency Changer 3 Sync Motor	Motor Circuit Analysis	Assessment identified high resistive imbalance	Plan rewind as needed
Frequency Changer 3 AC Generator	Motor Circuit Analysis	Assessment identified high resistive imbalance	Plan rewind as needed

Asset	Test Type	Issue Description	Remedial Action
Motor-Generator 1	Infrared	Area 1 max temp 308-degree F.201-Degree F delta temp rise across phases on the load side of fuses and fuse clips.	Repair immediately. Clean and inspect components. Properly grease fuse clips and operate dead switch. Properly install fuses securely into the fuse clips and torque all connections.
Vacuum Pump 1	Electrical Hardware & Panel Assessment	Visible signs of burning on B phase on low side of fuse	Investigate further and perform remedial actions as needed
Frequency Changer 3	Electrical Hardware & Panel Assessment	Corrosion on the 25hz feeder bus	Investigate further and perform remedial actions as needed
Frequency Changer 4	Electrical Hardware & Panel Assessment	Corrosion on the 60hz feeder bus	Investigate further and perform remedial actions as needed
Pump Pipework	Metal Thickness	Based on the numerous, widely scattered low-thickness areas, there is a high likelihood that the discharge piping in this station will experience leaks in the future. Several, larger areas of low thickness present a potential for more catastrophic failure.	Investigate further and perform remedial actions as needed
Frequency Changer 3 DC Gen	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer 3 DC Field	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer 4 Sync Motor	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer 4 AC Generator	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer 4 DC Gen	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer 4 DC Field	Motor Circuit Analysis	Test indicated low insulation resistance	Professionally Clean Windings
DPS 18			
Vertical Pump 1	Vibration	Vibration analysis result indicates abnormal impeller condition and / or piping flow-related issues (foreign material, etc.)	Remove from service immediately inspect impeller for wear and/or damage, inspect pump and associated piping for flow-related issues (foreign material, etc.)
DPS 19			

Asset	Test Type	Issue Description	Remedial Action
Vacuum Pump 3	IR	Area 1 max temp 308-degree F.201-Degree F delta temp rise across phases on the load side of fuses and fuse clips.	Repair immediately. Clean and inspect components. Properly grease fuse clips and operate dead switch. Properly install fuses securely into the fuse clips and torque all connections
Vacuum Pump 2	IR	Area 1 max temp 308-degree F.201-Degree F delta temp rise across phases on the load side of fuses and fuse clips.	Repair immediately. Properly grease fuse clips and operate dead switch. Properly install fuses securely into the fuse clips and torque all connections
Vacuum Pump 1	Vacuum Pump Testing	Tried to test pump 2x. During third try, noticed that seal water piping at pump had failed so pump was tripping out on low water pressure.	Repair pipework and test
Vacuum System: VP3 <- VP2 -> VP1 (& TO ALL HORIZONTAL PUMPS)	Vacuum Pump Testing	Portion of the vacuum system was unable to pull sufficient vacuum when tested: VP3 <- VP2 -> VP1 (& TO ALL HORIZONTAL PUMPS)	Investigate further and perform remedial actions as needed
Vacuum System: VACUUM PUMP 3 -> FIRST ISOLATION	Vacuum Pump Testing	Portion of the vacuum system was unable to pull sufficient vacuum when tested: VACUUM PUMP 3 -> FIRST ISOLATION	Investigate further and perform remedial actions as needed
DPS Elaine			
Electrical System	Electrical Hardware & Panel Assessment	There is an infestation of Rasberry Crazy ants that will cause serious problems with the electrical gear if they are not exterminated. They have already begun to cause problems at this site.	Exterminate ants and instate an ongoing extermination program
Vertical Pump 1 Discharge Bell	Suction and Discharge Bell Assessments	Significant rust on surface above and below water. No breaches or punctures were identified.	Investigate further and perform remedial actions as needed
Vertical Pump 2 Discharge Bell	Suction and Discharge Bell Assessments	Significant rust on surface above and below water. No breaches or punctures were identified.	Investigate further and perform remedial actions as needed
DPS I-10			
Vertical Pump 3	Vibration	Vibration analysis result indicates abnormal gearbox condition	Inspect gearbox, repair as needed

Asset	Test Type	Issue Description	Remedial Action
Vertical Pump 1	Vibration	Vibration analysis result indicates abnormal gearbox, coupling and impeller conditions	Inspect gearbox, coupling and impeller, repair as needed
Vacuum Pump 1	Vibration	Vibration analysis result indicates abnormal pump condition	Internally inspect pump, repair as needed
Vertical Pump 2	Vibration	Vibration analysis result indicates abnormal gearbox, coupling and impeller conditions	Inspect gearbox, coupling and impeller, repair as needed
Vacuum Pump 1	Vacuum Pump Testing	Tried to test pump 2x. Never could get seal water pressure reading, even with booster pump online. Possible clogged line.	Investigate further and perform remedial actions as needed
Grant			
Vertical Pump 3	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Vertical Pump 5	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Vertical Pump 6	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Pritchard			
Constant Duty 1	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Constant Duty Spare	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Oleander			
Vertical Pump 2	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Vertical Pump 3	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Powerhouse			
Turbine Generator 3 Exciter Field Rheostat	IR	Area 1 max temp 408-degree F	Repair immediately. Replace any annealed wire or component and inspect surrounding components for probable damage.
Turbine Generator 3 Exciter Field Rheostat	IR	Area 1 max temp 416-degree F	Repair immediately. Replace any annealed wire or component and inspect surrounding components for probable damage.
Boiler #2 Forced Draft Fan Electric Motor	MCA	Assessment identified high resistive imbalance	Plan rewind as needed
Westbank			

Asset	Test Type	Issue Description	Remedial Action
Frequency Changer #3 Sync Motor	MCA	Assessment identified high resistive imbalance	Plan rewind as needed
Frequency Changer-1 DC Field	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer-1 DC Gen	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer-1 DC	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer-2 DC Field	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer-2 DC Gen	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer-3 DC Gen	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer-3 DC Gen Field	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Carrollton Frequency Changer			
Frequency Changer-1 AC Generator	MCA	Tested high inductive imbalance	Perform a Rotor Influence Check (RIC)
Frequency Changer-2 Sync Motor	MCA	Tested high inductive imbalance	Perform a Rotor Influence Check (RIC)
Frequency Changer-2 AC Generator	MCA	Tested high inductive imbalance	Perform a Rotor Influence Check (RIC)
Frequency Changer-2 DC Generator	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer-2 DC Generator Field	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Plant Frequency Changer			
Frequency Changer DC Generator	MCA	Test indicated low insulation resistance	Professionally Clean Windings
Frequency Changer DC Generator Field	MCA	Test indicated low insulation resistance	Professionally Clean Windings

1.6 Ensure Pump Rebuilds Are Appropriately Specified and Delivered

Findings

Pumps that have been recently rebuilt and returned to service are not meeting their design capacity. S&WB should review the pump rebuild specification (as well as specifications for other critical asset types) and determine if restoration of design capacity is part of the scope. Pump capacity flow testing requirements should be added to the return to service acceptance criteria.

Recommendation Detail

Vertical Pump 1 at DPS20 tested at 56% to 62% of nominal capacity. This pump was returned to service in October 2017 following a major rebuild by a contractor. Veolia tested the pump shortly after acceptance by S&WB. Further troubleshooting is required to determine the cause of degraded flow following pump overhaul.

Impact / Benefit for S&WB

Enhancement of the rebuild specification will promote contractor accountability and ultimately ensure that pump capacity is restored following costly rebuilds rather than unknowingly returning pumps to service in a state of diminished capacity.

Implementation Outline

This task can be assigned to the maintenance contractor to complete once specified by S&WB Engineering and / or contracted engineering firms creating project specifications. Although the capital investment may increase due to the added labor for testing, the extra cost is worthwhile to ensure a quality rebuild is received.

Actions to Maintain Drainage System Functionality

Following the remedial actions necessary to return the drainage systems to an adequate level of performance, the S&WB must enact additional major strategic and procedural changes to maintain the systems in an appropriately functional state going forward. This section details the foundational items necessary to maintain system performance and ensure that events such as the August 5th flooding are avoided.

2.1 Maintain 100% Coverage of Assets

Findings

The collective drainage system was assessed and all of the functional systems were identified as the basis for developing a hierarchy and verifying the current asset registry. The existing asset registry was extracted from S&WB's CMMS and each asset was physically walked down to verify and add new assets as discovered. Developing an all-encompassing asset registry provides the basis to accurately track the overall function of conveying stormwater out of New Orleans.

Recommendation Detail

Develop a clear definition of an asset, preferably set to the level which maintenance is performed and tracked. Continue to update and refine the Asset Hierarchy that Veolia has established. Perform a formal and focused implementation of a suitable CMMS to supersede S&WB's current defunct program.

Impact / Benefit for S&WB

Complete asset coverage will allow S&WB to accurately track asset performance, condition, maintenance history, and ultimately life-cycle cost to support repair/replace decisions.

Implementation Outline

Adopt an asset-focused organization structure with a formal asset manager and an asset management executive champion. Update the existing CMMS with the asset registry provided as part of Task 1, and put in place a cross-functional core team that includes individuals from management, finance, operations and maintenance to focus on and improve the asset registry accuracy and the work processes surrounding the assets. Implement a new CMMS that can provide better accessibility to data. This should include mobile interface to CMMS and have the ability to pull asset condition scoring from performance data tracked in Task 6 Visibility and Analytics task on a continuous basis.

2.2 Develop Failure Management Policies to Maintain the Inherent Capability of S&WB Drainage System Assets

Findings

Current maintenance strategies are generally reactive and ineffective. Minimal application of predictive technologies is in place as well as trending of asset performance. Similarly, minimal functional testing of protective devices appears to be in place.

Recommendation Detail

First, determine the maintenance requirements of each physical asset in its presenting operating context. Then obtain the resources needed to ensure that these requirements are fulfilled effectively. Then set up the systems needed to ensure that these resources are managed efficiently.

Impact / Benefit for S&WB

Improved asset reliability and reduced costs associated with repairs and replacements.

Implementation Outline

Implement a team of appropriate individuals within S&WB across Operations, Maintenance, Engineering and Management tasked with determining and documenting the maintenance requirements of each of S&WB's physical assets in their presenting operating context. Then develop procedures and maintenance plans to provide the framework to trigger and manage the developed maintenance requirements. Finally, ensure staffing levels and other resources (parts, tools, specialist subcontractors, etc.) are in place to effectively execute the required maintenance effectively. An overarching requirement is also to establish the systems (e.g. CMMS, policies, procedures, etc.) needed to ensure that these resources are managed efficiently and the efforts are documented for periodic review and cyclical improvement.

2.3 Implement Optimal Operational Procedures and Training Program

Findings

Throughout Veolia's condition assessment, sub-standard operational practices were noted throughout S&WB's operations. These practices contribute to long-term degradation of station equipment and could potentially affect the ability of the station to emergently respond to a rain event in a timely manner. Standardized station operating procedures will provide the resources needed by station operators by mitigating human factors and ensuring proper operational practices are robustly developed and clearly communicated.

Recommendation Detail

Station Standard Operating Procedures (SOPs) should include a normal pump startup procedure, emergency operating procedures, such as starting up an emergency diesel generator, and abnormal operating procedures, such as siphoning water from the discharge for testing purposes. The SOP should also include normal operating parameters for water level, power, pressure, temperature, etc. to ensure that operators know when parameters reach levels that would affect safe and reliable operation of the equipment. SOPs must also be accompanied by equipment tagging at a minimum as well as valve lineup checklists to ensure that all valves are maintained in a normal position that does not inhibit operator response. In parallel to SOP development, operational changes such as operator monitoring and oversight processes need to be implemented. These are crucial to ensure operating procedures, testing, and training are being adhered to. Operations and Maintenance staff need to be trained, tested, and certified to ensure they have the knowledge and capability to properly run the facilities.

Impact / Benefit for S&WB

Development of SOPs will increase the likelihood that equipment is operated within its design operating parameters by improving the availability of resources to operations staff. SOPs along with improved data visibility and historical analysis will also lead to accountability among operations staff by clearly communicating expectations and monitoring performance.

Implementation Outline

A template SOP should be generated for a robust station that is representative of all operating modes and nuances (i.e. DPS06 or DPS13). Once the standardized format is developed and approved, it can be used as a guide for developing SOPs for the other stations.

2.4 Implement Planning and Scheduling Functions

Findings

Current maintenance practices appear inadequate based on equipment condition, interactions with staff, and importance of the S&WB drainage system.

Recommendation Detail

Mature planning and scheduling functions in a maintenance organization provide a means of minimizing inefficiencies associated with the execution of maintenance tasks. Recommend implementing planning and scheduling functions in the current maintenance organization with dedicated staff, training, processes and procedures. A goal should be established that 80% of work is planned at least one week ahead of work execution. The work order should contain enough detail on the scope of work, instructions, drawings, manuals, parts, tools, materials and crafts necessary for execution so that the work can be completed on the scheduled day (schedule compliance). This will be a major culture change for the S&WB and will bring them up to par with other mission critical organizations.

Impact / Benefit for S&WB

When the ideal ratio of planners to staff is achieved, a team is typically able to be 20% - 50% more effective as measured by **Wrench Time**[1].

Implementation Outline

Empower existing staff and / or hire planners to plan work for maintenance crews generally two to three weeks in advance.

Implement repeatable job plans or model work orders. Typically, 50% of corrective type work will be repeated in a year, 80% will be repeated in 5 years, so systematically following a process of detailed job planning and saving with naming convention that allows for the reuse of the job plans will reduce the planning work. The parts purchase requests associated with these jobs should also be saved and tracked to optimize parts acquisition and purchasing tasks.

Institute a Scheduling Committee (i.e. a weekly scheduling meeting attended by management) where scheduling is a coordinated effort led by the combination of asset criticality and work order priority.

Track Key Performance Indicators (KPIs) to identify and manage trends. Include: (1) Mean Time to Repair, (2) Mean Time to Procure, (3) Schedule conformance (tracking number of hours on planned work, emergency, and others), and (4) Backlog Management by asset criticality and work order priority. Consider other KPIs relative to S&WB's context and desired metrics to track performance.

[1] Wrench time is a measure of crafts personnel's effectiveness at physically performing maintenance work rather than non-productive uses of their time (e.g. obtaining parts, tools or instructions, travel, breaks, eating, sleeping, non-work related discussion, re-performing tasks that were done incorrectly, returning incorrect parts and tools, etc.).

2.5 Develop a Critical Spares Program

Findings

Veolia's review of S&WB's current spares revealed an overall lack of organization and discipline. Specifically, organization of parts were by craft (electrical, mechanical, etc.) and somewhat by part type. Veolia also observed that there was no control over parts check-out and that reporting usage is at the discretion of the person removing the part. The existing system creates and environment where theft of valuable parts, tools, equipment could become an issue.

Veolia's critical spares evaluation and suggestions are based on a multi-tiered approach depending on the level of an organization's maintenance program. There are three maintenance program approaches and Veolia based the Critical Spares evaluation on a Run-to-Fail Maintenance Program for S&WB. Currently S&WB operates in this vulnerable mode where spares sit in waiting until equipment fails. This style of maintenance leaves S&WB, as well as the local government and its residents, at risk since many areas flood in rainfall events without these vital systems. Without a reasonably predictable program in place, long-term failures can result in high priority equipment becoming inoperable at very inopportune times. To operate in this manner, the S&WB needs to carry a very high level of critical spare parts at all times to be sure equipment can be repaired quickly.

Recommendation Detail

The current lack of procedures contributes to the limited accountability of staff to manage inventory, report usage, and keep stores organized. Indeed, controlled critical spares accountability, requires consistent and enforced rules. S&WB should develop a defined part check out program, parts and reorder process, kitting for work orders, and controlled access to spare parts. Moreover, there are several key actions and tasks that must be addressed to set up basic controls:

- Create secure central storage or 3rd party storage locations for larger and less frequently used inventory
- Create secure local stores at drainage pumping stations and other remote sites for smaller and frequently used inventory
- Organize storage locations and define / document part locations
- Define parts replenishment process
- Create parts request and approval hierarchy and workflow
- Create work order process tied to the asset hierarchy
- Implement a policy that all parts must be charged to a work order

There are currently no standard operating procedures (SOPs) or workflows related to Critical Spares. S&WB should develop such SOPs to formalize and support the critical spares program.

Impact / Benefit for S&WB

Developing a critical spares program will mitigate risk, improve the overall uptime of critical equipment, and reduce the overall cost of repair for the drainage system.

Implementation Outline

Each critical system needs to undergo an in-depth RCM-based review with full equipment analysis and spare parts investigation to provide an extensive spare parts plan and robust maintenance program. Also, in-depth studies should be performed to review viable equipment upgrades throughout the system that would create common equipment designs so that spare parts requirements are redundant across each facility.

2.6 Implement a Reliability Centered Maintenance (RCM) Approach

Findings

S&WB's existing maintenance strategy is reactionary, which poses significant risks to operational reliability and results in unnecessary cost escalation that is passed through to taxpayers. One such way to facilitate a change of behaviors and mindsets is to implement a Reliability Centered Maintenance (RCM) approach. RCM integrates a review of operational failure consequences with an evaluation of safety and environmental hazards. This brings safety and the environment into the mainstream of maintenance decision-making. Furthermore, it continually focuses attention on the maintenance activities that have the greatest effect on the performance of the plant, ensuring that every dollar spent on maintenance is spent where it will have the greatest impact.

Recommendation Detail

Although they are not explicitly stated anywhere, such policies exist within S&WB. Routine maintenance within the SWBNO is essentially divided into three categories:

- **Predictive or condition-based tasks**. This involves checking whether a piece of equipment is in the process of failing and includes the operator daily or weekly inspections. Vibration readings taken by the machine shop are executed on an ad-hoc basis such that vibration points are not marked on equipment for consistency and data is not collected in a manner that would facilitate identification of degrading trends. Some oil analysis is also conducted on a regular basis for the diesel generators, combustion turbine, and steam turbines.
- **Preventive tasks**. This involves overhauling equipment or replacing components at fixed intervals, such as the oil changes carried out by operators.
- **Corrective tasks.** Corrective tasks involve fixing equipment when they are found to be either failing or failed. This represents the majority of the maintenance performed by S&WB.

Currently, each pump station follows an informal inspection system that does not specify (1) inspection requirements per machine and (2) inspection frequency per machine, which industry best practices show to vary widely. Indeed, the general absence of both clear equipment maintenance specifications and their associated maintenance frequencies leads to widely differing practices by the operators.

It is in the context of these inspection practices as well as the results of vibration and oil analysis testing that corrective work for S&WB arises. Any major defects identified are then addressed during plant shutdowns.

S&WB's maintenance practice is currently missing failure-finding tasks. Failure-finding applies only to hidden or unrevealed failures like that of sprinkler system that only reveals its failure when initiated in the event of a fire. Hidden failures in turn only affect protective devices. For example, when the gearbox oil pressure switch failed on Pump D at DPS12 and the pump could not be started because a start permissive could not be met, the question was asked of maintenance staff, "Do you check these switches?" The answer was, "No."

This is a rather troubling finding as most traditionally derived maintenance programs provide for fewer than one third of protective devices to receive any attention at all (and then usually at inappropriate intervals). The people who operate and maintain the plant covered by these traditional programs are aware that another third of these devices exist but pay them no attention, while it is not unusual to find that no one even knows that the final third exist. This lack of awareness and attention means that most of the protective devices within S&WB - our last line of protection when things go wrong - are maintained poorly or not at all.

Impact / Benefit for S&WB

The evaluation of maintenance policies and the selection of maintenance tasks is a key aspect of maintenance management and most engineers do it continuously. But the range of options is now so great and new techniques are emerging so rapidly that it is no longer possible to do it informally. RCM solves this problem with a strategic framework that permits the evaluation and selection process to be done quickly and confidently. To our knowledge, it is the only technique of its kind in existence, and it leads to extraordinary improvements in maintenance performance wherever it is applied. It does so in the following ways:

- RCM places at least as much emphasis on the consequences of each failure as it does on its technical characteristics. In doing so,
    - It integrates a review of operational failure consequences with the evaluation of safety and environmental hazards. This brings safety and the environment into the mainstream of maintenance decision-making
    - It continually focuses attention on the maintenance activities that have most effect on the performance of the plant. This means that every dollar spent on maintenance is spent where it will do the most good.
- RCM recognizes that all types of maintenance have some value, and provides rules for deciding which are most suitable in every situation. By doing so, it helps to ensure that the most effective forms of maintenance are chosen for each machine, and avoids the constraints and distortions that always follow the adoption of a single plant-wide maintenance policy.
- RCM separates evident failures from hidden failures and as a result provides a risk based rules for calculating the frequencies of how often these tasks should be checked reducing the probability of multiple failures
- If RCM is correctly applied to existing maintenance systems, it reduces the amount of routine maintenance work (usually by 40% to 70%). On the other hand, if RCM is used to develop a new maintenance system, the scheduled workload that results is much lower than it would be if the system were developed by traditional methods
- RCM was developed to help airlines draw up maintenance programs for new types of aircraft before they enter service. As a result, it is an ideal way to develop such programs for new equipment, especially complex equipment for which little historical information is available. This saves much of the trial and error that is so often part of the development of new maintenance programs - trial that is frustrating and time-consuming and error that can be very costly.
- RCM provides a common, easily understood technical language for anyone in the maintenance field. This gives maintenance and operations people a better understanding of what maintenance can (and cannot) achieve and what must be done to achieve it. This in turn improves effectiveness, motivation, morale and instilling ownership.
- An RCM review of the maintenance requirements of each item of plant in its operating context provides a firm basis for establishing labor policies and associated training programs, and for deciding what spares should be held in stock.
- Although it is new to industry, RCM has been used for fifty years in what is probably the most demanding maintenance arena of all - civil aviation. This means that it has been tested and refined in the field to a much greater extent than any similar techniques.

- RCM can be implemented by your own staff (after suitable training), which reduces the need for expensive outsiders. Drawing maintenance and operations people into the decision-making process also means that both sides are more inclined to work together, and the results are more likely to endure.

What RCM cannot do is lift the reliability of any item of equipment above the levels established by its design and the manufacturing processes that produced it. No form of maintenance can achieve this. However, RCM is exceptionally effective in helping management to achieve inherent reliability levels very quickly (hence its name). It also reveals when problems are beyond the scope of maintenance and redesign should be considered.

For these reasons, RCM could become a central feature of maintenance at the Sewerage and Water Board.

Implementation Outline

S&WB should consider hiring a program manager that has been trained in RCM theory to develop the RCM program for which Veolia has set the foundation.