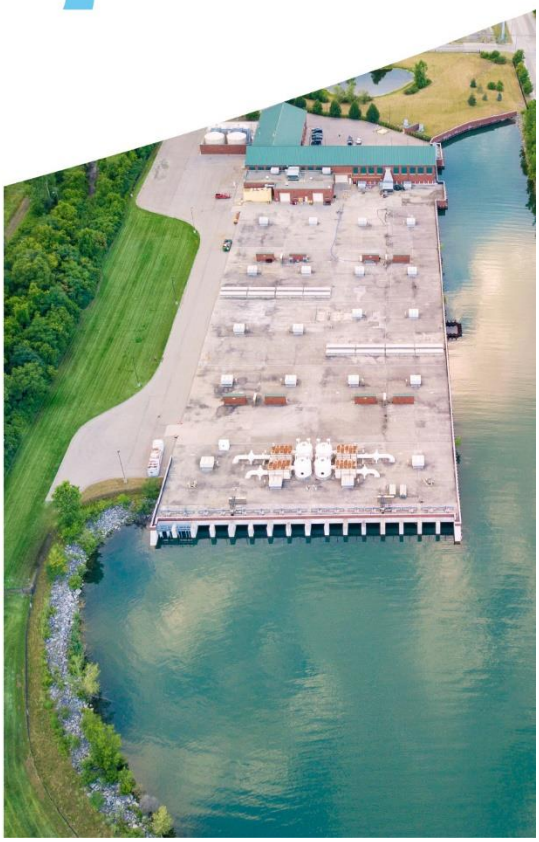
WwAMP

Wastewater Asset Management Plan

Strategies & Action Plan

June 10, 2022

GLWA
Great Lakes Water Authority



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Document History and Status

Revision	Date	Description	By	Reviewed	Approved
Original Draft	1/31/2022	Original Draft WwAMP	Jacobs	WwAMT	
Final	6/10/2022	Final WwAMP	Jacobs		

1 Executive Summary

The Great Lakes Water Authority (GLWA) Strategic Asset Management Plan (SAMP) sets forth the asset management (AM) strategic framework, improvement strategies, and business processes that the GLWA will employ to realize its vision and accomplish its mission. To define how the principles from the GLWA SAMP apply to the wastewater system managed by GLWA, this Wastewater Asset Management Plan (WwAMP) includes the existing state, specific improvement activities summarized as a series of defined Tactical Recommendations, resources, and timescales required to achieve GLWA's water system AM objectives. Figure 1-1 shows the location of the wastewater system composed of linear and vertical assets (Water Resource Recovery Facility (WRRF); Sewage Pump Stations (SPS) and Combined Sewer Overflow (CSO) facilities) and the extent of the service area, which covers 190 square miles.

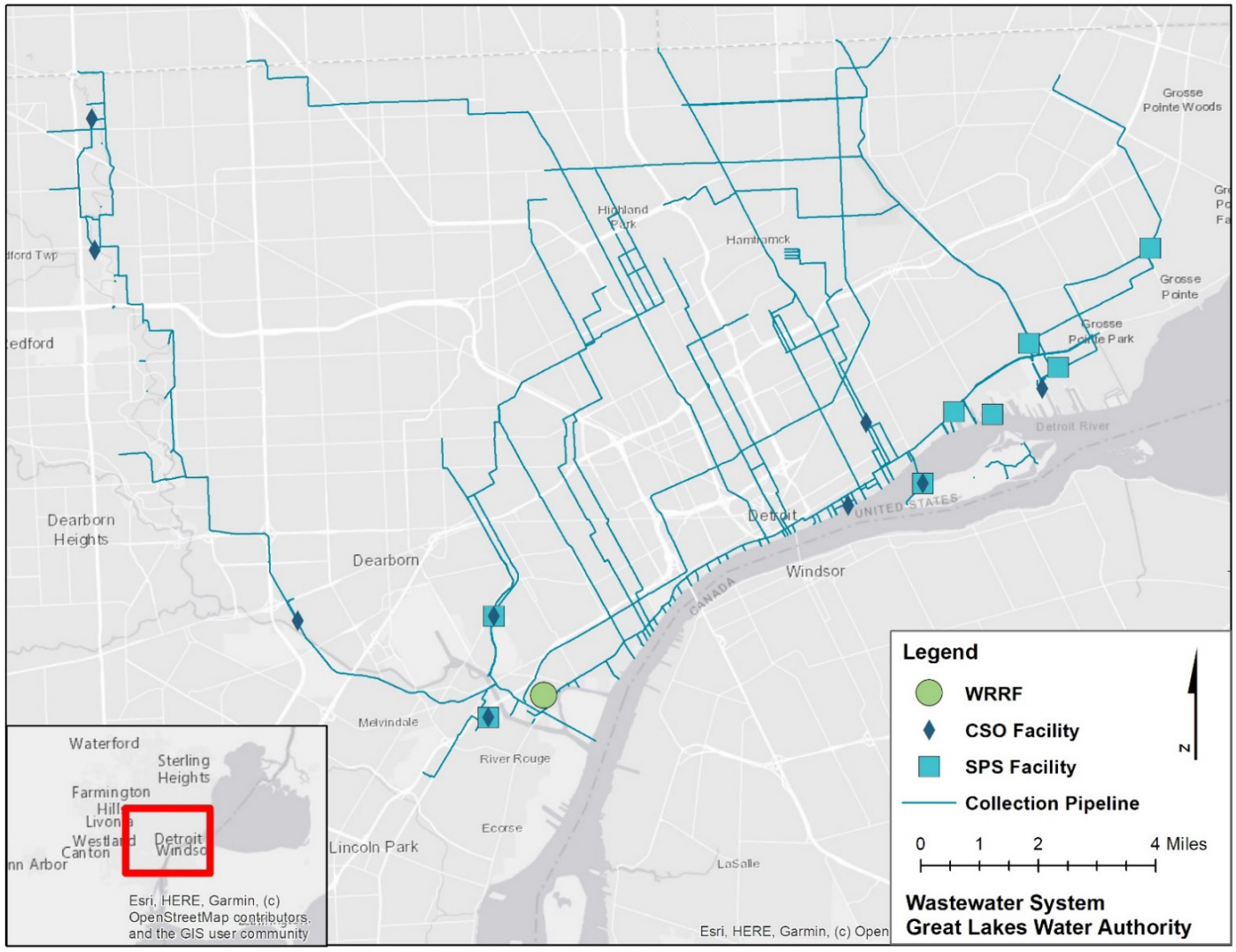

Figure 1-1: GLWA Wastewater System

1.1 Purpose of the AMP

This WwAMP serves as a guiding document for instilling AM concepts and promoting AM practices across internal and external stakeholders involved in managing water assets. It outlines activities and guidelines to meet service levels, optimize asset life cycles, and support AM decisions. Designed to be useful and timely, this WwAMP is a living document to be regularly updated every three years at a minimum, with amendments that can be implemented annually, if discovered, as AM drivers and managed assets change.

The WwAMP connects cost, performance, and risk while maintaining a line of sight among strategic decisions, GLWA planning documents, enhancement needs, operations and maintenance (O&M) activities, and renewal and replacement requirements. Tactical Recommendations, presented as being implemented over a three-year period, are presented together as a Continuous Improvement Plan in Chapter 9.

1.2 State of the Assets

The GLWA wastewater system is composed of linear and vertical assets. GLWA manages one WRRF, nine CSO facilities, eight SPS, and approximately 190 miles of gravity sewer lines with an average age of 79 years.

- Linear assets include gravity sewers, force mains, associated assets
- Vertical assets include SPS, CSO, WRRF

The state of the wastewater linear assets is summarized in Section 1.2.1 and the state of the wastewater vertical assets in Section 1.2.2. The state of the assets represents a snapshot in time at the time this WwAMP was developed, and dates are identified for each.

1.2.1 Linear Assets

1.2.1.1 Linear Asset Counts

The wastewater collection system pipeline diameters are generally 40 inches or larger, up to 261 inches. Pipe diameter size directly correlates to asset scoring processes and life cycle cost estimations presented in later sections. Three pipe diameter cohorts labeled small (less than 60 inches), medium (60 inches up to but not including 132 inches), and large (132 inches and greater) visually categorize data sets in tiered diameter size groupings. Figure 1-2 shows the distribution of sewer miles over the range of pipe diameters in the collection system.

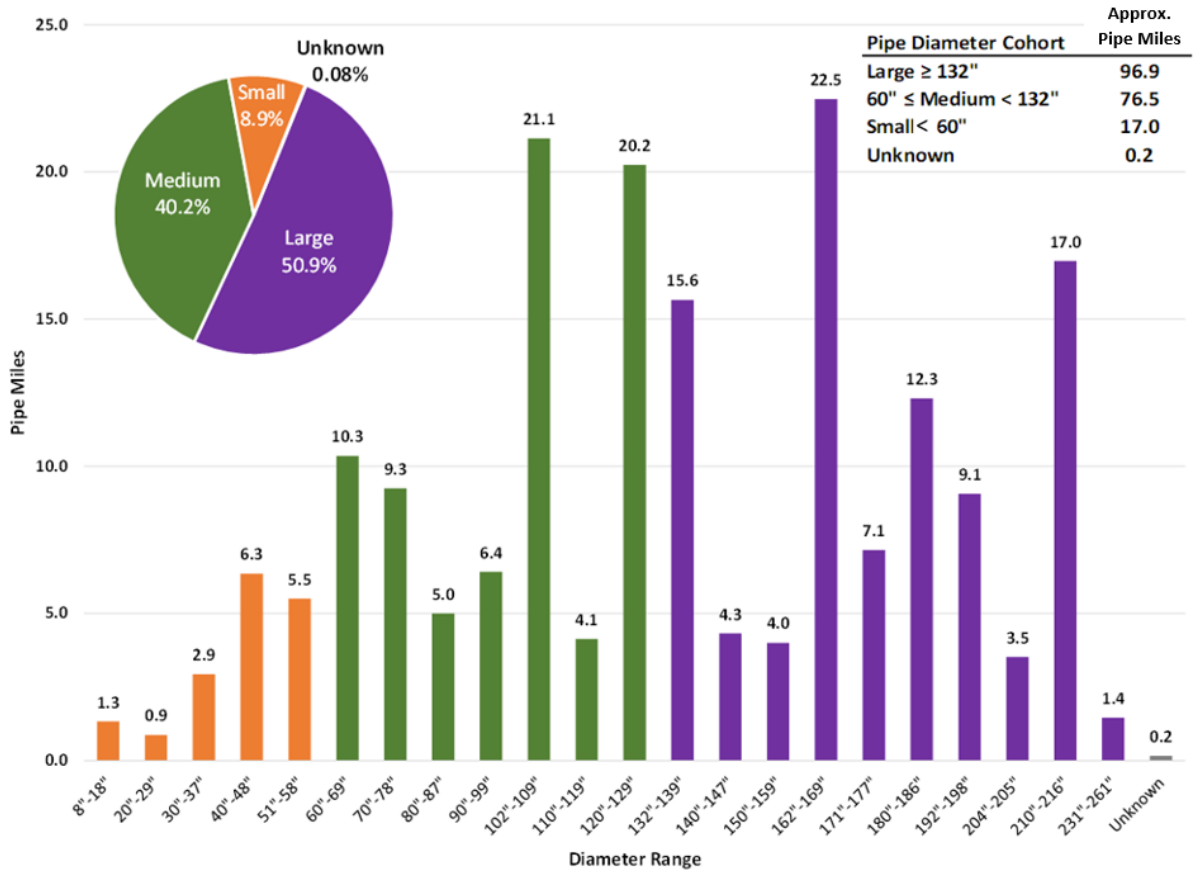

Figure 1-2: Wastewater Collection System Sewer Miles by Diameter

1.2.1.2 Linear Asset Condition

Three linear condition grades are presented in the WwAMP in alignment with the condition grades presented in Table 1-1. Approximately 64% of the collection system pipe miles with available CCTV inspection data are assigned a maintenance condition grade and a structural condition grade based on reported defect types (and severity) related to maintenance actions and structural actions, respectively. Maintenance actions and structural actions are discussed further in Chapter 6.

Table 1-1: Maintenance and Structural Condition Grade Descriptions

Condition Grade	Condition Description
0	No observed defects
1	Few observed defects
2	Minimum level of defect severity
3	Moderate level of defect severity
4	Major level of defect severity
5	Extreme defects/performance failure
No Inspection	No CCTV inspection data

Figure 1-3 and Figure 1-4 show the distribution of maintenance and structural condition grades, respectively, in terms of length for each inspected pipe diameter cohort.

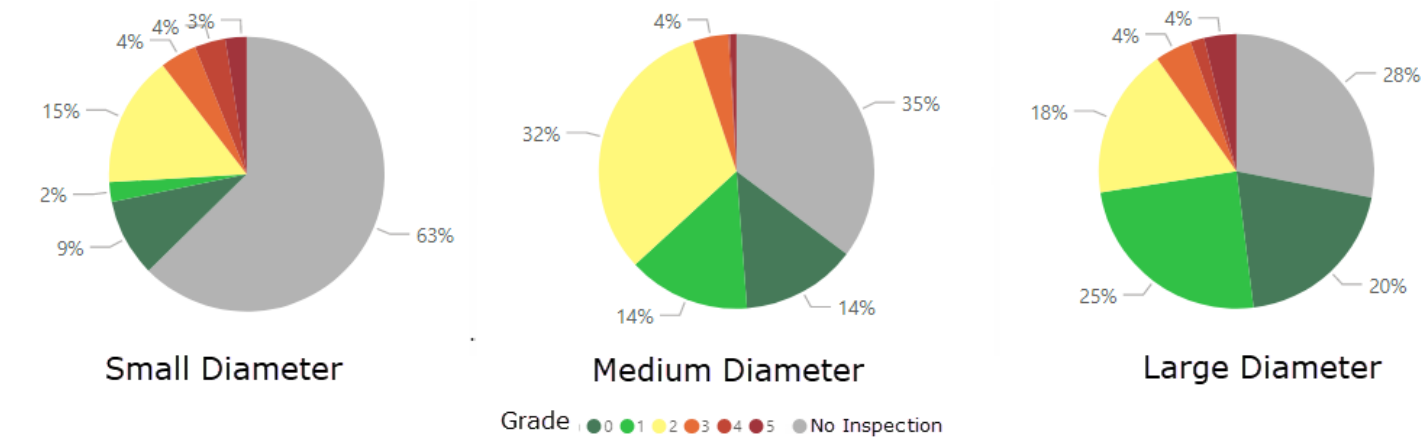

Figure 1-3: Distribution of Pipe Miles by Maintenance Condition Grade (based on 2020 data)

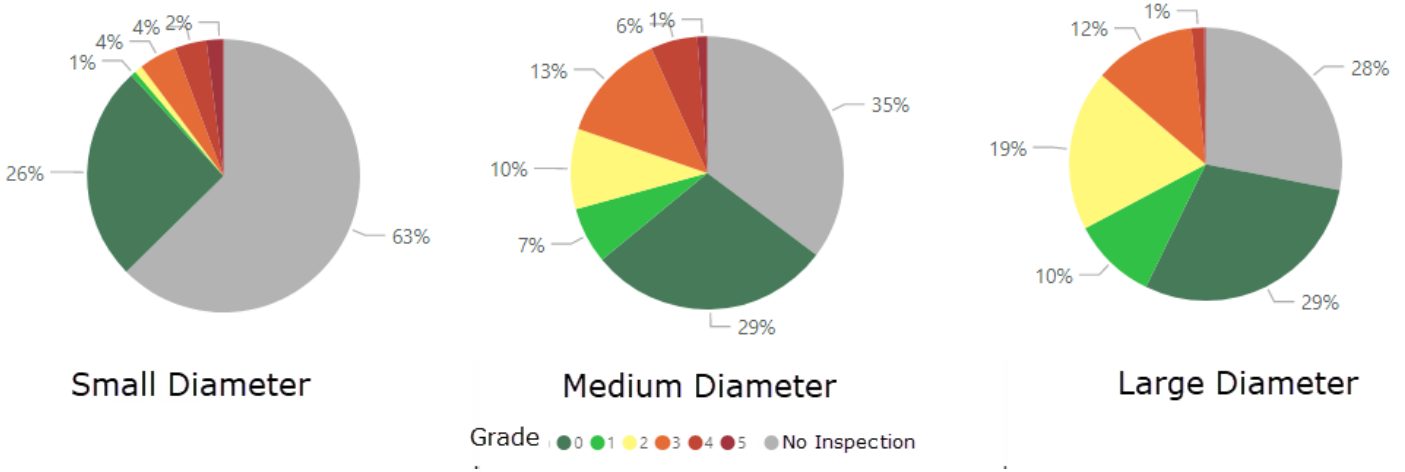

Figure 1-4: Distribution of Pipe Miles by Structural Condition Grade (based on 2020 data

1.2.1.3 Linear Asset Risk

Total asset risk is the product of likelihood of failure (LOF) and consequence of failure (COF). The following equation is used to calculate total asset risk:

Total Asset Risk = LOF x COF

Total risk for linear assets is presented in Figure 1-5 as miles of pipe on the risk severity heat map. The wastewater collection system generally has a high consequence of failure (COF) due to its function as the downstream endpoint for small-diameter collection systems owned by the member partners. Most of the pipe length, as shown below, has a relatively high COF score of 4 and an LOF score of 3. In the absence of providing redundant pipelines or significant changes to the system, reducing COF is often not an option. Total risk for linear assets is typically lowered by reducing the LOF through PM, monitoring, and rehabilitation. Reducing COF typically involves twinning or improving system connectivity, which may be cost prohibitive. Risk treatment options for linear assets are described in Chapter 5 – Asset Risk.

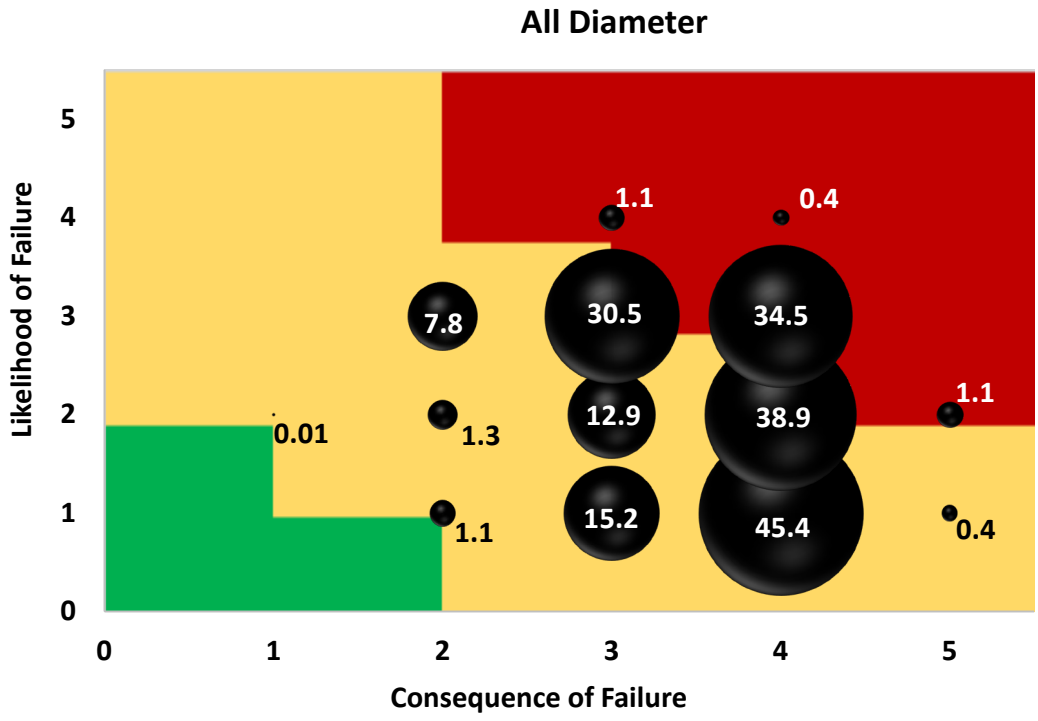

Figure 1-5: Miles of All-Diameter Pipe by Total Risk (based on 2020 data)

1.2.2 Vertical Assets

1.2.2.1 Vertical Asset Counts

WRRF

All WRRF assets are assigned to one of the five plant process areas: Primary, Dewatering, Incineration, Secondary, and Common Support. Figure 1-6 shows the total asset counts by process area. Secondary has the highest number of assets (28%), followed by Primary (23%), Incineration (20%), and Common Support (20%). Dewatering has the least number of assets (9%).

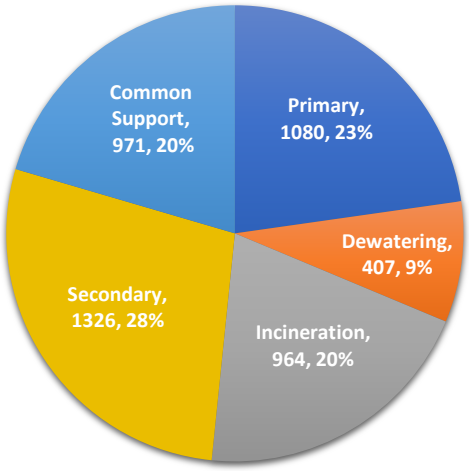

Figure 1-6: WRRF Asset Counts by Process Area

SPS

There are 665 active assets spread among the eight SPS facilities and included in the vertical asset register. Figure 1-7 shows the number and percentage of assets per SPS facility.

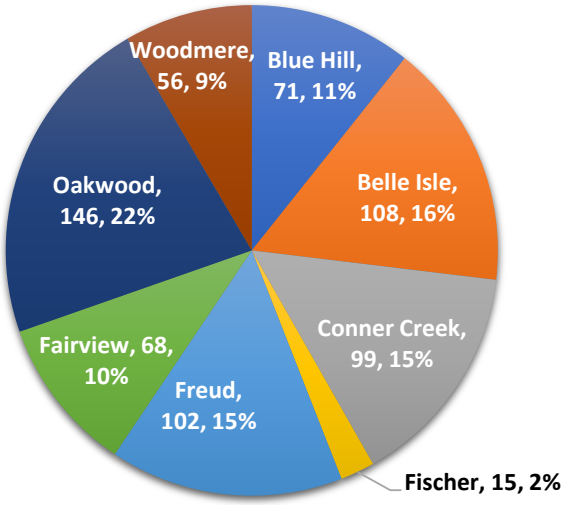

Figure 1-7: SPS Asset Counts by Facility

CSO

The nine CSO facilities include approximately 2,713 total active assets listed in the vertical asset register. Figure 1-8 shows the number and percentage of asset counts per facility.

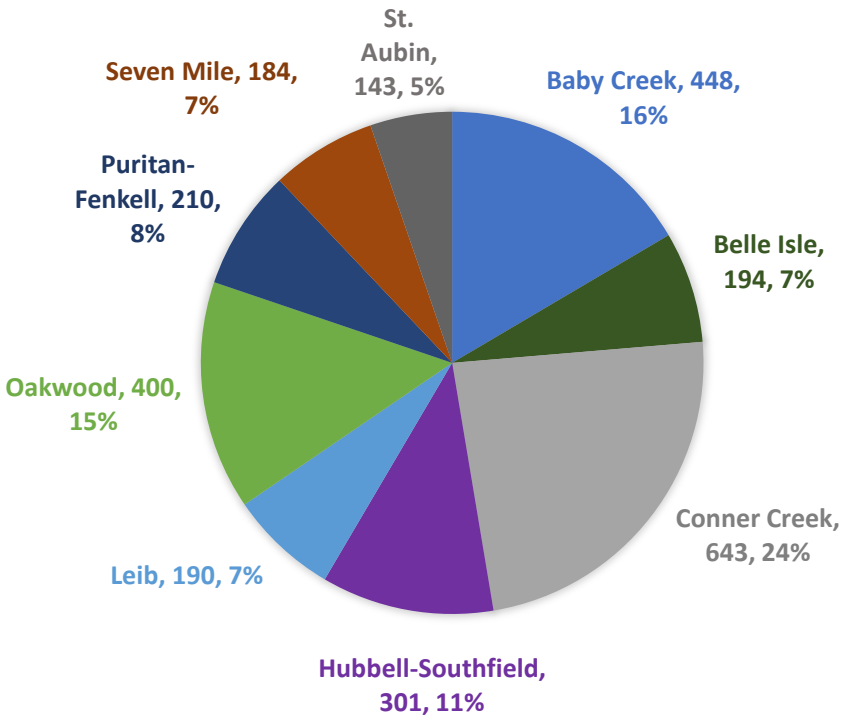

Figure 1-8: CSO Asset Counts per Facility

1.2.2.2 Vertical Asset Condition

Vertical asset condition grades are presented in Table 1-2. Results are broken down by the type of assessment the condition grade is based on and presented as percent of overall system and process area or facility. As more assets are assessed visually, condition grade accuracy will improve. Chapter 4 – Asset Profile, further describes how condition was assessed and assigned.

Table 1-2: Vertical Condition Grade Descriptions

Condition Grade	Condition Grade Description
1	Like-new condition. Continuation of current maintenance and operating procedures is recommended.
2	Good condition. Some minor additional maintenance may be required. Continuation of current maintenance and operating procedures is recommended.
3	Fair condition. One or more issues that require immediate attention. Modification or adjustment of current maintenance and operating procedures may be needed to avoid recurrence of identified issues.
4	Poor condition. Planning for a major overhaul or replacement should begin. Review of current maintenance practices and procedures is recommended.
5	Very poor condition. Failure of the asset is imminent or has already occurred. Greater than 50% of the asset requires replacement.

WRRF Condition

WRRF condition grades are shown in Figure 1-9. Visual assessments accounted for approximately 16% of WRRF assets, with the remaining assessments performed through tabletop analysis. Approximately half of all WRRF assets received a condition grade of 1 or 2.

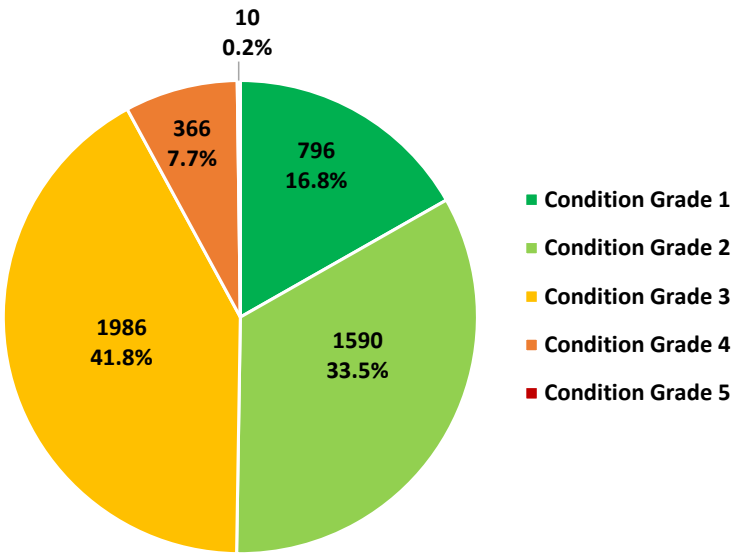

Figure 1-9: Distribution of WRRF Asset Condition Grades (based on 2020 data)

SPS Condition

SPS condition grades are shown in Figure 1-10. The majority (65%) of SPS assets received a condition grade of 1 or 2, and 21 (3%) assets were determined to be in very poor condition (Grade 5).

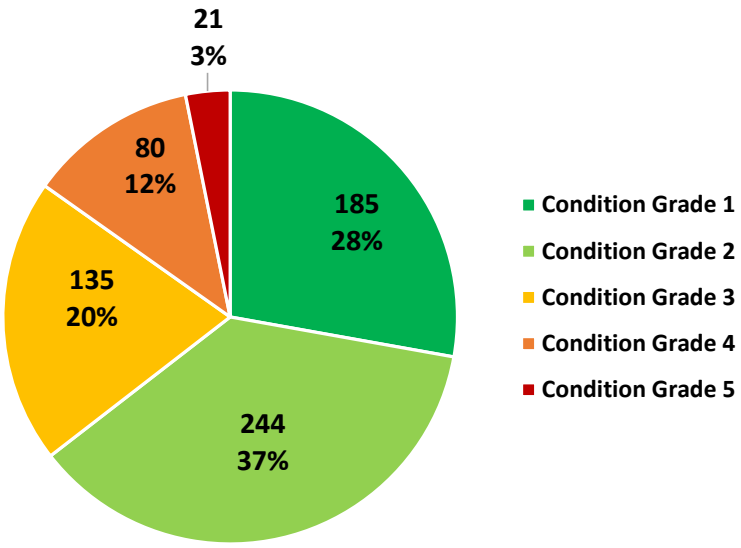

Figure 1-10: Distribution of SPS Asset Condition Grades (based on 2020 data)

CSO Facility Condition

CSO Facility condition grades are shown in Figure 1-11, the vast majority (84%) of CSO assets have condition grade ratings of 1 or 2, with 7% in poor or very poor condition.

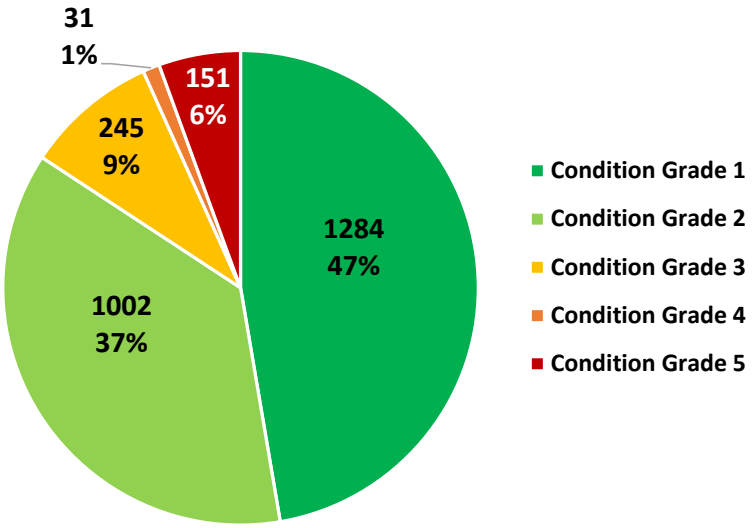

Figure 1-11: CSO Facility Distribution of Asset Condition Assessment Grades (based on 2020 data)

1.2.2.3 Vertical Asset Risk

Total asset risk is the product of likelihood of failure (LOF) and consequence of failure (COF). The following equation is used to calculate total asset risk:

Total Asset Risk = LOF x COF

WRRF Risk

Total risk for WRRF assets is presented in Figure 1-12 as count of assets on the risk severity heat map. A small proportion of the assets fall into the high-risk (red) category. These are distributed across the process areas with most occurring in secondary treatment.

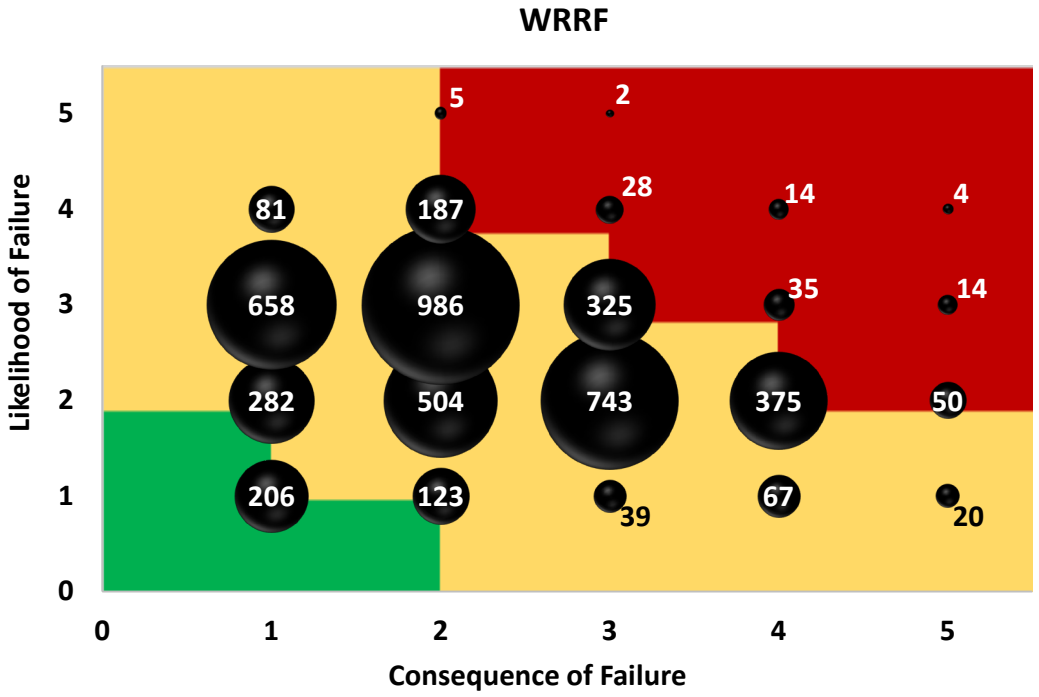

Figure 1-12: Count of WRRF Assets by Total Risk (based on 2020 data)

SPS Risk

Total risk is presented in Figure 1-13 as count of assets on the risk severity heat map. This shows a similar pattern to the WRRF with the majority of assets in the medium-risk category and a small proportion of high-risk assets. However, compared to WRRF assets, a larger portion of SPS assets have a high COF score of 4 or greater. The high COF assets are concentrated in Blue Hill, Conner Creek, and Freud SPS facilities.

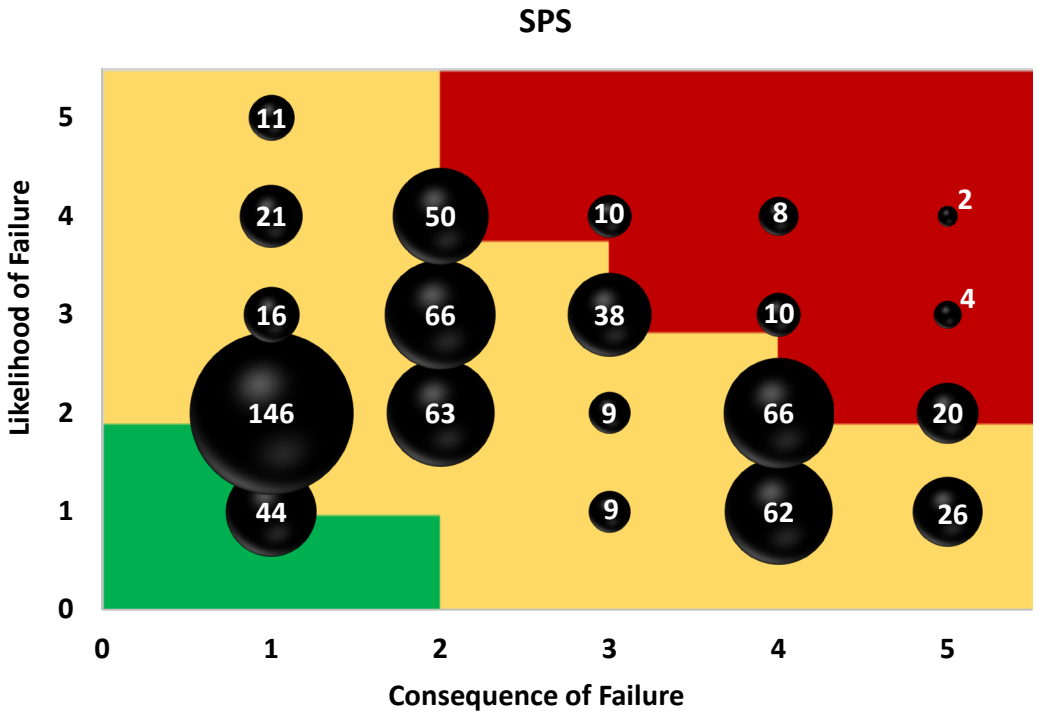

Figure 1-13: Count of SPS Assets by Total Risk (based on 2020 data)

CSO Facility Risk

Total risk is presented in Figure 1-14 as count of assets on the risk severity heat map. The majority of assets have low risk and only a small number of assets are high-risk.

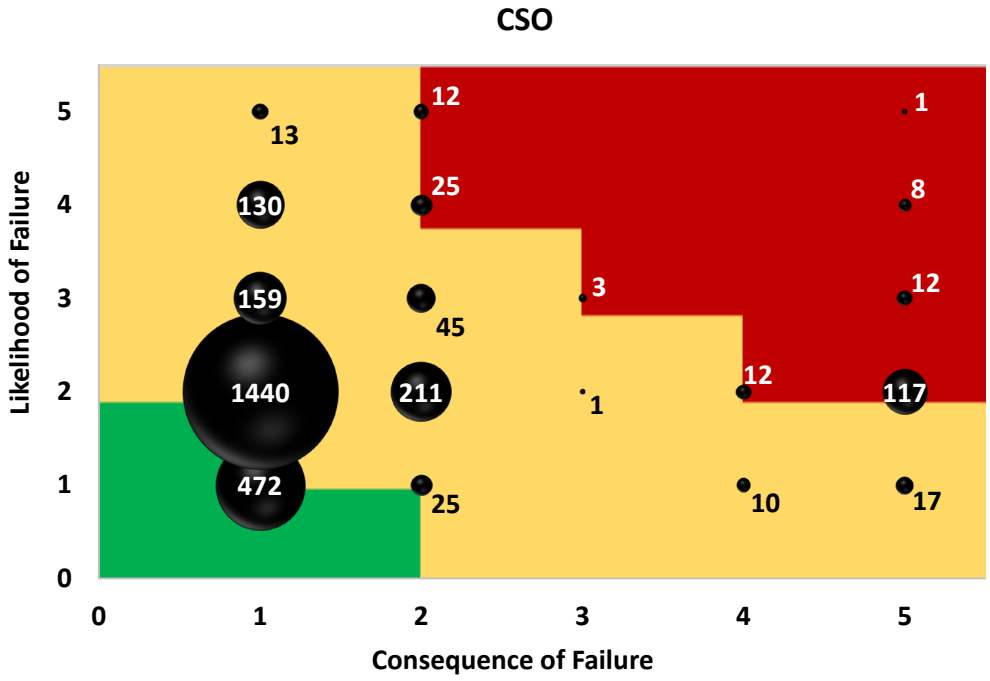

Figure 1-14: Count of CSO Facility Assets by Total Risk (based on 2020 data)

1.3 Service Levels and Performance

Drivers affect the management of the wastewater system assets within GLWA. The drivers identified by GLWA include stakeholder expectations, regulatory compliance, future demand, enhancements, efficiency and sustainability, resilience, and meeting service levels. A summary of drivers and performance is presented in Chapter 3. A suite of performance indicators (PIs) related to operations and maintenance (O&M) performance and meeting defined service levels for linear and vertical assets are discussed in Chapter 6.

Currently established service levels for the wastewater system vertical assets are presented in Table 1-3. Service levels for the linear system may be accessed from the GLWA Linear System Integrity Program (LSIP). GLWA is working to develop an integrated service level framework dashboard of these metrics as part of its implementation of NexGen Computerized Maintenance Management System (CMMS), which aligns with stakeholder expectations and can be supported by available data to drive planning and decision-making.

Table 1-3: Vertical System Performance Indicators

Development Tier	Development Description	Wastewater System Performance Indicators
Tier 1	Currently tracked and/or reported at an enterprise level	Maintenance Utilization Rate Work Backlog by Hours (Crew Weeks) % Preventive Maintenance (PM) Completion Rate (PMs Completed vs. PMs Scheduled) % PM Work Order vs. Total Work Orders % Estimated Labor Hour Accuracy - Estimated vs. Actual Number of Backlog Work Orders by Age % CM Estimating Accuracy PM Labor Hours vs. Total Labor Hours Hours Reported vs. Hours Available
Tier 2	Currently tracked within certain areas at GLWA, or not being tracked at all; recommend tracking at an enterprise level	Plant/System/Equipment Availability Mean Time Between Failure (MTBF) % Proactive Maintenance vs. Total Maintenance Hours % Predictive Maintenance vs. Total Maintenance Hours Total Reactive Labor Hours
Tier 3	Not currently tracked, but recommend tracking in the future as a part of the new Enterprise Asset Management (EAM) system implementation	Total Reactive Material Cost Planned or Scheduled Hours vs. Total Actual Labor Hours Scheduled vs. Available Hours Schedule Attainment Average Mean Time to Repair (MTTR) % Schedule Break in Labor Hours vs. Total Scheduled Labor Hours Average Asset Health Score Average Remaining Asset Life

1.4 Renewals

Renewal needs are identified by the scheduled replacement plan (SRP) models maintained by GLWA that are described in Chapter 7 and in Appendix K. Renewal needs based on 2020 data are reflected in Figure 1-15. Up-to-date information may be obtained in the SRP models. The five-year summary of projected Capital Improvement Program (CIP) expenditure shows average annual expenditure is approximately $150 million over the next five years. This is due to an average annual expenditure increase of $25 million to a peak of $184 million in 2025 and then decreases in 2026. Expenditures include continued upgrades and enhancements to WRRF pump stations 1 and 2, incineration upgrades, and major interceptor and sewer repairs and upgrades.

GLWA's financial plan for meeting these needs may be found in the Financial Resources documentation located here (Financial Resources - Great Lakes Water Authority (glwater.org).

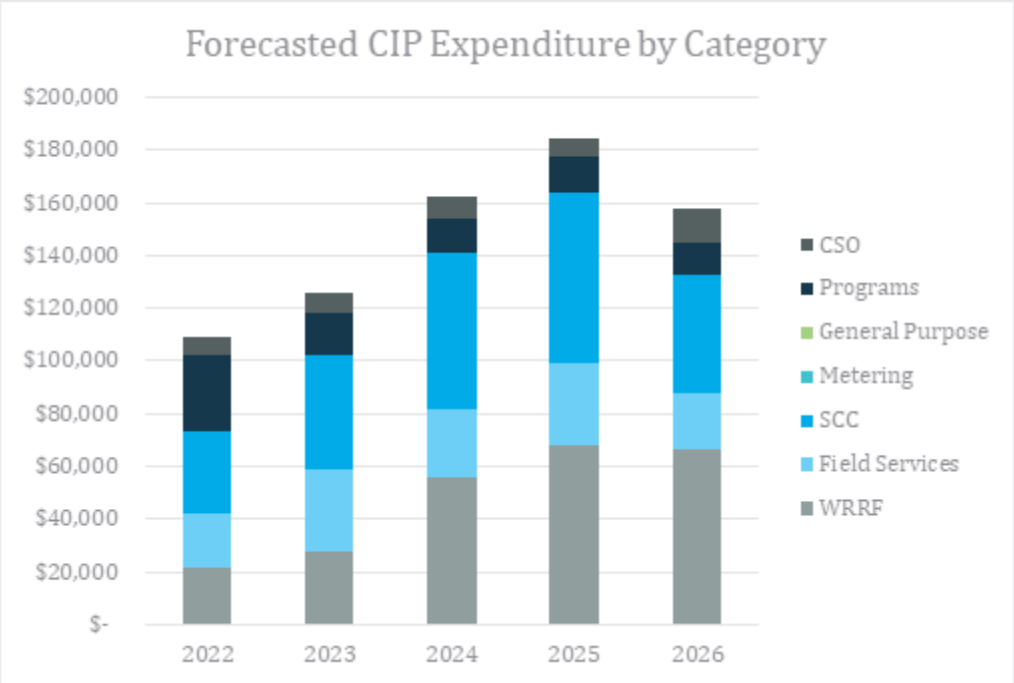

Figure 1-15: Renewal Needs - Wastewater System (based on 2020 and 2021 data)

1.5 Continuous Improvement Plan

The current Continuous Improvement Plan is shown in Table 1-4. It is composed of a series of Tactical Recommendations that will lead to significant steps moving forward. Detailed descriptions of each Tactical Recommendation are included in Chapter 9.

The Continuous Improvement Plan aims to close a number of key gaps associated with asset management governance, service levels, condition assessments, and O&M practices that include improvements in data quality and improvements in business processes and procedures. Table 1-4 also indicates reference to the SAMP Improvement Initiatives that each Tactical Recommendation supports. The WwAMP Governance Business Process is presented in Appendix M, and a summary of the roles and responsibilities is presented in Table 1-5.

Table 1-4 Continuous Improvement Summary Table

Tactical Recommendation #	Tactical Recommendation Title	Year 1 Activities	Year 2 Activities	Year 3 Activities
WW1	WwAMP - Asset Management Roles & Responsibilities	Define Asset Management Roles and Responsibilities	Assess and Refine Asset Management Champion Roles and Responsibilities	Perform Maturity Assessment Check-In
WW2	WwAMP - Service Levels	Develop Service Level Framework	Improve Data to Report on Service Levels	Develop Targets for Customer Service Levels
WW3	WwAMP - Asset Data and Information for WAM/NexGen	Address initial Data Gaps and Identify Data Collection Needs	Collect Data to Address Additional Data Gaps identified in Year 1	Evaluate Data Collection Performance
WW4	WwAMP - Digital Solutions	Configure NexGen to Display Key Data to Inform Asset Management Decision-Making	Integrate NexGen with Core Technologies	Convert WwAMP to Digital Format
WW5	WwAMP - Condition Assessment of Non-Inspected Vertical Assets	Perform Priority #1 and Priority #2 Condition Assessments – Year 1	Perform Priority #2 Condition Assessments – Year 2	Perform Priority #2 Condition Assessments – Year 3
WW6	WwAMP - Asset Risk for Vertical Assets	Refine Risk Register for Vertical Assets with updated Condition Data	Assess Risk Mitigation Strategies and Refine	Revisit Risk Register for Vertical Assets Criteria and Refine
WW7	WwAMP - Maintenance & Reliability Work Management Processes for Vertical Assets	Develop Improved Maintenance and Reliability Work Management Processes	Improve Planning and Scheduling Activities	NA

Tactical Recommendation #	Tactical Recommendation Title	Year 1 Activities	Year 2 Activities	Year 3 Activities
WW8	WwAMP - Maintenance & Reliability Improvement Implementation for Vertical Assets	Implement FMEA and PMO Activities	Expand FMEA and PMO and Develop a Predictive Maintenance Strategy	Implement Predictive Maintenance Strategy
WW9	WwAMP - Maintenance and Reliability Performance Measurement and Improvement for Vertical Assets	Develop Maintenance and Reliability Performance Tracking Platform with Tier I PIs	Develop Maintenance and Reliability Performance Tracking Platform with Tier 2 and 3 PIs	Perform Maintenance and Reliability Maturity Assessment
WW10	WwAMP - Scheduled Replacement Program Implementation	Update SRP Models with Year 1 Condition Assessments	Update SRP Models with Year 2 Condition Assessments and Assess SRP Model Options	Update SRP Models with Year 3 Condition Assessments and Identify and Secure New SRP Software (if needed)
WW11	WwAMP - Capital Improvement Program Process Improvement	Refine the CIP Process to Incorporate Results of Asset Management Analyses	Initiate Use of Asset Management Analyses Results into CIP Process	NA
WW12	WwAMP - Replacement Cost Database for Vertical Assets	Improve Asset Cost Data on Existing Assets in WAM/NexGen	Identify Process to Maintain Cost Data	Expand Asset Cost Data and Processes to all Assets

Table 1-5: WwAMP Governance Roles and Responsibilities

Responsible Owner	Business Process - Key Responsibilities	Frequency
EAMG	**1) WwAMP Management** – incorporate updates to each section of the WwAMP every 3 years (major update); annually (July) (minor updates) and as identified	• Every 3 Years • Annually • As identified
EAMG	**2) WwAMP - Continuous Improvement Plan Implementation** – ensure adherence to routine meeting schedule with identified Tactical Recommendation owners.	• Monthly
Local AM Team	**3) WwAMP - Asset Audit Program** - implement the improvements to data listed in the WwAMP - Asset Data and Improvement Summary (Appendix C) and WAM Data Gaps (Appendix D)	• Annually
Local AM Team	**4) WwAMP - Condition Assessment Program – Vertical and Building Assets** – implement visual and detailed condition assessments in alignment with the priorities listed in the WwAMP - Condition Assessment Activities –Vertical Assets (Appendix F)	• Annually • Failure Event • Monthly
Local AM Team	**5) WwAMP - Risk and Criticality Assessment Program** - follow the asset risk management and data management activities in alignment with Tactical Recommendation WW6: WwAMP - Asset Risk for Vertical Assets and Tactical Recommendation WW3: WwAMP Asset Data and Information for WAM/NexGen	• New asset driver affecting COF • Annual review of COF • New O&M optimization activity • New condition data
Operations and Maintenance Supervisors	**6) WwAMP - Strategic Maintenance and Reliability Program** Manage and run the PMO Tool and use as needed following review of the Performance Indicator Report from NexGen Manage Failure Modes Effects Analysis (FMEA) development and usage following review of the Asset Failure Report from NexGen – identify and prioritize and implement development of additional FMEAs beyond the pilot activities completed in 2022.	• Weekly
Finance/ Maintenance Director	**7) WwMP - Asset Replacement and Retirement Program –**determine projects for Capital Outlay or CIP	• As Identified
EAMG	**8) WwAMP - Scheduled Replacement Program (SRP) –** update data in the SRP models on an annual basis and obtain refined future financial outlooks that can be used in the CIP Planning Process as inputs. *Note: This tool is reflected as part of the WwAMP - Asset Replacement and Retirement Program Business Process.*	• Annually

2 Introduction

The acronyms used throughout this document are included in Appendix A. For a Glossary of Terms, see the SAMP.

The Great Lakes Water Authority (GLWA) Strategic Asset Management Plan (SAMP) establishes the asset management (AM) strategic framework, improvement strategies, and business processes that GLWA will employ to realize its vision and accomplish its mission. Figure 2-1 illustrates the example practices and activities contained in an effective asset management plan (AMP).

Figure 2-1: Example Practices and Activities Contained in an AMP

To define how principles in the GLWA SAMP apply to the wastewater system, this Wastewater Asset Management Plan (WwAMP) builds on the model illustrated above and includes the existing state, specific improvement activities, resources, and timescales required to achieve GLWA's wastewater system AM objectives. The goal is to provide the framework that will guide GLWA toward more informed decisions regarding life cycle management of wastewater assets from planning to decommission.

2.1 WwAMP Objectives and Content

This WwAMP serves as a useful and timely guiding document to instill AM concepts and promote AM practices across internal and external stakeholders involved in managing wastewater assets. It outlines AM activities and guidelines to meet service levels, optimize asset life cycles, and support decisions. This WwAMP is designed to be a living document to be updated every three years as AM drivers and managed assets change in accordance with the Michigan Department of Environmental Quality (MDEQ) National Pollution Discharge Elimination System (NPDES) permit. MDEQ issues this NPDES permit once every five years to GLWA.

The WwAMP connects cost, performance, and risk while maintaining a line of sight between strategic decisions, GLWA planning documents, enhancement needs, operations and maintenance activities (O&M), and renewal and replacement requirements. Tactical Recommendations (Chapter 9) are included that further develop AM processes. These Tactical Recommendations are laid out over a three-year time horizon with assigned owners to each recommendation. Together, the Tactical Recommendations comprise the Continuous Improvement Plan.

2.1.1 WwAMP Objectives

The WwAMP provides information needed to optimize resources, responsibly manage assets, and demonstrate GLWA's commitment to member partner expectations and long-term stewardship of wastewater assets.

By documenting current and future AM strategies, the WwAMP provides staff with a logical framework to support communication and justify funding needs to maximize asset life and maintain a reliable wastewater system. Figure 2-1 below provides the specific objectives of this WwAMP and includes the respective chapter where each objective is discussed.

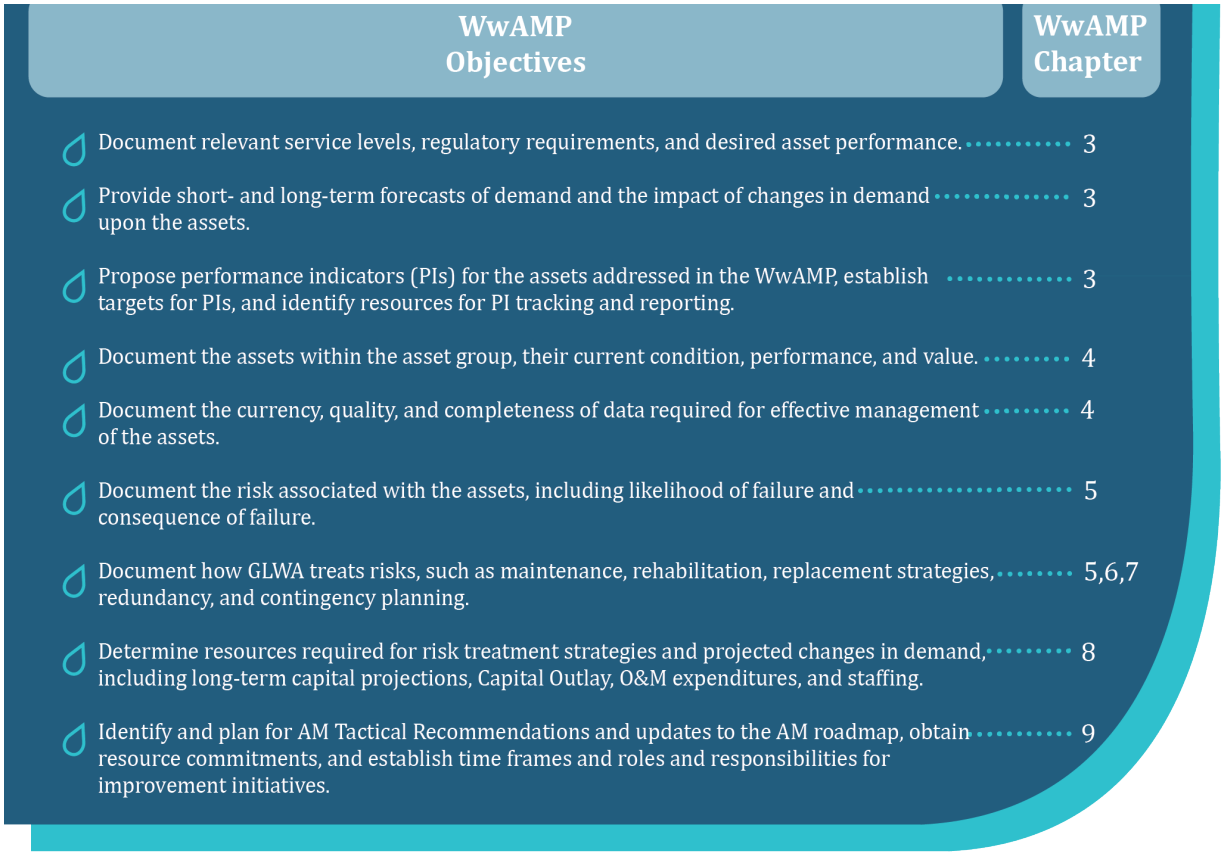

Figure 2-2: Summary of GLWA WwAMP Objectives

2.1.2 WwAMP Contents

Table 2-1 below briefly summarizes the information included in each WwAMP chapter and source material used to develop the content. The WwAMP was prepared in a collaborative manner with dedicated engagement from team members. Approximately 55 team members participated in about 51 meeting/workshops. These team members included, but not limited to, those responsible for operations, maintenance, planning, engineering, regulatory compliance, safety, and enterprise AM. A summary table of attendees and number of engagement meetings/workshops held is located in Appendix B.

The Tactical Recommendations (in Chapter 9) to continuously improve on AM are summarized in Table 2-1 and presented at the beginning of each chapter. These Tactical Recommendations for improvements and related artifacts or supporting tools were developed to assist GLWA with implementation.

Table 2-1: WwAMP Chapters and Tactical Recommendations

Chapter		Content	Tactical Recommendation
1	Executive Summary	▪ GLWA wastewater system overview ▪ State of the assets ▪ Service levels and performance ▪ Renewals ▪ Continuous Improvement Plan	NA
2	Introduction	▪ Purpose and intent of the WwAMP ▪ Overview of components that are key to the development of this WwAMP and future updates	NA
3	WwAMP Drivers	▪ Overview of key drivers affecting management of wastewater assets within GLWA, including regulatory drivers, stakeholder expectations, service levels and PIs, and future demand	▪ WW2: WwAMP _ Service Levels ▪ WW4: WwAMP - Digital Solutions
4	Asset Profile	▪ Overview of the asset portfolio, including inventory, valuation, asset age, condition, type ▪ Approach to condition assessment	▪ WW3: WwAMP- Asset Data and Information for WAM/NexGen ▪ WW4: WwAMP – Digital Solutions ▪ WW5: WwAMP– Condition Assessment of Non-Inspected Vertical Assets ▪ WW12 – WwAMP - Replacement Cost Database for Vertical Assets
5	Asset Risk	▪ Results of the asset risk assessments carried out for wastewater assets ▪ Key findings ▪ High-level recommendations, including actions associated with the Operations and Maintenance and Renewals chapters	▪ WW4: WwAMP – Digital Solutions ▪ WW6: WwAMP– Asset Risk for Vertical Assets
6	Operations and Maintenance	▪ Review of GLWA's existing O&M practices ▪ Key recommendations related to O&M improvements	▪ WW4: WwAMP – Digital Solutions ▪ WW7: WwAMP - Maintenance and Reliability Work Management Processes for Vertical Assets ▪ WW8: WwAMP - Maintenance and Reliability Improvement Implementation for Vertical Assets ▪ WW9: WwAMP - Maintenance and Reliability Performance Measurement and Improvement for Vertical Assets

Chapter		Content	Tactical Recommendation
7	Renewals	▪ Scheduled Replacement Plan (SRP) and funding forecasts over a 20-year horizon	▪ WW10: WwAMP – Scheduled Replacement Program Implementation ▪ WW11: WwAMP - Capital Improvement Program Process Improvement

8	Funding Needs	▪ Overview of asset base spending, including:
		  ▪ Historical (previous five years) and future (next 20 years) budgeted/allocated capital expenditures (CAPEX)
		  ▪ Historical operational expenditures (OPEX)
		▪ Estimates of magnitude of infrastructure gaps, or differences in funding requirements to deliver O&M, renewals strategies, and funds allocated for next 10 years
		▪ Key considerations for GLWA associated with the funding gap estimation
			None

9	Continuous Improvement Plan	▪ High-level improvement and monitoring actions in two main categories:
		  ▪ AM practices: Recommended changes to the practices and processes that underpin AM and will improve the overall performance of the service area on an ongoing basis
		  ▪ Next iteration of WwAMP: Changes to scope of assets covered by the plan, improvements to life cycle modeling approaches for the SRP, changes to data collection, or other actions that will improve the overall quality of the WwAMP
		▪ Actions that can be completed in the intervening period between this WwAMP publish date and subsequent update required in five years
			▪ WW1: WwAMP - Asset Management Roles & Responsibilities
			▪ WW4: WwAMP – Digital Solutions

2.2 WwAMP Strategic Alignment

The WwAMP identifies specific actions that are aligned to GLWA's overall AM strategy. Its strategic alignment begins with GLWA's commitment to achieving the organization's vision and mission, which is supported by GLWA's asset management vision, mission, policy and principles, and asset management objectives. Figure 2-3 shows this relationship. Chapter 1 – Executive Summary – provides the details of each framework. [1]

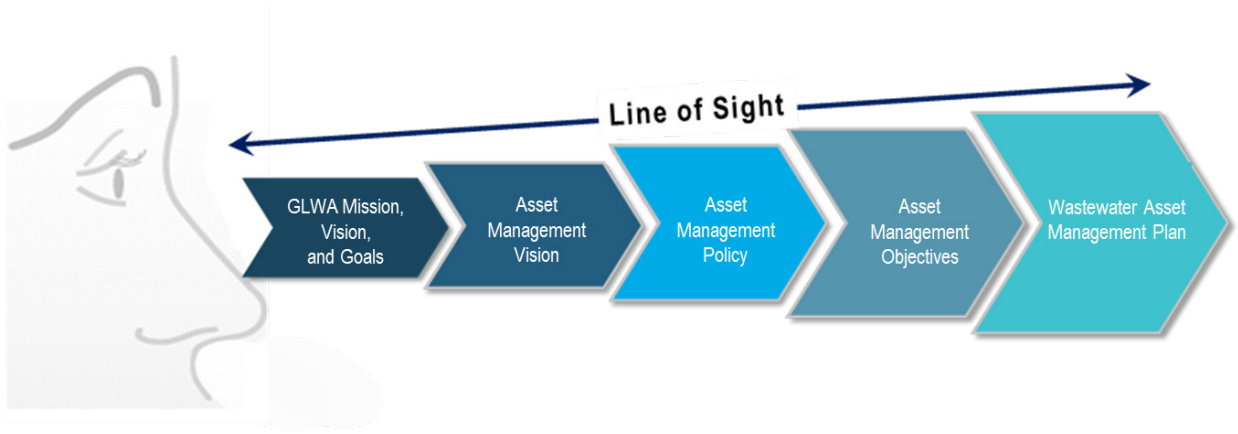

Figure 2-3: GLWA's Overall Asset Management Strategy

[1] GLWA's vision and mission are stated in the 2019 GLWA SAMP (GLWA, 2019).

3 WwAMP Drivers and Performance

The acronyms used throughout this document are included in Appendix A. For a Glossary of Terms, see the SAMP.

The purpose of this section is to provide an overview of the key drivers affecting management of the wastewater assets within GLWA, including stakeholder expectations, regulatory compliance, future demand, enhancements, efficiency and sustainability, resilience, and meeting service levels. This section also includes summaries of relevant information extracted from GLWA's Wastewater Master Plan (2020).

Tactical Recommendation:
WW2: WwAMP — Service Levels
WW4: WwAMP — Digital Solutions

Supporting Artifacts:
- Tier 1-3 Performance Indicators (PIs) (Chapter 3 of the WwAMP)
- LSIP Performance Metrics Dashboard

Tactical Recommendations WW2: WwAMP - Service Levels and WW4: WwAMP – Digital Solutions are presented in Chapter 9 to support continuous improvement for how GLWA tracks and aligns organizational and operational performance.

3.1 Stakeholder Expectations

Consistent with its organizational vision, GLWA places great emphasis on collaboration with its member partners, team members, and other external and internal stakeholders. In keeping with this emphasis, a workshop focused on asset drivers was held on January 31, 2019. During this workshop, GLWA used a stakeholder mapping tool to score identified external and internal stakeholders in terms of their degree of influence over GLWA and interests.

Figure 3-1 and Figure 3-2 show the results of this stakeholder mapping; Figure 3-1 illustrates GLWA's external stakeholders and interests, while Figure 3-2 illustrates internal stakeholders and interests.

Figure 3-1: External Stakeholders and Interests

Figure 3-2: Internal Stakeholders and Interests

To connect with stakeholders, GLWA provides outreach through its dedicated One Water Partnership Member Outreach Program. The program consists of work groups that involve members in technical service as well as financial discussions that support decision-making for GLWA's water and wastewater systems. To support SAMP Improvement Initiative #8 (Engagement and Networking), GLWA has designated team members working within the program, which also includes a contracted third-party facilitator responsible for sustaining the rules of collaboration and furthering the transparent exchange of information between GLWA and its members. The One Water Partnership Member Outreach Portal is available

online to facilitate information sharing and ongoing communications. GLWA also holds informational workshops, hosts symposia, and provides educational materials to the public.

Additionally, GLWA Public Affairs engages stakeholders through internal communications initiatives, proactive media relations, social media strategies, and system-wide community outreach. GLWA employs a cross-section of additional tools such as video monitors, communication centers, posters, and other media to share information with team members across the enterprise, many of whom do not sit at a desk every day.

As part of the GLWA SAMP development in 2019, GLWA defined its Wastewater Service Level Objectives, including its approach to engaging defined stakeholders. These service level objectives are fully aligned with the GLWA AM principles and objectives in Chapter 2 and are discussed further in Section 3.7.

3.2 Regulatory Compliance

GLWA wastewater operations are strictly regulated, with the National Pollution Discharge Elimination System (NPDES) Permit No. M10022802 serving as the primary source of existing regulatory requirements. The renewal of GLWA's NPDES permit is slated for negotiation in 2022 and may result in changes to the requirements outlined in this AMP.

In addition to regulatory requirements for the operation of GLWA's wastewater system, the NPDES permit requires the development and implementation of an AM program that contains goals of effective performance, demonstrates ample funding, and provides for adequate operator staffing and training. The AM program required under the NPDES permit must also be centered on a framework of five core elements, which include the following:

1. Current state of the assets
2. Required sustainable service level
3. Assets critical to sustained performance
4. Best-value life cycle costs
5. Best long-term funding strategy

Additionally, the NPDES permit states AM requirements related to the following:

- Operations, maintenance, replacement, and overall asset management, including a capital planning process, preventive maintenance program, needs assessment, and monitoring of PIs
- Production of an annual report that covers implementation of the AM program during the prior fiscal year
- A staffing plan that provides adequate resourcing to carry out the operation, maintenance, repair, and testing functions required to ensure compliance with the permit

Compliance with the NPDES permit requires GLWA to submit monthly reports related to the operation of the wastewater system, as well as the AM Program Update (AMPU) annual report, which covers the implementation of the AM program during the prior fiscal year.

3.2.1 Water Resource Recovery Facility

Figure 3-3 below highlights the Water Resource Recovery Facility (WRRF) key indicators of compliance reported to the Michigan Department of Environment, Great Lakes, and Energy (EGLE) on a monthly basis to demonstrate NPDES permit compliance.

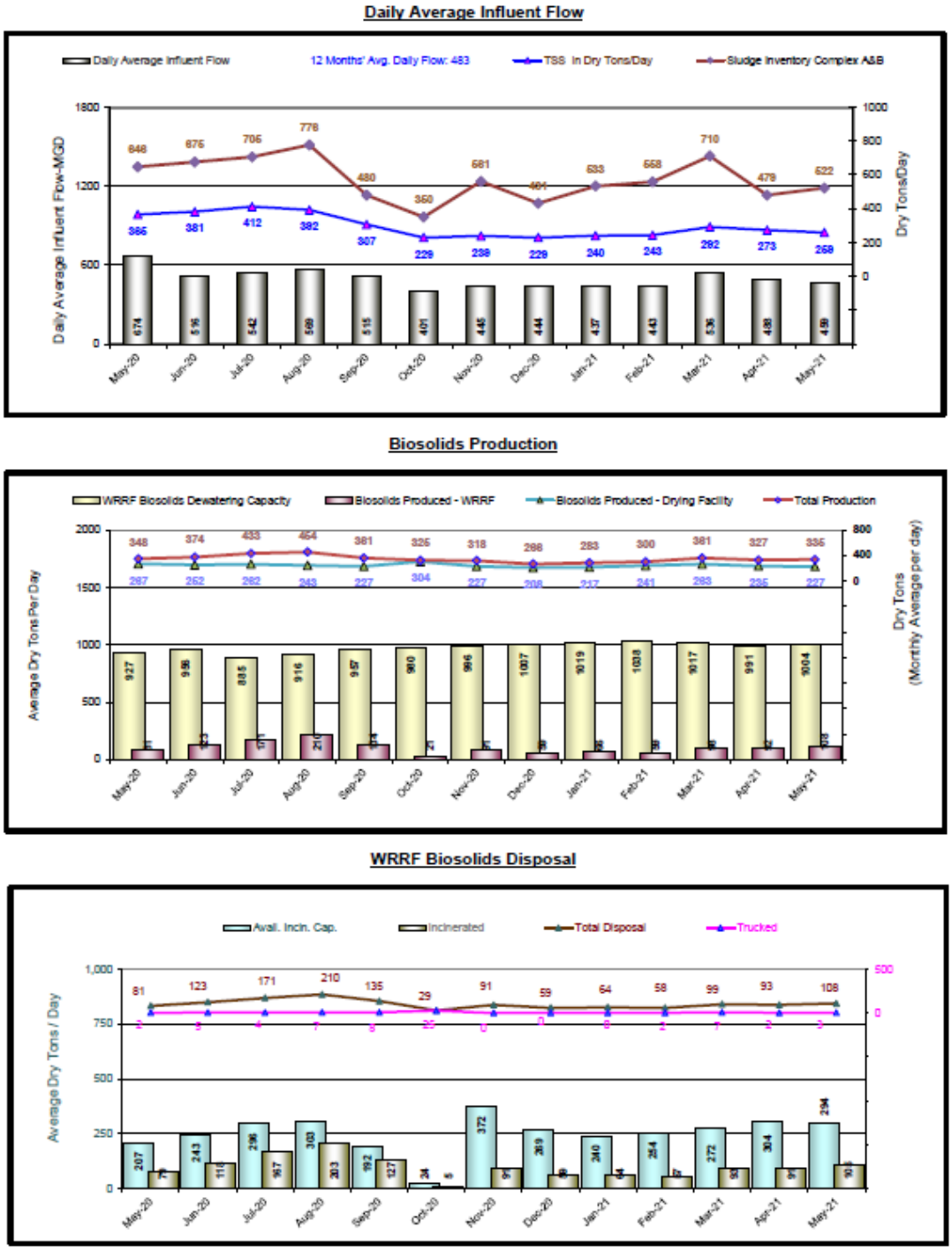

Figure 3-3: WRRF Key Indicator Report for EGLE (May 2021)

The GLWA Wastewater Master Plan states that, based on a review of performance data from 2014 to 2017, the plant routinely achieved effluent quality standards with secondary effluent concentrations for Carbonaceous Biochemical Oxygen Demand (CBOD), total suspended solids (TSS), and Total Phosphorous (TP) averaging 5.8 milligrams per liter (mg/L), 9.0 mg/L, and 0.39 mg/L, respectively. Figure 3-4 illustrates the number of NPDES permit violations from 2007 to 2016.

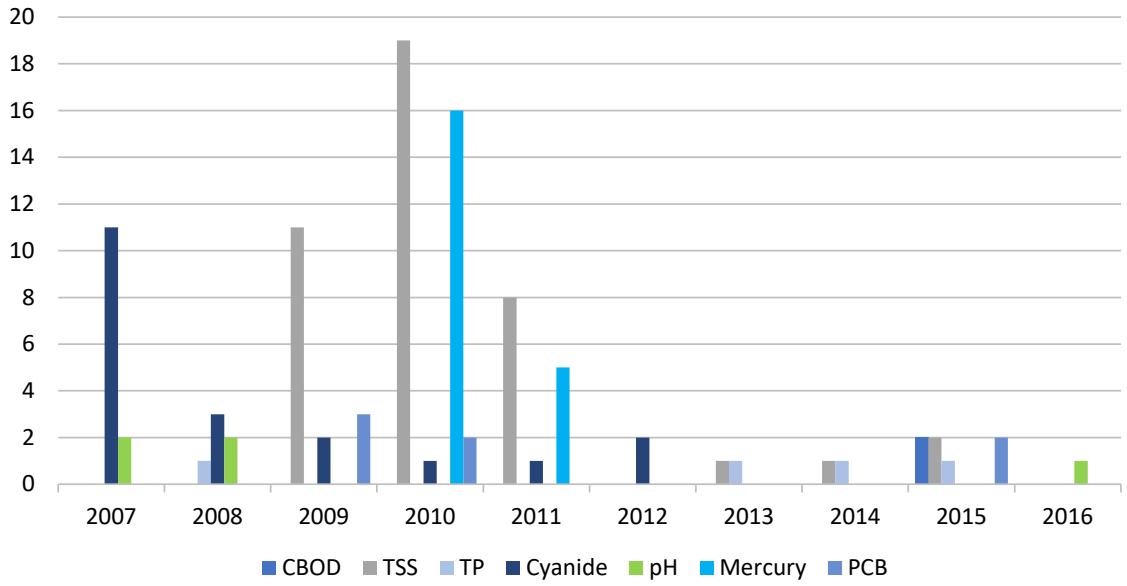

Figure 3-4: WRRF Historic NPDES Permit Violations

3.2.2 CSO Facilities

Overall, GLWA achieves the Combined Sewer Overflow (CSO) treatment performance requirements included in its regulatory permits. The NPDES permit outlines requirements to provide effective disinfection and goals to minimize total residual chlorine (TRC) concentrations. According to the permit, an event starts when combined sewage influent enters a CSO facility and ends when effluent ceases and does not resume within 24 hours. During an event, grab samples for effluent fecal coliform and TRC are collected every two hours for the first six hours of the discharge and every four hours thereafter for the duration of the discharge. On multi-day events, the pollutant concentrations for the event are reported on the day the discharge event ends.

The permit also contains seasonal event maximum CSO discharge limits for fecal coliform as well as goals for the TRC event average and peak concentrations. Table 3-1 details the NPDES CSO discharge limits and goals for events.

Table 3-1: NPDES Permit Limits and Goals for CSO Facility Discharges

Parameter	Event Average[1]	Event Maximum[2]	
		Winter (Nov. 1 - April 30)	Summer (May 1 - Oct. 31)
Fecal Coliform Bacteria (Permit Limit)	--	1,000 counts/100 ml	400 counts/100 ml
TRC (Goal)	1.5 mg/L	2.0 mg/L	3.0 mg/L

[1]The average of all samples in an event.

[2]For fecal coliform, reported as geometric mean of all samples taken during an event, provided 3 or more samples are collected. For TRC, maximum individual sample in an event.

As part of the CSO Facilities Assessment Project (CS-299), the Effluent Performance Technical Memorandum (January 2020) evaluated effluent performance in relation to NPDES permit limits and goals. To this end, the document compared maximum and average TRC measurements and event maximum fecal coliform for the period 2016 through 2018. The document presents the following summary conclusions:

- The fecal coliform limit is typically met for every event, with a few exceptions. The following CSO facilities had violations: Conner Creek (1), Leib (1), St. Aubin (2), and Baby Creek (2).
- The summer and winter maximum effluent TRC goals of 2 and 3 mg/L are typically met. The Screening & Disinfection Facilities (SDFs) appear to have slightly higher maximum values than the Retention Treatment Basins (RTBs).
- The operational goal for average TRC of 1.5 mg/L is typically exceeded for all facilities that discharge. This is likely due to the variable nature of CSO influent water quality and the fact that the operator's first priority is to achieve permit compliance for fecal coliform.
- There was no discharge from Puritan-Fenkell or Seven Mile CSO facilities during this period.

3.3 Future Demand

According to the Wastewater Master Plan, as of 2018, the WRRF serves approximately 2.7 million residents in southeast Michigan through a combination of separate and combined sewers. Over the period FY2015 to FY2017, the WRRF treated approximately 630 million gallons per day (mgd) of wastewater. The permitted peak primary treatment capacity is 1,700 mgd (the largest in the nation) and the peak secondary treatment capacity is 930 mgd. Flow in excess of the peak secondary treatment facility capacity bypasses secondary treatment and is discharged through the Detroit River Outfall. Flow in excess of the Detroit River Outfall capacity is directed to the Rouge River Outfall. The capacity of the Detroit River and Rouge River outfalls is a function of the water surface elevation in the rivers, which can be compromised if river elevations exceed 98 ft (Detroit City datum). During the summer of 2019, Detroit River elevations approached historic maximum levels.

3.3.1 Population Projections and Future Demand

According to projections in GLWA's Wastewater Master Plan, the GLWA regional service area population is forecasted to grow up to 9% by 2060. This is expected to cause a WRRF influent flow increase of 10 mgd by 2060. Table 3-2 shows projected population and influent flow for 2045 and 2060 future planning years.

Table 3-2: GLWA Service Area Population and Influent Flow Forecast (2019)

Planning Year		2019	2045[1]	2060[1]
Service Area Population Forecast[1] (residents)		-	2.90 million	3.06 million
WRRF Influent Flow[1] (mgd)	Average Daily	630	651-662	668-679
	Maximum Day	1,257	1,299-1,321	1,333-1,355
	Peak Hour	1,902	1,700	1,700
[1]Source: GLWA Wastewater Master Plan, 2020				

Using the projected population increase in the service area, the annual average dry weather flow is estimated to increase by 5% (up to 662 mgd) in 2045 and by 7% (up to 679 mgd) in 2060 over the 2019 reported flows. The nominal increase in flow has led GLWA to prioritize optimization of process equipment over accommodating growth and installing additional capacity. Flow projections can be impacted by other factors, including water conservation, shifts in service area and customer user types, and repairing infiltration and inflow (II) defects in the wastewater collection system.

3.4 Enhancements

GLWA's 2020 Wastewater Master Plan is based around five key outcomes as shown below:

1. Protect Public Safety
2. Preserve Natural Resources and a Healthy Environment
3. Maintain Reliable, High-Quality Service
4. Assure Value of Investment
5. Contribute to Economic Prosperity

To achieve these outcomes, the Wastewater Master Plan presents an Adaptive Integrated Plan, as shown in Figure 3-5, comprising a range of enhancements to be implemented in three major phases:

- **Phase 1**: Optimize Use of Existing Facilities and Integrated Planning
- **Phase 2:** Adapt and Expand Facilities Based on Phase 1 Progress
- **Phase 3:** Sustain System Performance to Achieve All Desired Outcomes

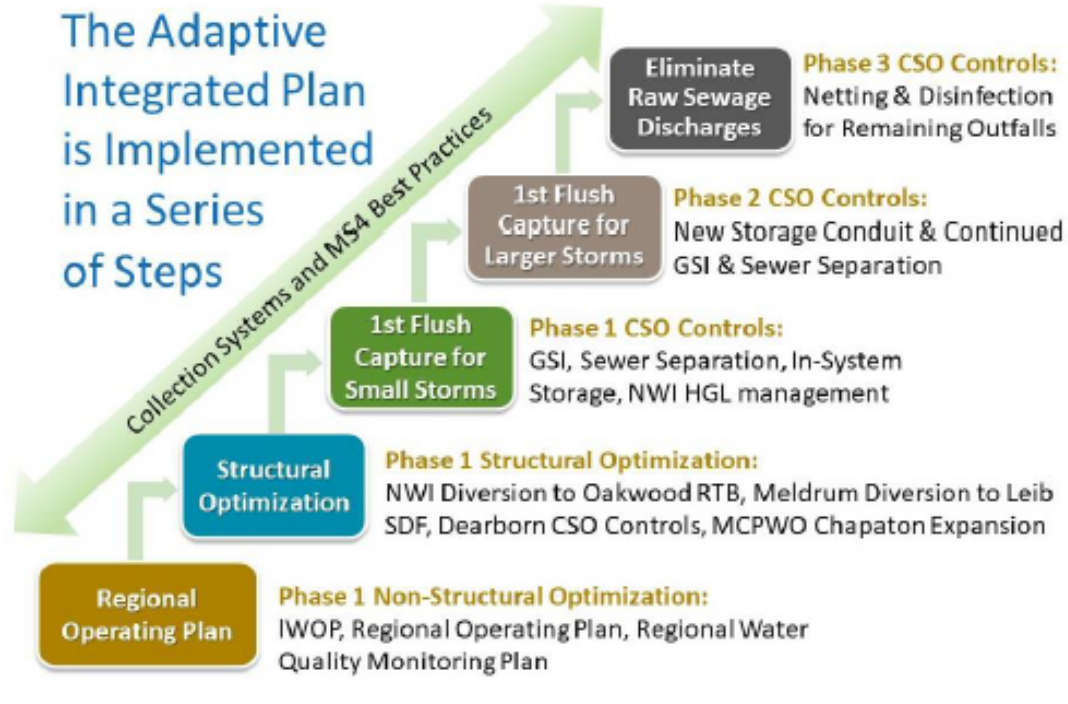

Figure 3-5: Adaptive Integrated Plan of the WwAMP

GLWA has made significant progress on key Phase 1 actions. The status of these actions is provided below in Table 3-3 and Table 3-4.

Table 3-3: Non-Structural Optimization

Key Master Plan Actions	Status
▪ Interim Wet Weather Operating Plan (IWOP) ▪ Capacity Management, Operations and Maintenance (CMOM) ▪ Municipal Separate Storm Systems (MS4) controls ▪ Regional Operating Plan (ROP) ▪ Regional Water Quality Monitoring Program	▪ The IWOP has initially focused on the items GLWA has control over to increase throughput. GLWA is actively pursuing or has completed a range of improvements and is continuing to work with Member Partners on additional items. ▪ The ROP is in place, which encourages collaboration and coordination across the region. ▪ A system-wide coordinated pre-storm pump down has been implemented in the last couple of years. This creates additional in-system capacity in the event of a storm to reduce the potential for CSO spills. ▪ The Regional Water Quality Monitoring Program –Phase 1 is complete as of January 2021 with further developments to be implemented over the next five years.

Table 3-4: Structural Optimization & CSO Control

Key Master Plan Actions	Status
▪ Long-Term CSO Plan (LTCSO) ▪ Committed Projects (Dearborn and Macomb) ▪ Detroit Water and Sewerage Department (DWSD) Green Stormwater Infrastructure (GSI) & Sewer Separation ▪ Northwest Interceptor (NWI) Interceptor to Oakwood RTB ▪ Meldrum Sewer to Leib SDF ▪ In-System Storage	▪ Two major sewer projects — Meldrum to Leib SDF and NWI to Oakwood RTB — are in progress and will increase utilization and further optimize CSO performance. ▪ Work is continuing on the Long-Term CSO (LTCSO) strategy, which will further review how best to optimize the system, identify viable projects, and prioritize projects moving forward.

In addition to the above, the Master Plan also recommended some key actions around WRRF life extension and optimization (see Table 3-5). The key objectives of these actions are the following:

- Manage downstream equipment deterioration
- Maximize secondary treatment
- Improve process efficiency
- Improve safety

Table 3-5: Key Master Plan Actions

Key Master Plan Actions	Status
▪ Screenings and grit removal ▪ Transition from chlorine gas and sulfur dioxide for disinfection and dechlorination ▪ Optimize secondary treatment to reduce oxygen and chemical use through implementation of biological phosphorus removal ▪ Reduce phosphorus loading to Lake Erie ▪ Position for potentially lower effluent limits in the future ▪ Stabilize rates through energy efficiency and recovery, power generation, and water reuse	▪ Work is generally covered by GLWA's existing CIP, which is proceeding as planned, notwithstanding some minor sequencing issues and delays. ▪ Phosphorous removal is not just biological removal. There is a need to also optimize ferric to manage phosphorous. ▪ There is currently no knowledge of any upcoming more stringent U.S. Environmental Protection Agency (EPA) requirements on phosphorous. ▪ Incineration has been upgraded to meet current air quality standards. There is an expectation of more stringent requirements in 10 years or so. It may be necessary to move beyond current practices. ▪ There is an ongoing batch of research projects aimed at efficiency. See Section 3.5

3.5 Efficiency and Sustainability

Alongside the pursuit of general energy efficiency opportunities, a key focus for efficiency and sustainability efforts is the WRRF biosolids process train, which includes sludge thickening, dewatering, drying, incineration, and lime addition processes and related equipment. The NPDES permit requires that the sludge processing systems have the combined capacity to process 850 dry tons per day (dtpd). The three treatment trains provide flexibility in the type of end product generated (e.g., pellets, ash or cake), and offer resiliency in the event of a significant system failure in one of these areas or challenges with the disposal of a certain type of product. However, the diversity in sludge processing equipment comes at a cost to operate and maintain multiple processes and associated ancillary systems.

Potential drivers for change identified in the Master Plan are the following:

- Long-term integrity of the incinerators and the high cost to operate in a standby mode
- Desire for additional resource recovery (e.g., energy, phosphorus)
- Goal to reduce greenhouse gases (GHG)
- Capacity limitations on the existing drying facility
- Potential for more restrictive regulations in the future associated with land application and air emissions

As a result, GLWA has been developing a range of research and associated enhancement projects, which are included in the CIP. Table 3-6 presents a list of these biosolids and resource recovery projects.

Table 3-6: Current Energy, Research, and Innovation Projects Related to Biosolids/Resource Recovery

Project Name	Project Number	Project Type	Status	Initiation Date	Duration	End Date/ Projected End Date	GLWA Commitment	Partnering Entities	Short Project Description
Energy Recovery Assessment	CS-217	Research	Ongoing	10/1/ 2017	2 years	9/30/2019 (Extension in process)	Cash $355,800	Michigan State University Steve Stafferman	This research project is designed to assess the biogas potential of the biosolids, with and without added organics, the ability of the current plan to handle the recycle stream, perform preliminary energy balances and cost benefit analysis and move the bench scale testing to pilot scale to validate the digestion and characteristics, the stability when feeding additional organics and biogas characteristics.
Hydrothermal Liquefaction (HTL)	EERE 325 (HYDRO POWERS-LIFT20S G17)	Pilot Scale Study	Completed	Early 2nd Qtr. 2017	2 years	4/31/2019	In-kind $10,000	Water Environment & Reuse Foundation (WE&RF), DOE, Pacific Northwest Laboratory & others	A consortium led by the WE&RF has been selected by the Department of Energy for award negotiations to begin Phase 1 design and planning for a pilot plant to produce clean hydrocarbon fuels at a municipal wastewater treatment facility. The project will use breakthrough technology to produce fuels such as gasoline, jet fuel, diesel and renewable natural gas from wastewater solids. Due to GLWA participation with bench scale testing, GLWA will be participating on the project advisory committee.

Project Name	Project Number	Project Type	Status	Initiation Date	Duration	End Date/ Projected End Date	GLWA Commitment	Partnering Entities	Short Project Description
Transport and Fate of Nutrients in Biosolids	1902059	Research	Procurement	TBD	24 months	TBD	Cash $227,500	Michigan State University Steve Stafferman/ Ehsan Ghane/Wei Zhang	Assess fate and transport of nutrients in GLWA biosolids. Estimate amount of nutrients available for plant growth, predict the amount of nutrients that migrate below the root zone, and impact of microbiome of nutrient mobility.
Per- and Polyfluoroalkyl Substances (PFAS) Release from Finished Biosolids	WRF X (Tailored collaboration)	Research	WRF Procurement	TBD	12 months	TBD	Cash $20,000 In-kind $5,000	Water Research Foundation, CDM Smith, Purdue, NEBRA	Assess poly and perfluoroalkyl substance releases from finished biosolids; as a function of PFAS loading, post digestion processing and field aging.
Characterization and Contamination Testing of Source Separated Organics	WRF 4915	Study	On Hold	March 2019	20 months	TBD	Project Advisory Committee	Water Research Foundation, Carollo Engineers, Michigan State University	Develop industry guidance for characterization and quality evaluation of source separated organics (SSO) to be used as feedstock to resource recovery facilities co-digestion units. Partner dropped out, Carollo had to locate a new one. The new university partner will be UM - Lute Raskin's group. Has yet to restart.

3.6 Resilience

The projected differences in temperature and precipitation for the Detroit area due to climate change are shown in Table 3-7.

Table 3-7: Projected Changes in Temperature and Precipitation

Category	2041–2070 Compared with 1971–2000
Average annual temperature	Increase of 4.5 - 5.0 degrees F
Number of days per year over 90 degrees F	Increase of 40 - 50 days
Number of days per year over 95 degrees F	Increase of 10 - 15 days
Number of nights per year falling below 32 degrees F	Decrease of 25 - 35 nights
Average total precipitation per year	Increase of 3 - 4 inches per year
Average number of heavy precipitation days (Note 1)	Increase of 1 - 1.5 days
Number of consecutive dry days per year	Increase of 0 - 1 day
Note: 1. Heavy precipitation is defined as the 2% heaviest precipitation events in a given area.	

The 2020 Wastewater Master Plan concludes that such climate change may result in the following impacts to the GLWA's wastewater infrastructure:

- Extreme precipitation events can overwhelm combined sewer systems, potentially resulting in more frequent discharge of untreated wastewater into the Detroit River and Rouge River as well as more frequent discharge of primary effluent at the WRRF.
- Warmer river and lake water levels may contribute to lower dissolved oxygen concentrations and algal blooms.
- Extreme precipitation events may cause localized flooding and increases in water levels of the Detroit River. These may result in flooding of low-lying GLWA assets, the consequences of which may range from minor asset damage to lengthy outages.
- GLWA's operations depend on reliable power from the electric grid. Increased heat waves and extreme storm events may lead to more frequent power outages in the region.

GLWA has been undertaking a review of electrical systems at the WRRF to address aging power infrastructure. State standards require two independent sources of power, and the utility provider is not confident in its ability to supply from existing dual feeds. This could be further exacerbated by the climate change effects mentioned above. A third electrical feed to the plant is was implemented; this will deliver increased resilience for the plant as a whole. In parallel, GLWA is developing a range of condition monitoring and predictive and preventive maintenance (PM) tasks on the WRRF electrical infrastructure to ensure its ongoing reliability and due to flooding, efforts are underway to improve service to critical pump stations.

3.7 Service Levels

Service levels are typically organized in a hierarchical structure shown in Figure 3-6.

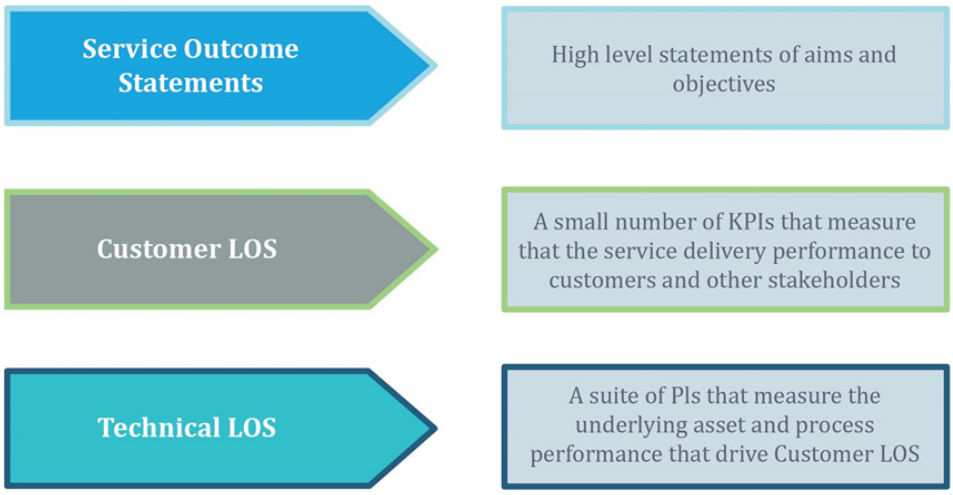

Figure 3-6: Typical Service Level Hierarchy

Note: LOS = Levels of Service; PI = Performance Indicators; KPIs = Key Performance Indicators

GLWA has several components of the service level framework in place. The SAMP contains four high-level service objectives:

1. Convey and treat wastewater to protect public health, the environment, and recreation
2. Convey wastewater to maximize treatment and minimize untreated overflows
3. Minimize detrimental wastewater service disruptions
4. Provide wastewater services that satisfy commitments

GLWA has identified a suite of technical service level performance indicators (PIs) that include well-established PIs to track regulatory compliance. The O&M PIs for vertical assets are shown in Table 3-8 and discussed further in Chapter 6.

Table 3-8: Wastewater O&M Performance Indicators by Development Tier

Development Tier	Development Description	Wastewater System Performance Indicators
Tier 1	Currently tracked and/or reported at an enterprise level	▪ Maintenance Utilization Rate ▪ Work Backlog by Hours (crew weeks) ▪ % Preventive Maintenance (PM) Completion Rate (PMs Completed vs. PMs Scheduled) ▪ % PM Work Order vs. Total Work Orders ▪ % Estimated Labor Hour Accuracy - Estimated vs. Actual ▪ Number of Backlog Work Orders by Age ▪ % Corrective Maintenance (CM) Estimating Accuracy ▪ PM Labor Hours vs. Total Labor Hours ▪ Hours Reported vs. Hours Available
Tier 2	Currently tracked within certain areas at GLWA, or not being tracked at all; recommend tracking at an enterprise level	▪ Plant/System/Equipment Availability ▪ Mean Time Between Failure (MTBF) ▪ % Proactive Maintenance vs. Total Maintenance Hours ▪ % Predictive Maintenance vs. Total Maintenance Hours ▪ Total Reactive Labor Hours
Tier 3	Not currently tracked, but recommend tracking in the future as part of the new Enterprise Asset Management (EAM) system implementation	▪ Total Reactive Material Cost ▪ Planned or Scheduled Hours vs. Total Actual Labor Hours ▪ Scheduled vs. Available Hours ▪ Schedule Attainment ▪ Average Mean Time to Repair (MTTR) ▪ % Scheduled Break in Labor Hours vs. Total Scheduled Labor Hours ▪ Average Asset Health Score ▪ Average Remaining Asset Life

GLWA is working to align an integrated service level framework with stakeholder expectations and that can be supported by available data to drive planning and decision-making. These improvements are presented in Chapter 9 – Continuous Improvement Plan, Tactical Recommendation WW2-Service Levels.

4 Asset Profile

The acronyms used throughout this document are included in Appendix A. For a Glossary of Terms, see the SAMP.

Tactical Recommendation:
- WW3: WwAMP — Asset Data and Information for WAM/NexGen
- WW4: WwAMP — Digital Solutions
- WW5: WwAMP — Condition Assessment of Non-Inspected Vertical Assets
- WW12: WwAMP — Replacement Cost Database for Vertical Assets

Supporting Artifacts:
- WwAMP — Asset Data and Improvement Summary (Appendix C)
- WwAMP — Work and Asset Management (WAM) Data Gaps (Appendix D)
- Information Technology Master Plan
- WwAMP — Condition Assessment Activities for Vertical Assets (Appendix F)
- Financial System

The purpose of this section is to provide an overview of the asset portfolio, including inventory, asset age, condition and type of key asset attributes, asset condition and assessment approach, and valuation.

Tactical Recommendations WW3: WwAMP - Asset Data and Information for WAM/NexGen; WW4: WwAMP - Digital Solutions; WW5: WwAMP - Condition Assessment of Non-Inspected Vertical Assets; and WW12: WwAMP - Replacement Cost Database for Vertical Assets presented in Chapter 9 are planned to be implemented to continuously improve the way GLWA defines the wastewater system assets and tracks important attribute information to inform AM decision-making.

Appendix C Asset Data and Information Improvement Summary lists the current data gaps, and the Work and Asset Management (WAM) Data Gaps Spreadsheet to improve data in WAM is included in Appendix D.

4.1 Asset Definition

To support alignment and continuity, the WwAMP uses the definitions included in the GLWA SAMP.

4.2 Wastewater System Assets

The GLWA wastewater system is composed of linear and vertical assets.

Linear assets include:

- Gravity sewers
- Force mains
- Utility access structures (manholes)
- Associated assets (valves, gates, storage devices, and metering/monitoring equipment)

Vertical assets include:

- Sewage Pump Stations (SPS)
- Combined Sewer Overflow facilities (CSO)
- Water Resource Recovery Facility (WRRF)

GLWA manages approximately 190 miles of gravity sewer mains and 1.25 miles of force main with an average age of 79 years. GLWA receives flow from surrounding systems into the collection system pipe network. The wastewater collection system flows are managed by eight SPS facilities, nine CSO facilities, and in-system diversion chambers, regulators, inflatable dams, and other control structures. The wastewater collection system and facilities are remotely monitored and controlled through the Systems Control Center located at the Detroit Water and Sewerage Department (DWSD) Central Services Facility. Figure 4-1 shows the location of the WRRF and the extent of the wastewater collection service area.

Figure 4-2 shows a map of the wastewater collection system interceptors and sewers, Figure 4-3 shows a map of SPS locations, and Figure 4-4 shows a map of the CSO facilities.

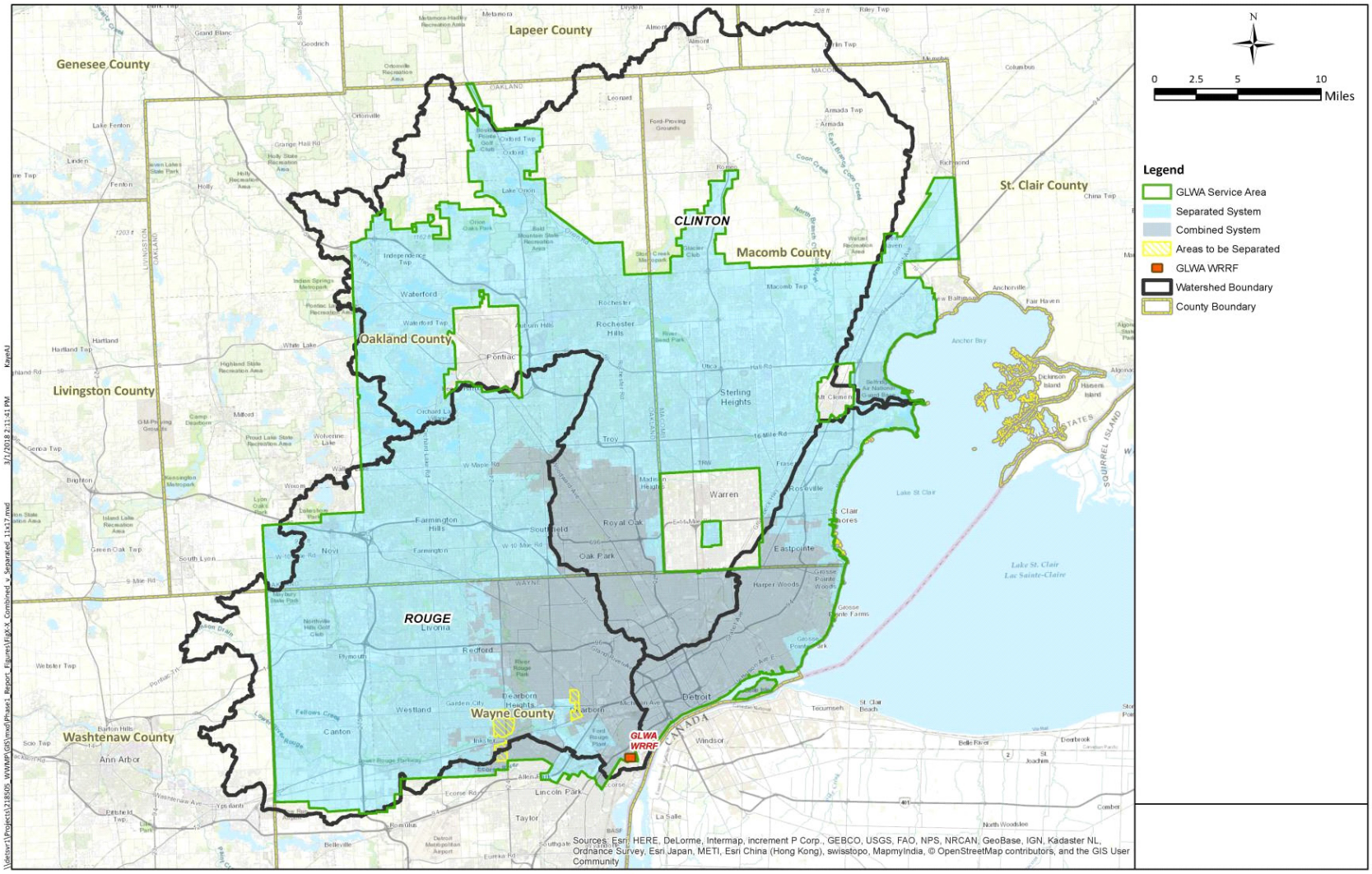

Figure 4-1: GLWA Wastewater Service Area

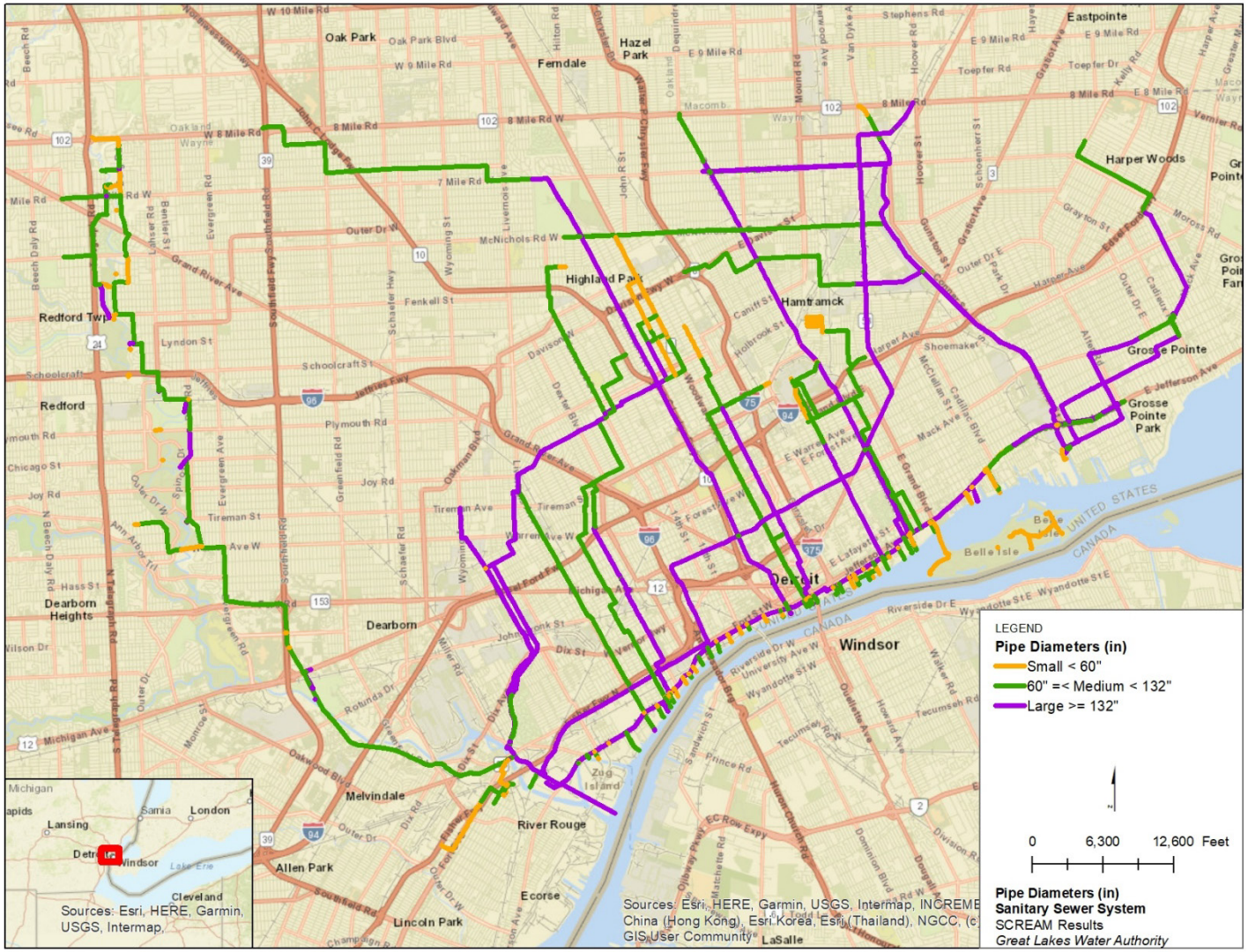

Figure 4-2: Map of Wastewater Collection Pipeline

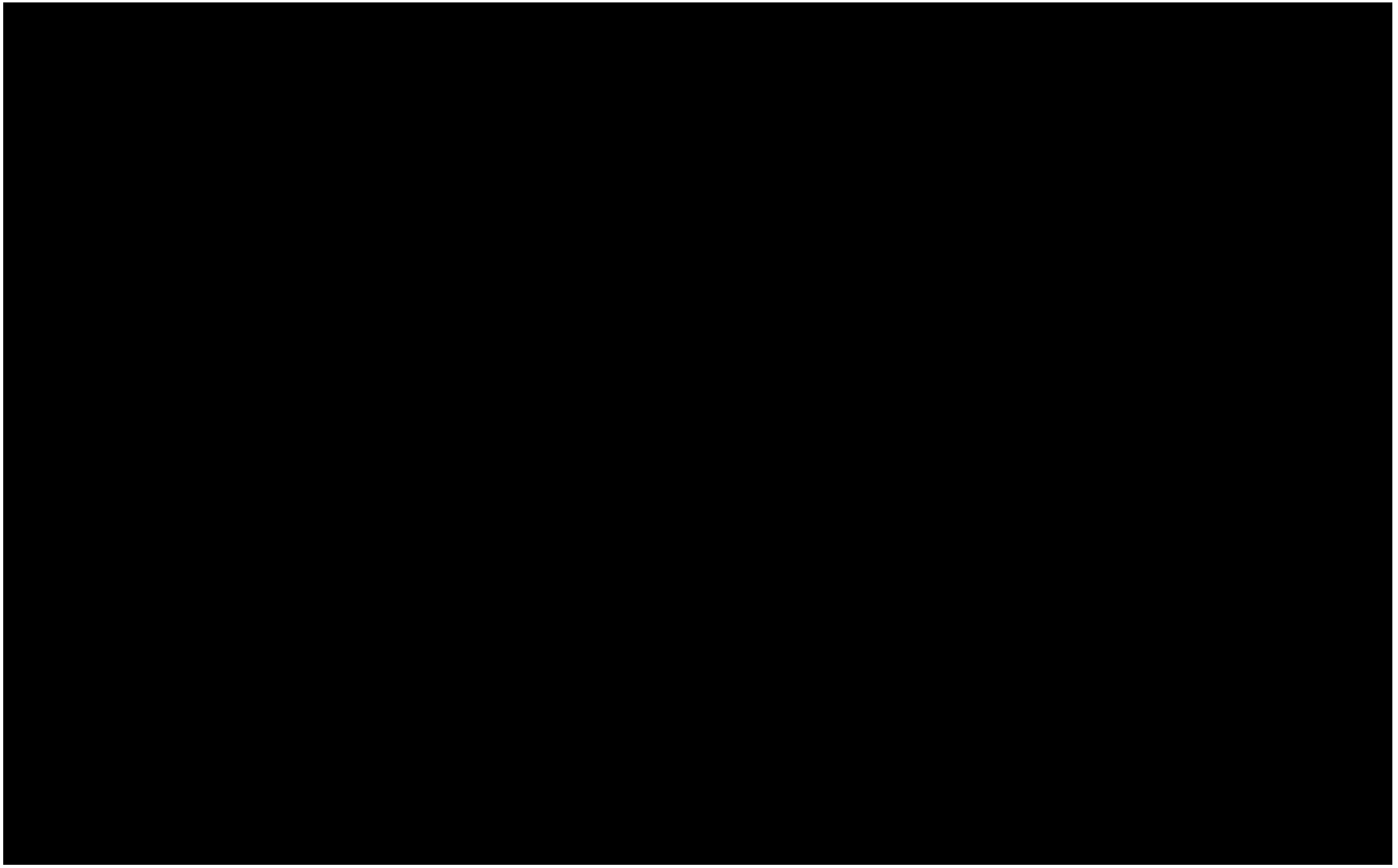

Figure 4-3: Map of Sewage Pump Station Locations

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(y) Records or information of measures designed to protect the security or safety of persons or property, or the confidentiality, integrity, or availability of information systems, whether public or private, including, but not limited to, building, public works, and public water supply designs to the extent that those designs relate to the ongoing security measures of a public body, capabilities and plans for responding to a violation of the Michigan anti-terrorism act, chapter LXXXIII-A of the Michigan penal code, 1931 PA 328, MCL 750.543a to 750.543z, emergency response plans, risk planning documents, threat assessments, domestic preparedness strategies, and cybersecurity plans, assessments, or vulnerabilities, unless disclosure would not impair a public body's ability to protect the security or safety of persons or property or unless the public interest in disclosure outweighs the public interest in nondisclosure in the particular instance.

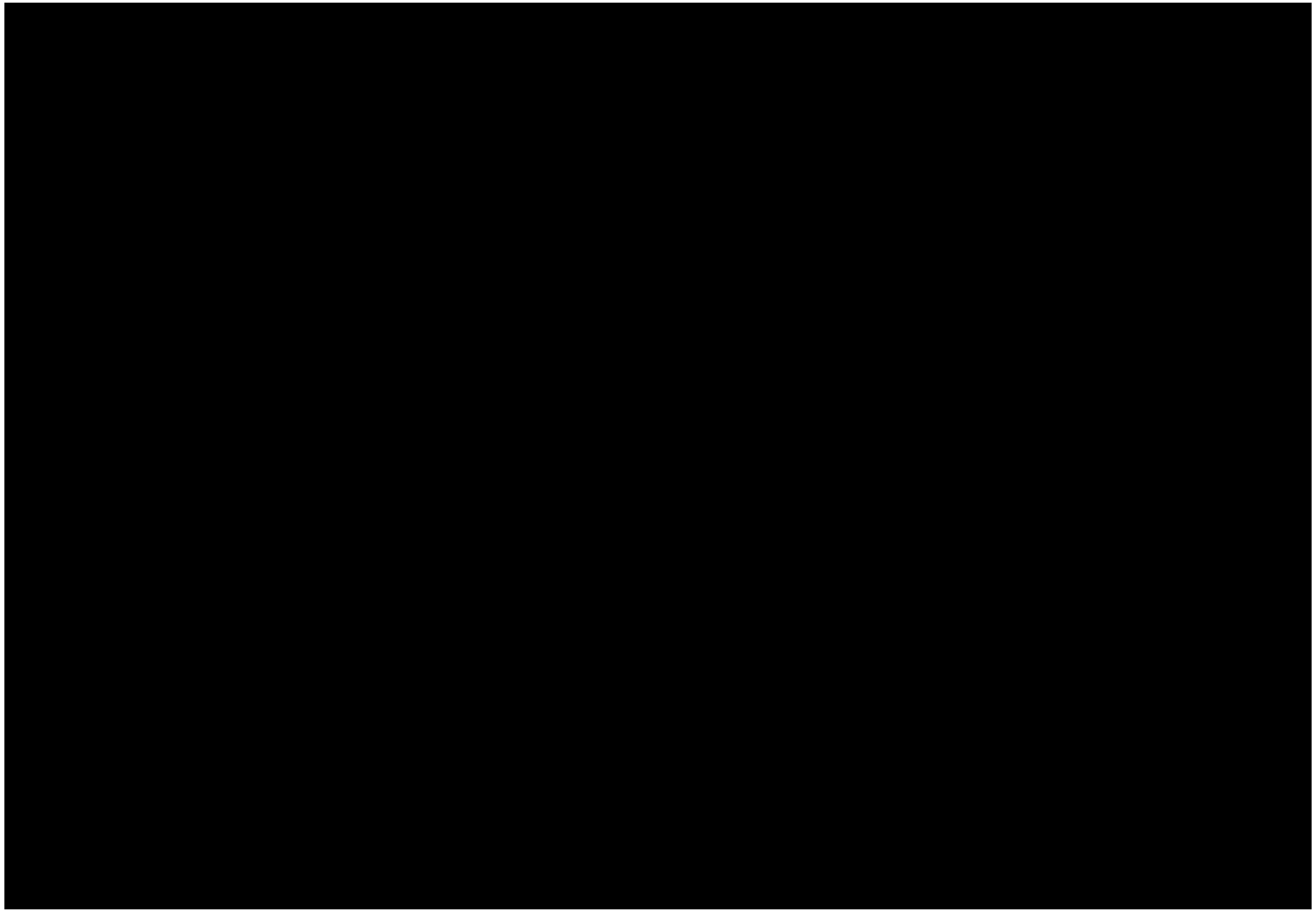


Figure 4-4: Map of CSO Facility Locations

Figure Removed pursuant to MCL - Section 15.243

(y) Records or information of measures designed to protect the security or safety of persons or property, or the confidentiality, integrity, or availability of information systems, whether public or private, including, but not limited to, building, public works, and public water supply designs to the extent that those designs relate to the ongoing security measures of a public body, capabilities and plans for responding to a violation of the Michigan anti-terrorism act, chapter LXXXIII-A of the Michigan penal code, 1931 PA 328, MCL 750.543a to 750.543z, emergency response plans, risk planning documents, threat assessments, domestic preparedness strategies, and cybersecurity plans, assessments, or vulnerabilities, unless disclosure would not impair a public body's ability to protect the security or safety of persons or property or unless the public interest in disclosure outweighs the public interest in nondisclosure in the particular instance.

The wastewater collection system collects and transports flow to the WRRF. The WRRF is the largest wastewater treatment facility in the State of Michigan and the largest single-site facility in the United States. The WRRF began operation in 1940 as a primary treatment facility. Expansions and upgrades in the 1960s and 1970s added secondary treatment. The WRRF has a 1,700-mgd primary treatment capacity and a 930-mgd secondary treatment capacity .

WRRF process areas include Primary, Secondary, Dewatering, Incineration, and Common Support. The WwAMP vertical asset register contains more than 4,700 active WRRF assets. Wastewater enters the WRRF through one of the two influent pump stations, which include screening and grit removal. The wastewater is conveyed to primary treatment and then secondary treatment. During dry weather, the flow receives chlorination and dechlorination through the Detroit River Outfall before being discharged to the Detroit River. During wet weather, peak flows receive chlorination and dechlorination through the Rouge River Outfall, before being discharged to the Rouge River. Biosolids are processed through Dewatering using centrifuges or belt filter presses and then they are processed through Incineration or the Biosolids Drying Facility. Common Support is composed of assets that provide support to the plant in general (e.g., security and generators) and are located throughout the WRRF.

4.3 Asset Hierarchy

The WwAMP asset hierarchy follows the GLWA AM format. Figure 4-5 shows examples of assets and asset groups at each level across GLWA. The WwAMP asset hierarchy is a top-down organizational structure that facilitates easy rollups of costs and performance metrics. An asset or asset group one level above or below another asset or asset group has an AM parent-child relationship. The parent-child context is useful in many aspects of this WwAMP, including discussions around comparing risk, O&M costs, and life cycle costs across processes, as well as up and down GLWA business operation levels.

As shown in Figure 4-5, GLWA wastewater assets are organized into a hierarchy with GLWA sitting at the top (Level 1) followed by the wastewater system (Level 2).

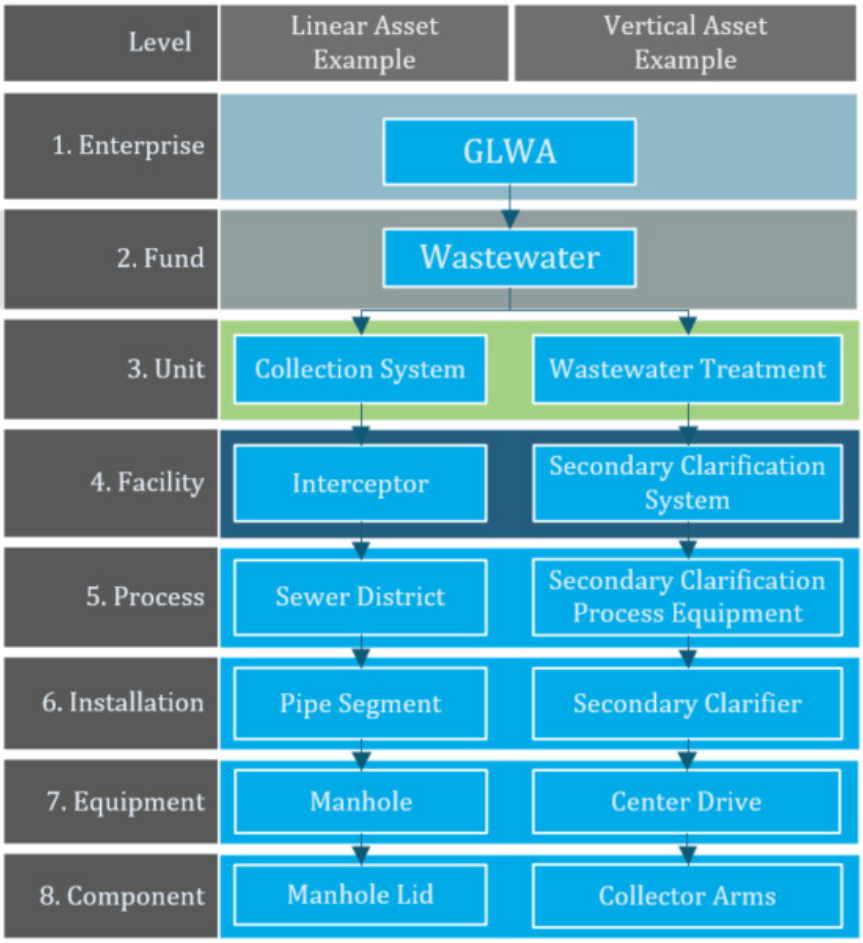


Figure 4-5: GLWA Wastewater Asset Hierarchy Format

The wastewater system is the parent asset group to four Level 3 asset groups listed in Table 4-1.

Table 4-1: WwAMP Asset Groups (Level 3)

Level 3 Type	Level 3 Unit Name	Facilities and Pipeline Network
Linear	Wastewater Collection System	▪ Gravity pipe ▪ Force main ▪ Associated wastewater collection system assets (manholes, valves, storage devices, and metering/monitoring equipment)
Vertical	SPS	▪ Blue Hill ▪ Belle Isle ▪ Conner ▪ Fischer ▪ Freud ▪ Fairview ▪ Oakwood ▪ Woodmere
Vertical	CSO Control Facilities	▪ Baby Creek ▪ Belle Isle ▪ Conner Creek ▪ Hubbell-Southfield ▪ Leib ▪ Oakwood ▪ Puritan-Fenkell ▪ Seven Mile ▪ St. Aubin
Vertical	WRRF	▪ Primary process area ▪ Secondary process area ▪ Dewatering process area ▪ Incineration process area ▪ Common Support

4.4 Asset Registry

The wastewater system linear and vertical assets are tracked in the Environmental Systems Research Institute (ESRI) ArcGIS and Oracle Work and Asset Management (WAM) information systems, respectively.

4.4.1 Linear Asset Register

The linear asset inventory and attribute data are largely based on the wastewater collection system ArcGIS geographic information system (GIS) data for location and associated asset attributes, supplemented by available closed-circuit television (CCTV) field inspection condition data. .

Table 4-2 lists the WwAMP collection pipeline data attributes and sources.

Table 4-2: WwAMP Linear Asset Register Field Descriptions

Data	Data Source	Description of Data
Pipe Diameter	CCTV and GIS	Diameter listed on the CCTV inspection data and from GIS data.
Install Date	GIS	Installation date tracked in GIS.
Pipe Material	CCTV and GIS	Pipe material listed on the CCTV inspection data and from GIS data.
Buried Depth	GIS	Average depth of the pipe from upstream and downstream manhole inverts measured in GIS.

Pipe Diameter

The wastewater collection system pipeline diameters are generally 40 inches or larger, up to 261 inches. Pipe diameter size directly correlates to asset scoring processes and life cycle cost estimations presented in later sections. Three pipe diameter cohorts labeled small (less than 60 inches), medium (60 inches up to but not including 132 inches), and large (132 inches and greater) visually categorize data sets in tiered diameter size groupings. Figure 4-6 shows the distribution of sewer miles over the range of pipe diameters in the collection system.

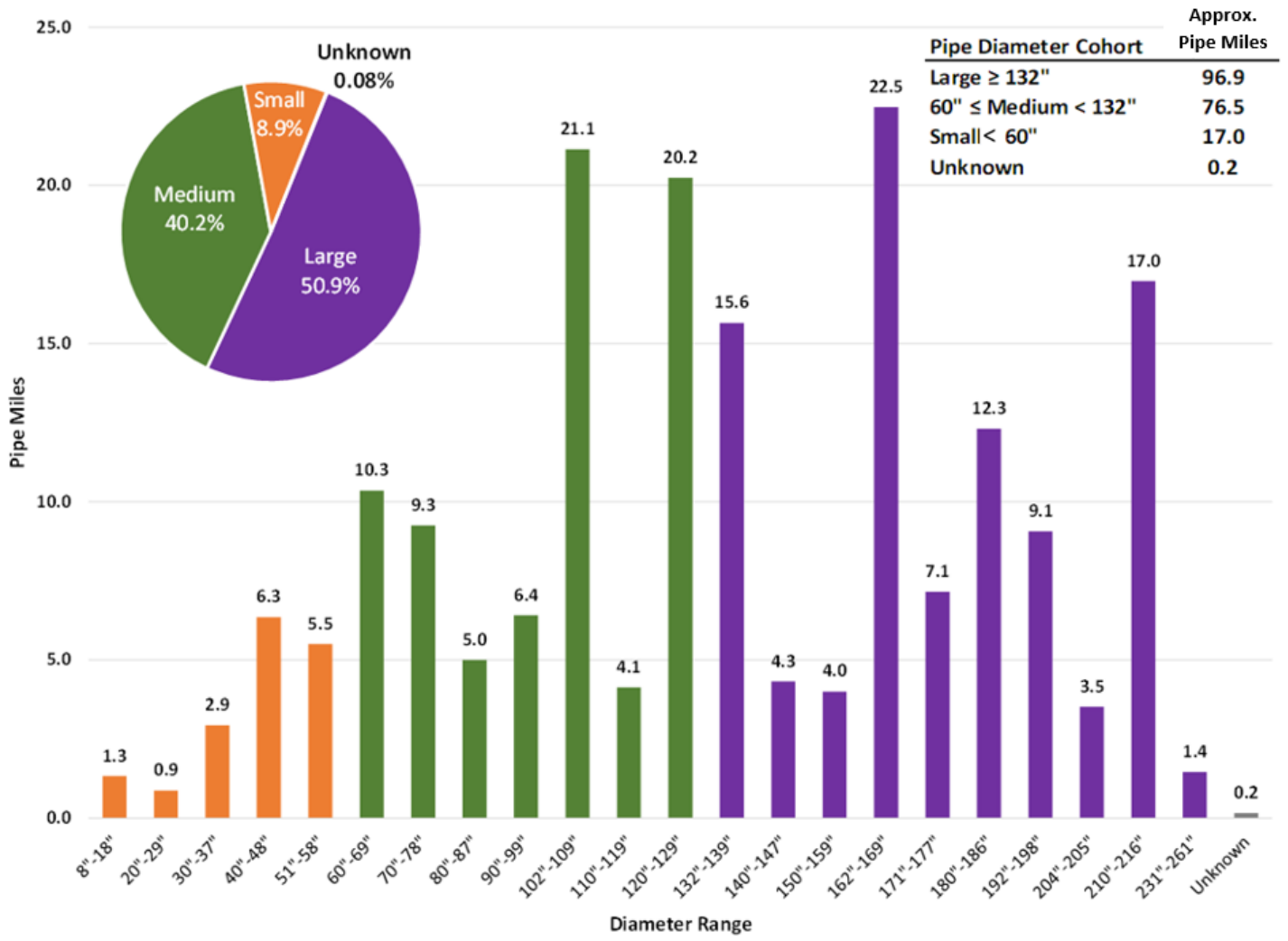
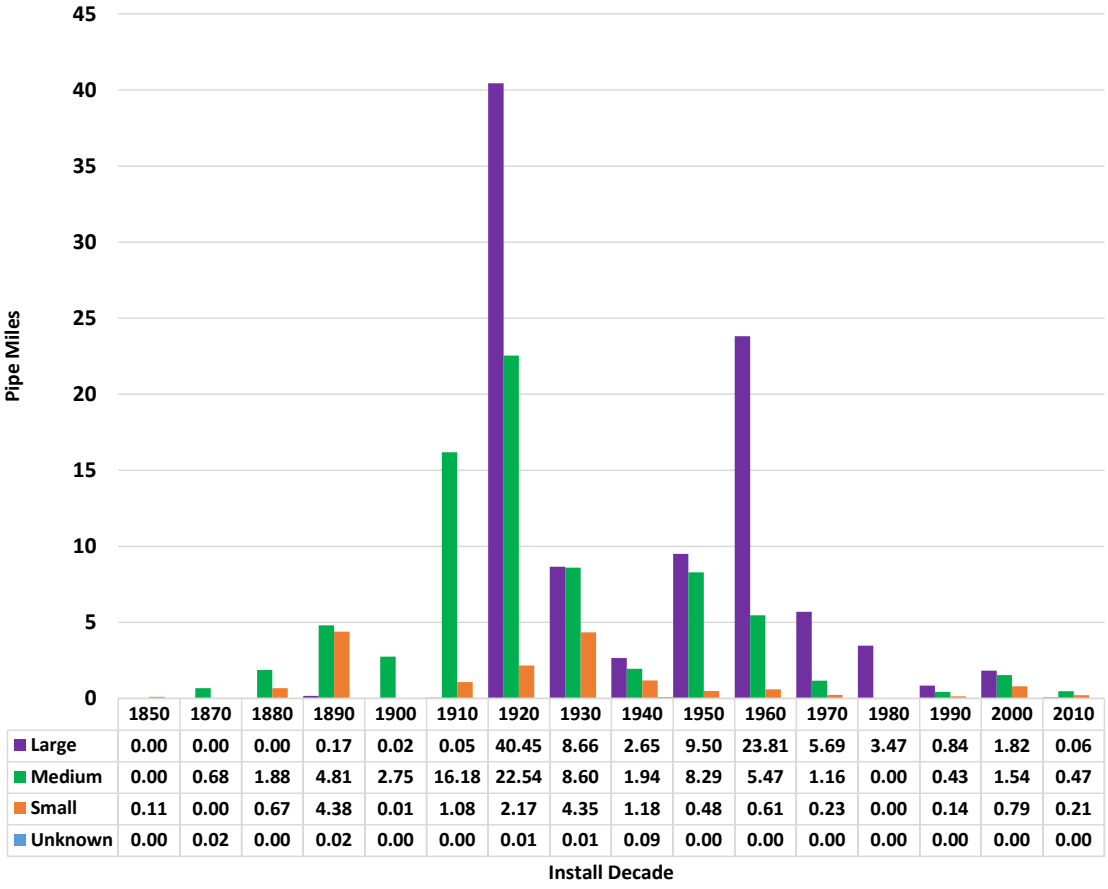


Figure 4-6: Wastewater Collection System Sewer Miles by Diameter

The large-diameter cohort data represents 51% of the pipe miles in the collection system and includes pipe diameters up to 261 inches. Pipes with the smallest diameters in the system (less than 60 inches) account for 9% of the pipe mile data, and the remaining 40% of pipe miles in the system fall within the medium-diameter cohort.

Install Date

Figure 4-7 shows pipe miles by known install decade starting in the 1850s. Approximately 34% of pipe miles in the system have an install date in the 1920s, including 42% (42.5 miles) of the large-diameter cohort.



	1850	1870	1880	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
Large	0.00	0.00	0.00	0.17	0.02	0.05	40.45	8.66	2.65	9.50	23.81	5.69	3.47	0.84	1.82	0.06
Medium	0.00	0.68	1.88	4.81	2.75	16.18	22.54	8.60	1.94	8.29	5.47	1.16	0.00	0.43	1.54	0.47
Small	0.11	0.00	0.67	4.38	0.01	1.08	2.17	4.35	1.18	0.48	0.61	0.23	0.00	0.14	0.79	0.21
Unknown	0.00	0.02	0.00	0.02	0.00	0.00	0.01	0.01	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 4-7: Wastewater Collection System Interceptor or Sewer Installation Decade

Pipe Material

Figure 4-8 shows the distribution of pipe materials in terms of pipe miles contributing to the wastewater collection system as a whole and by pipe-diameter cohort.

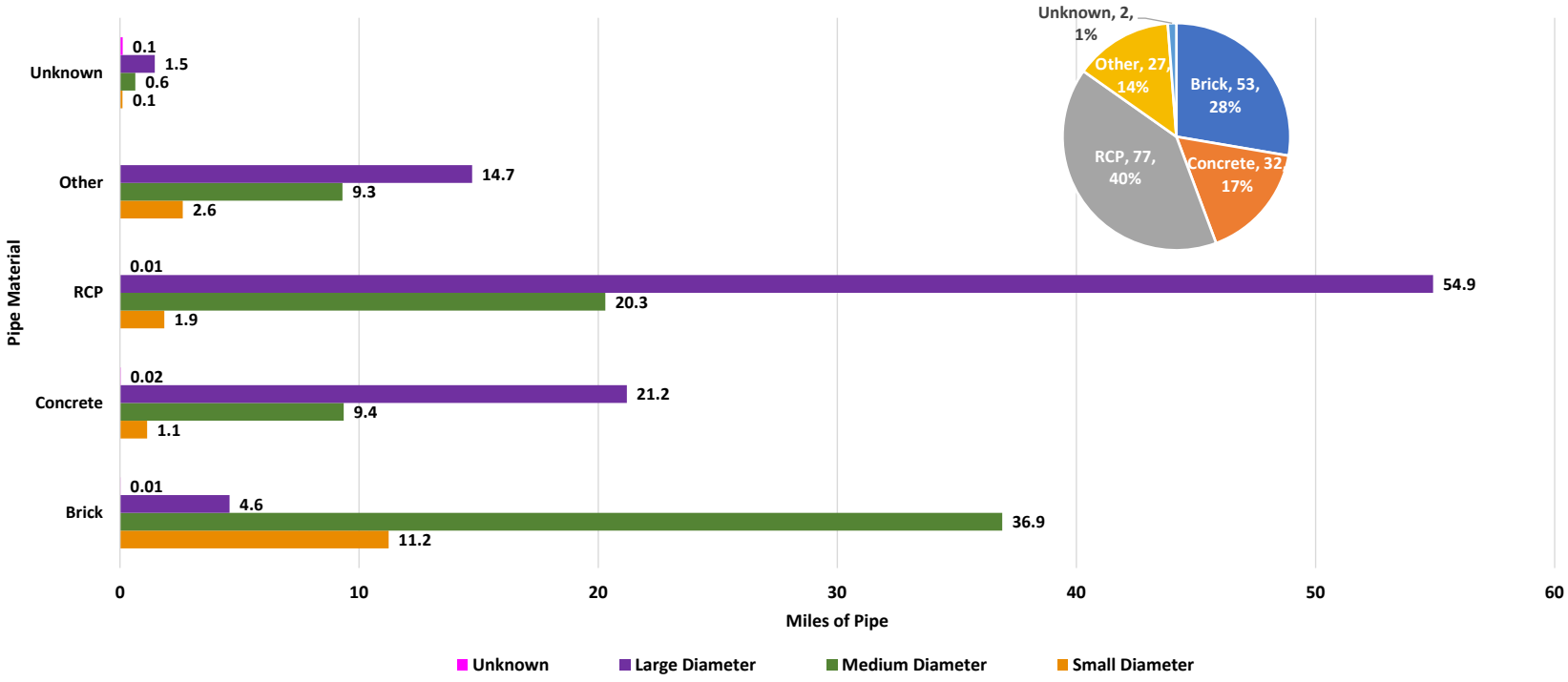
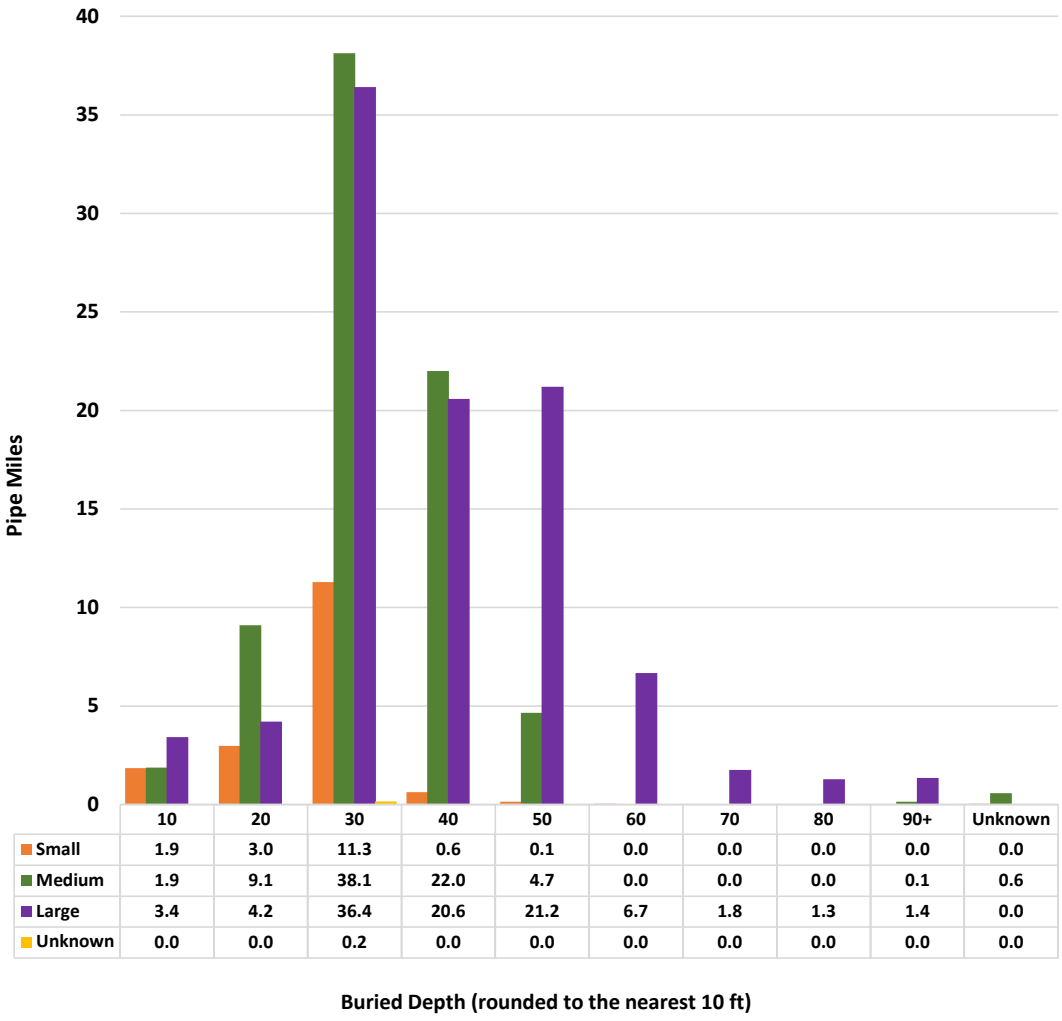


Figure 4-8: Wastewater Collection System Sewer Material Type

Collection system sewer miles by material is predominately reinforced concrete (40%), brick (28%), and concrete (17%). Concrete and reinforced concrete represent approximately 76 miles (78%) of the large-diameter cohort, 30 miles (39%) of the medium-diameter cohort, and 3 miles (18%) of the small-diameter cohort. The most common pipe material in the small cohort is brick (67%), with approximately 11 miles.

Buried Depth

The wastewater collection system is designed to be buried deep underground, allowing for gravity inflow from connected systems. Figure 4-9 shows sewer pipe miles at 10-foot increments of buried depth for each cohort. Buried depth is measured from grade to pipe invert (bottom of inner diameter).



	10	20	30	40	50	60	70	80	90+	Unknown
Small	1.9	3.0	11.3	0.6	0.1	0.0	0.0	0.0	0.0	0.0
Medium	1.9	9.1	38.1	22.0	4.7	0.0	0.0	0.0	0.1	0.6
Large	3.4	4.2	36.4	20.6	21.2	6.7	1.8	1.3	1.4	0.0
Unknown	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 4-9: Wastewater Collection System Sewer Buried Depth

Approximately 82.4 miles (85%) of the large-diameter cohort are distributed between 10 and 50 feet of buried depth. The total length of collection pipe with a buried depth listed as greater than 50 feet is approximately 11.3 miles (6%) of the large-diameter cohort. Buried depth is directly related to consequence and total risk of a pipe failure (Chapter 5) and is a factor for estimating linear life cycle costs (Chapter 7).

Only a few pipes had unknown buried depths. They were assigned an average buried depth of 10 feet for pipes with diameters below 40 inches, and 20 feet for pipes with diameters above 40 inches.

Collection System Secondary Assets

Table 4-3 shows the quantities of active secondary assets, such as manholes, valves, storage devices, and metering/monitoring equipment in the wastewater collection system. Secondary linear assets are assumed to be ancillary to collection system piping and included in linear asset life cycle costs. Linear asset risk (Chapter 5), recommendations for maintenance (Chapter 6) and renewal planning (Chapter 7), and funding needs (Chapter 8) are based on GLWA GIS data and available CCTV inspection data for collection system pipelines. Secondary asset inventory and attribute data, such as diameter, depth, materials, sensor ranges, manufacturer, model, etc. is not fully known at this time and should be collected after the inventory and attribute data for collection system piping is completed. Risk scores and methodology, described in Section 5, for these individual secondary assets have not been completed, however the condition, risk, and replacement costs of these secondary assets are assumed to be related to the corresponding collection system piping and included in those costs

Table 4-3: Wastewater Collection System Secondary Assets

Asset Type	Quantity
Manholes	1,526
In-System Storage Devices	17
Regulators	67
Valves	58
Member Partner Sewer Metering Sites	27
System Metering Sites	56
Level Sensors	62
Precipitation Gauges	36

4.4.2 Vertical Asset Register

The vertical asset register is tracked in Oracle WAM and includes the WRRF, SPS, and CSO facilities. Table 4-4 lists data fields in the vertical asset register and applicable WAM fields used as initial data sources. The vertical asset register is not a complete inventory of all assets. It focuses mostly on electrical and mechanical assets. Civil assets are not in the inventory.

Table 4-4: WwAMP Vertical Asset Register Field Descriptions

WAM Field Data Source[1]	Vertical Asset Register Field[2]	Description
N/A	Order No.	Sort order for asset hierarchy
Asset ID	Asset ID	▪ Assets in WAM data export use a unique alphanumerical identifier composed of a letter followed by 15 numbers generated in WAM ▪ Assets added or updated during WwAMP preparation are noted with a description that says, "Newly added asset" and followed by a short asset description
Parent Asset ID	Level 1, Level 2, Level 3, Level 4, Level 5, Level 6, Level 7, Level 8, Level 9	Parent/child asset hierarchy in descending hierarchal order from Level 1 to Level 9
Area	Master process area or facility	GLWA process group
Asset Type	Master asset type	Asset type (valve, pump, etc.)
Asset Status	Master asset status	Operational status of asset (e.g., active, inactive, retired)

[1]Asset data updated through the development of the WwAMP vertical asset register will be used to update fields in WAM.
[2]WAM data served as the basis of the vertical asset register and then asset data was updated through GLWA staff workshops and analysis.

Asset records in the vertical asset register with an "active" status have been included in asset count quantities and results.

4.4.2.1 WRRF

All WRRF assets are assigned to one of the five plant process areas: Primary, Dewatering, Incineration, Secondary, and Common Support. Table 4-5 provides a short list of selected assets by process area and Figure 4-10 shows the total asset counts by process area.

Table 4-5: WRRF Abbreviated List of Assets by Process Area

Process Area	Assets	
Primary	• Bar screens • Grit chambers • Influent pump stations • Primary clarifiers	• Sludge pumps • Scum pumps • Scum concentrators • Scum storage tanks
Dewatering	• Belt filter presses • Primary thickeners • Secondary thickeners • Sludge storage tanks (circular)	• Sludge storage tanks (rectangular) • Sludge pumps • Sludge cake pumps • Thickened sludge pumps
Secondary	• Aeration tanks • Bisulfite pumps • Chlorine evaporators • Final clarifiers •	• Hypochlorite pumps • Intermediate pumping stations • Return activated sludge pumps • Sulfur dioxide evaporators
Incineration	• Ash crushers • Ash handling conveyors • Incinerator dampers	• Incinerators • Off-load conveyors • Silos
Common Support	• Generators • Security gates	• Switchgear • Transformers

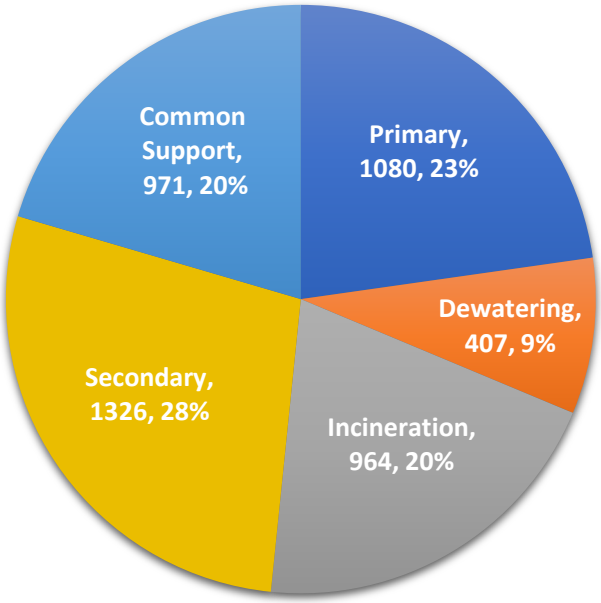


Figure 4-10: WRRF Asset Counts by Process Area

Secondary has the highest number of assets (28%), followed by Primary (23%), Incineration (20%), and Common Support (20%). Dewatering has the least number of assets (9%). The full list of assets can be found in the WwAMP vertical asset register discussed in Chapter 5.

4.4.2.2 Sewage Pump Stations

There are 665 active assets spread among the eight SPS facilities and included in the vertical asset register. Figure 4-11 shows the number and percentage of assets per SPS facility.

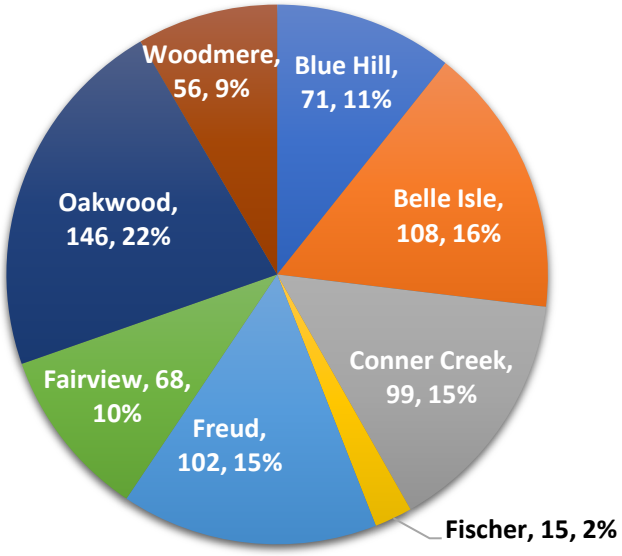


Figure 4-11: SPS Asset Counts by Facility

Fischer SPS has the least number of assets (2%) of the SPS facilities. The Fischer asset record count in WAM will increase by the next WwAMP update due to the 2020 station overhaul.

Table 4-6 lists the installation year and dry/wet weather capacity for each SPS facility. It should be noted that CSO facilities located at SPS facilities contribute to the overall wet weather capacity.

Table 4-6: SPS Facility Install Year and Capacity

Sewage Pump Station	Placed In Service	Last Major Rehabilitation	Dry Weather Pumps / Capacity	Wet Weather Pumps / Capacity
Belle Isle	1920s	2000	2 pumps / 4 mgd total	3 pumps / 33 mgd total
Blue Hill	1947	2013	2 pumps / 6 mgd total	4 pumps / 865 mgd total
Conner Creek	1928	2009	4 pumps / 336 mgd total	8 pumps / 2,560 mgd total
Fairview	1913	1995	4 pumps / 336 mgd total	-

Sewage Pump Station	Placed In Service	Last Major Rehabilitation	Dry Weather Pumps / Capacity	Wet Weather Pumps / Capacity
Fischer	1963	2013	2 pumps / 14 mgd	-
Freud	1954	2011	2 pumps / 40 mgd total	8 pumps / 2,320 mgd total
Oakwood	2012	N/A	4 pumps / 26 mgd total	8 pumps / 1,256 mgd total
Woodmere	1958	2013	2 pumps / 10 mgd total	3 pumps / 495 mgd total

4.4.2.3 CSO Facilities

The nine CSO facilities include approximately 2,713 total active assets listed in the vertical asset register. Figure 4-12 shows the number and percentage of asset counts per facility.

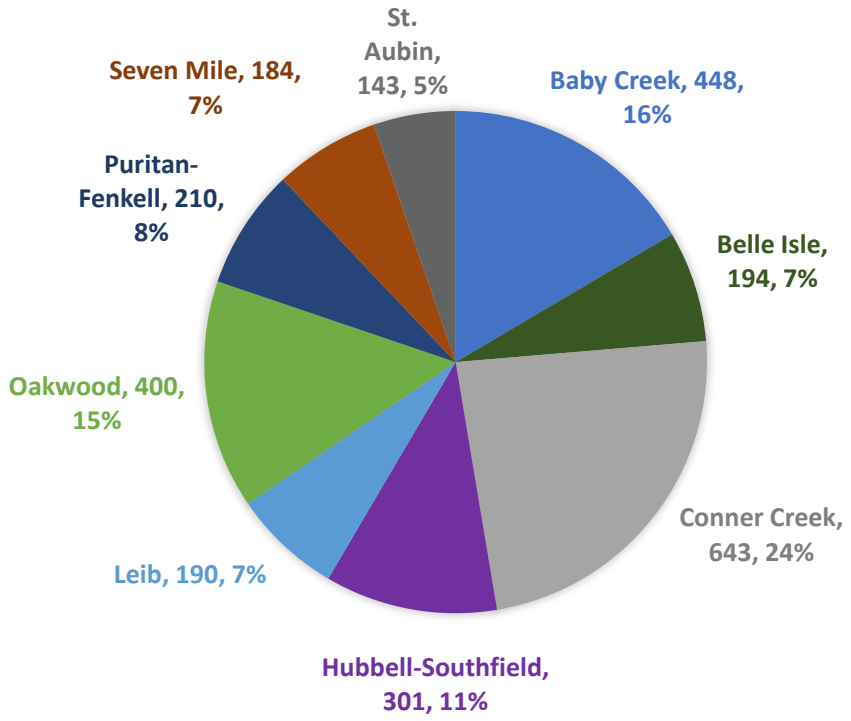


Figure 4-12: CSO Asset Counts per Facility

The nine CSO facilities include six RTBs and three SDFs. Table 4-7 lists the facility installation year, storage capacity, screen type, and hydraulic capacity for each CSO facility.

Table 4-7: CSO Facility Installation Year and Capacity

Facility	RTB	SDF	Placed In Service	Storage Retention	Screen Type (size of slot or opening)	Hydraulic Capacity in Cubic Feet per Second (CFS) / Million Gallons per Day (mgd)
Belle Isle	✓		2007	0.3 MG	Perforated plate (6 mm)	33 cfs / 21 mgd
Conner Creek	✓		2005	30 MG	Bar screen (1.5 inch)	13,963 cfs / 9,024 mgd
Hubbell-Southfield	✓		1996	22 MG	Bar screen (1.5 inch)	3,200 cfs / 2,068 mgd
Oakwood	✓		2012	9 MG	Perforated plate (6 mm)	1,660 cfs / 1,073 mgd
Puritan-Fenkell	✓		1996	2.8 MG	Bar screen (0.5 inch)	845 cfs / 546 mgd
Seven Mile	✓		1997	2.2 MG	Bar screen (0.5 inch)	655 cfs / 423 mgd
Baby Creek		✓	2005	3 MG	Perforated (6 mm)	5,100 cfs / 3,296 mgd
Leib		✓	2002	9.9 MG	Raked vertical & horizontal bar screens (4 mm)	2,000 cfs / 1,293 mgd
St. Aubin		✓	2002	2.4 MG	Raked vertical bar screens (4 mm)	310 cfs / 200 mgd

4.5 Condition

Asset condition is the primary driver for asset performance, plays a significant role in determining asset risk, and is crucial in determining strategies for O&M and asset renewal. Organizations can use condition data for identifying which assets should be placed on CIPs and when required, and support optimizing maintenance frequencies based on whether an asset is in good or poor condition.

Asset condition scores for linear assets are managed by LSIP. See Appendix E for prioritization methodology and condition assessment activities performed in 2020 for vertical assets. The related inspection reports and photos have been imported into the OnBase Document Management System and linked to assets in WAM.

Appendix F. WwAMP- Condition Assessment Activities Spreadsheet for Vertical Assets, which supports Tactical Recommendation WW5: WwAMP – Condition Assessment of Non-Inspected Vertical Assets, includes the list of activities to perform in future condition assessments.

4.5.1 Linear Asset Condition

4.5.1.1 Condition Grades

Three linear condition grades are presented in the WwAMP. Approximately 64% of the collection system pipe miles with available CCTV inspection data are assigned a maintenance condition grade and a structural condition grade based on reported defect types (and severity) related to maintenance actions and structural actions, respectively. Maintenance actions and structural actions are discussed further in Chapter 6. For pipes without CCTV inspection data, the System Condition Risk Enhanced Assessment Model (SCREAM) used the install date listed in GIS to estimate remaining useful life (RUL) and assign an overall condition grade. This information has been provided to GLWA to use in any related tools. Pipes without CCTV inspection data were not assigned a maintenance or structural condition grade. Additionally, an overall condition grade was assigned to each pipe based on the collective reported defect types and severity. The overall condition grade was used to determine likelihood of failure (LOF) and total asset risk scores.

Descriptions for each of these condition grade types are included below in Table 4-8.

Table 4-8: Linear Condition Grade Types

Basis for Condition	Condition Grade Type		
	Maintenance	Structural	Overall
CCTV Inspection Data	Condition grade of the maintenance type defects (like grease and roots) which can be corrected with routine maintenance	Condition grade of the structural type defects (like cracks, corrosion or offset joints) which can be corrected with rehab/repair/replacement	Condition grade of all defect types, used for LOF and total asset risk scores
Install Date/RUL	N/A	N/A	Condition grade of RUL, used for LOF and total asset risk scores

4.5.1.2 Maintenance and Structural Condition Grades

The maintenance and structural condition grade results summarized below are based on CCTV inspection data collected from 2016 to 2020 using the National Association of Sewer Service Companies (NASSCO) standard inspection formats and Pipeline Assessment Certification Program (PACP). CCTV inspection data results covered approximately 122 miles (64%) of the wastewater collection system pipelines. Figure 4-13 shows the distribution of miles inspected for each pipe cohort. In 2021, additional inspections were performed. See LSIP for a description of the latest activity.

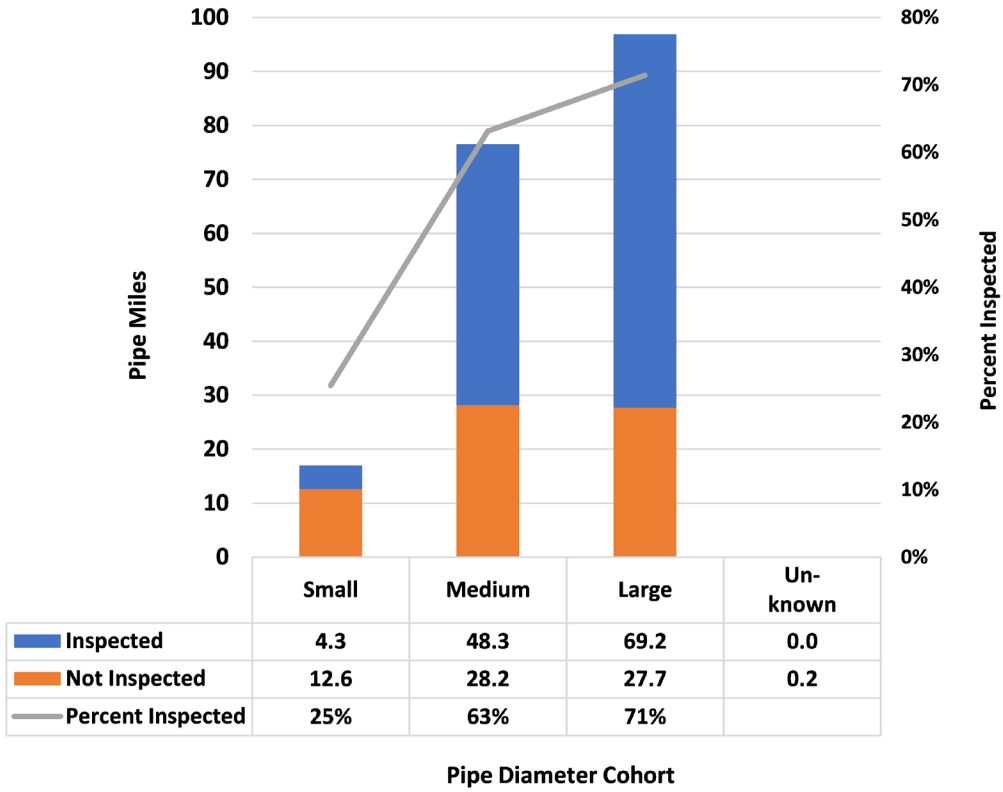


Figure 4-13: Collection Pipeline CCTV Inspection - Miles

Table 4-9 lists the condition grades with descriptions for maintenance and structural condition grades.

Table 4-9: Maintenance and Structural Condition Grade Descriptions

SCREAM Condition Grade	Condition Description
0	No observed defects
1	Few observed defects
2	Minimum level of defect severity
3	Moderate level of defect severity
4	Major level of defect severity
5	Extreme defects/performance failure
No Inspection	No CCTV inspection data

Figure 4-14 summarizes the number of pipes by defect type found in available GLWA CCTV inspection data. The results for all diameters show infiltration and deposits as leading defect types found in the collection system. However, most pipes affected had minor issues (e.g., staining) and were assigned a defect grade of 1 or 2. Major or extreme severity grades (4 or 5) were primarily concentrated in connection seal, debris, crack broken or collapse, obstacle built or introduced, and corrosion defect families. The results were similar when reported for each pipe cohort.

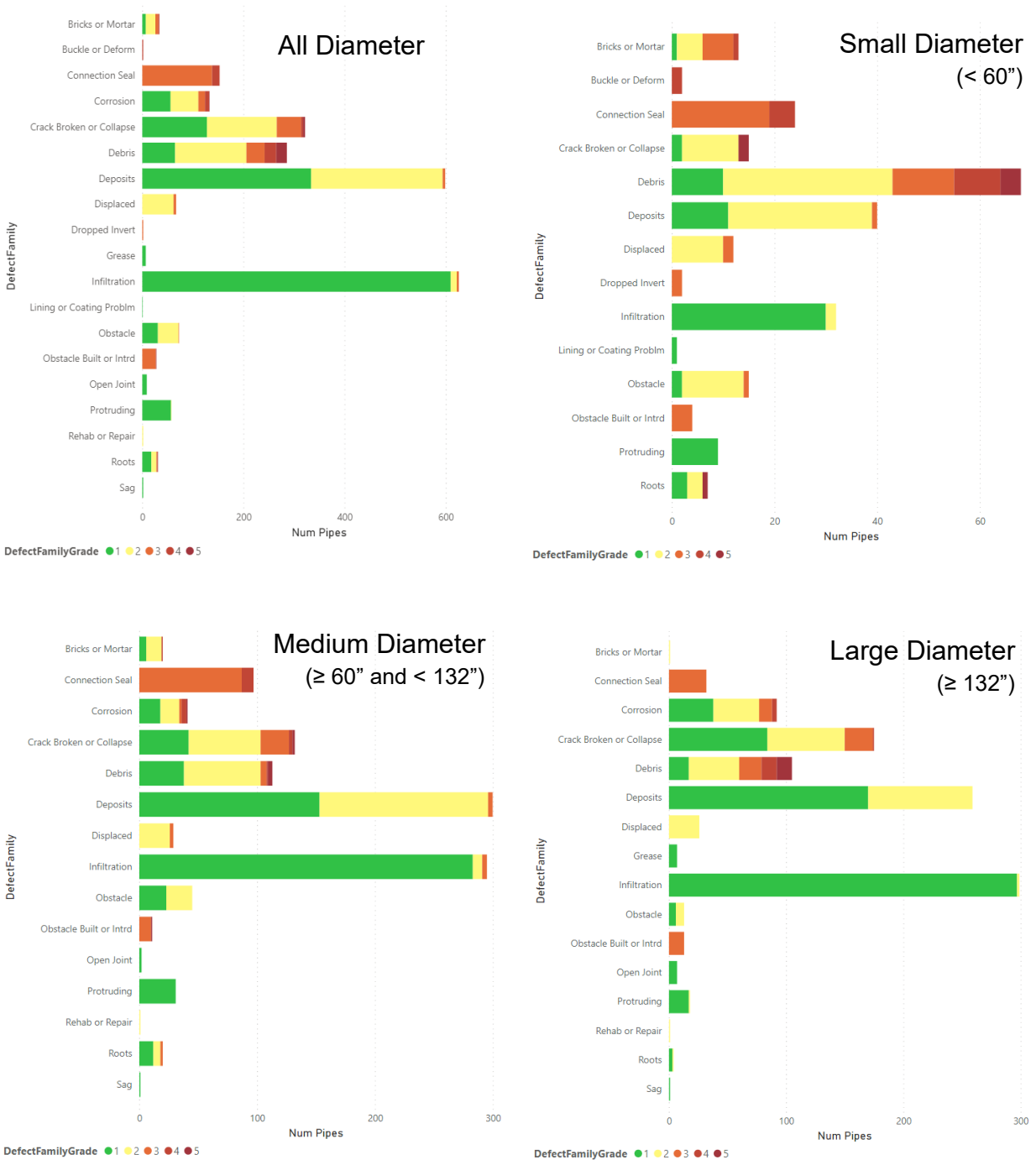


Figure 4-14: Number of Pipes Affected by Defect Types (based on 2020 data)

Figure 4-15 and Figure 4-16 show the distribution of maintenance and structural condition grades, respectively, in terms of length for each inspected pipe diameter cohort.

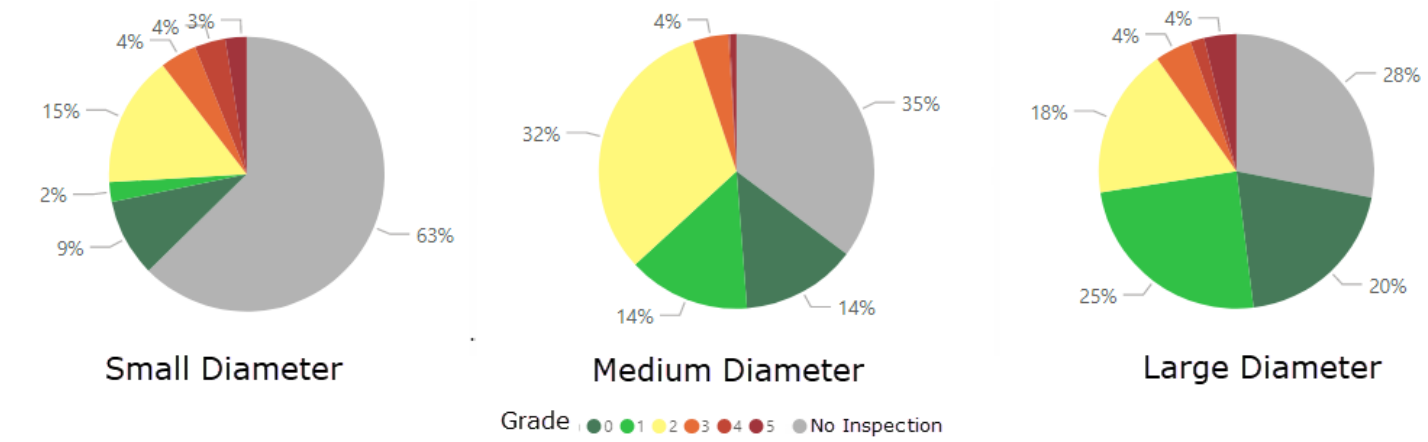


Figure 4-15: Distribution of Pipe Miles by Maintenance Condition Grade (based on 2020 data)

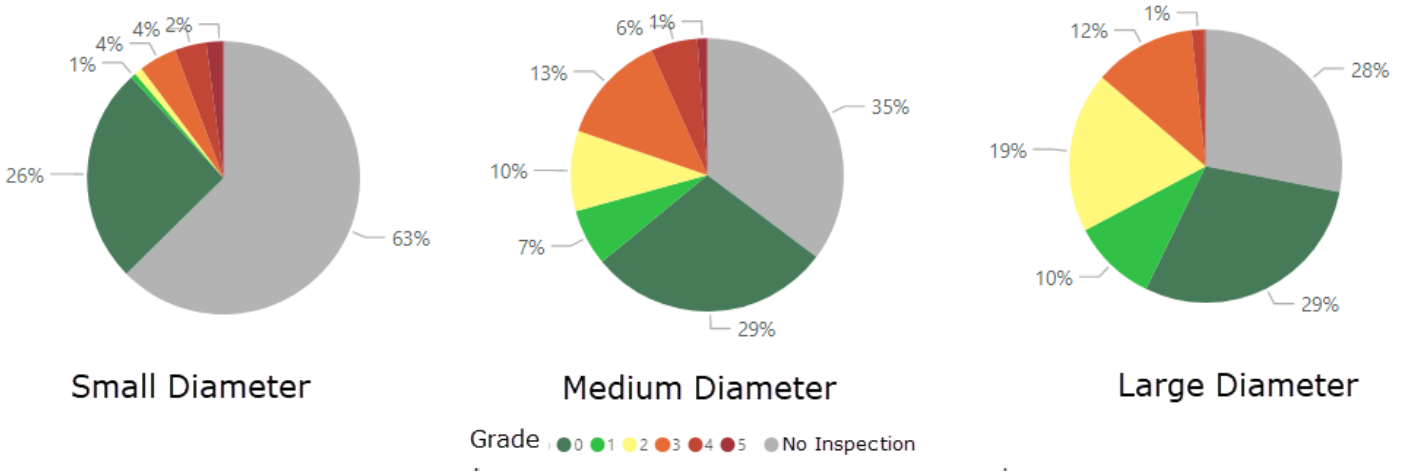


Figure 4-16: Distribution of Pipe Miles by Structural Condition Grade (based on 2020 data)

For maintenance condition grades, a high percentage of large-diameter pipes were in good condition (zero to few defects). In comparison, a smaller percentage of the medium- and large-diameter pipes were in good condition. However, these results are inconclusive because many of the small- (75%) and medium- diameter (37%) pipes have not yet been inspected.

Most of the inspected pipes had low structural grades of 0, 1, and 2 (shown as green and yellow in Figure 4-16), meaning that rehabilitation or repair would not be needed for these pipes in the near future. A sizable portion of the medium- and large-diameter pipes were Grade 3 (orange). These Grade 3 pipes should be reinspected more frequently to monitor the rate of deterioration. The grade 4 and 5 (red) pipes are those needing rehabilitation. Note that many of the small-diameter pipes have not been inspected.

4.5.1.3 Overall Condition Grade

Table 4-10 defines the linear overall condition grades.

Table 4-10: Linear Overall Condition Grade Descriptions

SCREAM Condition Grade	Condition Description
0	No observed defects
1	Few observed defects
2	Minimum level of defect severity
3	Moderate level of defect severity
4	Major level of defect severity
5	Extreme defects/performance failure

Figure 4-17 shows the distribution of overall condition grades in terms of length for each inspected pipe diameter cohort.

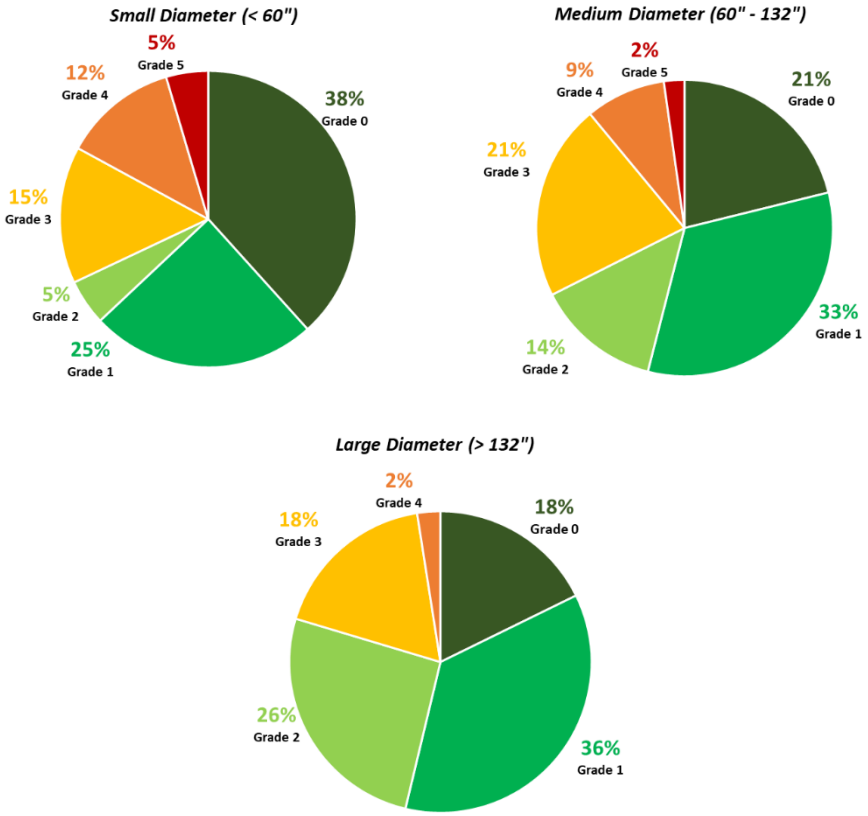


Figure 4-17: Distribution of Pipe Miles by Overall Condition Grade (based on 2020 data)

Small-diameter pipes had the highest percentage (63%) of pipes in condition grades 0 and 1 (no or few defects). Large-diameter pipes had the highest percentage of pipes with condition Grade 2 (minimum defects), the lowest combined percentage (20%) of grade 3 and 4 pipes, and no large-diameter pipes had an extreme level of defects.

4.5.2 Vertical Asset Condition

Vertical assets (WRRF, SPS, and CSO facilities) were initially prioritized for condition assessments using a preliminary risk score. The preliminary risk score was determined through various activities, including 2020 GLWA team member workshops, a desktop analysis for consequence of failure (COF), maintenance history, and field inspections. See Appendix E for prioritization methodology and condition assessment activities performed in July – August of 2020. Appendix F, WwAMP Condition Assessment Activities - Vertical Assets, which supports Tactical Recommendation WW5: WwAMP – Condition Assessment of Non-Inspected Vertical Assets, includes the list of activities to perform in future condition assessments.

Condition grades were then determined through one of the following tiers of analysis:

- **Tier 1 Analysis –** Desktop analysis
- **Tier 2 Analysis –** Visual condition assessment
- **Tier 3 Analysis –** Detailed field condition assessment

For example, 20% of CSO assets received a detailed field condition assessment, and 80% received a visual condition assessment. Additionally, contracting requirements allowed for the inspection of 1,000 WRRF assets, which received visual condition assessments only.

Tier 3 condition assessments were performed using the Asset Condition Evaluation System (ACES), a tool Jacobs developed to monitor asset condition. ACES is based on information from the International Infrastructure Management Manual and uses asset type-specific questions, developed in conjunction with the client, to assess observable and measurable (Tier 3) information related to the current condition of an asset. For GLWA, a team of two maintenance and reliability professionals – each with more than 20 years of experience operating and maintaining wastewater facilities – evaluated the condition questions for each asset. Using collected data and the ACES tool, they then determined an overall asset condition score.

The vertical asset condition grade was used to determine vertical asset LOF and total risk scores. Results are broken down by the type of assessment the condition grade is based on and presented as percent of overall system and process area or facility. As more assets are assessed visually, condition grade accuracy will improve.

Table 4-11 lists the condition grade descriptions for vertical assets.

Table 4-11: Vertical Condition Grade Descriptions

Condition Grade	Condition Grade Description
1	Like-new condition. Continuation of current maintenance and operating procedures is recommended.
2	Good condition. Some minor additional maintenance may be required. Continuation of current maintenance and operating procedures is recommended.
3	Fair condition. One or more issues that require immediate attention. Modification or adjustment of current maintenance and operating procedures may be needed to avoid recurrence of identified issues.
4	Poor condition. Planning for a major overhaul or replacement should begin. Review of current maintenance practices and procedures is recommended.
5	Very poor condition. Failure of the asset is imminent or has already occurred. Greater than 50% of the asset requires replacement.

4.5.2.1 WRRF Condition Grades

WRRF condition grades are shown by assessment type in Figure 4-18 and by process area in Figure 4-19. Visual assessments accounted for approximately 16% of WRRF assets, with the remaining assessments performed through tabletop analysis.

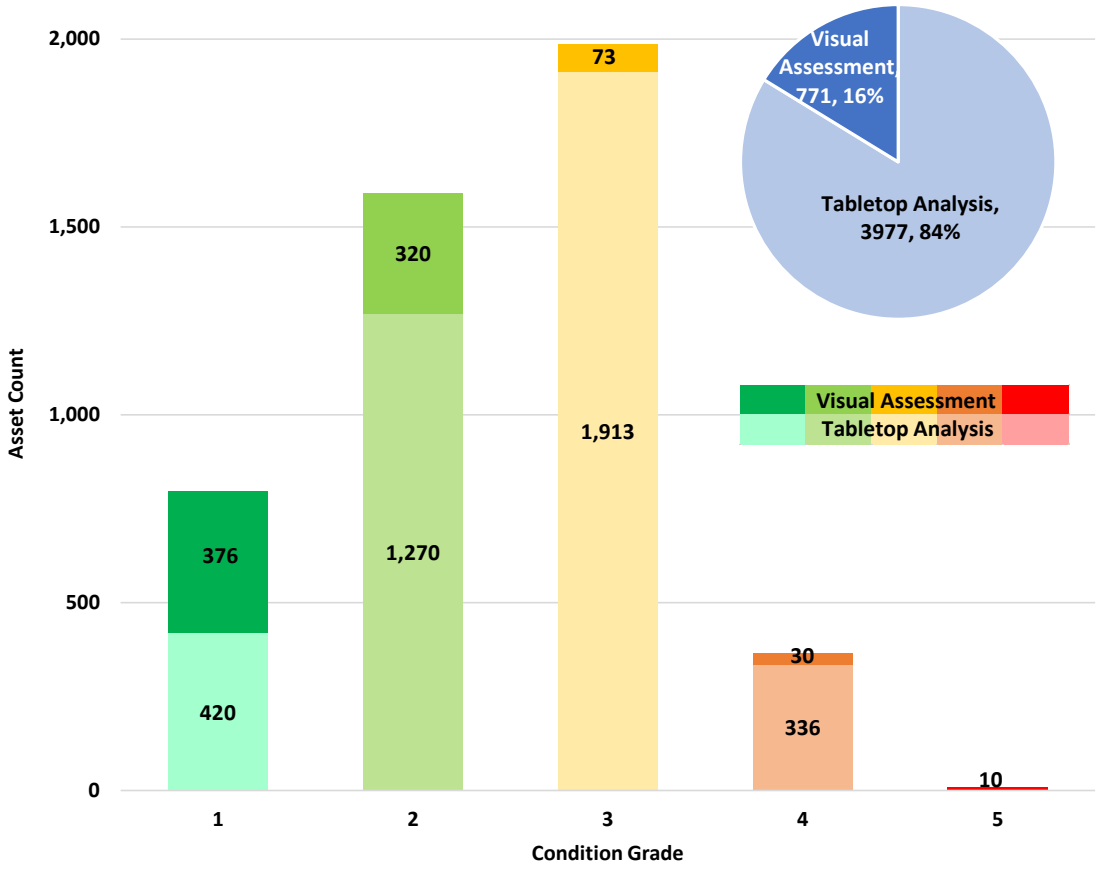


Figure 4-18: WRRF Condition Grades by Assessment Type (based on 2020 data)

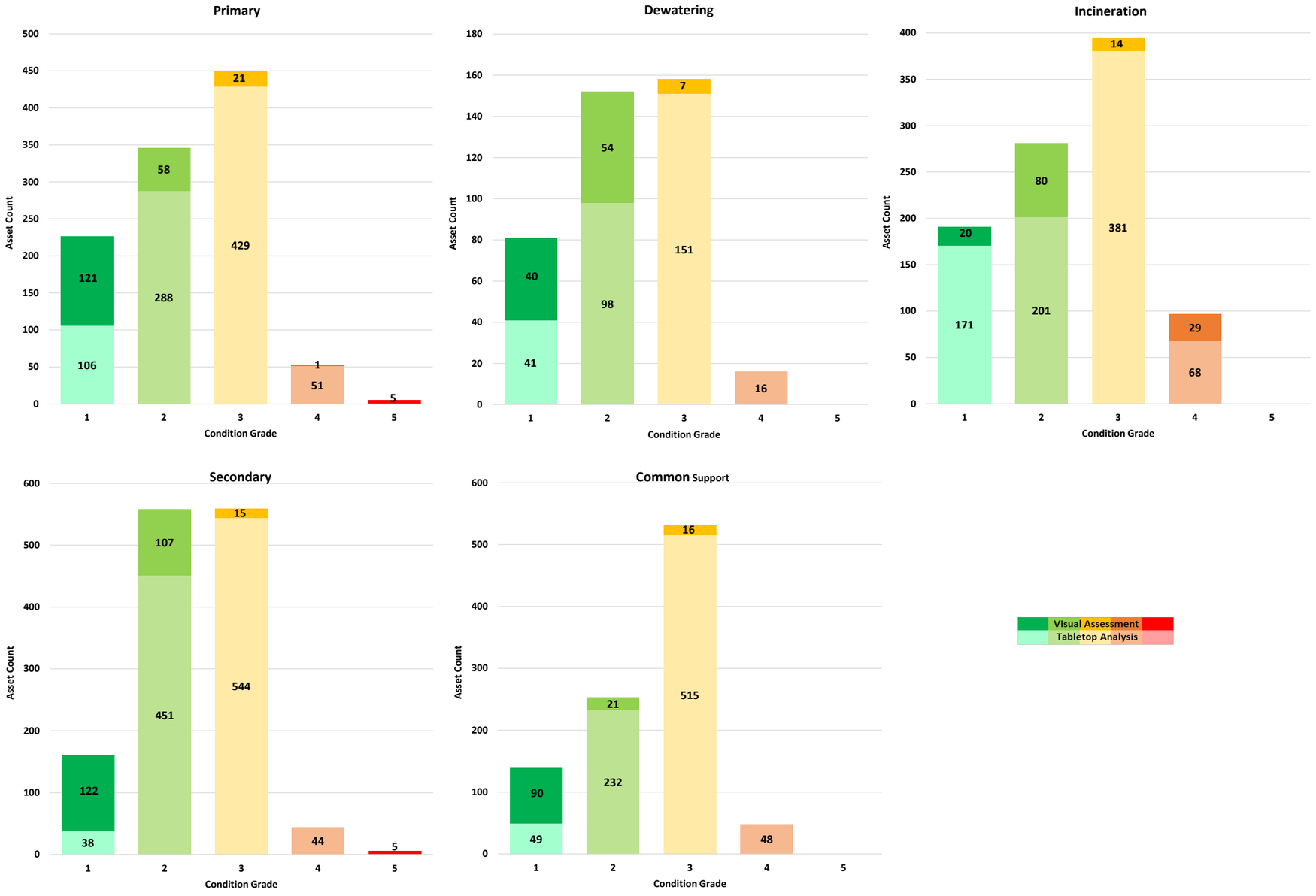


Figure 4-19: WRRF Process Area Condition Grades by Assessment Type (based on 2020 data)

Figure 4-20 below shows the distribution of condition grades, regardless of assessment types. Approximately half of all WRRF assets received a condition grade of 1 or 2.

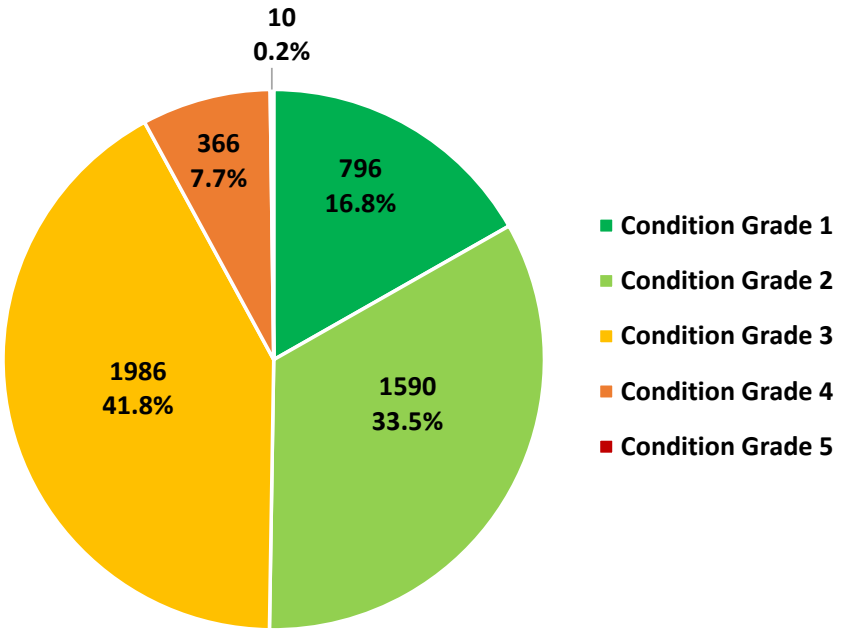


Figure 4-20: Distribution of WRRF Asset Condition Grades (based on 2020 data)

Figure 4-21 shows the distribution of condition grades for all assessment types by process area:

- Approximately half or slightly more than half of each process area's assets received a condition grade of 1 ("very good") or 2 ("good").
- Common Support was an exception, with approximately 40% of assets receiving a condition grade of 1 or 2.
- Common Support had approximately 51% of assets with a condition grade of 3 ("fair").

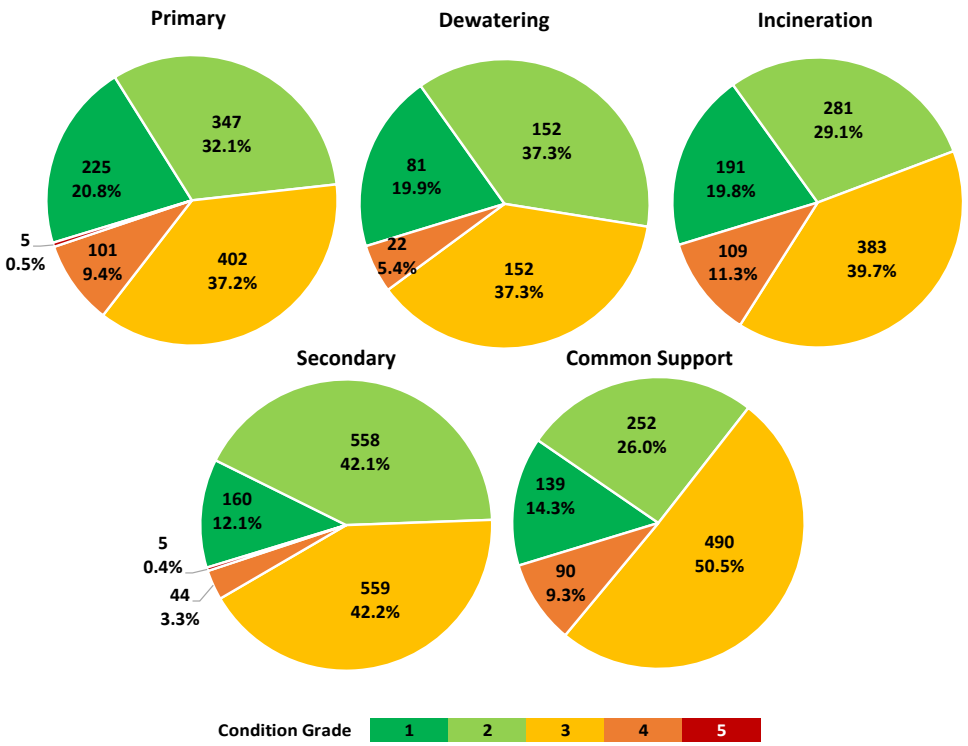


Figure 4-21: Distribution of WRRF Process Area Asset Condition Grades (based on 2020 data)

For Primary, Dewatering, Incineration, and Secondary process areas, between approximately 37% and 51% of their respective assets received a condition grade of 3:

- Incineration had the highest percentage (11.3%) of assets with a score of 4 ("poor").
- Primary, Dewatering, Secondary, and Common Support having between approximately 3% and 9% of assets with a score of 4.
- Less than 1% of total WRRF assets received a condition grade of 5 ("very poor"), split between Primary and Secondary.

4.5.2.2 SPS Condition Grades

A total of 211 (32%) SPS assets received either a visual or detailed condition assessment, as shown in Figure 4-22.

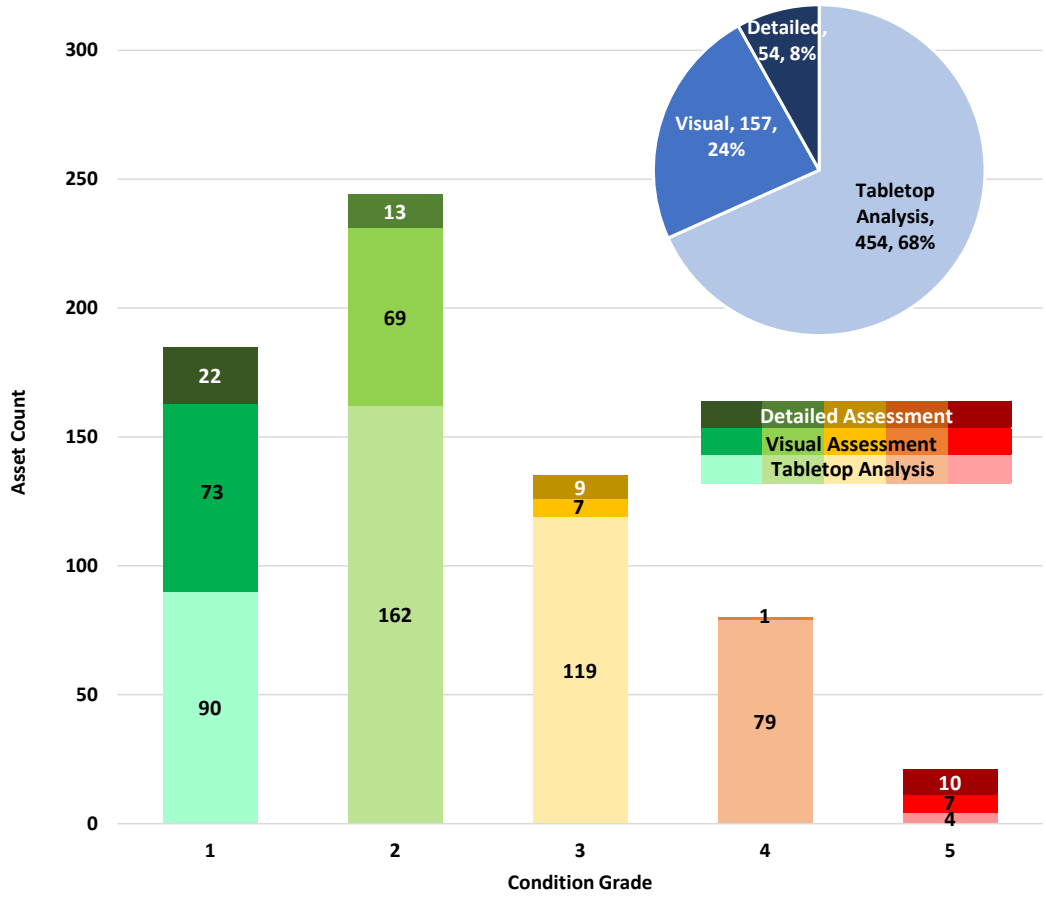


Figure 4-22: SPS Asset Condition Grades by Assessment Type (based on 2020 data)

Visual assessments were distributed among four of the eight SPS facilities shown in Figure 4-23, with percentages between 23% and 32% for Blue Hill, Conner Creek, and Freud facilities, and 90% for Oakwood, which also included detailed assessments. Approximately 37% of Oakwood assets received a detailed assessment as part of the CSO Asset Summary Report.

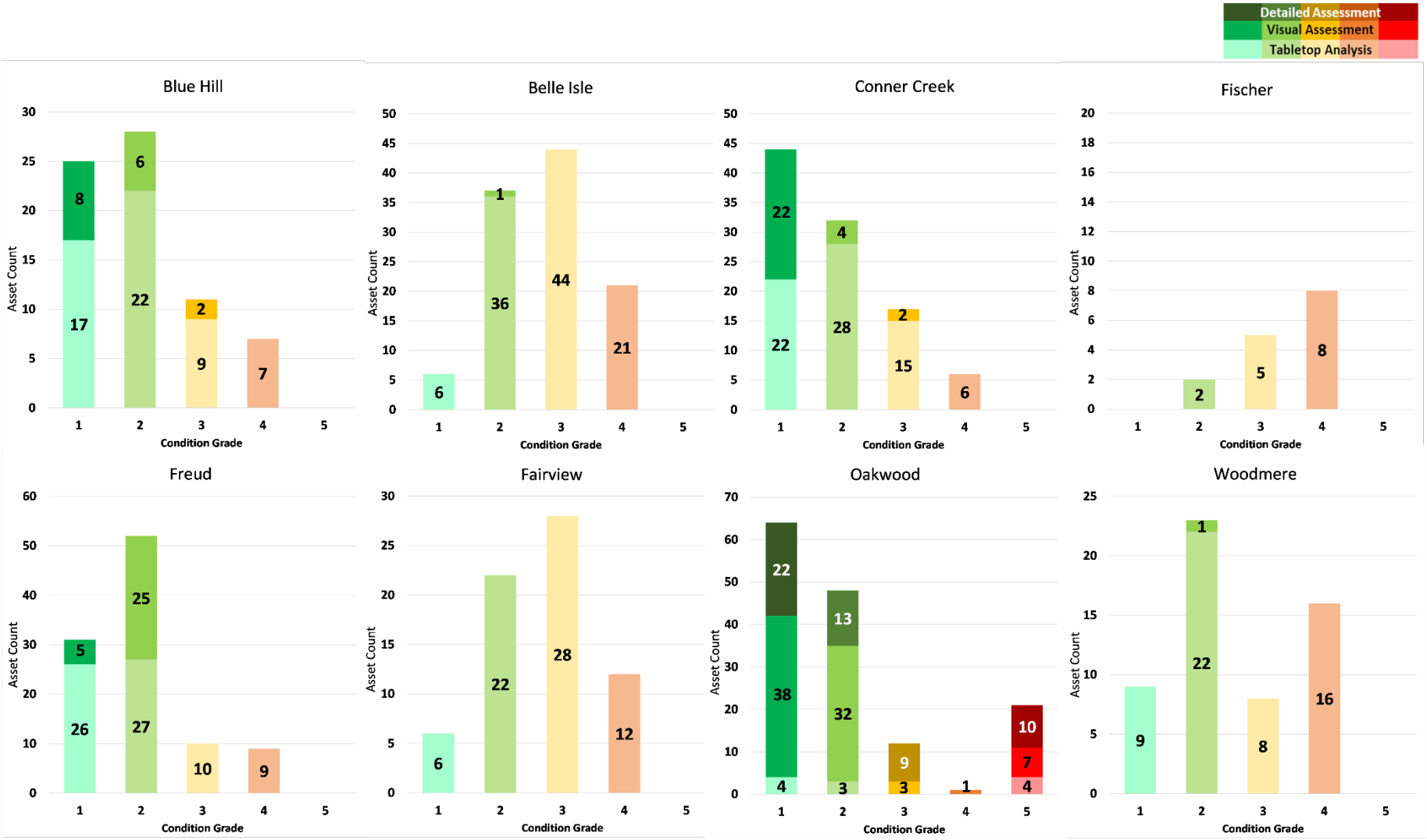


Figure 4-23: SPS Asset Condition Grades by Assessment Type (based on 2020 data)

Figure 4-24 shows the combined results of condition grades from both assessment types. The majority (65%) of SPS assets received a condition grade of 1 or 2, and 21 (3%) assets were determined to be in very poor condition (Grade 5).

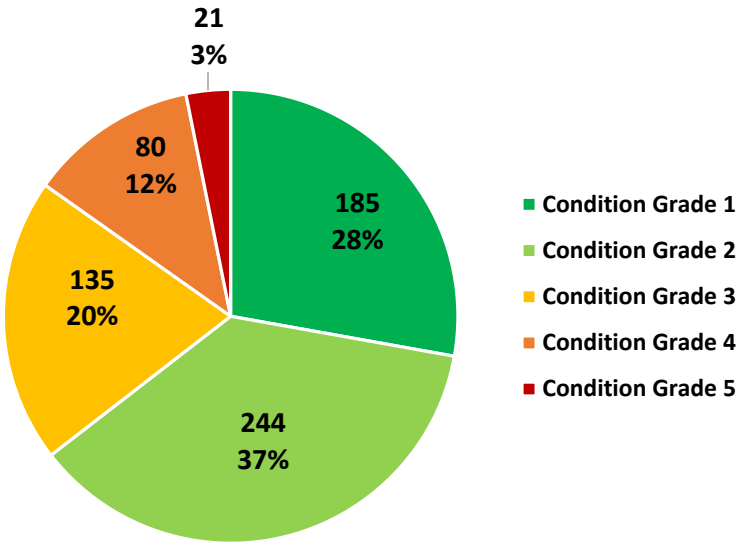


Figure 4-24: Distribution of SPS Asset Condition Grades (based on 2020 data)

Figure 4-25 shows the distribution of condition grades for all assessment types by SPS location. Excluding Belle Isle, Fairview, and Fischer SPSs, approximately half or slightly better of the remaining SPS's assets received a condition grade of 1 ("very good") or 2 ("good"). Each SPS is listed below with a summary of condition scores:

- Blue Hill SPS has approximately 53 (74%) of the assets receiving a condition grade of 1 ("very good") or 2 ("good")
- Belle Isle SPS has approximately 65 (60%) of the assets receiving a condition grade of 3 ("fair") or 4 ("poor").
- Conner Creek SPS has approximately 76 (77%) of the assets receiving a condition grade of 1 ("very good") or 2 ("good")
- Fischer SPS has approximately 13 (87%) of the assets receiving a condition grade of 3 ("fair") or 4 ("poor")
- Freud SPS has approximately 83 (81%) of the assets receiving a condition grade of 1 ("very good") or 2 ("good")
- Fairview SPS has approximately 40 (59%) of the assets receiving a condition grade of 3 ("fair") or 4 ("poor")

- Oakwood SPS has approximately 112 (77%) of the assets receiving a condition grade of 1 ("very good") or 2 ("good") and 21 (14%) receiving a condition grade of 5 ("very poor")
- Woodmere SPS has approximately 32 (57%) of the assets receiving a condition grade of 1 ("very good") or 2 ("good")

While the high percentages of Belle Isle and Fischer SPS assets resulting in fair or poor condition grades could be reflective of the entire condition of these SPS facilities, the percentages could also be influenced by the low number of assets receiving a Planned Maintenance Optimization (PMO) analysis. Oakwood SPS had 21 (14%) of the assets receive a score of 5 ("very poor") as part of the detailed assessments carried out for the CSO Asset Summary Report.

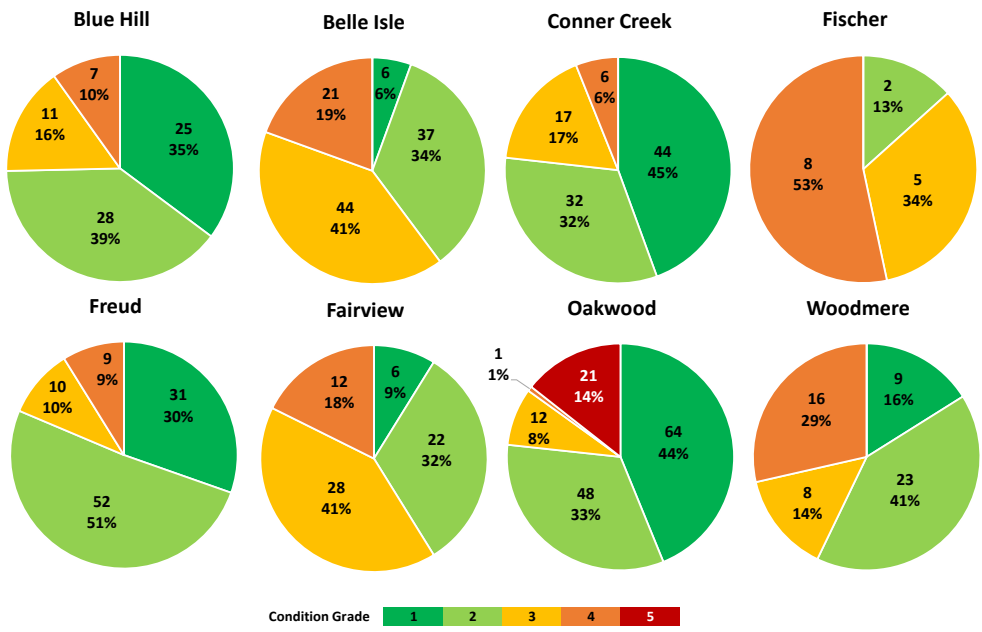


Figure 4-25: Distribution of SPS Facility Asset Condition Grades (based on 2020 data)

4.5.2.3 CSO Facilities

Figure 4-26 displays the CSO condition grades by assessment type for CSO assets.

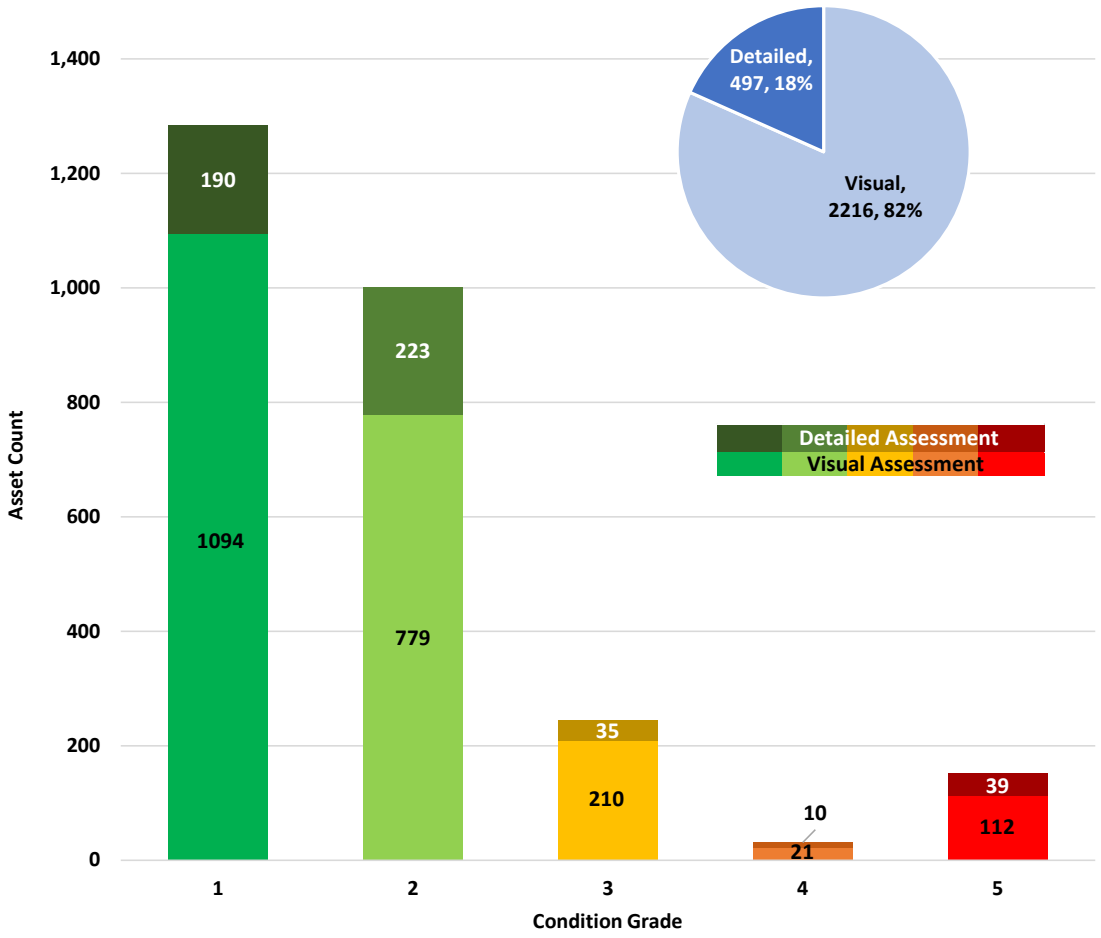


Figure 4-26: CSO Asset Condition Grades by Assessment Type (based on 2020 data)

Figure 4-27and Figure 4-28 below show condition grades by assessment type for the nine CSO facilities.

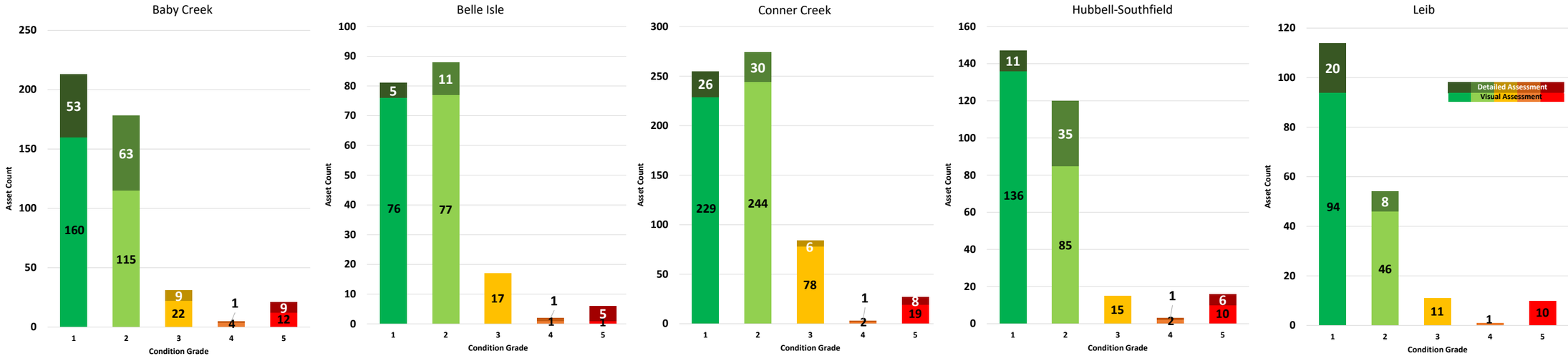


Figure 4-27: CSO Facility Asset Condition Grades by Assessment Type (based on 2020 data)

As shown in Figure 4-28, the vast majority (84%) of CSO assets have condition grade ratings of 1 or 2, with 7% in poor or very poor condition.

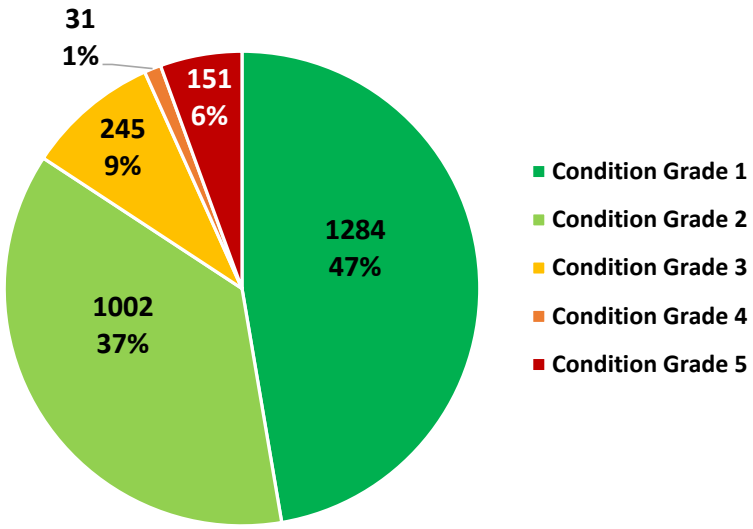


Figure 4-28: CSO Facility Distribution of Asset Condition Assessment Grades (based on 2020 data)

Figure 4-29 shows the distribution of condition grades for all assessment types by CSO facility location. Approximately 84% of the assets received a condition grade of 1 ("very good") or 2 ("good").

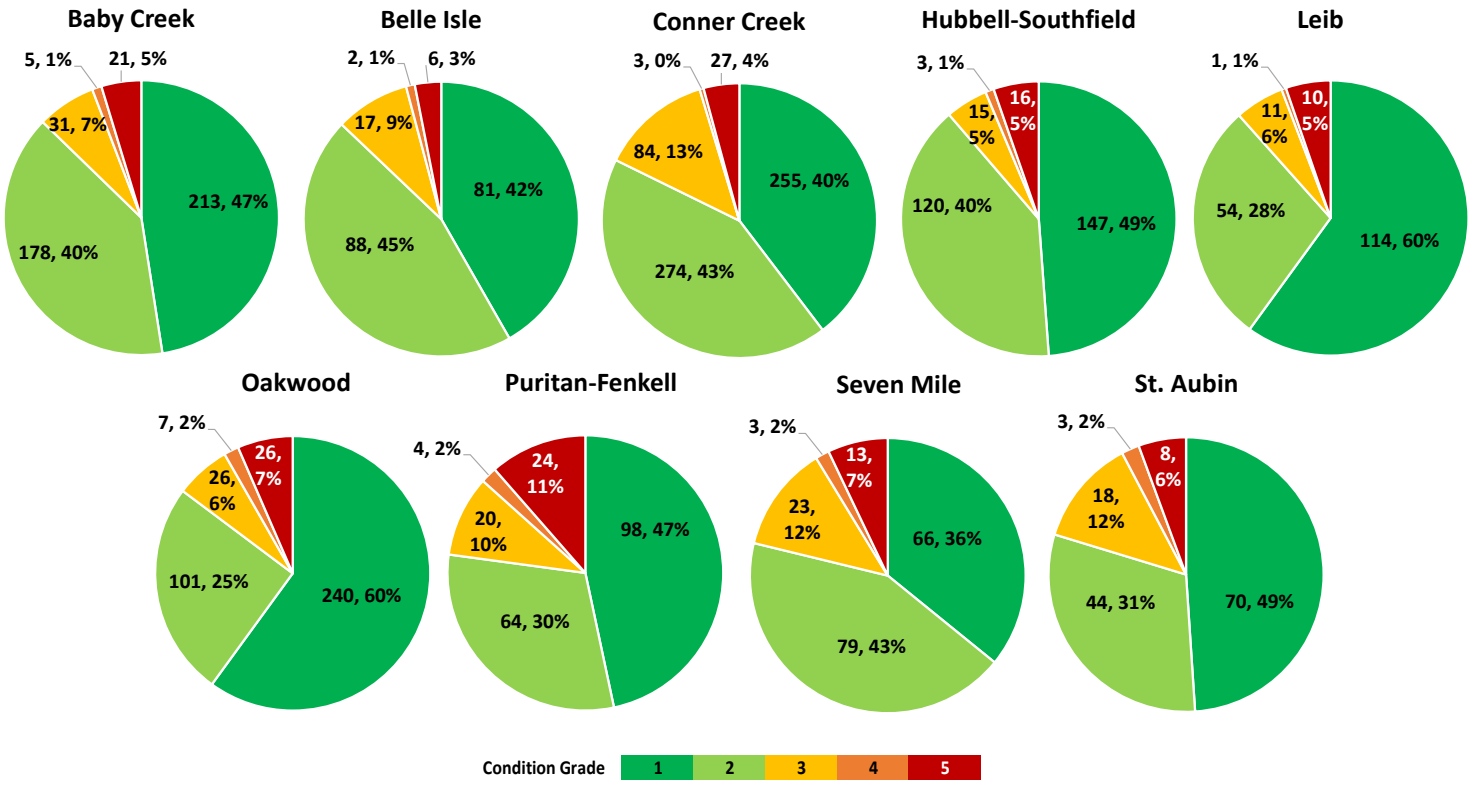


Figure 4-29: CSO Facility Distribution of Asset Condition Assessment Grades (based on 2020 data)

4.6 Asset Value

Asset values can roll up to a total wastewater system cost and inform the development and use of a life cycle model and asset renewal strategy. Chapter 7 summarizes GLWA's current life-cycle models in use. Asset values are tracked in the Financial Asset Registry and are important data points for use with the Scheduled Replacement Plan (SRP) life-cycle model.

Tactical Recommendation WW12: WwAMP - Replacement Cost Database for Vertical Assets is intended to support GLWA with improving alignment between the asset hierarchy and asset valuation to boost confidence in asset valuation data.

5 Asset Risk

The acronyms used throughout this document are included in Appendix A. For a Glossary of Terms, see the SAMP.

Tactical Recommendation:
WW4: WwAMP — Digital Solutions
WW6: WwAMP — Asset Risk for Vertical Assets

Supporting Artifacts:
WwAMP — Risk Register for Vertical Assets (Appendix G)

The purpose of this section is to provide an overview of asset risk levels associated with the asset portfolio to inform prioritization decisions for maintenance, renewals, and rehabilitations.

GLWA risk management is an iterative, continual improvement process. GLWA strives to manage risk through demonstrably improving the ability to meet objectives in a repeatable fashion. GLWA has standardized risk management guidance for organizational risk. The guidance documents are collectively known as the GLWA Risk Management Framework. The framework's principal components include purpose, definitions, and instructions; and the asset risk assessments in this WwAMP align with this framework.

Asset risk is the primary metric for AM planning and decision-making. At GLWA, risk management principles established in the GLWA SAMP serve as the basis for determining asset risk.

Tactical Recommendations WW4: WwAMP – Digital Solutions and WW6: WwAMP - Asset Risk for Vertical Assets presented in Chapter 9 are planned to be implemented to continuously improve the way GLWA identifies and manages wastewater system asset risk. Appendix G includes the WwAMP – Risk Register for Vertical Assets to support ongoing asset management activities.

5.1 GLWA Risk Management and Framework

5.1.1 Risk Management Activities

Risk management activities follow a three-step process:

1. **Risk Identification.** Identifying asset risks centers around understanding asset failure, GLWA service levels, processes, and asset performance expectations required to support service levels.
2. **Risk Analysis.** Analyzing risk involves developing a risk score based on the likelihood that an event will occur and the consequences if the event occurs. A risk score is determined by multiplying the LOF by the COF.
   Risk Score = LOF × COF

3. **Risk Treatment.** Risk treatment refers to GLWA's chosen risk mitigation technique. Section 5.5 discusses risk treatment in further detail.

5.1.2 Risk Scoring

Risk scoring is a powerful tool for the prioritization and selection of activities within a program of work, such as an inspection program, maintenance program or investment program. Risk scores are based on likelihood and consequence. LOF and COF scores are determined by scoring criteria for each category of the respective LOF and COF matrices.

Likelihood Scoring. The LOF Matrix was developed as part of the WwAMP to answer the question, "What is the likelihood the asset will fail?" The six categories are listed below:

1. **Remaining Useful Life (RUL) –** The estimate of the percent of remaining years the asset will function before requiring replacement.
2. **Performance –** An asset's capacity to meet system demands.
3. **Reliability –** History of CM work orders.
4. **Physical Condition –** The condition grade of an asset, measured on a scale of 1 to 5, with 1 being "very good" and 5 being "very poor." Chapter 4 discusses condition grade in more detail.
5. **Adherence to Operation and Maintenance Strategy –** Completeness of, and in accordance with, written O&M strategies for asset performance.
6. **Other –** Other sources of LOF data, including, but not limited to, industry performance trends and institutional knowledge.

Consequence Scoring. For asset risk, the consequence score answers the question, "How bad will it be if the asset fails?" The enterprise risk COF matrix categories were used to maintain consistency of COF scoring. The seven categories are as follows:

1. **Regulatory Compliance –** Regulatory requirements, permit obligations, or enforcement actions.
2. **Impact to Service Levels –** GLWA's ability to achieve service level targets.
3. **Financial Impact –** Requirements for GLWA funds or sources of funds.
4. **Health and Safety –** Near- and long-term health or safety impacts on the public or GLWA team members not addressed in other categories.
5. **Public Impact –** Community priorities, such as quality of life or aesthetics not addressed in other categories.
6. **Environmental Stewardship –** Near- or long-term environmental impacts not addressed in other categories.
7. **Public Trust –** Public confidence in GLWA.

Risk scores are based on consequence and likelihood, each on a scale of 1 to 5, with 5 representing the highest likelihood or consequence and 1 the lowest likelihood or

consequence. Thus, a score of 25 is the highest risk score possible and represents the most severe risk. LOF and COF matrices and category scoring criteria can be found in Appendix E and Appendix H. The actual risk score is not as key as the distribution of risk and the prioritization of assets within the risk scoring.

5.1.3 Risk Tolerance

Risk tolerance is defined as the willingness to bear risk. Figure 5-1 is a risk severity heat map used to illustrate risk tolerance. The map shows how risk tolerance may be determined by considering the likelihood of asset failure and the consequence of that failure. For GLWA, 'Very High' and 'High' asset risk scores, equating to a score of 11 or above, are viewed to be above the GLWA tolerance level.

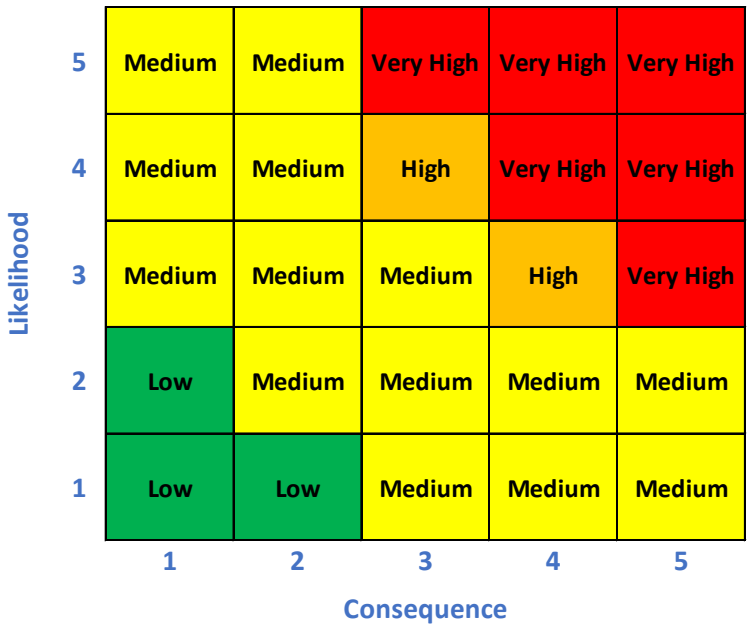


Figure 5-1: Risk Severity Heat Map

5.2 Linear Asset Risk

The detailed methods for calculating LOF, COF, and total risk for linear assets are described in Appendix H. Current risk scores are tracked by LSIP. The data sources that have been used in the methods to populate the risk scores are shown in Table 5-1.

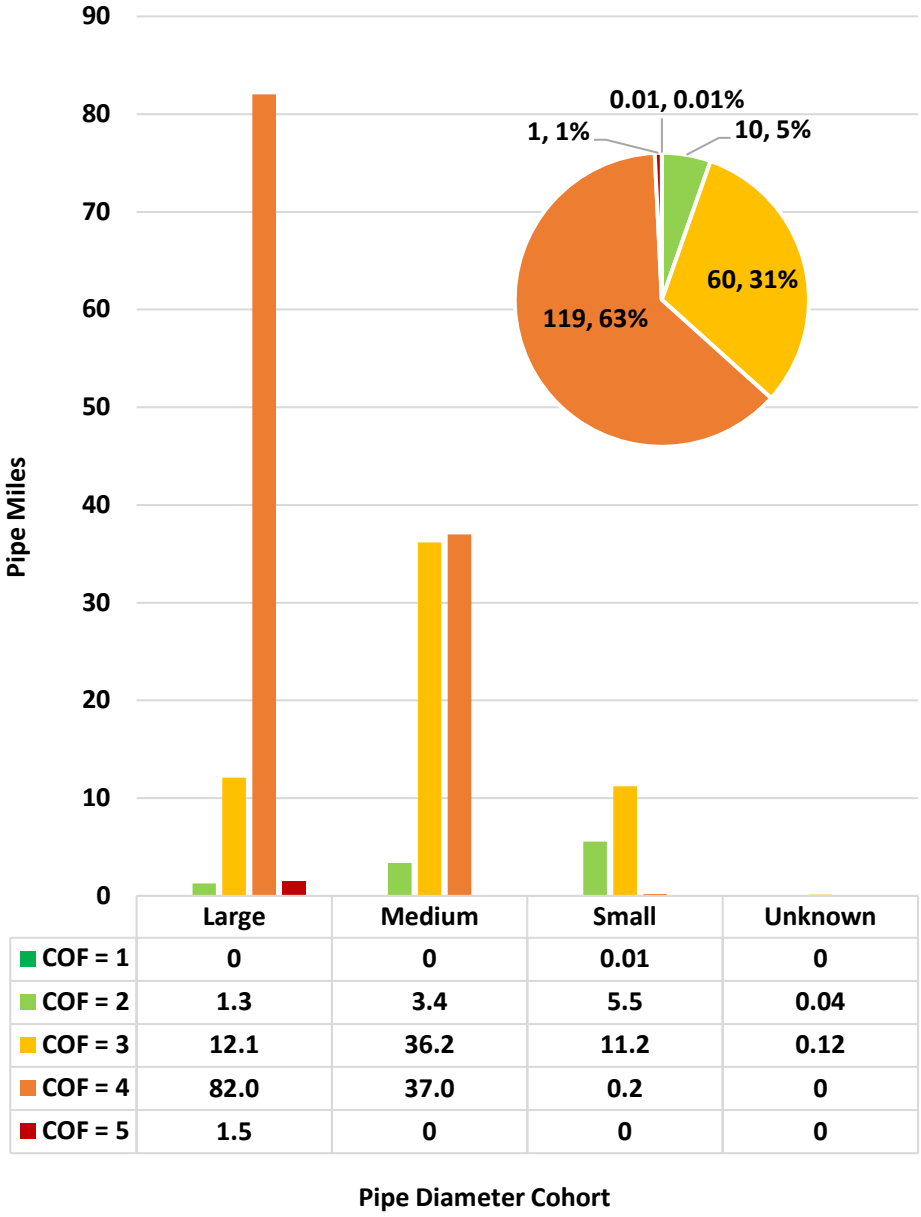
Table 5-1: Data Sources for Linear Risk

Data Source	Source	Description of Data
Replacement Cost	SCREAM (see Appendix E)	Cost to replace the pipe, estimated based on pipe length, diameter, and look-up tables in the SCREAM tool.
Depth	GIS	Average depth of the pipe from upstream and downstream manhole inverts.
Diameter	CCTV and GIS	The diameter listed on the CCTV inspection data was used; if unavailable, then the diameter in GIS was used.
Proximity to: Railroad, Building, Street, and/or Water Body	GIS	The distance in feet from the asset to each of the items (e.g., railroad, street, and water body) was calculated using GIS. The layers came from GIS and other sources [e.g., Water Body uses United States Geological Survey (USGS) wetlands data].
Street Type	GIS	The type of the nearest street (e.g., interstate, other freeways and expressways, minor arterial, major collector, minor collector, or local).
RUL %	SCREAM (see Appendix E)	For inspected pipes, SCREAM estimates RUL by examining structural score and decay curves. For non-inspected pipes, the install date was used. For lined pipes, this date was set equal to 50 years.
Average Maintenance Grade	SCREAM (see Appendix E)	The average condition grade relating to maintenance defect over all inspections on a pipe.
Sag Grade	SCREAM (see Appendix E)	The latest condition grade, looking at only sag defects on the pipe.
Slope Less than Minimum	GIS	A combination of diameter and pipe slope was used to determine whether the slope was below the minimum slope per the Ten-State Standards.
Structural Grade	SCREAM (see Appendix E)	The latest structural condition grade, looking at only structural defects on the pipe.
II Score (Infiltration and Inflow)	SCREAM (see Appendix E)	The latest II score (0-100), looking at only infiltration and inflow defects on the pipe.

5.2.1 Consequence of Failure

The calculated COF scores showing the miles of pipe for each COF score are shown in Figure 5-2. Current risk scores are tracked by LSIP.

Approximately 90% of the pipe miles have a COF score of 3 or 4. This result seems reasonable because most of the GLWA system contains large-diameter, deeply buried pipes that lead to a high COF.



	Large	Medium	Small	Unknown
COF = 1	0	0	0.01	0
COF = 2	1.3	3.4	5.5	0.04
COF = 3	12.1	36.2	11.2	0.12
COF = 4	82.0	37.0	0.2	0
COF = 5	1.5	0	0	0

Figure 5-2: Miles of Pipe by COF Score (based on 2020 data)

Figure 5-3 maps the COF scores of each pipe in the system.

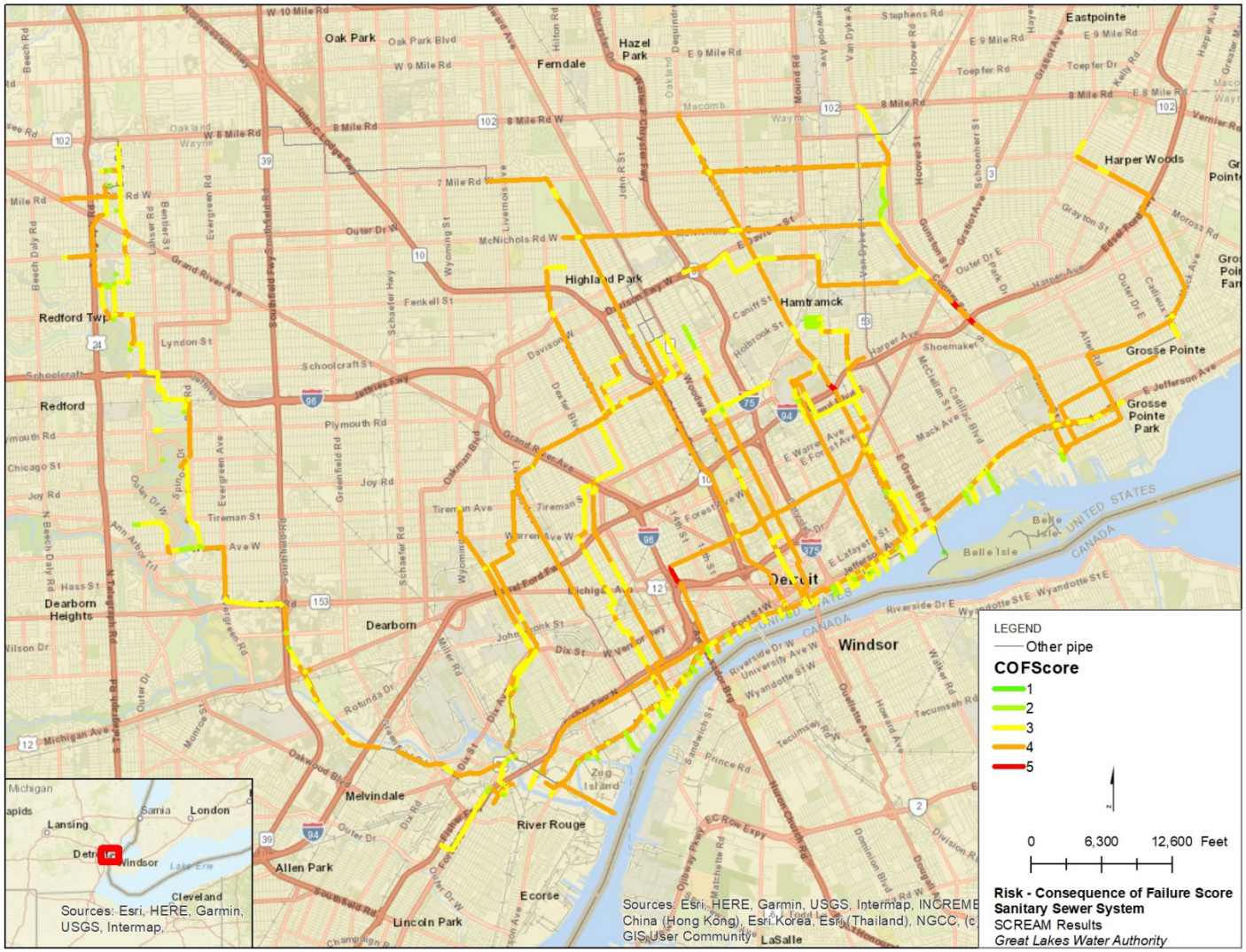
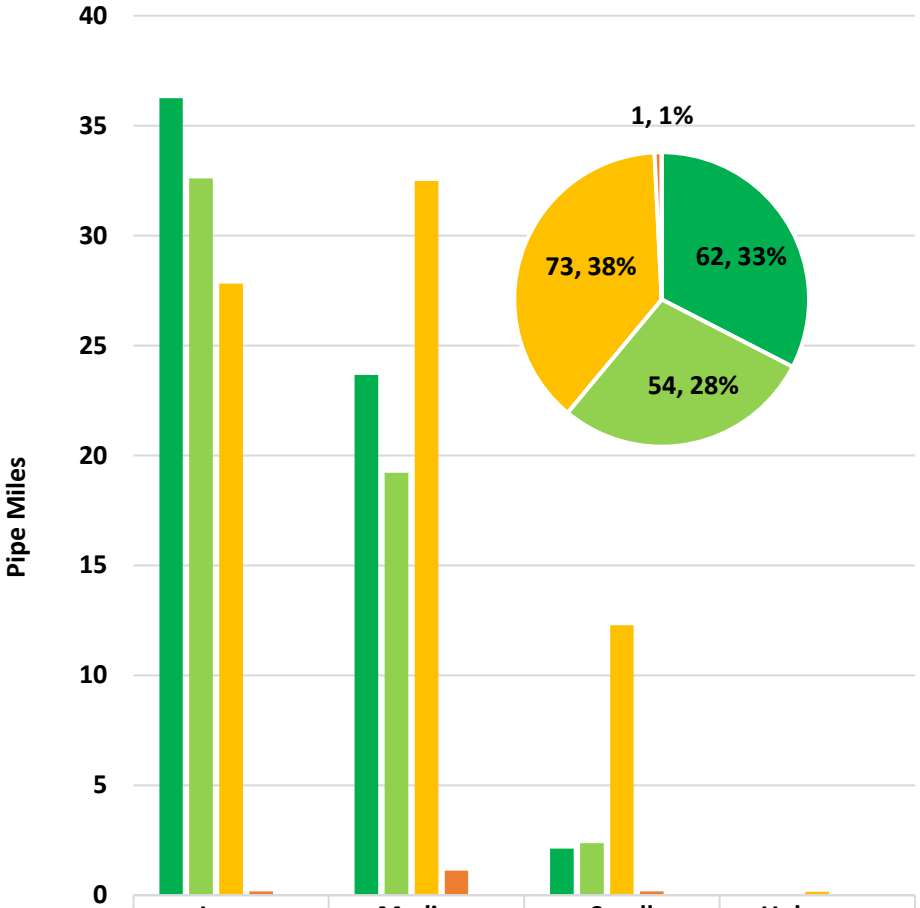


Figure 5-3: Map of Linear COF Scores

5.2.2 Likelihood of Failure

The calculated LOF scores showing the miles of pipe for each LOF score are shown in Figure 5-4. Approximately 61% of the pipe miles have an LOF score of 1 or 2.



	Large	Medium	Small	Unknown
LOF = 1	36.3	23.7	2.1	0
LOF = 2	32.6	19.2	2.4	0
LOF = 3	27.8	32.5	12.3	0.2
LOF = 4	0.2	1.1	0.2	0
LOF = 5	0	0	0	0

Pipe Diameter Cohort

Figure 5-4: Miles of Sewer by LOF Score (based on 2020 data)

Figure 5-5 maps the LOF scores of each pipe in the system.

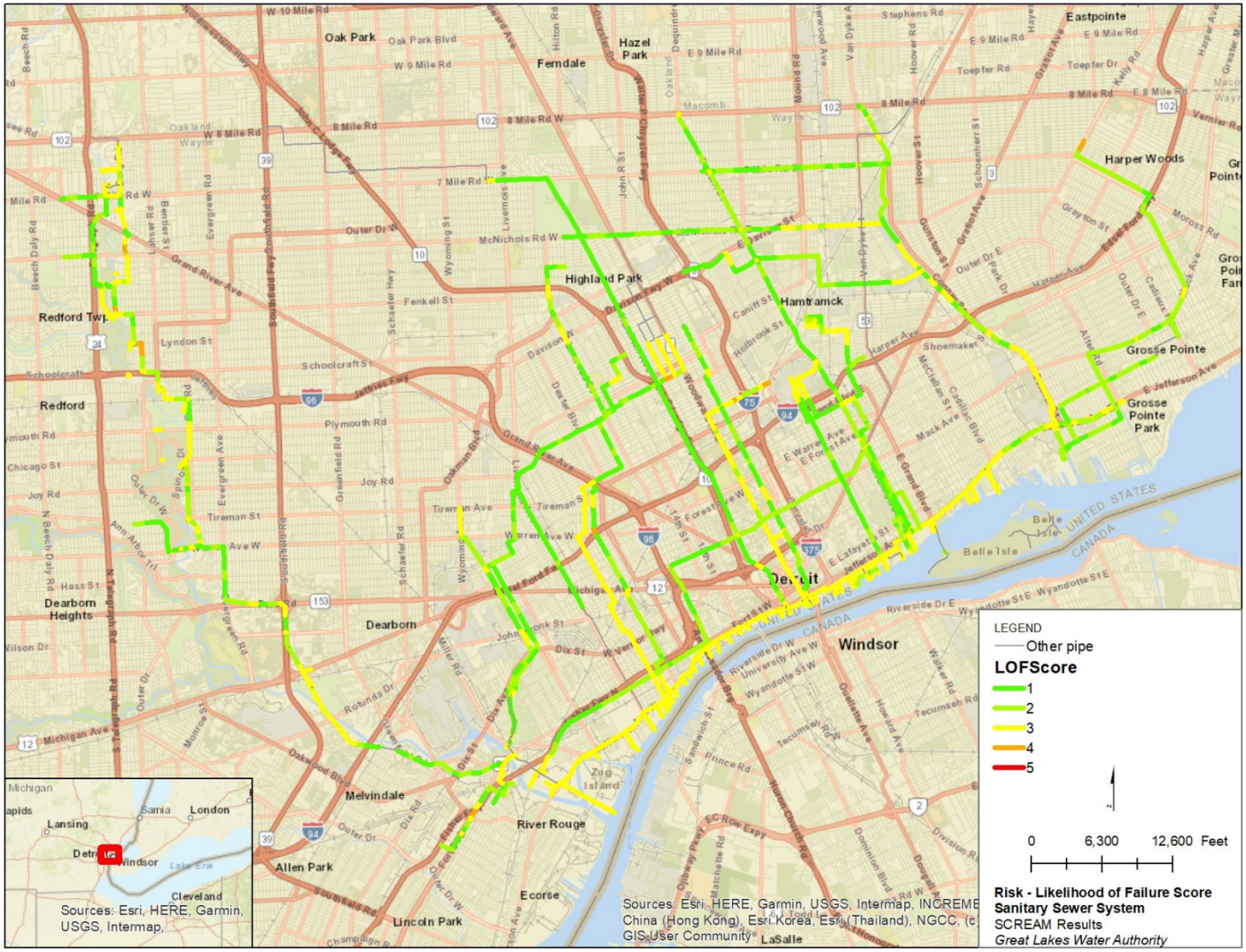


Figure 5-5: Map of Linear LOF Scores

5.3 Vertical Asset Risk

The risk scores for vertical assets were developed through a multi-step, iterative process as shown in Figure 5-6. First, a preliminary set of risk scores were calculated based on available data in WAM and workshops with staff. The methodology is described in Appendix H. Using the preliminary scores, high-risk assets were selected for condition assessments. The risk scores were then updated with the results of the condition assessment to develop a draft Risk Register that was reviewed with GLWA staff. The risk scores were then subject to multiple further rounds of review and update. The resulting Risk Register (Appendix G) includes the resulting heat map graphs.

The detailed methods for calculating LOF, COF, and risk scores for vertical assets are given in Appendix H.

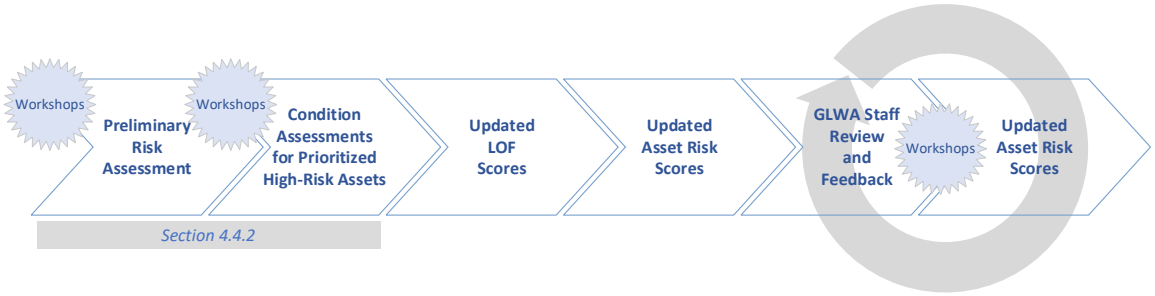


Figure 5-6: Vertical Asset Risk Process Flow Diagram

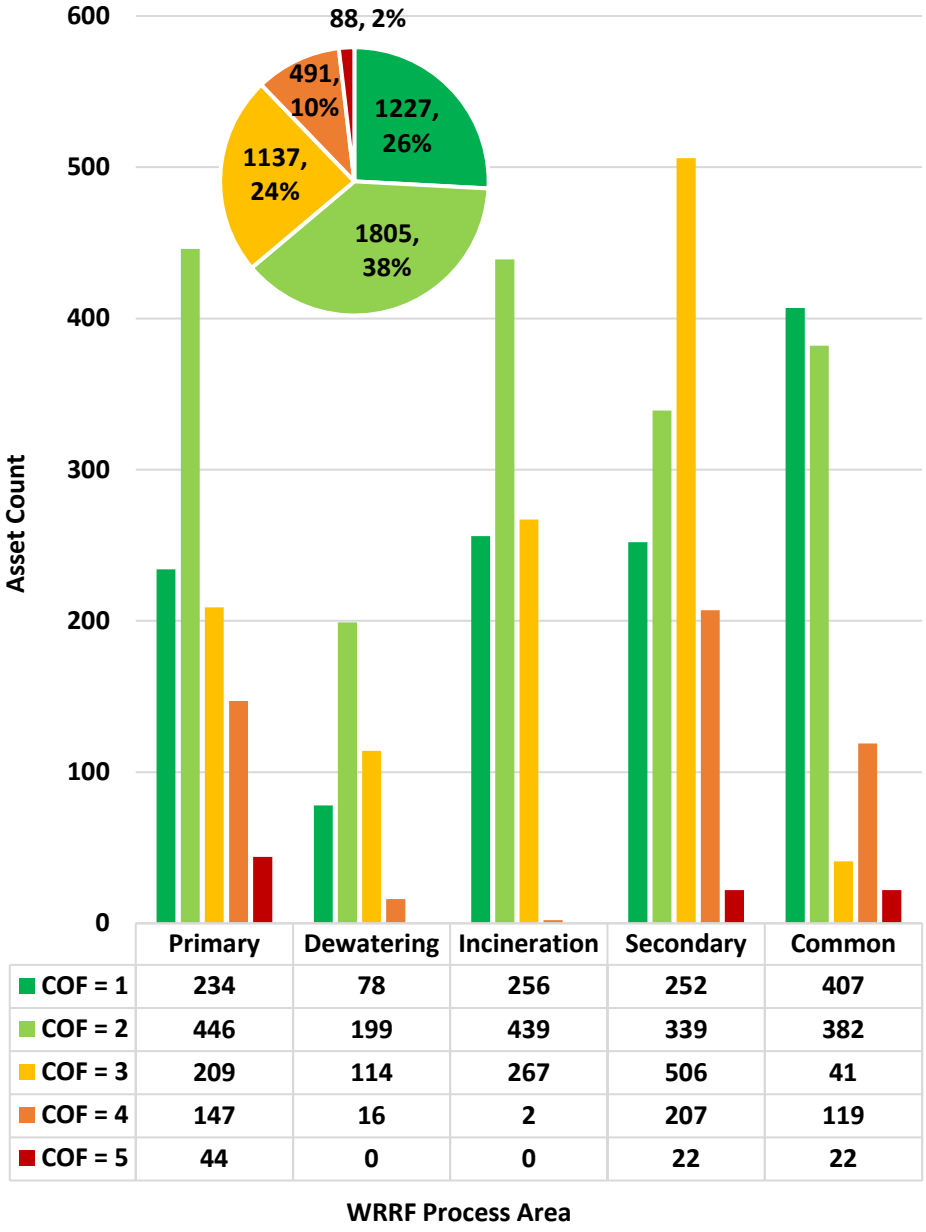
5.3.1 Consequence of Failure

Water Resource Recovery Facility

The calculated COF scores by process area are shown in Figure 5-7.

- Approximately 64% of WRRF assets received a COF score of 1 or 2
- Approximately 24% received a 3
- Approximately 12% received a 4 or 5

The higher COF scores of 4 and 5 were concentrated in the Primary, Secondary, and Common Support process areas, which contain equipment such as the main lift pumps, chlorination and dechlorination feed, and electrical distribution infrastructure for power, respectively.



	Primary	Dewatering	Incineration	Secondary	Common
COF = 1	234	78	256	252	407
COF = 2	446	199	439	339	382
COF = 3	209	114	267	506	41
COF = 4	147	16	2	207	119
COF = 5	44	0	0	22	22

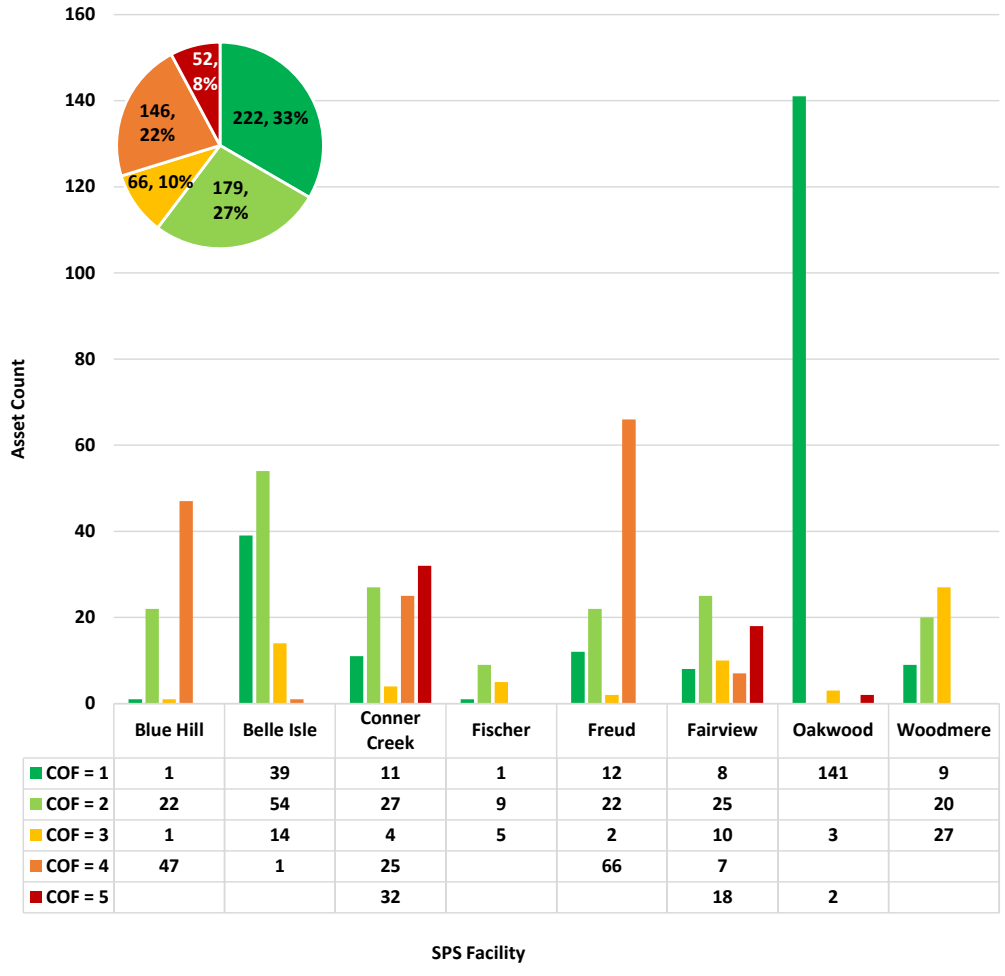
Figure 5-7: Count of WRRF Assets by COF Score (based on 2020 data)

Sewage Pump Stations

The calculated COF scores by SPS are shown in Figure 5-8. Approximately 62% of SPS assets received a COF score of 1 or 2.

- Approximately 7% received a 3
- Approximately 31% received a 4 or 5

The higher COF scores of 4 and 5 occurred at the electrical distribution infrastructure, pumping systems, and facility storage wells. Conner Creek and Fairview SPS facilities account for almost all (96%) of the assets with a COF score of 5. Conner Creek and Fairview are two of the most critical SPS facilities and have the largest dry weather flow capacities, at 336 mgd each.



	Blue Hill	Belle Isle	Conner Creek	Fischer	Freud	Fairview	Oakwood	Woodmere
COF = 1	1	39	11	1	12	8	141	9
COF = 2	22	54	27	9	22	25		20
COF = 3	1	14	4	5	2	10	3	27
COF = 4	47	1	25		66	7		
COF = 5			32			18	2	

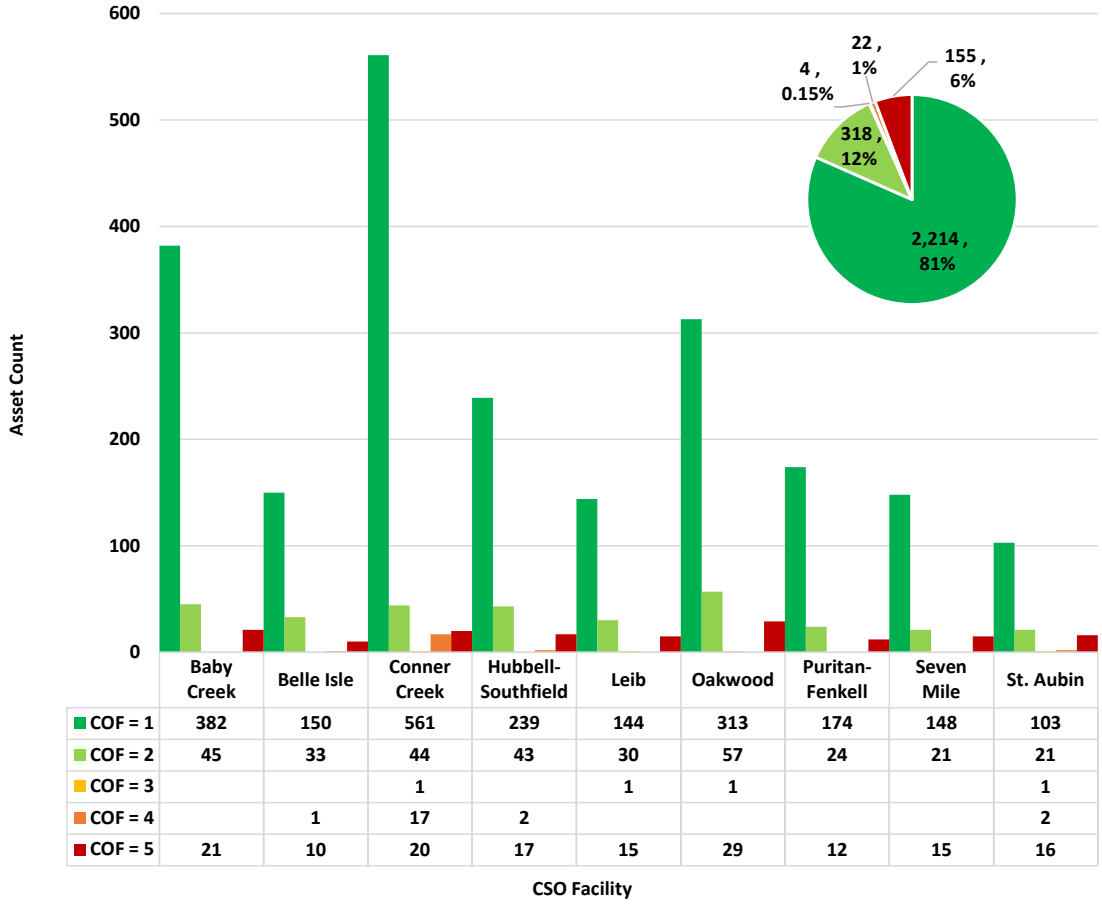
Figure 5-8: Count of SPS Assets by COF Score (based on 2020 data)

Combined Sewer Overflow Facilities

The calculated COF scores by CSO facility are shown in Figure 5-9.

- The majority of CSO assets received a COF score of 1 or 2 (approximately 93%)
- Approximately 7% received a 4 or 5

The higher COF scores of 4 and 5 occurred at electrical distribution infrastructure, disinfection piping, screening systems, and retention basins. Conner Creek has the largest CSO hydraulic capacity (approximately 9,000 mgd) and storage volume (30 MG) as well as the highest number of high COF scores.



	Baby Creek	Belle Isle	Conner Creek	Hubbell-Southfield	Leib	Oakwood	Puritan-Fenkell	Seven Mile	St. Aubin
COF = 1	382	150	561	239	144	313	174	148	103
COF = 2	45	33	44	43	30	57	24	21	21
COF = 3			1		1	1			1
COF = 4		1	17	2					2
COF = 5	21	10	20	17	15	29	12	15	16

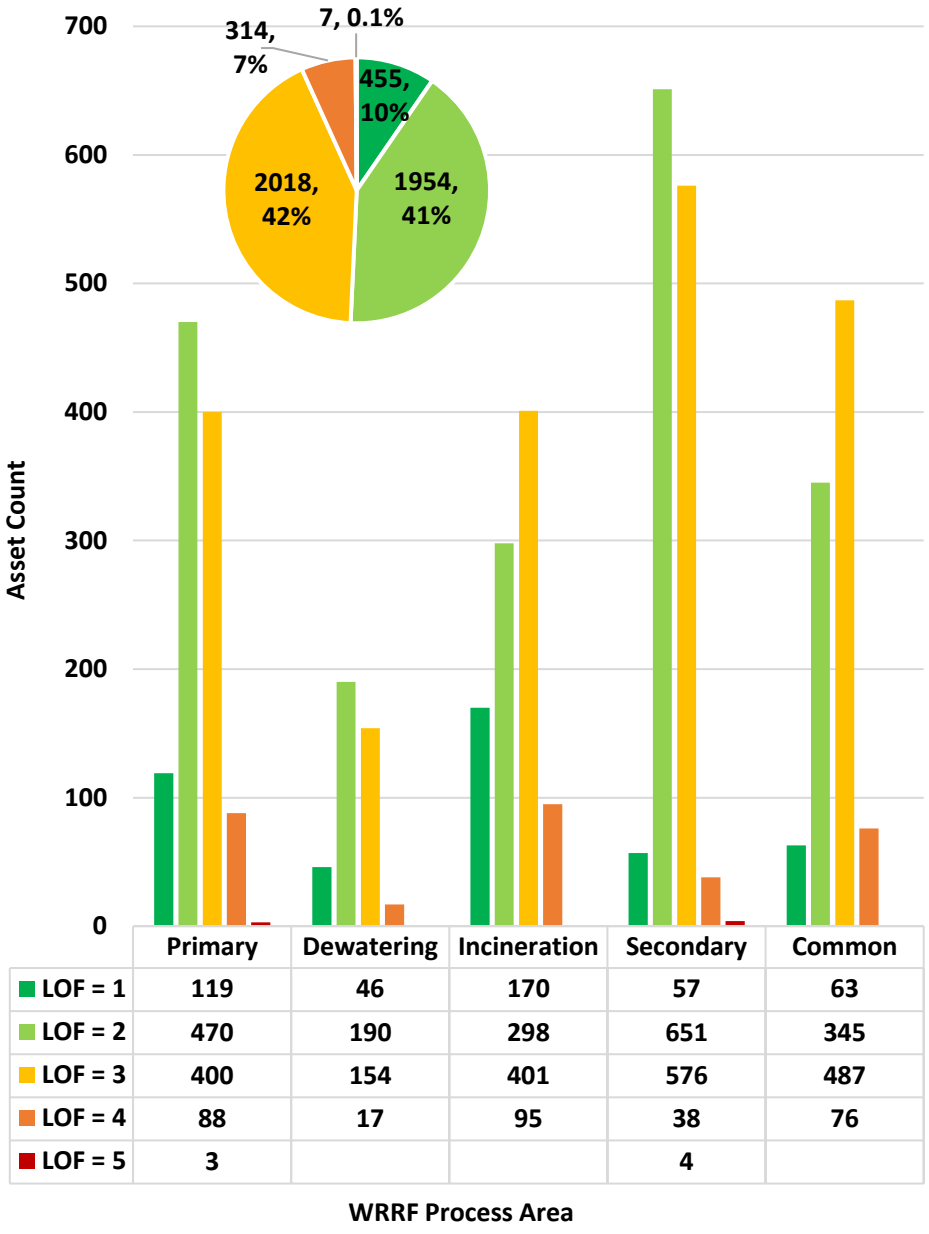
CSO Facility

Figure 5-9: Count of CSO Assets by COF Score (based on 2020 data)

5.3.2 Likelihood of Failure

Water Resource Recovery Facility

The calculated LOF scores by process area are shown in Figure 5-10. Approximately 51% of WRRF assets received an LOF score of 1 or 2, approximately 42% received a 3, and slightly over 7% received a 4 or 5. The majority of the assets in Primary, Dewatering, and Secondary received an LOF score of 1 or 2, and the majority of assets in Incineration and Common Support received a score of 3 or higher.

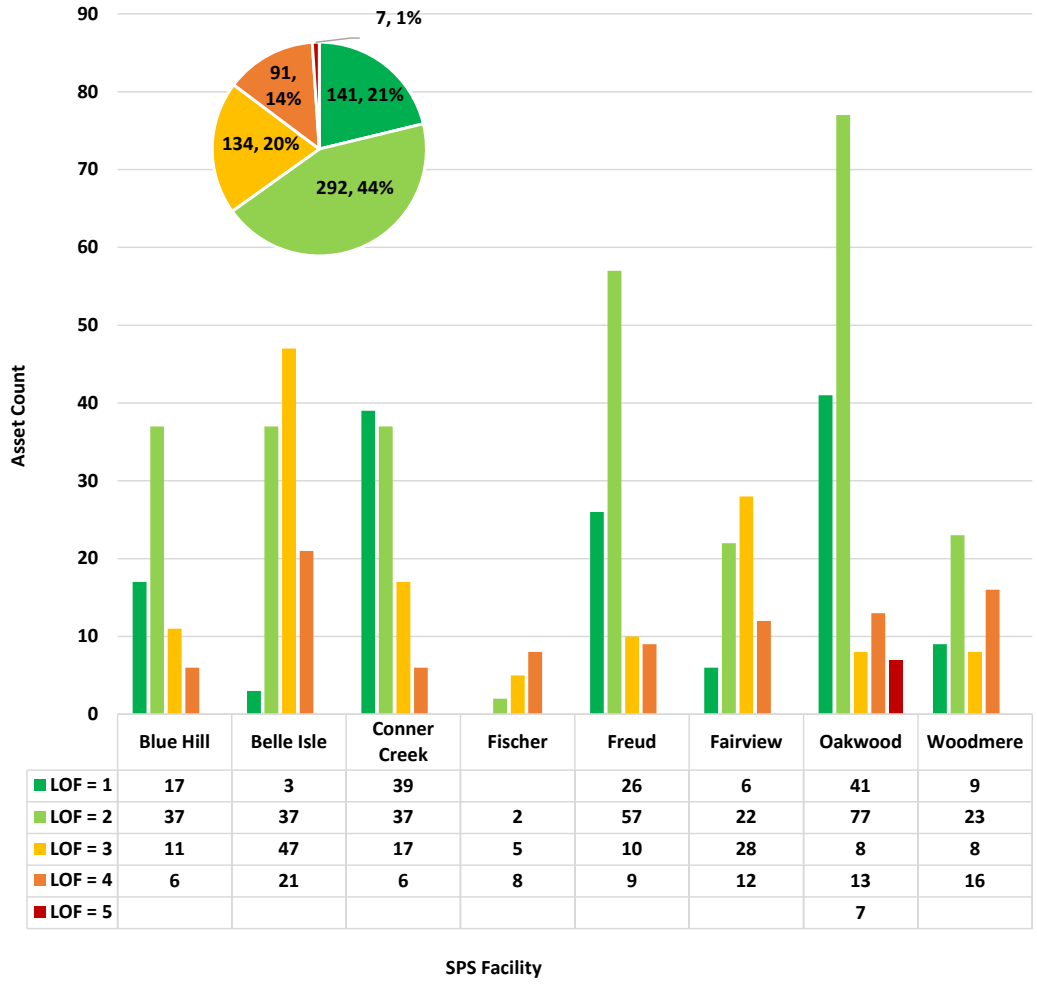


	Primary	Dewatering	Incineration	Secondary	Common
LOF = 1	119	46	170	57	63
LOF = 2	470	190	298	651	345
LOF = 3	400	154	401	576	487
LOF = 4	88	17	95	38	76
LOF = 5	3			4	

Figure 5-10: Count of WRRF Assets by LOF Score (based on 2020 data)

Sewage Pump Stations

The calculated LOF scores by SPS are shown in Figure 5-11. Approximately 64% of SPS assets received an LOF score of 1 or 2, approximately 20% received a 3, and approximately 15% received a 4 or 5. The majority of the assets for Blue Hill, Conner Creek, Freud, Oakwood, and Woodmere received an LOF score of 1 or 2, while the majority of assets in Belle Isle, Fairview, and Fischer have an LOF score of 3 or higher.

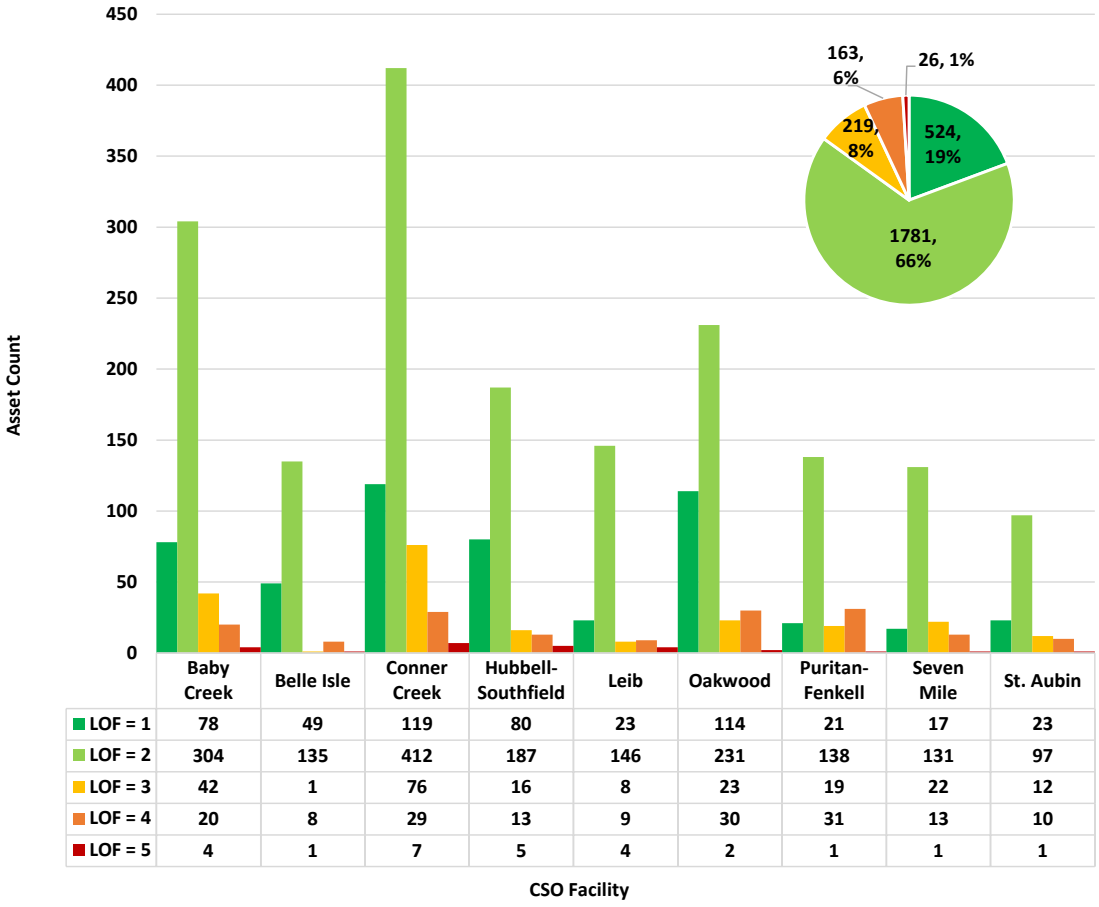


	Blue Hill	Belle Isle	Conner Creek	Fischer	Freud	Fairview	Oakwood	Woodmere
LOF = 1	17	3	39		26	6	41	9
LOF = 2	37	37	37	2	57	22	77	23
LOF = 3	11	47	17	5	10	28	8	8
LOF = 4	6	21	6	8	9	12	13	16
LOF = 5							7	

Figure 5-11: Count of SPS Assets by LOF Score (based on 2020 data)

Combined Sewer Overflow Facilities

The calculated LOF scores by CSO are shown in Figure 5-12. Approximately 85% of CSO assets received an LOF score of 1 or 2, approximately 8% received a 3, and approximately 7% received a 4 or 5. At all CSO facilities, the majority of the assets received an LOF score of 1 or 2.



	Baby Creek	Belle Isle	Conner Creek	Hubbell-Southfield	Leib	Oakwood	Puritan-Fenkell	Seven Mile	St. Aubin
LOF = 1	78	49	119	80	23	114	21	17	23
LOF = 2	304	135	412	187	146	231	138	131	97
LOF = 3	42	1	76	16	8	23	19	22	12
LOF = 4	20	8	29	13	9	30	31	13	10
LOF = 5	4	1	7	5	4	2	1	1	1

CSO Facility

Figure 5-12: Count of CSO Facility Assets by LOF Score (based on 2020 data)

5.4 Summary of Total Risk Scores

Total asset risk is the product of LOF and COF. The following equation is used to calculate total asset risk:

Total Asset Risk = LOF x COF

5.4.1 Linear Assets

Total risk for linear assets is presented in Figure 5-13 as miles of pipe on the risk severity heat map. The wastewater collection system generally has a high consequence of failure (COF) due to its function as the downstream endpoint for small-diameter collection systems owned by the member partners. Most of the pipe length, as shown below, has a relatively high COF score of 4 and an LOF score of 3. In the absence of providing redundant pipelines or significant changes to the system, reducing COF is often not an option. Total risk for linear assets is typically lowered by reducing the LOF through PM, monitoring, and rehabilitation. Reducing COF typically involves twinning or improving system connectivity, which may be cost prohibitive. Risk treatment for linear assets is described in Section 5.5.

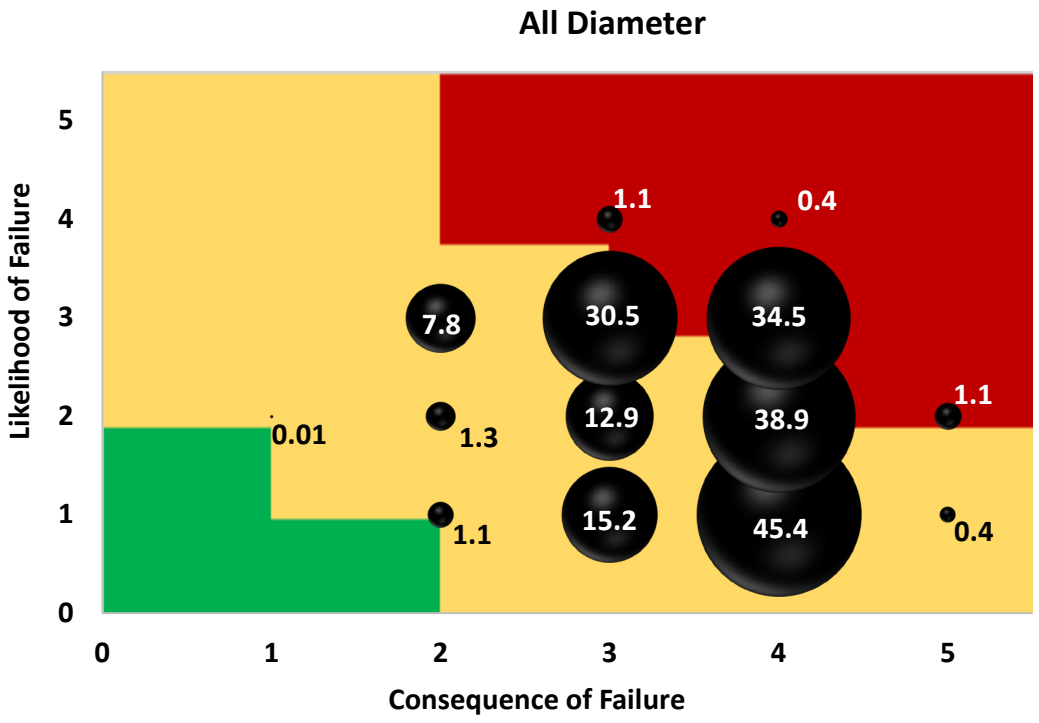


Figure 5-13: Miles of All-Diameter Pipe by Total Risk (based on 2020 data)

Figure 5-14 provides a breakdown of total risk by pipe diameter cohort (small, medium, large). The large-diameter pipes have a higher COF, and thus higher total risk.

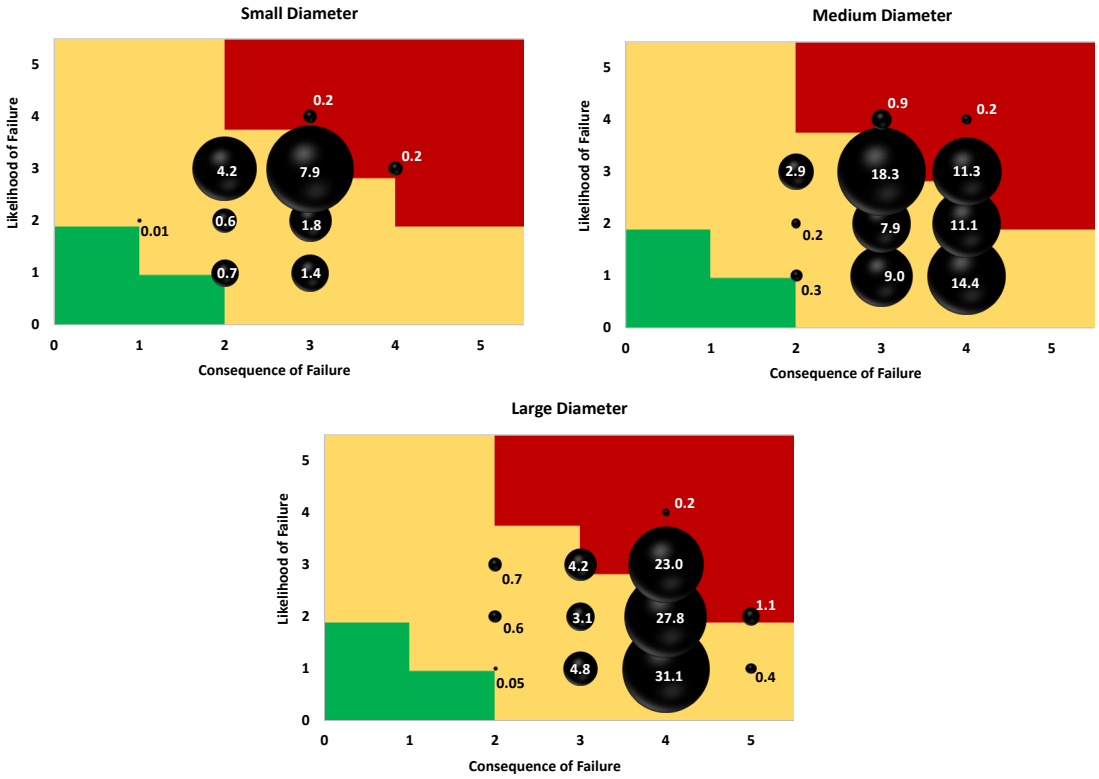


Figure 5-14: Miles of Pipe by Diameter Cohort by Total Risk (based on 2020 data)

5.4.2 Vertical Assets

5.4.2.1 Water Resource Recovery Facility

Total risk for WRRF assets is presented in Figure 5-15 as count of assets on the risk severity heat map. A small proportion of the assets fall into the high-risk (red) category. These are distributed across the process areas with most occurring in secondary treatment as shown in Figure 5-16.

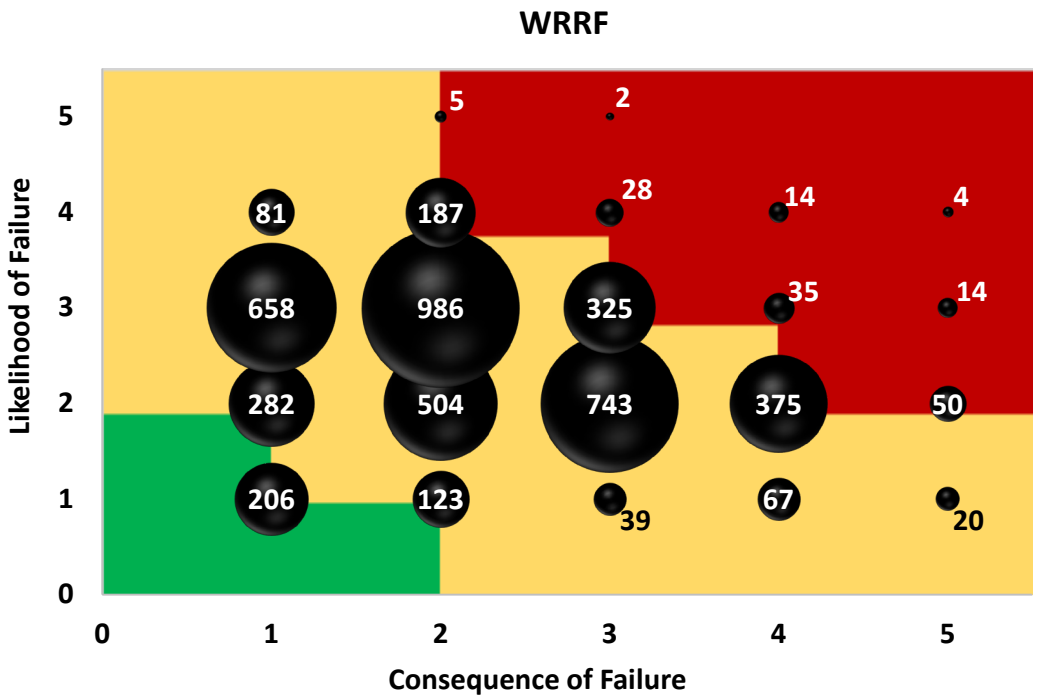


Figure 5-15: Count of WRRF Assets by Total Risk (based on 2020 data)

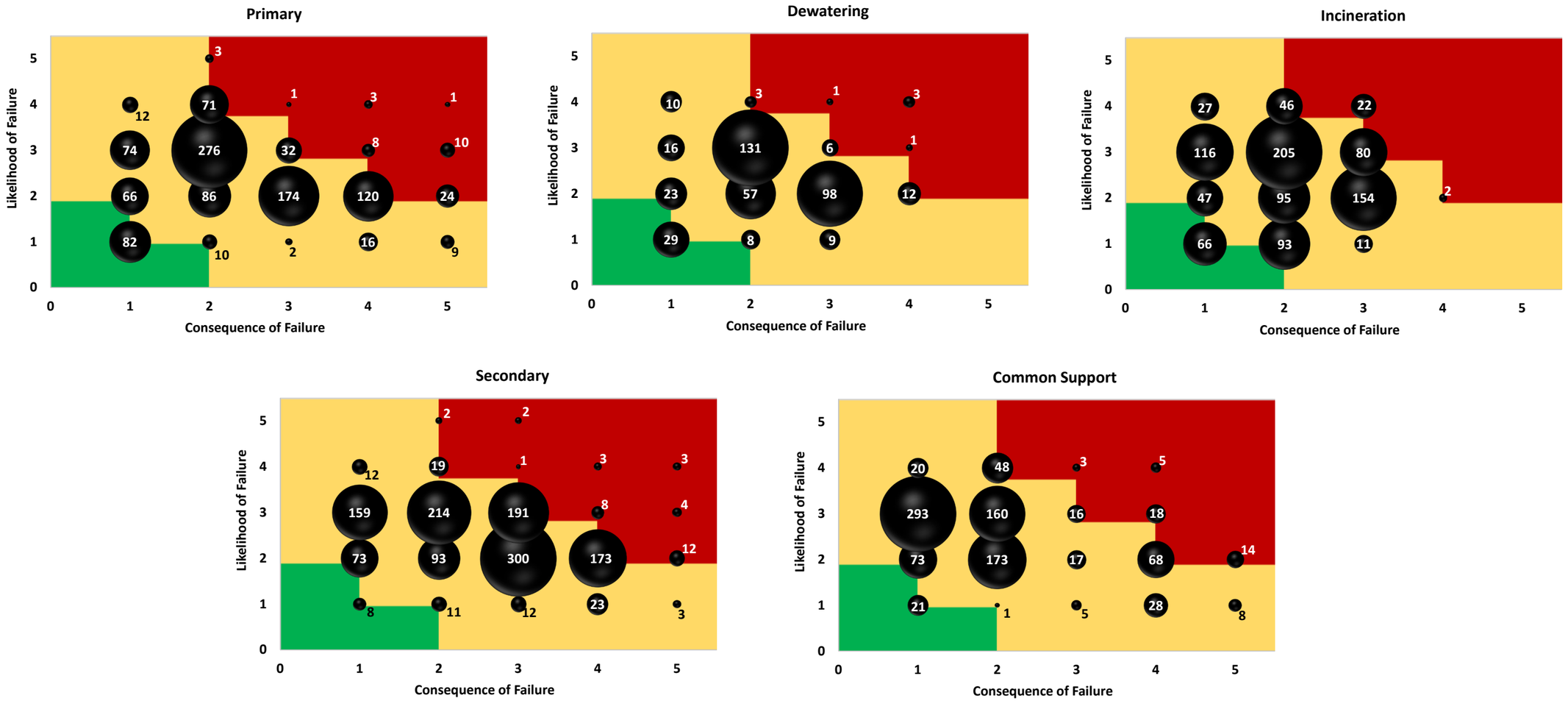


Figure 5-16: Count of WRRF Assets by Process Area by Total Risk (based on 2020 data)

5.4.2.2 Sewage Pump Stations

Total risk is presented in Figure 5-17 as count of assets on the risk severity heat map. This shows a similar pattern to the WRRF with the majority of assets in the medium-risk category and a small proportion of high-risk assets. However, compared to WRRF assets, a larger portion of SPS assets have a high COF score of 4 or greater. The high COF assets are concentrated in Blue Hill, Conner Creek, and Freud SPS facilities as shown in Figure 5-18.

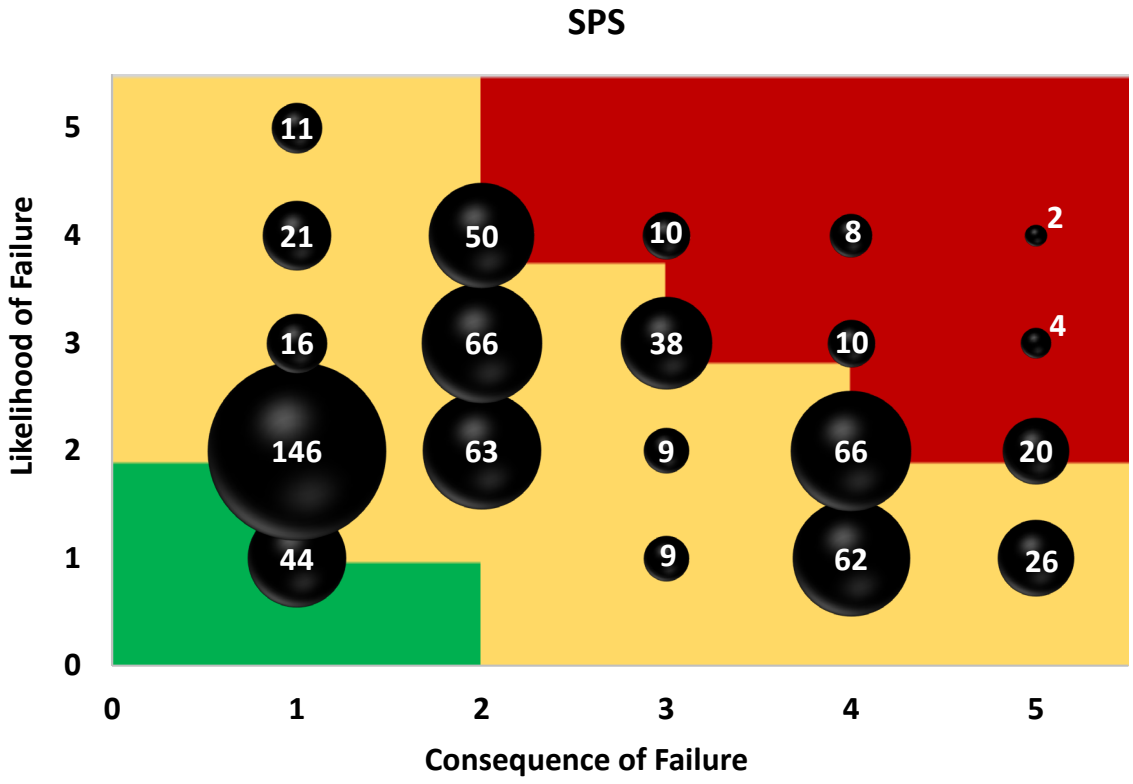


Figure 5-17: Count of SPS Assets by Total Risk (based on 2020 data)

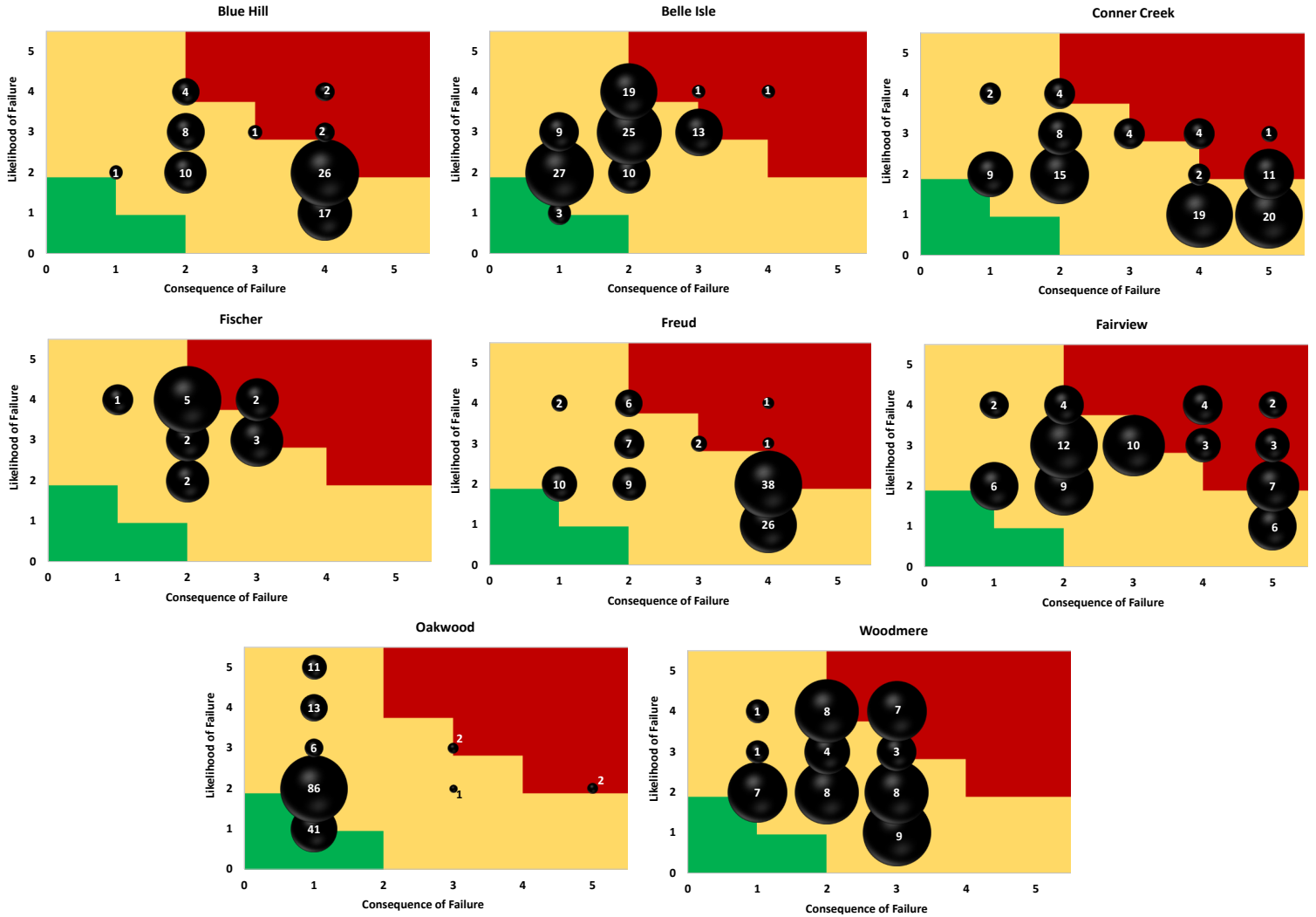


Figure 5-18: Count of SPS Assets by SPS by Total Risk (based on 2020 data)

5.4.2.3 Combined Sewer Overflow Facilities

Total risk is presented in Figure 5-19 as count of assets on the risk severity heat map. The majority of assets have low risk and only a small number of assets are high-risk. The high-risk assets are distributed across the CSO facilities as shown in Figure 5-20.

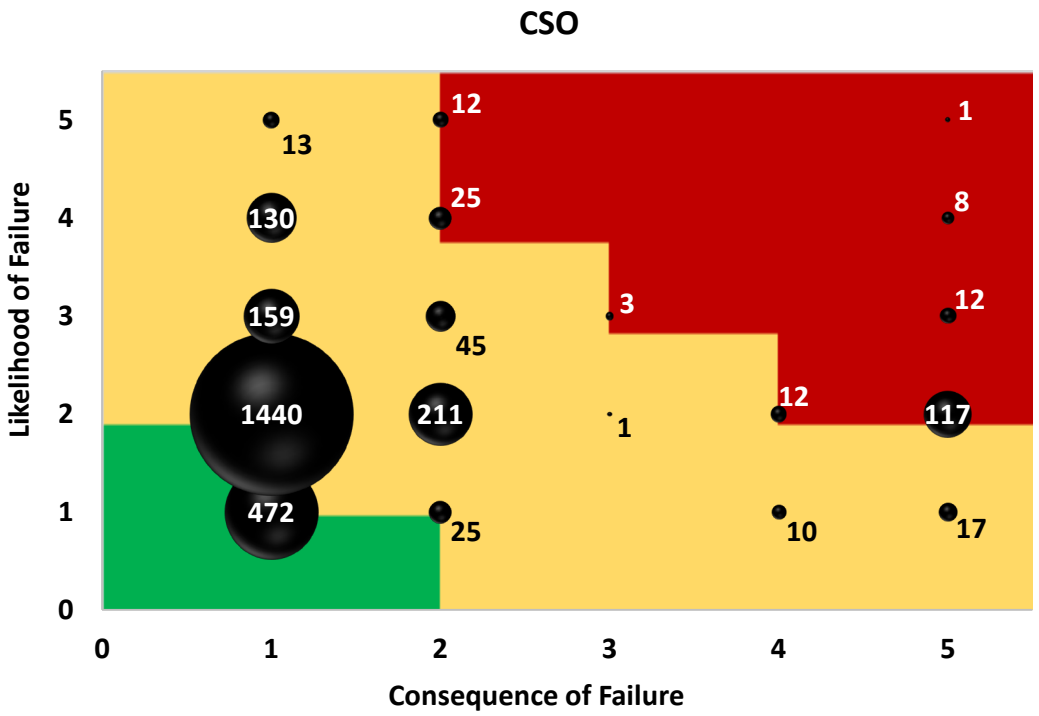


Figure 5-19: Count of CSO Facility Assets by Total Risk (based on 2020 data)

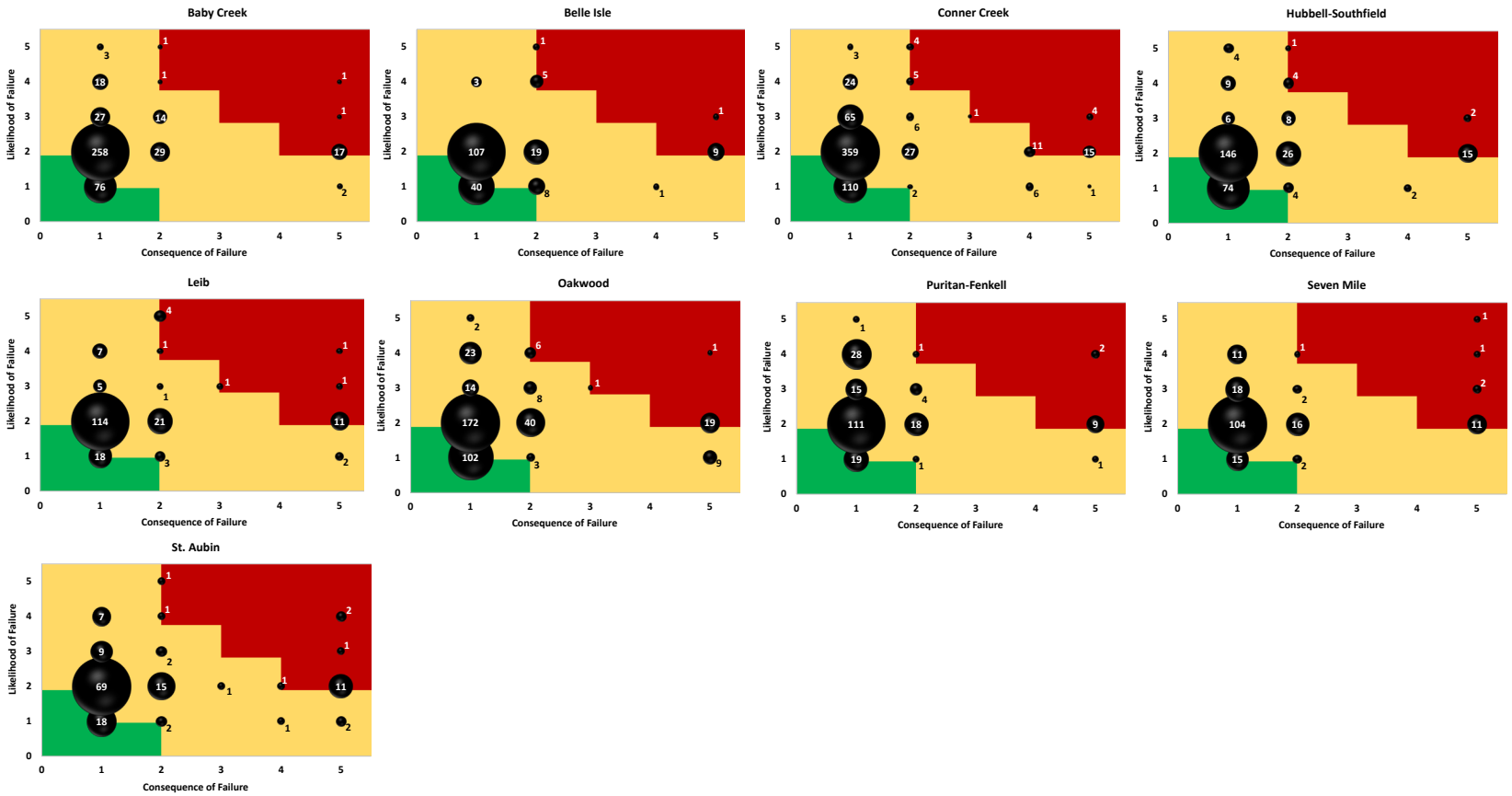


Figure 5-20: Count of CSO Assets by Total Risk for Each CSO Facility (based on 2020 data)

5.5 Risk Treatment

Risk assessment and the resulting risk scores are the first steps in the overall risk management process. Understanding risk is a valuable tool for the prioritization of work such as inspections, maintenance, and renewals.

Risk should be treated as an early value management activity and consideration given to a range of possible treatment options before committing to a particular solution. For utility assets, there are a range of potential treatment options that are commonly employed such as the following:

- Major capital projects (CIP) that address one or more risks
- Minor capital projects (Capital Outlay, improvements and extension (I&E))
- Emergency response plans or arrangements
- O&M strategies such as modified operational regimes or modified maintenance regimes
- Interim solutions that partially reduce risk for a short, defined period of time until a permanent solution is implemented
- Educational or other strategies that address the behavior or actions of third parties

5.5.1 Linear Assets

For the linear assets, pipe defects found through CCTV field inspection drive the identification of risk treatment options. SCREAM incorporates defect counts, severities, and types for determining the best options for the pipe, which include the following:

- Pipe segments renewals
- Defined intervals for cleaning and/or CCTV inspection

The preliminary program for CCTV inspections is reported further in Chapter 6, and the preliminary program for renewals of pipe segments is reported further in Chapter 7.

5.5.2 Vertical Assets

For the vertical assets, risk scores drive the identification of risk treatment options, which include the following:

- Condition Assessment - The prioritization and selection of 1,000 assets across WRRF and SPS (see Chapter 4)
- Planned Maintenance Optimization (PMO) and FMEA - The prioritization and selection of assets within the WRRF (see Chapter 6)
- CIP
- Emergency Response Preparation

5.5.2.1 High-Risk Assets

As discussed in Section 5.1.3, risk tolerance was established by relating risk scores (on a 1-25 scale) to risk severity (from low to very high). For GLWA, 'Very High' and 'High' asset risk scores, equating to a score of 11 or above, are viewed to be above the GLWA tolerance level.

The risk assessment performed in 2021 resulted in the identification of 280 high-risk assets across WRRF and SPS. The assets were cross-checked against the pre-existing CIP; results revealed all but 47 assets were addressed by projects in the CIP. The remaining 47 assets were investigated in more detail and resulted in further updates to the risk scores, leaving eight high-risk assets not addressed by the CIP as shown in Table 5-2.

Table 5-2: High-Risk WRRF Assets without CIP Project

Process Area	Asset Type	Asset Description	Revised Risk
Common	SWITCHGR	SUBSTATION, 4800V SWITCHGEAR, FOR EMERGENCY GENERATOR D2, LOCATED NORTH OF EB-2, WRRF	12.61
Common	TRANSFRMR	SUBSTATION, EB-4, 24,000V TO 4160V, BUILDING SOUTHWEST OF CHLORINATION & DECHLORINATION, WRRF	12.35
Common	TRANSFRMR	SUBSTATION, EB-5, SUB CD-2, 480V SWITCHGEAR, DECHLORINATION FACILITY, WRRF	12.35
Common	BUILDING	ELECT. BLDG. NO.21, EB-21, SLUDGE PROCESSING A, WRRF	12.00
Common	SWITCHGR	SUBSTATION, EB-4, 24,000V TO 4160V, BUILDING SOUTHWEST OF CHLORINATION & DECHLORINATION, WRRF	11.71
Incineration	SWITCHGR	SUBSTATION, EB-17, SUB ST-3, OUTDOOR SWITCHGEAR, 480 V SWITCHGEAR, CENTRIFUGE (BIRD) BUILDING, WRRF	12.30
Incineration	COND-AIR	HVAC, A/C- PAC 1, INC C II, ID FAN VFD ENCLOSURE, ROOF; MFG: TRANE, INTELLIPAK	11.10
Incineration	COND-AIR	HVAC, A/C- PAC 2, INC C II, ID FAN VFD ENCLOSURE, ROOF; MFG: TRANE, INTELLIPAK	11.10

Examples of some of the outstanding asset needs for the WRRF and SPS are described in Table 5-3 and Table 5-4. These needs include a range of underlying causes (such as flooding, high-flow events and low-flow events) and a range of potential treatment strategies (including O&M, redesign and interim solutions awaiting permanent solutions).

Table 5-3: WRRF Outstanding Asset Needs

Asset Areas	Outstanding Asset Needs
Electrical Distribution	The plant has addressed a hot spot of breaker failures at the EB 4 substation that were caused by flooding issues. Similar older, high failure equipment is being monitored and regularly reviewed by the local AM team. Typically, this equipment would be replaced as part of larger process replacements and upgrades, but this is not currently planned.
HVAC	The plant had experienced significant heating, ventilation, and air conditioning (HVAC) issues and took steps to correct issues in most occupied areas of the plant. However, since switching HVAC contractors, an increase in HVAC failures has occurred. This led to the termination of the contractor and the procurement of a new contractor is in progress.
Buildings	There is an inspection program of building roofs by contractors to identify defects and develop a prioritized a list of repairs. It is anticipated that the repairs will be funded through the I&E program. The plant has a number of small-value buildings that are nearing the end of useful life and typically would lead to complete replacement. For the larger, more complex buildings, building needs are typically addressed in combination with upgrades to major process equipment.
Incineration System	There has been a program of inspections of the incineration systems. This identified several issues in system 1 and the repair projects are underway. As a result, the inspections in system 2 have been delayed until system 1 repairs are complete.

Table 5-4: SPS Outstanding Asset Needs

Asset Areas	Outstanding Asset Needs
Sump Pumps	Sump pump failures have resulted in station flooding. Flooding can lead to extensive repair projects where controls and motors are not located in a dry well above the flood plain.
Internal Piping	In several of the older stations there is significant deterioration of the internal piping, which requires replacement.
Flow Control	Each station has special procedures for operating the pumps in both high- and low-flow conditions. Pumps are used to draw down the water levels when there are unexpected high-flow storm events as part of overall system operations to minimize overflows.

CSO Facilities

The risk assessment performed on the CSO facilities in 2021 resulted in 63 CSO assets with a total asset risk score of 11 or greater. Of those, 38 are electrical assets with a high COF. High-risk and high COF CSO assets were reviewed with GLWA to confirm accuracy and alignment of the likelihood, consequence, and risk scores. Assets in poor condition were either already being addressed or were imminently being addressed to improve condition. Remaining assets were included in the Scheduled Replacement Plan (SRP) (Chapter 7) or included in the needs-based Capital Improvement Program (CIP). The CIP considered other drivers such as future service level changes (flow or regulatory changes) in addition to risk.

Reducing the COF typically involves the addition of redundant equipment, which may be cost prohibitive, or the reduction in service level, which may be unacceptable to stakeholders. Typically, high-risk assets are addressed by reducing LOF through planned maintenance activities, scheduled replacement, or capital improvement.

5.5.2.2 High Consequence Assets

The risk assessment yielded 80 assets at WRRF with a COF score of 4 or greater and a LOF score of less than 2. These assets were investigated and analyzed further, resulting in 15 high COF, low LOF assets at WRRF as shown in Table 5-5.

Table 5-5: WRRF High COF Assets

Process Area	Asset Type	Asset Description	Revised COF Score
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#4: PUMP STATION #1 *CA: # 1 PUMP STATION BASEMENT	4
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#6: PUMP STATION #1 *CA: # 1 PUMP STATION BASEMENT	4
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#8: PUMP STATION #1 *CA: # 1 PUMP STATION BASEMENT	4
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#14: PUMP STATION 2A *CA: P.S. NO-2A MAIN PMP-14	4
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#15: PUMP STATION 2A *CA: P.S. NO-2A MAIN PMP-15	4
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#12: PUMP STATION 2A *CA: P.S. NO-2A MAIN PMP-12	4
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#11: PUMP STATION 2A *CA: P.S. NO-2A MAIN PMP-11	4
Primary	PUMP	*CA: PUMP, LIFT, MAIN; M.L.P.#9: PUMP STATION 2A *CA: P.S. NO-2A MAIN PMP-09	4
Secondary	METER	FLOW METER, ACCUSONIC 8510, SE EAST CHANNEL C, HYPO BLDG, WRRF	4
Secondary	METER	FLOW METER, ACCUSONIC 8510, SE EAST CHANNEL D, HYPO BLDG, WRRF	4
Secondary	METER	FLOW METER, ACCUSONIC 8510, SE WEST CHANNEL A, HYPO BLDG, WRRF	4
Secondary	METER	FLOW METER, ACCUSONIC 8510, SE WEST CHANNEL B, HYPO BLDG, WRRF	4
Secondary	PUMP	**PR: MAP;PUMP, CHLORINATION, CAUSTIC, NEUTRALIZING PUMP #1 FOR LIQUID CHLORINE WWTP PROCESS EQUIPMENT **PR: MAP; IN BASEMENT UNDER CHLORINATORS IN NEW CHLORINE BLDG	4

Process Area	Asset Type	Asset Description	Revised COF Score
Secondary	SWITCH	HI LEVEL FLOAT SWITCH, PE VALVE VAULT, HYPO BLDG, WRRF	4
Secondary	SWITCH	HI LEVEL FLOAT SWITCH, RRO EAST DIFFUSER CHAMBER, HYPO BLDG, WRRF	4

None of these assets are candidates for emergency response plans.

5.5.2.3 Summary of Risk Treatment

The risk scores for vertical assets have performed well for the prioritization and selection of programs, and a significant number of risk correlate well with the projects in the CIP. However, the risk scores are driven by the physical condition of the assets; so they only represent one underlying cause (aging assets) and only lead to one type of treatment (renewal at end of life). There are other risks in the asset base that are driven by alternative underlying causes (for example high-flow events) and that may attract different types of treatment. Further investigation and analysis are required in order to drive out the full range of asset needs and their underlying causes and to identify the precise treatments that address the needs. GLWA has already implemented an Annual Review process at the WRRF to implement this investigation and analysis.

The Annual Review process has been established to review emerging issues, prioritize mitigations, and identify funding sources. The current approach combines the use of the planned maintenance program funded through the O&M budget; a major equipment overhaul program of process equipment—including major pump assemblies and motors—funded through the Improvements and Extensions budget; and more complex process upgrades, including replacements of aging equipment, which are packaged into CIP projects.

The Annual Review should be enhanced and then extended across SPS and CSO facilities, as further described in Chapter 9.

6 Operations and Maintenance

The acronyms used throughout this document are included in Appendix A. For a Glossary of Terms, see the SAMP.

Tactical Recommendation:
- WW4: WwAMP — Digital Solutions
- WW7: - WwAMP — Maintenance and Reliability Work Management Processes for Vertical Assets
- WW8: WwAMP — Maintenance and Reliability Improvement Implementation for Vertical Assets
- WW9: WwAMP — Maintenance and Reliability
- Performance Measurement and Improvement for Vertical Assets

Supporting Artifacts:
- WwAMP — Governance Business Processes (Appendix M)
- FMEA Pilot — Approach and Results (Appendix I)
- Planned Maintenance Optimization (PMO) Report and Tool (Appendix J}
- Tier 1-3 Performance Indicators (PIs) (Chapter 3 of the WwAMP)

The purpose of this section is to summarize GLWA's existing linear and vertical asset O&M practices and describe improvement activities in place.

A key element of AM planning is determining the most cost-effective blend of planned and unplanned maintenance. This includes regularly scheduled inspection and maintenance, as well as more significant repairs and activities associated with unexpected events. The overall O&M strategy is intended to maintain the current service level while mitigating risk and minimizing cost. This section discusses GLWA's strategies for operating linear and vertical assets in compliance with required service objectives.

Tactical Recommendations WW4: WwAMP – Digital Solutions; WW7: WwAMP - Maintenance and Reliability Work Management Process for Vertical Assets; WW8: WwAMP - Maintenance Reliability Improvement Implementation for Vertical Assets; and WW9: WwAMP - Maintenance and Reliability – Performance Measurement and Improvement for Vertical Assets presented in Chapter 9 are planned to be implemented to continuously improve the way GLWA operates and maintains wastewater system assets.

6.1 Operations and Maintenance Strategies

6.1.1 O&M Strategy Guidance

GLWA administers a comprehensive PM and CM program for wastewater assets. Several documents guide GLWA's O&M strategy for its wastewater system. For example, the 2019 Interim Wet Weather Operating Plan (IWOP) provides a roadmap for optimizing the use of regional pipelines, the WRRF, remote pumping, and CSO treatment facilities. Additionally, the Regional Operating Plan (ROP) builds on the IWOP. The ROP provides a framework within which member partners act collaboratively with GLWA in response to storm events to optimize the regional system's wet weather performance. Table 6-1 describes this and other operational planning documents that guide GLWA's O&M strategy.

Table 6-1: Wastewater System Operations Strategic Documents

Operational Planning Document	Overall Strategy
Long-Term CSO Control Plan (2008)	Addresses the control of discharges from combined sewer outfalls to the Detroit River and the Rouge River. Required under NPDES.
Supplement to Long-Term CSO Control Plan (2010)	Provides a supplement to the Long-Term CSO Control Plan. Required under NPDES.
The Wastewater Collection System Best Practices and Separated Storm Sewer System (CMOM/MS4)	Describes capacity management in the sewer system and water quality control from separate storm drainage outfalls.
Regional Water Quality Monitoring Program (RWQM)	Provides continuous monitoring of water quality parameters essential to protection of public health and aquatic life from pollutants associated with untreated sanitary sewage and separated storm water.
Regional Collection System Rehabilitation and AM (recommendation from 2020 Master Plan)	Provides long-term planning for the regional wastewater collection system, including goals for inspection, rehabilitation, river inflow monitoring and control, increased redundancy, and reduction in the number of pump stations.
GSI and Sewer Separation (recommendation from 2020 Master Plan)	Offers source reduction sewer overflow control solutions that prevent stormwater inflow from entering the combined sewer system.
NPDES Permit	Oversees the control of discharges to the waters of the state.
IWOP	Optimizes the use of regional pipelines, the WRRF, remote pumping, and CSO treatment facilities.
ROP	Builds on the IWOP and extends it to operation of other member wastewater collection systems.
GLWA Wastewater Master Plan (2020)	Outlines a holistic and regionally integrated planning approach to CSO, SSO, wastewater treatment, stormwater, capacity management, and receiving water quality.
GLWA SAMP	Establishes GLWA's AM framework.

6.1.2 Linear Asset O&M Strategies

Preventive maintenance activities for linear assets include cleaning, CCTV inspection/re-inspection, and community action, as shown in Table 6-2.

Table 6-2: Linear Preventive Maintenance Activities

Current PM Activities	Action
Maintenance Activities	Cleaning
	CCTV inspection
Community Outreach	To assist with PM, GLWA has implemented member partner education programs. These programs provide information about cross-connection control; proper disposal of fats, oils, and grease; and proper disposal of materials that should and should not be disposed of in the sewer system.

Currently, PM activities and pipe rehabilitation projects are recommended and prioritized by a contractor independent of the GLWA risk framework. As part of the ongoing GLWA Linear System Integrity Program (LSIP), the wastewater collection system risk framework will be incorporated into the GLWA Info Asset Planner (IAP) software, and this will drive future recommendations for PM activities and prioritize pipes for rehabilitation. Incorporating a risk framework into scheduling and prioritizing maintenance for linear assets will allow GLWA to effectively monitor O&M performance.

In the development of the WwAMP, a maintenance action or structural repair action, described in Table 6-3, was assigned to repair each pipe based on defects reported in the CCTV inspection data.

Table 6-3: Description of Pipe Maintenance and Structural Repair Actions

Scheduled Action Category	Scheduled Action	Timeline for Action
Maintenance Action	Cleaning	As soon as possible
	CCTV inspection	18 months – 10 years
	CCTV inspection with multi-sensor	18 months – 10 years
Structural Repair Action	CCTV inspection	12 months – 10 years
	Priority 1 Rehabilitation List Priority 2 Rehabilitation List Priority 3 Rehabilitation List	As determined through development of rehabilitation plan (LSIP)

Pipes that are assigned a structural repair action are included in forecasting renewal needs and prioritized as Priority 1 (highest COF), Priority 2 (next highest consequence), and Priority 3 (lowest relative consequence). The SCREAM model results are intended to be used for planning needs until the risk framework logic for GLWA IAP is fully functional.

Figure 6-1 displays a plan for inspection and renewal actions on the sewer system for the period 2022 to 2028. Pipes that were inspected in previous years and determined to be overdue for re-inspection with COF of Grade 5 are prioritized followed by uninspected (No Inspection) pipes for PM. Pipes that are damaged or require more in-depth data than a standard inspection can provide are recommended for a multi-sensor inspection (MSI). MSI typically includes lidar, CCTV, and sonar technologies. Pipes recommended for rehabilitation are prioritized with one year for planning.

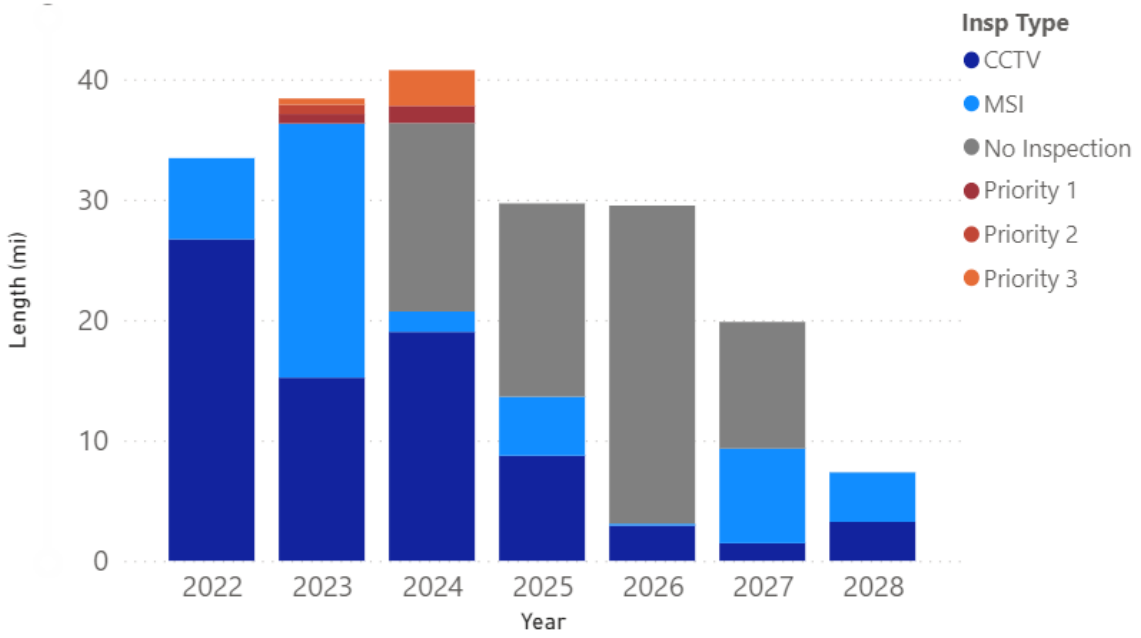


Figure 6-1: Schedule for New Inspections, Re-Inspections, and Rehabilitation of Pipes

GLWA CCTV inspection pipe miles per year are listed in Table 6-4. In 2017, GLWA made a concentrated investment in CCTV inspection data.

Table 6-4: Historic Annual CCTV Inspection Miles

	2016	2017	2018	2019	2020	2021	2022	Total
Total miles inspected	14.9	106.9	8.2	0.1	14.2	2.8	0.2	147.4
Total miles with re-inspections	14.9	106.9	8.9	1.7	71.6	28.5	0.2	232.8

6.1.3 Vertical Assets O&M Strategies

GLWA optimizes strategies for operating the vertical assets, including inspection and PM schedules. Preventive maintenance activities are tied to individual assets (SPS, CSO facilities, WRRF listed in Chapter 4) and tracked in WAM. Current PM activities are listed in Table 6-5.

Table 6-5: Vertical Preventive Maintenance Activities

Current PM Activities	Action
Time-Based Maintenance *Maintenance that is undertaken based on timing, regardless of an asset's condition*	• Lube oil changes • Filter changes • Belt drive inspections • Mechanical inspections • Electrical inspections • Greasing • Instrument calibration • Cleaning (motors, coils, vents, etc.) • Electrical switchgear testing and inspection • Regulatory inspections (tanks, fire systems, eyewash, cranes, emergency lighting, backflow preventers, permit related)
Condition-Based Maintenance *Maintenance that is performed based on an asset's condition*	• Oil sampling and analysis • Thermographic inspection on electrical assets • Vibration monitoring and analysis • Static motor testing (Megger and Polarization Index) • Dynamic motor testing (via GE Multilin motor control systems)

GLWA reviews maintenance activities either on a periodic basis or in response to premature asset failures.

In 2018, with the assistance of Jacobs, GLWA conducted an internal self-assessment of the WRRF maintenance and reliability program. Table 6-6 presents the list of improvement opportunities generated by the assessment.

Table 6-6: Vertical Asset Maintenance Strategies and Improvement Opportunities

Category	Current Approach	Improvement Opportunities (referenced in Tactical Recommendation WW6 – Operations and Maintenance)
Operations and Maintenance Training	Maintenance training is provided based on staff requests or limited to regulatory required training. Not related to specific issues or equipment needs.	Create Workforce Development strategy to improve skill sets and morale.
Dependency on Senior Staff Knowledge	There is heavy dependence on the undocumented senior (close to retirement) staff knowledge base.	Develop and implement a process to identify critical knowledge held by senior personnel and document the knowledge in the way of procedures, work instructions, etc.
Computerized Maintenance Management System (CMMS) Skills	Evidence of a large percentage of personnel exhibiting frustration in using the CMMS.	In concert with the Nexgen implementation, develop a CMMS training curriculum to provide additional exposure to functionality that will benefit plant personnel in performing their jobs and understanding the purpose and benefits of Nexgen. For example, showing plant staff how to run metrics will encourage them to enter more accurate information.
Failure Code Usage	Failure codes exist in CMMS but are either not being used consistently, documented once failure is understood, or the list is so large that selected codes are incorrect or so generic that codes provide little benefit.	In concert with the Nexgen implementation, develop a set of failure codes (as CMMS allows) to be used across the various asset owner groups. The analysis of failure code patterns is typically an initial phase of reliability analysis.
Work Management Policy	A formal work management policy with flow process does not exist.	Create a formal written work management procedure that documents the desired process to include roles, responsibilities, and activities. Jacobs can provide a best-in-class work management procedure as an example.
Housekeeping Performance	The housekeeping theme hasn't been tied to maintenance excellence OR spaces are not maintained and orderly.	Continue to drive and monitor the WRRF housekeeping improvement initiative. Housekeeping performance has been tied directly to both morale and safety performance improvement.
Maintenance Planning and Scheduling	Planning and scheduling function is not performing well at WRRF due to multiple issues.	Improve planning and scheduling function by, providing Planning and Scheduling (P&S) training, P&S mentoring, and additional tools.

6.2 Operations and Maintenance Performance

6.2.1 Linear Assets

GLWA is in the process of developing a performance dashboard for the wastewater collection system that will be beneficial to internal and external stakeholders. Table 6-7 lists linear PIs in development for inclusion in the collection system dashboard through LSIP.

Table 6-7: Linear Asset Performance Indicators in Development

Linear Performance Indicators	Status
Miles of pipe surveyed	Currently tracked, not reported
Pipe condition	Currently tracked, not reported
Pipes abandoned with breakdown of reason for abandonment	Currently tracked, not reported
Break rates by diameter/material	Not currently tracked
Leak rates by material	Not currently tracked
Heat maps of areas of concern	Not currently tracked
Wire breaks per prestressed concrete cylinder pipe (PCCP)	Not currently tracked

Figure 6-2 and Figure 6-3 show current dashboards in development.

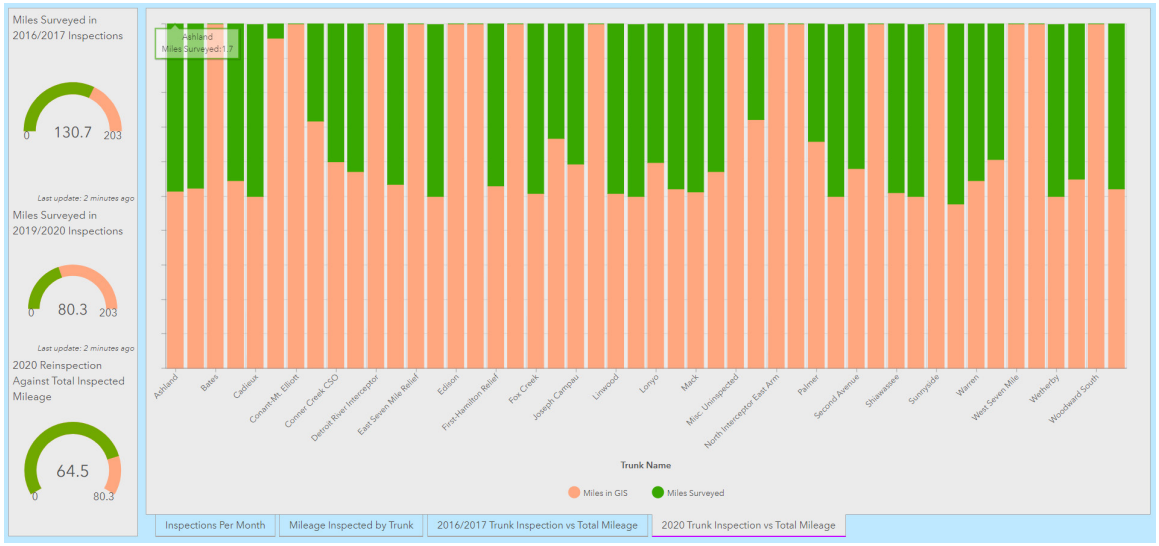


Figure 6-2: Pipe Miles Surveyed Dashboard in Development

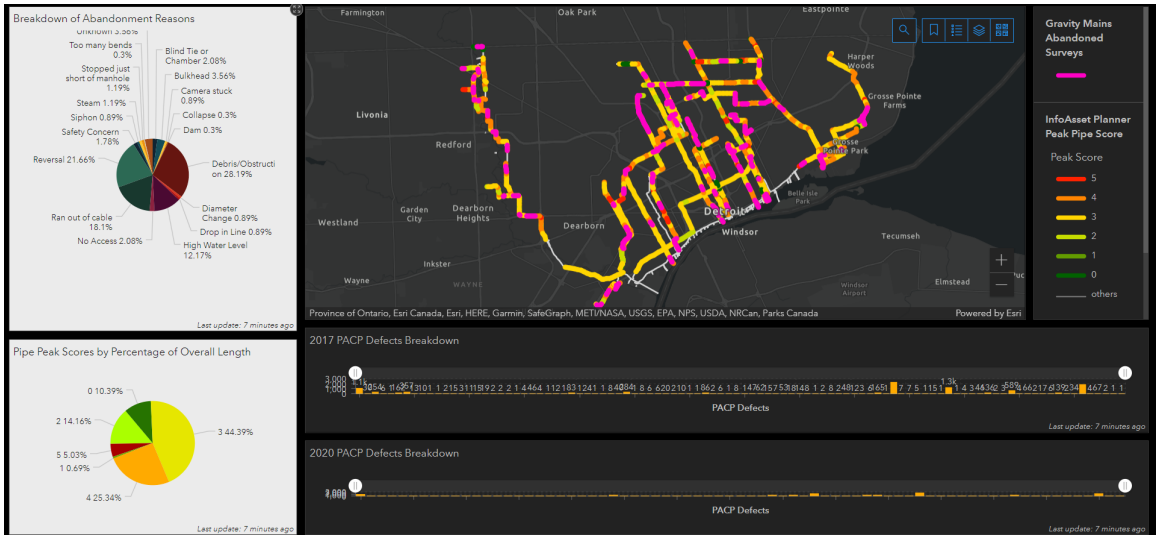


Figure 6-3: Pipe Condition and Pipes Abandoned Dashboard in Development

6.2.2 Vertical Assets

In 2017, GLWA established the following PIs to track maintenance performance:

- Wastewater PM completion rate
- PM vs. total maintenance
- Maintenance backlog

Industry best practices suggest that PM decreases asset failure rates and associated asset downtime related to failures; additionally, PM is typically administered at a lower cost compared to CM. Thus, GLWA has established targets for these PIs that aim to maximize the PM completion rate and optimize the ratio of PM-to-total-maintenance.

The initial target for the wastewater PM completion rate PI was to achieve greater than 75% completion rates of PM work orders. As work management improved, GLWA revised this target to achieve greater than 80% completion rate of PM work orders.

Figure 6-4 shows the PM completion rate from July 2019 through June 2020.

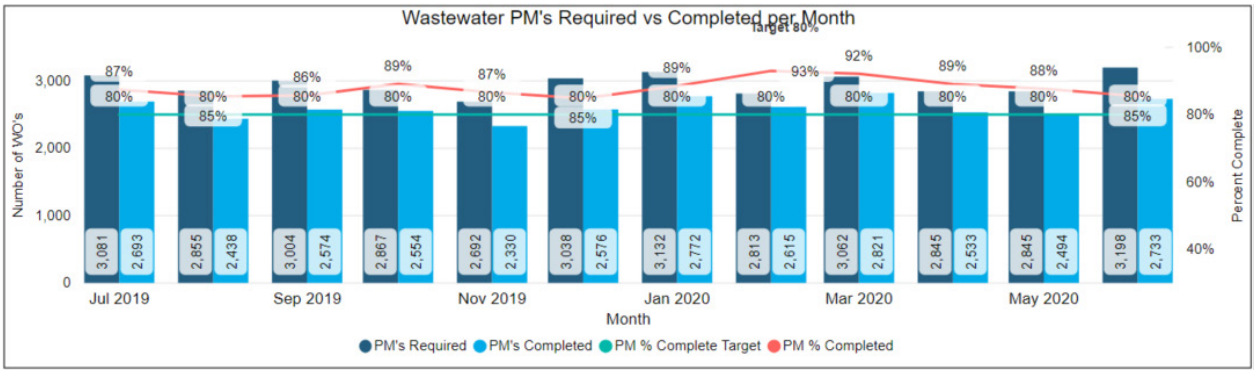


Figure 6-4: Wastewater Preventive Maintenance Completion Monthly Performance (July 2019 through June 2020)

Note: Maintenance work orders were completed by GLWA wastewater maintenance teams at the WRRF and CSO facilities.

GLWA's maintenance program strives to balance the value of PM activities with the negative impacts of asset failures requiring CM activities. Excessive PM activities that do not improve performance or reliability provide little value and can result in increased costs and workloads. Additionally, excessive CM activities may indicate a reactive approach to maintenance that could leave GLWA vulnerable to expensive failures. Therefore, GLWA has established the PM-to-total-maintenance ratio target of 80% to balance PM and CM activities. Figure 6-5 shows the ratio of PM-to-total-maintenance from July 2019 through June 2020.

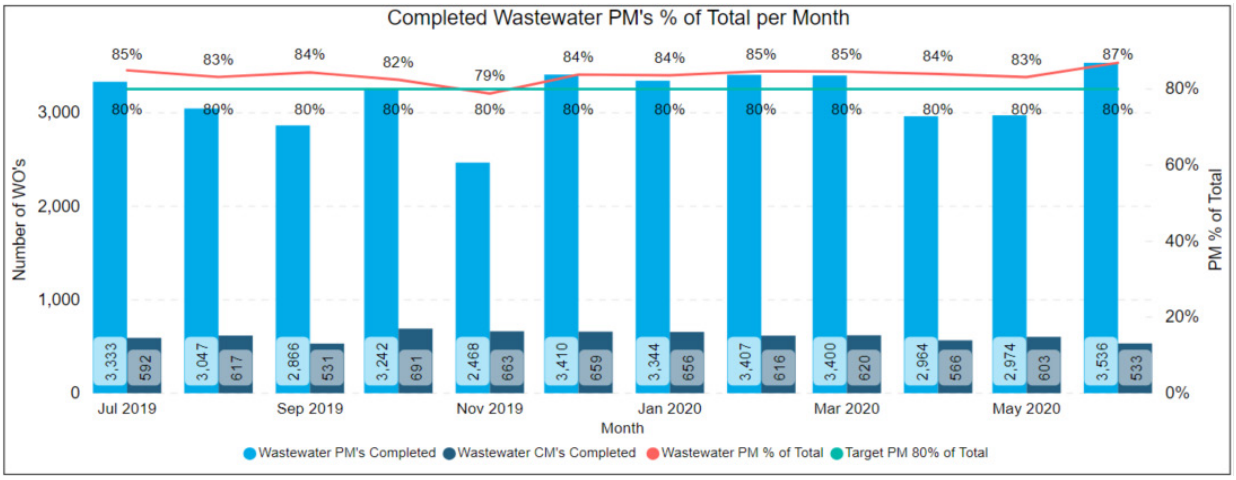


Figure 6-5: Preventive Maintenance vs. Total Maintenance Monthly Performance (July 2019 through June 2020)

Note: Maintenance work orders were completed by GLWA wastewater maintenance teams at the WRRF and CSO facilities.

The estimated time it takes to clear the maintenance backlog is a measure of the total estimated available hours, the maintenance utilization rate, and the estimated hours of backlog from work orders. The initial target clearing the maintenance backlog is four to six weeks.

GLWA is currently working to identify additional PIs, drawing from industry maintenance best practice performance metrics. The metrics are categorized into the following three tiers:

- **Tier 1 –** PIs are identified as needed reports that can be developed now using current WAM data and business processes.
- **Tier 2 –** PIs are identified as reports that may be created using WAM data after configuration changes and business process changes are made.
- **Tier 3 –** PIs are identified as reports that cannot be obtained with WAM data and business process changes using WAM. It is expected that these reports will be developed as part of the Nexgen project.

Table 6-8, Table 6-9, and Table 6-10 present the three tiers of performance metrics and their respective PIs.

Table 6-8: GLWA Tier 1 Performance Indicators

PI Name	PI Objective
Maintenance Utilization Rate	To measure the ability to manage maintenance resources in a manner that generates the most value to the organization by using available resource time effectively and by ensuring a high percentage of the available time spent completing maintenance work on the assets.
Work Order Backlog by Hours (Weeks of Backlog)	To measure the ability of the maintenance team to complete the amount of maintenance work being generated in a timely manner and to implement corrective actions if the backlog grows above the standard.
Percent PM Completion Rate (PMs Completed vs. PMs Scheduled)	To measure the ability and capacity of the organization to execute the preventive maintenance strategy as designed. The factors that may influence this metric include work inefficiency, inventory issues, ineffective scheduling, inaccurate labor estimates, and resource availability.
Percent PM Work Orders vs. Total Work Orders	To measure the PM work orders as a percentage of the total maintenance being performed.
Percent Estimated vs. Actual Hours	To measure the labor estimating accuracy of the maintenance planning function. The estimated hours on a work order serve to provide the maintenance scheduler an understanding of the duration and resources required to complete the work activity, so an accurate work schedule can be developed.
Number of Backlog Work Orders by Age	To measure the ability of the maintenance team to complete the amount of maintenance work being generated in a timely manner and to implement corrective actions if the backlog grows above the standard.
Percent PM by Labor Hours vs. Total Labor Hours	To measure the proactive versus reactive nature of the maintenance program.

PI Name	PI Objective
Hours Reported vs. Hours Available	To track the delta between labor hours documented within the timekeeping system and those documented within WAM against work orders. Any delta will potentially identify groups or persons that may not be documenting completed work within the WAM system.

Table 6-9: GLWA Tier 2 Performance Indicators

PI Name	PI Objective
Plant or System or Equipment Availability	To measure the ability of the organization to keep its critical assets available for service in supporting its mission.
MTBF	To measure and trend the reliability performance of a population of assets. The factors that impact this metric are many and include design, purchasing, operations, maintenance, age of assets, etc.
Percent Proactive Maintenance Hours vs. Total Maintenance Hours	To track the ratio of proactive maintenance time spent working vs. the total maintenance hours.
Percent Predictive Maintenance Hours vs. Total Maintenance Hours	To track the level of effort (LOE) being expended executing predictive maintenance as compared to all other types of maintenance.
Total Reactive Labor Hours	To provide a simple measure of overall AM performance by tracking the level and trend of reactive maintenance.
Total Reactive Material Costs	To measure the value of materials consumed performing reactive maintenance work.
Average Mean Time to Repair	To provide a measure of the average time required to place a failed system or asset back into service.

Table 6-10: GLWA Tier 3 Performance Indicators

PI Name	PI Objective
Planned or Scheduled Hours vs. Total Actual Labor Hours	To measure the percentage of work that is being processed through the P&S process.
Scheduled Hours vs. Available Hours	To measure the percentage of available maintenance labor hours that are being scheduled via the scheduling process.
Schedule Attainment	To provide a measure of the effectiveness of the maintenance scheduling process.
Scheduled Break in Labor Hours vs. Total Scheduled Labor Hours	To measure the stability of the maintenance scheduling process as compared to the reactive nature of the maintenance program.
Average Asset Health Score	To provide a measure of the average asset health indicating the effectiveness of the AM strategy.
Average Remaining Asset Life	To provide a measure of the remaining asset life in support of reliability and asset life extension.

6.3 FMEA and PMO Analysis

Failure Modes and Effects Analysis (FMEA) and Planned Maintenance Optimization (PMO) analysis both focus on higher risk assets to determine where to redirect O&M resources in order to increase reliability and reduce overall costs. What distinguishes FMEA from PMO is the level of analysis performed and the basis used for making recommendations. As FMEA is a more detailed analysis, it is a more viable process for making difficult decisions that may have higher consequences.

The metrics that measure the success of FMEA and PMO are the same. The only metrics available immediately to either process include impact on labor hours and number of work orders being generated to execute the strategy. The true impact of either FMEA or PMO is longer term and should be measured as part of the GLWA performance measurement model.

Table 6-11 details the goals, impacts, and metrics of the FMEA and PMO analysis initiatives.

Table 6-11: Goals, Impacts, and Metrics of the FMEA and PMO Analysis

Goal	Impact	Metrics
Increase asset reliability and reduce number of failures	Reduce downtime	▪ System or asset availability ▪ MTBF ▪ CM total labor hours
	Reduce level of CM	▪ CM cost ▪ CM work order count
	Reduce safety incidents	Safety metrics
	Reduce environmental incidents	Environmental metrics
Maintain or improve asset condition	Reduce capital replacement or overhaul	▪ Capital reinvestment costs ▪ Condition assessment results
	Reduce energy consumption	Energy costs
Optimize use of PM resources	Increase the return on investment for PM activities	▪ PM/CM ratio total (for critical equipment) ▪ PM total work order count ▪ PM total labor hours
Increase use of condition-based maintenance	Reduce occurrence of unexpected in-service failures	Emergency maintenance (EM) work order count
	Reduce occurrence of secondary damage	▪ CM maintenance cost ▪ Predictive maintenance-based “saves”
Improve operator practices for asset inspections during operation	Reduce occurrence of unexpected in-service failures	EM work order count
	Reduce occurrence of secondary damage	▪ CM maintenance cost ▪ Operator-based “saves”

6.3.1 Failure Modes and Effects Analysis

An FMEA deconstructs an asset into its various sub-components and then defines the various ways a component failure is likely to occur; this failure is referred to as a "failure mode." For example, a failure mode may be defined as bearing seizes with associated causes of lack of lubrication or misalignment of drive shaft. GLWA can use the results of an FMEA to inform maintenance activities and address failure modes before failures occur.

What is a Failure Mode?

A failure mode identifies the various ways a component failure is likely to occur. Understanding as asset's failure mode and cause is useful when mitigating risk.

In 2021, GLWA piloted an FMEA approach for a single asset from four major process areas: Primary, Secondary, Dewatering, and Incineration. GLWA selected assets for the FMEA pilot by considering asset risk scores developed for the WwAMP and input from the WRRF maintenance team on asset performance history, using 2020 data. Detailed information about the FMEA approach and results is included in Appendix I.

6.3.2 Planned Maintenance Optimization

PMO evaluates the preventive maintenance (PM) strategy across the asset population as it compares to the criticality of the assets. PMO also aims to redistribute the performance of PM from low-value activities to high-value activities in order to achieve greater value per hour of PM completed. PMO achieves this by working to identify and remove duplicate PM tasks. This includes increasing or decreasing PM intervals, applying the use of predictive maintenance (PdM) where beneficial, improving work instructions, improving operator inspections, and achieving greater overall efficiency and safety. By carefully analyzing PM tasks, PMO can streamline PM without increasing the risk of failure. Thus, PMO has the potential to significantly reduce overall annual PM hours and improve delivered service levels and performance.

GLWA's PMO goals include the following:

- Delete maintenance tasks that provide little value
- Extend or reduce PM interval based on type of task, equipment usage, environment, and industry guidelines
- Improve PM scheduling
- Add PM and PdM, where beneficial
- Take credit for current PdM activities
- Make use of and improve operator rounds

- Reassign PM tasks that would be better served by having the Operations Department perform the task
- Make use of installed instrumentation and monitoring
- Strengthen work packages (task instructions, parts, and tools)

While the results of the PMO analysis have reduced the overall LOE in terms of labor hours per year, and much of that is related to mechanical maintenance, it is not the intent or suggestion of this initiative to reduce the number of maintenance technicians currently supporting the WRRF maintenance program. The purpose and benefit of the reduction are to redirect those hours and maintenance personnel to more valuable tasks and to allow them to execute the critical tasks more effectively. Additionally, if the maintenance team has more availability, it can spend more time on reactive maintenance execution and failure analysis to improve overall asset reliability.

6.3.2.1 Vertical Assets PMO Activity

In 2021, GLWA embarked on an initiative to optimize PM activities. The intent of the PMO initiative was to conduct an evaluation of the existing PM program for a limited number of assets located within each of the WRRF plant's five process areas, which include Primary, Secondary, Dewatering, Incineration, and Common Support. The PMO initiative also aimed to identify opportunities for improving the effectiveness and efficiency of the proactive maintenance activities.

GLWA utilized 2020 data and the Jacobs PMO tool to allow quick and easy review of PM-related information in a concise format. The WRRF assets included in the PMO initiative were selected based on a combination of asset criticality and current level of PM being performed. PMO was performed on 22% of the total asset population across the five areas.

Appendix J describes the PMO methodology for WRRF assets. GLWA maintains the PMO tool.

The results of the PMO optimization activity were measured in labor hours and work order counts. Reducing work order counts increases efficiency in work execution as there is less time spent administering work orders. Currently, maintenance LOE is the only metric available to measure PMO impact today. In contrast, reliability performance and risk reduction must be measured across many months or years.

Results of the pilot show a net reduction of annual PMO hours and annual PM work orders across the full scope of assets included in the study. The largest reduction in LOE occurred in the Maintenance Department, with a net reduction of 2,614 hours per year (15.7%), which equates to approximately 1.75 full-time equivalent maintenance staff.

Contributing to that reduction in maintenance hours is the intentional transfer of responsibility for frequent machinery inspections from the Maintenance Department over

to the Operations Department. This transfer increases the LOE for the Operations Department by 449 hours per year (11.8%). Table 6-12 provides a summary of the impact of PMO on the maintenance LOE by department.

Table 6-12: PMO Impact – Labor Hours by Department

	All Work	Maintenance	Operations	Contractor
Current Annual PM Hours	25,477	19,458	4,164	1,855
Recommended Annual PM Hours	24,427	18,361	4,587	1,480
PMO Impact Annual PMO Hours	-1,050	-1, 097	+423	-375
PMO Impact % Annual PM Hours	-4%	-6%	+10%	-20%

Although the overall impact on total PM labor hours per year is limited to just a 4% reduction in total PM hours annually across all responsible groups, the analysis revealed a substantial number of opportunities to reduce the PM interval on existing PMs to increase PM effectiveness and opportunities to add PM activities to assets that did not currently have PMs assigned. Therefore, the quality of the PM program is improved substantially while still reducing overall labor effort.

The analysis worked to transfer responsibility for short interval PMs that include only equipment inspection tasks over to Operations, which should be done during operational rounds of their areas. This alleviates the maintenance staff from performing activities that can be, and should be, carried out by Operations. Many of the tasks included in these PMs need to be conducted on a much shorter interval than what is currently assigned and are better performed by Operations on a daily or weekly basis.

Much of the recommended additional PM hours are associated with mechanical HVAC tasks. A decision was made, due to the poor quality of the ambient air, to shorten all air handling unit (AHU) filter inspections across the plant to two weeks. This is a substantial change as many AHUs had either monthly or quarterly filter inspections. Considering that dirty filters in AHUs can contribute to a number of secondary issues such as increased energy consumption, coil freezing due to low air flow, fouled coils, unhealthy air supply, etc., PMO recommendations on filter inspections across all AHUs were standardized, which added approximately 1,400 PM hours annually just for filter inspections. The filter inspection intervals may be adjusted depending on plant area or AHU function, but those decisions will be made during the PMO recommendation review.

Table 6-13 summarizes the impact of PMO on the maintenance LOE by maintenance category type.

Table 6-13: PMO Impact – Labor Hours by Maintenance Category

Maintenance Category	Annual PM Hours - Current	Annual PM Hours Recommended	PMO Impact Annual PM Hours	PMO Impact % Annual PM Hours
ELECTRICAL	5,109	5,629	520	10.2%
MECHANICAL	12,065	8,986	-3,079	-25.5%
MECHANICAL-HVAC	256	1,810	1,554	606.8%
INSTRUMENTATION	1,037	793	-244	-23.5%
PLUMBING	991	1,143	152	15.3%
OPERATIONS	4,164	4,587	423	10.2%
CONTRACTOR	1,855	1,480	-375	-20.2%
Total	25,477	24,427	-1,050	-4.1%

The most dramatic impact of the PMO by maintenance category was in mechanical maintenance, where the overall LOE was reduced by 3,079 hours annually. Other maintenance categories, with the exception of Instrumentation, increased slightly, with the largest increase in mechanical HVAC. Mechanical HVAC work increased by 1,554 hours per year due to the increase in the frequency of HVAC filter inspections from monthly to biweekly and adding filter inspections on units that are currently not inspected. The maintenance team has communicated that air quality around the WRRF is such that biweekly inspections are warranted, although the intervals may be adjusted based on as-found conditions.

The reduction in instrumentation (ITTE) work is related to removal of calibration activities on hazardous gas monitors due to the sensors having self-diagnostics that alert the Operations Department when a unit needs calibration or sensor replacement. This recommendation is still under review.

Plumbing (PLMB) PM was impacted the least as this is limited to inspection of eyewash and safety showers, and backflow preventers. The PLMB PMO recommendations include adding PM on assets without existing PM and revising language on eyewash inspections to reflect OSHA-recommended weekly inspections.

The 20% reduction in contractor hours is due to the increase in HVAC PM inspection intervals and standardization across all HVAC assets. As these recommendations impact contract language, they must be carefully considered.

Implementation should be completed by the area Maintenance Planner and Operations Department staff responsible for operations instructions in accordance with the PMO implementation report generated by the PMO tool (Appendix J).

7 Renewals

The acronyms used throughout this document are included in Appendix A. For a Glossary of Terms, see the SAMP.

Tactical Recommendation:
- WW10: WwAMP — Scheduled Replacement Program Implementation
- WW11: WwAMP — Capital Improvement Program Process Improvement

Supporting Artifacts:
- WwAMP - Scheduled Replacement Program (SRP) Models (WRRF, SPS) (Appendix K)
- WwAMP - Governance Business Processes (Appendix M)

The purpose of this section is to identify needed renewals for linear and vertical wastewater assets. A good understanding of the life cycle behavior of each asset is needed to identify long-term renewal needs. This understanding can then be used to develop long-term life cycle models based on the replacement and rehabilitation needs of the current asset base.

Tactical Recommendations WW10: WwAMP - Scheduled Replacement Program Implementation and WW11: WwAMP - Capital Improvement Program Process Improvement presented in Chapter 9 are planned to be implemented to continuously improve the way GLWA identifies needed renewals and invests in capital projects.

7.1 Life Cycle Models

Life cycle modeling is an approach that combines the asset condition, installation dates, expected service lives, and estimated replacement costs with an appropriate rehabilitation or replacement strategy in alignment with asset life cycle behavior. The linear assets, WRRF and SPS, and CSO facilities all use slightly different life cycle models. Appendix H includes a description of each.

Peaks of needs are useful prompts that can be used to trigger further study of potential intervention needs and timing so that adjustments can be considered as part of GLWA CIP planning and delivery. The program is informative to the CIP and Capital Outlay needs for renewals.

Further, as asset condition data and asset improvement work are continuously completed, the needs as indicated by the life cycle model are always evolving.

7.2 Renewal Needs

7.2.1 Linear Assets

A risk-based rehabilitation and renewal logic was used in the WwAMP to identify pipes needing rehabilitation (see Appendix E for a description of the logic that includes a description of the Jacobs SCREAM model, which uses CCTV pipe inspection data to assign a maintenance action or structural repair and indicate renewal needs). The model identified 53 "priority pipes" needing structural attention upon review of 2020 data. The results presented below are a snapshot in time; current cost estimates can be accessed through LSIP.

The estimated cost of rehabilitating these pipes is $37.8 million reflected in 2021 dollars. Up-to-date financial information may be obtained from the LSIP. Figure 7-1 shows a 10-year forecast for rehabilitating all the priority pipes. The pipes were scheduled based on their remaining life estimates and their COF, prioritizing pipes with more critical COF risk scores and pipes with less estimated remaining life. The renewal needs for pipes included lining (32 pipes), repair (20 pipes), and replacement (one pipe).

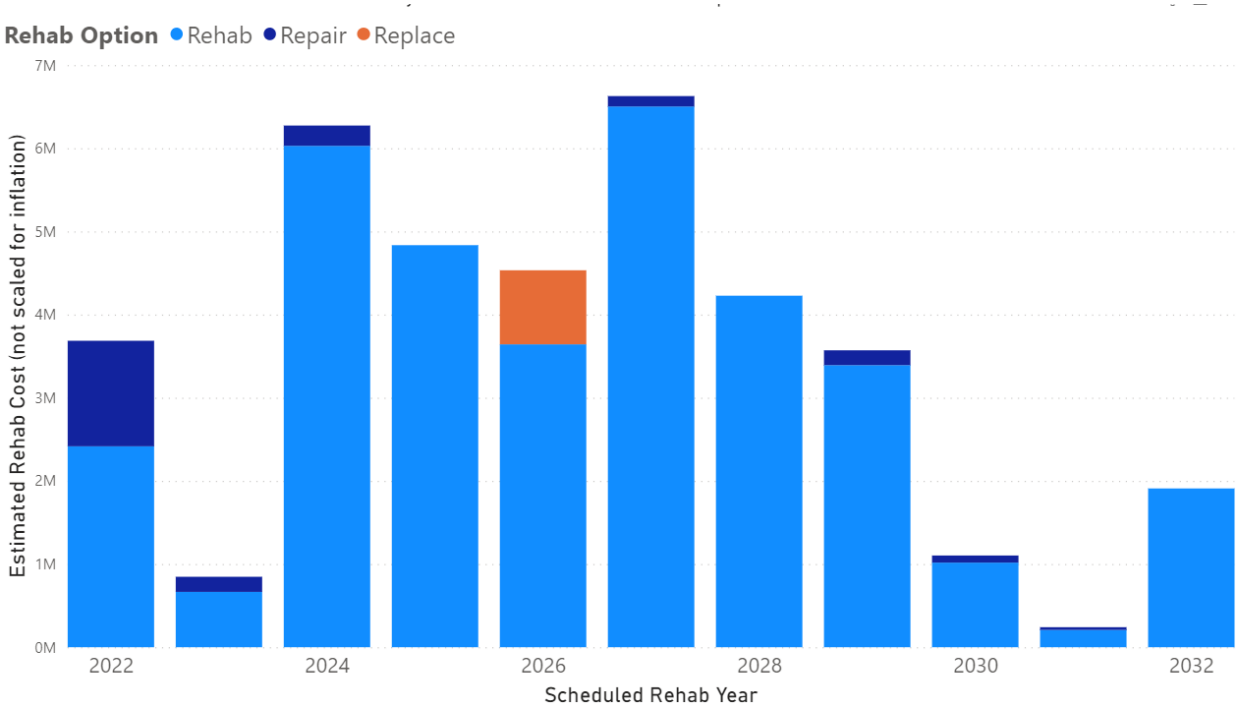


Figure 7-1: Estimated Costs for Recommended Pipe Rehab Over Next 10 Years (based on 2020 data in 2021 dollars)

When uninspected pipes are included in the renewal needs results, the estimated number of pipes increases to about 90 and the estimated renewal cost increases to $71 million as shown in the SCREAM model described in Appendix E. *Note that since the pipes have not been inspected, this is a high-level estimate of the condition and remaining life of the uninspected pipes.* Figure 7-2 displays the 10-year estimate for rehabilitation and first-time inspection for pipes, including some uninspected pipes (those that had adjusted RULs within the next 10 years).

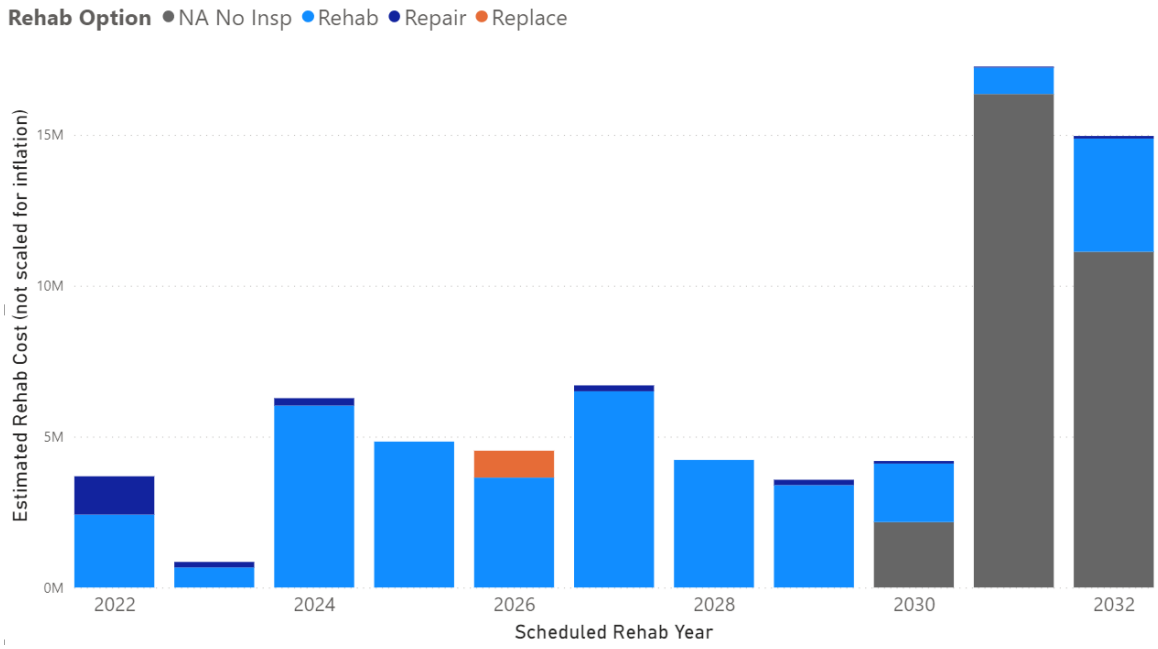


Figure 7-2: Projected Costs for Rehabilitation and First-time Inspection for Pipes with Remaining Useful Life of 10 Years or Less (based on 2020 data, in 2021 dollars)

7.2.2 Vertical Assets

A condition-based rehabilitation and renewal logic was used to identify vertical assets needing rehabilitation (see Appendix H for description of the logic). Replacement and rehabilitation strategies for each asset type documented in the Scheduled Replacement Plan (SRP) models are referenced in Appendix K. For WRRF/SPS assets, condition assessment work was performed in 2020 on only 982 assets (electrical and mechanical) and the remaining assets were assumed to be mid-life, receiving a condition grade score of 3. Costs were based on 2013 and were escalated to 2021 dollars with soft costs. The results presented below are a snapshot in time; current cost estimates can be accessed by the SRP models.

Figure 7-3 shows the summary of vertical asset capital renewal needs for the WRRF, CSO, SPS systems based on the output of the SRP model. The total estimated expenditure from the SRP model is $1.19 billion (2021 dollars), which is equivalent to an annual average of

$59.3 million over 20 years. This information can be used to inform CIP decisions. The highest peaks in renewal expenditures are projected for the years 2035 and 2040 and are driven primarily by the current conditions of assets located at the WRRF. Many assets at the WRRF are of similar asset lifespan and condition. Therefore, many assets are predicted to be due for renewal at the same time, causing the peaks and valleys. For SPS, there are a larger variety of assets at various ages and conditions, resulting in a smoother renewal projection. The CSO facilities, based on current asset conditions, have significant peaks in 2035, 2036, and 2040, while the SPS maintains a fairly consistent annual renewal need (no large peaks or troughs projected). Further details of the main renewal need for each system are summarized in the following section.

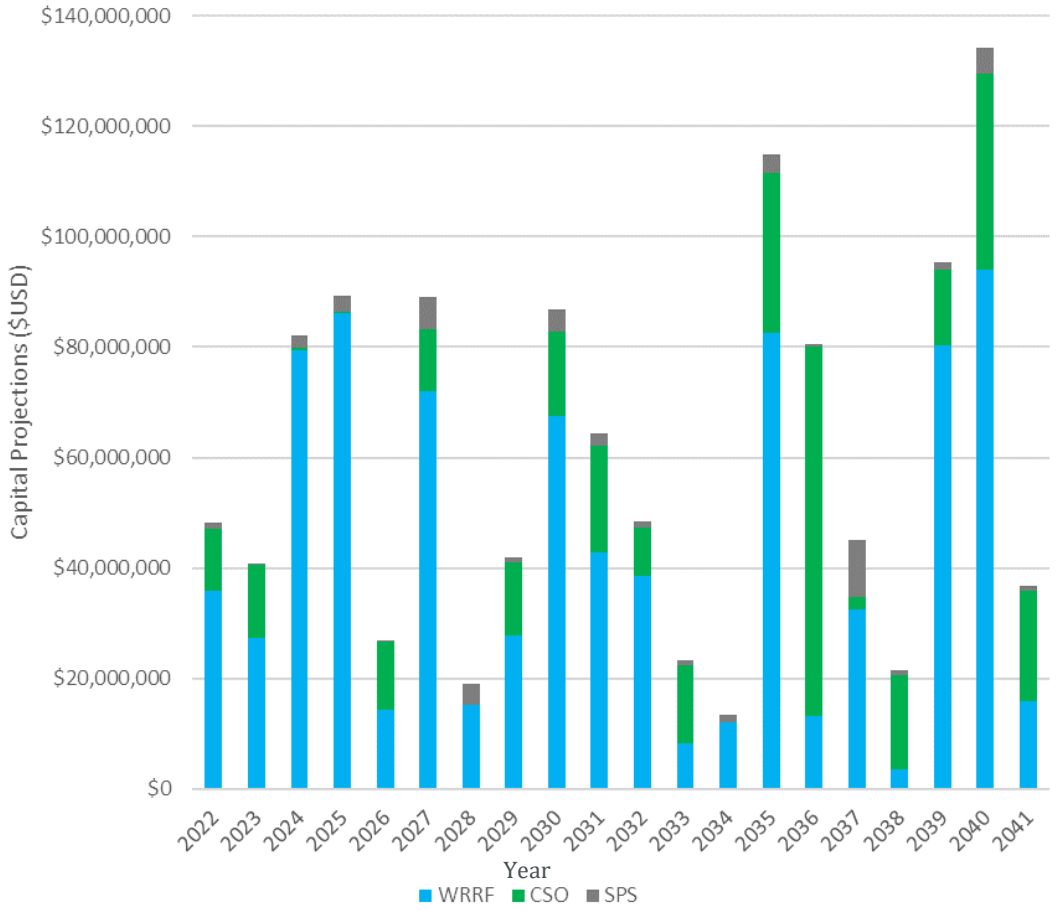


Figure 7-3: Projected Capital Costs for WRRF, SPS and CSO Facility Vertical Assets (based on 2020 data, in 2021 dollars)

A detailed breakdown of projected costs by vertical asset type (WRRF, SPS, CSO) is presented below.

WRRF

The 20-year projection is shown in Figure 7-4 based on 2020 data, in 2021 dollars. The projection includes an estimated $849 million in renewals, which is equivalent to an annual average of $42.5 million. This investment profile includes planned interventions in some of the building and process equipment in the Primary process area in years one through five. Following year five, the investment peaks in 2035 and 2040 reflect several assets that currently have a condition grade of 3.

Peaks of needs are useful prompts that can be used to trigger further study of the potential intervention needs and timing so that adjustments can be considered as part of GLWA CIP planning and delivery. The program is informative to the CIP and capital outlay needs for renewals.

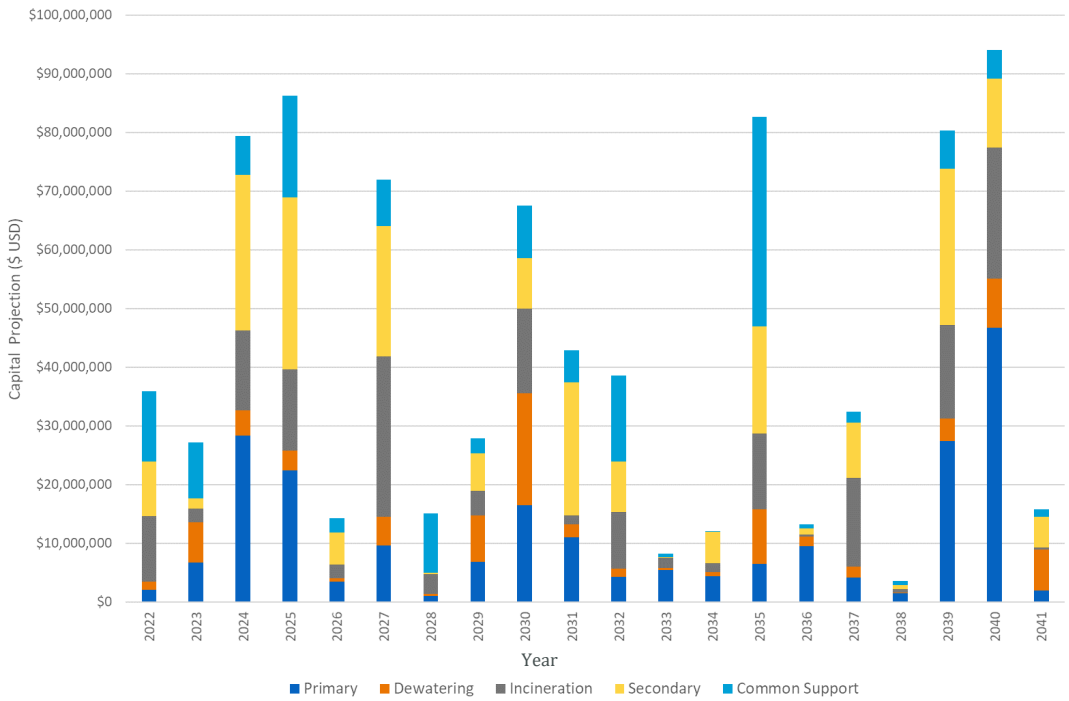


Figure 7-4: WRRF Condition-Based Capital Projections (based on 2020 data, in 2021 dollars)

SPS

Figure 7-5 shows the 20-year projection for SPS assets. The projection includes an estimated $49.3 million in renewals, which is equivalent to an annual average of $2.5 million based on 2020 data, in 2021 dollars. This investment profile includes planned

interventions to the Belle Isle Pumping Station process and instrumentation assets for the first five years. Since they are owned by Detroit Water and Sewer District (DWSD) and operated by GLWA, communication and coordination of needs will be completed. Following year five, there are investment peaks in 2027 and 2037 that reflect several assets with a current condition grade of 3.

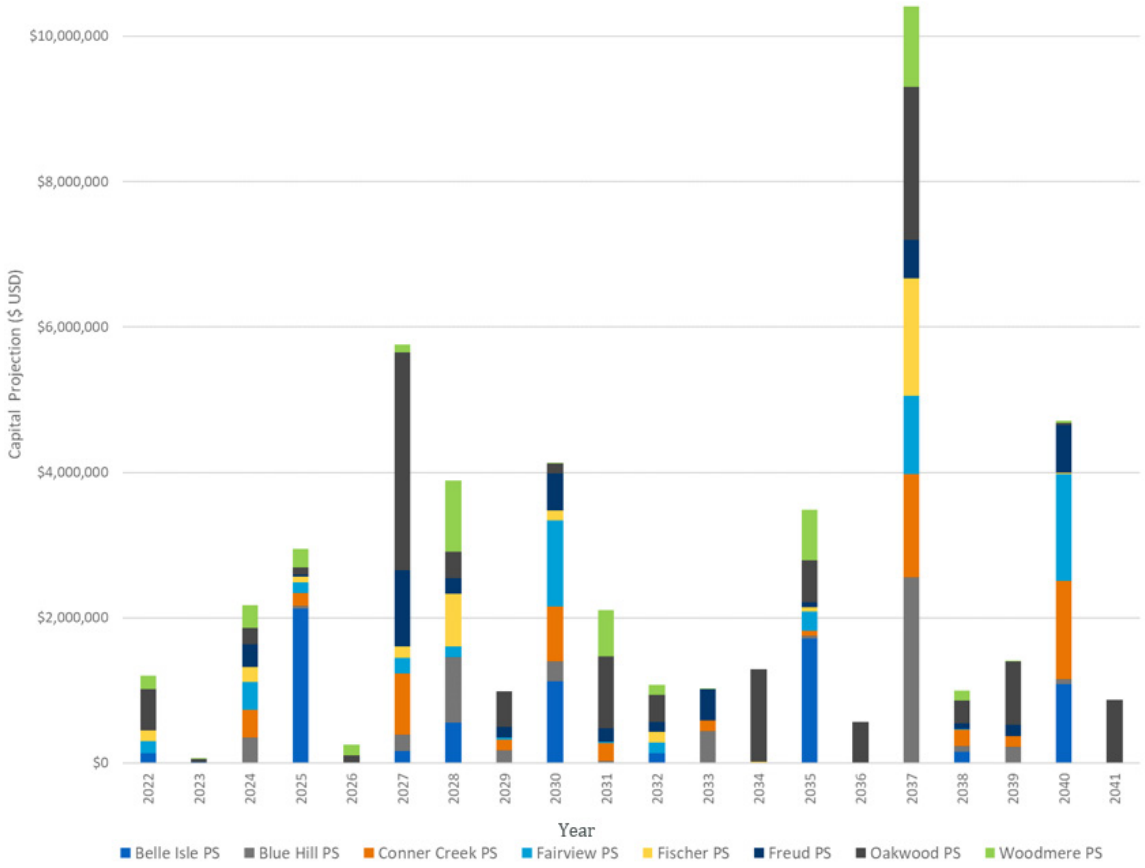


Figure 7-5: SPS Condition-Based Capital Projections (based on 2020 data, in 2021 dollars)

CSO Facilities

Figure 7-6 shows the 20-year projection for CSO assets based on 2020 data from WAM [in 2021 dollars. The projection is based on assumed asset decay curves, current asset condition grades, replacement costs from past CSO asset experience and vendor quotes, and calculated asset replacement dates. The projection includes an estimated $287 million in renewals, which is equivalent to an annual average of $14.3 million. This investment profile indicates several investment peaks in years 2035, 2036, and 2040. While Figure 7-6 shows the calculated investment forecast, or "financial plan impact," this investment profile may not be financially feasible or practical to manage. Therefore, in the CSO CS-299 project,

these results were smoothed out and some asset replacements were included in CIP projects in order to develop a flatter investment plan that is financially feasible and practical to manage. As asset condition data and asset improvement work are continuously completed, the plan is always evolving and is supported through the CSO SRP model.

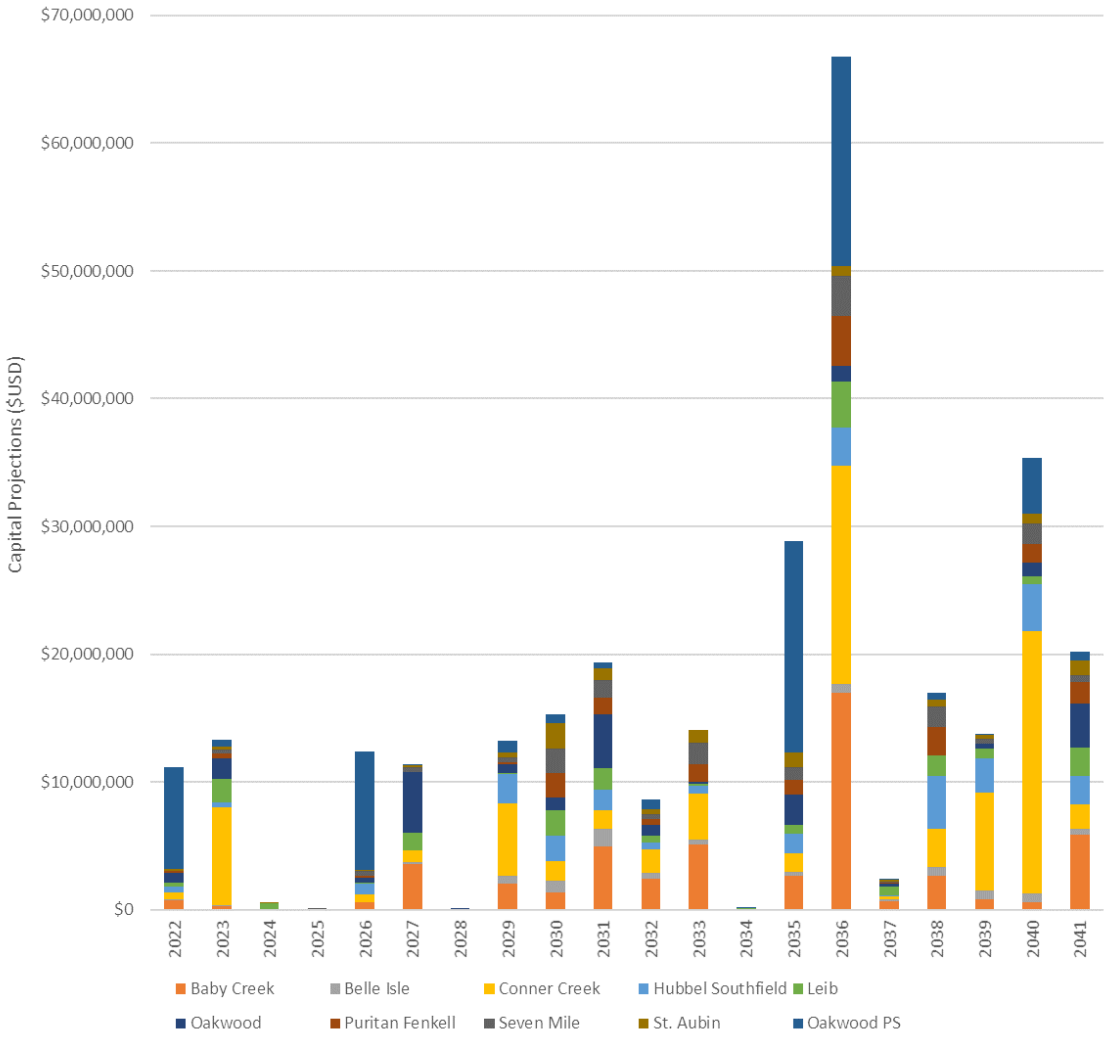


Figure 7-6: CSO Condition-Based Capital Projections (based on 2020 data, in 2021 dollars)

8 Funding

The acronyms used throughout this document are included in Appendix A. For a Glossary of Terms, see the SAMP.

Tactical Recommendation:
N/A

Supporting Artifacts:
Financial Plans

The purpose of this section is to provide an overall financial view for the GLWA wastewater system. It documents the most recent historical operating and capital expenditures and summarizes GLWA's allocated capital expenditures in response to renewal and enhancement drivers.

This chapter aims to provide visibility to maintain the existing service level for the next 10 years[2]. These estimates of funding shortfalls, while developed in a conservative manner, are good indicators of where additional evaluations, improvements, and decision-making are required.

8.1 Historical Expenditures

The following sections provide a summary of the expenditure history of the wastewater system linear and vertical assets, including historical operating and capital expenditures from 2017 to 2020. Since GLWA began operations of the wastewater system in 2016, efficiencies and cost management of the wastewater system assets have significantly improved, and the total cost of ownership of the wastewater system has been optimized. Financial information may be reviewed at the GLWA website Financial Resources - Great Lakes Water Authority (glwater.org).

8.1.1 Operations

The historical operating expenditures for the core programs delivering wastewater services by expense category are shown reflected in Schedule 2b, page 117 of the GLWA 2020 Financial Report https://www.glwater.org/wp-content/uploads/2020/12/Great-Lakes-Water-Authority-2020-CAFR-FINAL-web-version.pdf.

[2] The GLWA began operations in January of 2016; Therefore, only information for the financial years 2017-2020 has been included in the analysis.

8.1.2 Capital

The historical capital expenditures occur through two main programs: Capital Outlay, which includes O&M and I&E; and the CIP. Each is described in the succeeding sections.

8.1.2.1 Capital Outlay

Capital Outlay is defined as equipment and system improvements that are not part of a CIP. GLWA uses its Capital Outlay to fund routine equipment replacements (e.g., a sump pump) as well as the renewal, rehabilitation, or replacement of major process equipment (e.g., a main lift pump). Capital Outlay is intended to cover these periodic replacement and rehabilitation strategies. The Wastewater Capital Outlay budget is found in the Biennial Budget file each year on the GLWA public web site https://www.glwater.org/wp-content/uploads/2019/08/GLWA-FY-2020-and-FY-2021-Biennial-Budget-FINALrev8.12.2019.pdf page 96-97.

8.1.2.2 Capital Improvement Plan

GLWA uses the CIP to fund the enhancement and renewal of long-lived assets. The CIP is developed annually and includes ongoing projects approved in previous years as well as new projects and programs. There have been significant investments in upgrades to the Primary process area at the WRRF, including Pump Station 1 and Pump Station 2. Other major expenditures include sewer and interceptor rehabilitations and the Freud and Connor Creek Pump Station improvements. The CIP budget is found on the GLWA public web site Financial Resources - Great Lakes Water Authority glwater.org.

8.2 Forecasted Expenditures

Forecasted expenditures may be obtained from the GLWA Financial Plan (Financial Resources - Great Lakes Water Authority (glwater.org). Revenue sources are also described. The SRP models are referenced in Chapter 7 – Renewals and described in Appendix K to inform the forecasted needs.

9 Continuous Improvement Plan

9.1 Overview

Tactical Recommendation:
WW1: WwAMP — Asset Management Roles and Responsibilities
WW4: WwAMP — Digital Solutions

Supporting Artifacts:
- WwAMP — Governance Business Processes (Appendix M)

The Wastewater Continuous Improvement Plan is composed of a series of Tactical Recommendations starting in FY22/23 that were identified to achieve significant milestones for improving the way Great Lakes Water Authority (GLWA) manages its wastewater system assets that include linear (pipe) and vertical assets [Water Resource Recovery Facility (WRRF)], sewer pump stations (SPS), and combined sewer overflow (CSO) facilities. Current asset management (AM) activities are identified in the Wastewater Asset Management Plan (WwAMP). The Wastewater Continuous Improvement Plan aims to address a number of key gaps, including refining service levels based on stakeholder expectations; performing targeted condition assessment activities to improve GLWA's condition assessment program; and refining operations and maintenance (O&M) practices that focus on improving data quality, business processes, and use of technology. These recommendations focus primarily on vertical assets and are complemented by a separate set of improvement activities for linear assets under GLWA's Linear System Integrity Program (LSIP).

A summary of the Tactical Recommendations with key supporting artifacts (tools and datasets) are presented in Table 9-1, followed by detailed descriptions for each Tactical Recommendation. Details include the purpose, benefits, and context and background for how the Tactical Recommendations were identified, related Strategic Asset Management Plan (SAMP) Initiatives the Tactical Recommendations support, tasks to guide GLWA with implementing the continuous improvement plan, and estimated internal and external resource requirements. A summary of the level of effort (LOE) and estimated costs for each are outlined in the Staffing Plan presented in Appendix N. Each Tactical Recommendation is numbered with a prefix of "WW," which indicates "wastewater."

Table 9-1: Summary of Tactical Recommendations

Tactical Recommendation	Supporting Artifact/Technology
WW1: WwAMP - Asset Management Roles & Responsibilities	• WwAMP Governance Processes – Appendix M
WW2: WwAMP - Service Levels	• Tier 1-3 Performance Indicators (PIs) • LSIP Performance Metrics Dashboard
WW3: WwAMP - Asset Data and Information for WAM/NexGen	• WwAMP – Asset Data and Information Improvement Summary (Appendix C) • Work and Asset Management (WAM) Data Gaps (Appendix D) • WwAMP – Governance Business Processes (Appendix M)
WW4: WwAMP - Digital Solutions	• GLWA Information Technology (IT) Master Plan
WW5: WwAMP - Condition Assessment of Non-Inspected Vertical Assets	• WwAMP - Asset Condition Assessment Methodology (Appendix E) • WwAMP Condition Assessment Activities – Vertical Assets (Appendix F) • WwAMP – Governance Business Processes (Appendix M)
WW6: WwAMP - Asset Risk for Vertical Assets	• WwAMP Risk Register for Vertical Assets (Appendix G) • WwAMP – Governance Business Processes (Appendix M)
WW7: WwAMP - Maintenance and Reliability Work Management Processes for Vertical Assets	• WwAMP Governance Business Processes (Appendix M)
WW8: WwAMP - Maintenance and Reliability Improvement Implementation for Vertical Assets	• Failure Modes Effects Analysis (FMEA) Pilot – Approach and Results (Appendix I) • Planned Maintenance Optimization (PMO) Report and Tool (Appendix J) • WwAMP – Governance Business Processes (Appendix M)
WW9: WwAMP - Maintenance and Reliability Performance Measurement and Improvement for Vertical Assets	• Tier 1-3 Performance Indicators (PIs) – Chapter 3 of the WwAMP
WW10: WwAMP - Scheduled Replacement Program Implementation	• Scheduled Replacement Program (SRP) Models (WRRF and SPS); CSO Facilities; and Linear Assets (Appendix K) • WwAMP – Governance Business Processes (Appendix M)
WW11: WwAMP - Capital Improvement Program Process Improvement	• WwAMP Governance Business Processes (Appendix M)
WW12: WwAMP - Replacement Cost Database for Vertical Assets	• Financial System

9.2 Tactical Recommendation Descriptions

This section provides details of each Tactical Recommendation and a proposed plan for implementation, including resource requirements and the SAMP improvement initiatives they support, which are listed in Appendix L.

9.2.1 WW1: WwAMP - Asset Management Roles & Responsibilities

GLWA Owner: Enterprise Asset Management Group

Alignment to SAMP Improvement Initiatives:

- P1 - Dedicated Asset Management (AM) Team Members within Business Units (BU)
- O6 - Future AM Assessments and Benchmarking

Supporting Artifacts: WwAMP Governance Business Processes – Appendix M

Purpose

The purpose of this Tactical Recommendation is to establish Asset Management Champions within the GLWA organizational structure with representatives from Planning and Operations and Maintenance (O&M) who have defined roles and responsibilities to support collaborative development and roll-out of the Tactical Recommendations included in this Wastewater Continuous Improvement Plan.

Benefits

The benefit of this Tactical Recommendation is that it establishes ownership and accountability for implementation of the Tactical Recommendations in the Wastewater Continuous Improvement Plan so that GLWA ensures continuation of making improvements in the way it manages wastewater system assets.

Context and Background

GLWA participated in the Water Services Association of Australia (WSAA) Asset Management Assessment and Benchmarking in 2018 and developed a 5-year program of improvement initiatives. Section 10.3 – Current Asset Management Maturity of the SAMP describes this effort. This assessment identified the need for GLWA to identify Asset Management Champions who work to manage asset management performance across vertical and linear assets, with specific responsibility to monitor performance indicators and bring attention to key subject matter experts within the organization when service level objectives are falling short of desired performance.

The Wastewater Asset Management Team (WwAMT) championed the development of the WwAMPby, and during development of the WwAMP, Asset Management Champions within this group with specific asset management roles and responsibilities for implementing the WwAMP and the recommendations contained therein, were identified. The WwAMP governance process is included in Appendix M of the WwAMP.

An Asset Management Champion can monitor performance indicators that track asset management program performance and asset health, and foster collaboration with each part of the organization to discuss performance related to meeting asset management service level objectives. Figure 9-1 depicts this recommended collaboration structure. Table 9-2 details tasks needed to support implementation and Table 9-3 describes resources required.

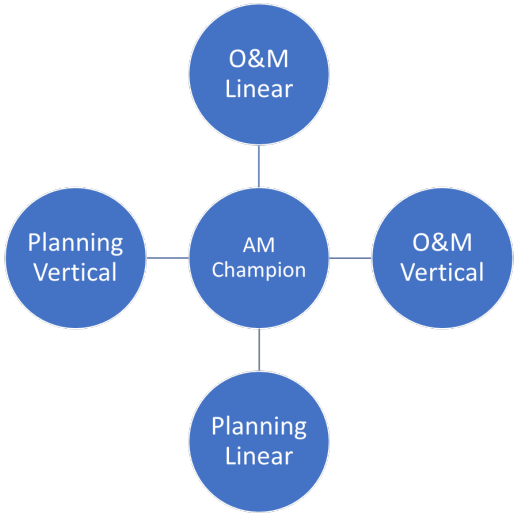


Figure 9-1: Asset Management Champion Collaboration Structure

Table 9-2: Tasks to Support Implementation

Year and Task
Year 1- Define Asset Management Champion Roles and Responsibilities • Discuss the roles and responsibilities of the Asset Management Champion and assess potential to incorporate into the existing asset management governance structure. • Develop the Asset Management Champion job description with clearly defined responsibilities. • Identify owners of the key artifacts listed in Table 9-1 (supporting tools and datasets) and document responsibilities for managing these. • Implement the new roles (Asset Management Champion, owners of supporting tools and datasets).
Year 2 – Assess and Refine Asset Management Champion Roles and Responsibilities • Review the successes and challenges of the Asset Management Champion as part of an annual meeting and refine job description as needed. • Discuss and document succession planning strategy for the Asset Management Champion and owners of key artifacts and implement.

Year and Task
Year 3 – Perform Maturity Assessment Check-In • Review the asset management assessment and benchmarking activity performed in 2018 during SAMP development and compare to other maturity assessment methods within the industry. The results of the maturity assessment performed during SAMP development are documented in the "Asset Management Assessment Summary – April 18, 2019." • Conduct asset management maturity assessment and compare results to the maturity assessment documented in the "Asset Management Assessment Summary – April 18, 2019."

Table 9-3: Resource Requirements for Tactical Recommendation WW1: WwAMP - AM Roles & Responsibilities

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
40 hours (5 staff at four, 2- hour meetings)	$0	10 hours (5 staff at one, 2-hour meetings)	$0	60 hours (10 staff at three, 2-hour meetings)	$50,000 (cost to facilitate meetings for the maturity assessment and development of report)

9.2.2 WW2: WwAMP - Service Levels

GLWA Owner: Enterprise Asset Management Group

Alignment to SAMP Improvement Initiatives:

- S1 - Refined Service Levels

Supporting Artifacts: Tier 1-3 PIs and LSIP Performance Metrics Dashboard

Purpose

The purpose of this Tactical Recommendation is to create/refine service levels dashboards and performance targets.

Benefits

The benefit of this Tactical Recommendation is that it supports GLWA with refining service level objectives and performance targets in alignment with internal and external stakeholder expectations reflected in the SAMP.

Context and Background

During development of the WwAMP, it was identified that GLWA does not have detailed service levels and identified targets fully defined by service area, in alignment with internal and external stakeholder expectations. However, while the WwAMP was being developed, GLWA has been actively working to define more detailed service level metrics and improve performance tracking. The metrics and service level targets for vertical assets are reflected in the Tier 1-3 PIs for vertical assets and metrics for linear assets are defined as part of the LSIP as described in Section 3.7 – Service Levels of the WwAMP.

Service levels are typically organized in a hierarchy reflected in Figure 9-2 and included in the SAMP. Identifying targets for each service level can be used to drive planning processes to understand the impact on costs (and prices/charges).

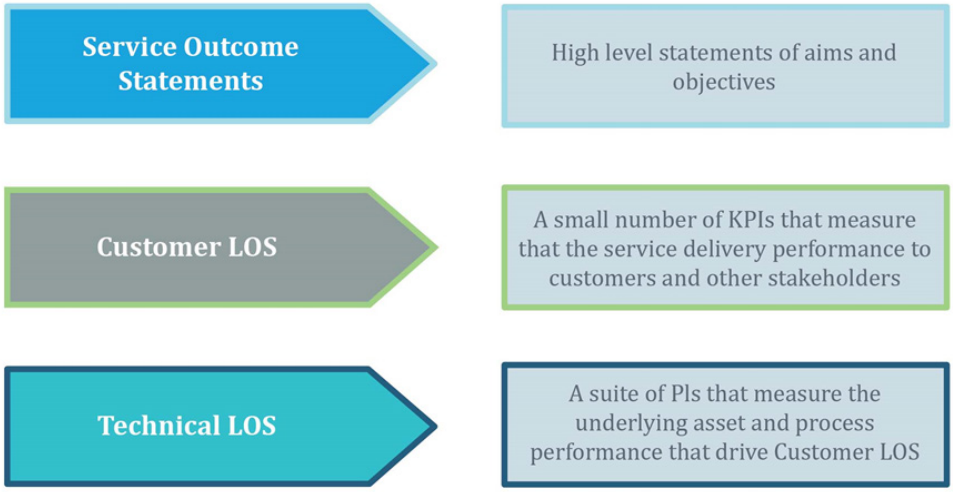


Figure 9-2: Industry Standard Service Levels Hierarchy

Note: LOS = Levels of Service; PI = Performance Indicators; KPIs = Key Performance Indicators

Customer service levels are at the heart of the performance measurement framework. A useful method for developing customer service levels is to consider the six universal customer values reflected in Table 9-4. These are intended to be used as a series of prompts rather than a rigid template. Table 9-5 details tasks needed to support implementation and Table 9-6 describes resources required.

Table 9-4: Six Universal Customer Values

Universal Customer Values	
Accessibility	The ease of access to services such as the quantity per capita, proximity and allowance for customer of different abilities to access, and use of a service provided by the asset owner.
Reliability/Availability	The service is available as advertised. Often measured as interruptions, delays, and reductions to service.
Quality	The quality of the service delivery provided by the asset owner. Meeting functional and aesthetic needs.
Customer Service	The interaction between staff and customers.
Safety	Providing a safe environment for staff and customers.
Sustainability	Environmental sustainability goals such as waste minimization, resource recovery, water/land/air pollution and greenhouse gas emission reduction.

Table 9-5: Tasks to Support Implementation

Year and Task
Year 1 – Develop Service Level Framework • Collate existing relevant material for GLWA's wastewater service levels [including Mindmaps and American Water Works Association (AWWA) measures]. • Collect wastewater service level examples from other jurisdictions. • Meet to discuss the current overall framework for service levels and discuss the following topics: ✓ A tiered approach that considers service outcome statements, customer service levels and technical service levels ✓ The use of universal customer values in establishing customer service levels ✓ Improvements based on other jurisdictions • Meet with leadership to: ✓ Define service outcome statements and a succinct set of customer service levels aligned to internal and external stakeholder expectations • Refine Tier 1-3 PIs based on input from leadership. • Define required data to incorporate refinements to the service levels.
Year 2 – Improve Data to Report on Service Levels • Define cost effective strategies to fill data gaps [incorporate into Tactical Recommendation WW3: WwAMP - Asset Data and Information for WAM/NexGen (as needed)].
Year 3 – Develop Targets for Customer Service Levels • Establish preliminary targets for customer service levels (and a selection of technical service levels).

Table 9-6: Resource Requirements for Tactical Recommendation WW2: WwAMP - Service Levels

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
200 hours (10 staff at 10 hours each; 50 hours of one staff to facilitate compilation of metrics; 50 hours of one staff create initial baseline of data)	$0	20 hours (5 staff, 2, 2-hour meetings)	$0	50 hours (10 staff at 5 one-hour meetings)	$0

9.2.3 WW3: WwAMP - Asset Data and Information for WAM/NexGen

GLWA Owner: Data Stewards

Alignment to SAMP Improvement Initiatives:

- D1 - AM Information System Strategies
- D6 – Asset Audit Program with Tagging Standards

Supporting Artifacts: WwAMP- Asset Data and Information Improvement Summary – Appendix C; Work and Asset Management (WAM) Data Gaps Spreadsheet – Appendix D; WwAMP– Governance Business Processes (Appendix M)

Purpose

The purpose of this Tactical Recommendation is to actively work to address identified data gaps in WAM/NexGen and implement strategic business processes to improve data quality and improve confidence in data integrity.

Benefits

The benefit of this Tactical Recommendation is that it addresses data gaps to track service level objectives and provide asset management information that improves staff decision-making.

Context and Background

The data gap summary presented below is the result of an assessment performed in 2020 as part of the development of the WwAMP. Improving asset data is an ongoing task and improvements have been performed by GLWA while the WwAMP was under development.

Data gaps specific to asset condition, maintenance and reliability, asset valuation, and asset risk are referenced in the related Tactical Recommendations, which will improve programs/processes that leverage that data. Chapter 4 – Asset Profile describes the current state of asset data. Table 9-7 details tasks needed to support implementation and Table 9-8 describes resources required.

Table 9-7: Tasks to Support Implementation

Year and Task
Year 1 – Address Initial Data Gaps and Identify Data Collection Needs • Address data gaps listed in the WAM Data Gaps Spreadsheet -Appendix D under the columns "Asset Data Changes for WwAMP." • Incorporate civil assets in the asset registry and break assets into further subcategories: Roof, pavement, fencing, windows, etc. • Review the asset hierarchy and update as needed during the NexGen implementation. • Establish business processes for performing asset data collection activities. • Review and define data owner roles and responsibilities, including overseer/reporter of wastewater asset data collection and quality control progress. • Review WwAMP Asset Data and Information Improvement Summary (Appendix C) and identify Year 2 Data Collection Needs to address gaps listed.
Year 2 – Collect Data to Address Data Gaps Identified in Year 1 • Implement asset data collection activities identified in Year 1.
Year 3 – Evaluate Data Collection Performance • Evaluate data collection performance from Year 2 and set goals for performance for Year 3.

Table 9-8: Resource Requirements for Tactical Recommendation WW3: WwAMP - Asset Data and Information for WAM/NexGen

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
150 hours (5 staff at 10 hours each to participate in five, 2-hour meetings; 100 hours for 2 staff (50 hours each) to address gaps)	$0	400 (4 staff at 100 hours each)	$0	20 hours (5 staff at 4 hours each; over two, 2-hour meetings)	$0

9.2.4 WW4: WwAMP - Digital Solutions

GLWA Owner: Data Stewards

Alignment to SAMP Improvement Initiatives:

- D1 – AM Information System Strategies
- D3 – Consistent Data Standards
- D7 – Useful Life of Assets
- O1 – Asset Management Plans

Supporting Artifacts: GLWA Information Technology (IT) Master Plan

Purpose

The purpose of this Tactical Recommendation is to support GLWA with improving the use and configuration of technologies that support staff with performing work, entering critical data, and displaying data in concise reports/dashboards.

Benefits

The benefit of this Tactical Recommendation is that it supports GLWA with tracking Asset Management Program performance and readily displays data to support staff with day-to-day asset management decision-making.

Context and Background

During development of the WwAMP, GLWA staff described business processes/activities followed to perform asset management activities and their use of existing technology. These business processes/activities were compared to other asset management-focused organizations, and improvements for GLWA were identified.

Table 9-9 details tasks needed to support implementation and Table 9-10 describes resources required.

Table 9-9: Tasks to Support Implementation

Year and Task
Year 1 – Configure NexGen to Display Key Data to Inform Asset Management Decision-Making • Create a data field in NexGen to display asset risk scores that are visible to operations and maintenance (O&M) staff. • Configure NexGen to support roll-out and track Condition Assessment Program activities. • Determine/finalize service level dashboard platforms that can be viewed by internal and external stakeholders to report performance aligned to service levels.

Year and Task
Year 2 – Integrate NexGen with Core Technologies • Integrate NexGen to GLWA's Project Management Information System (PMIS) to support asset onboarding and improve analytics across the asset life cycle. • Align asset hierarchies between NexGen and the financial system to improve asset valuation reporting. • Create a work plan to move the WwAMP into a digital format (linking all data sources and asset management strategies to provide information to staff and support workflow).
Year 3 – Convert WwAMP to Digital Format • Implement the work plan to move the WwAMP into a digital format.

Table 9-10: Resource Requirements for Tactical Recommendation WW4: WwAMP - Digital Solutions

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
40 hours (10 staff at four, 1-hour meetings)	$75,000 (to configure NexGen to allow risk scores; populate NexGen with condition assessment work orders, and create the service level dashboard)	60 hours (10 staff at three, 2-hour meetings – one meeting per task activity)	$75,000 (to configure the integration with PMIS)	50 hours (5 staff at 10 hours each; over five, 2-hour meetings)	$75,000 (to create the Asset Management Plan in a digital format)

9.2.5 WW5: WwAMP - Condition Assessment of Non-Inspected Vertical Assets

GLWA Owner: Local Asset Management Team

Alignment to SAMP Improvement Initiatives:

- R8 – Condition Assessment Program for Vertical Assets

Supporting Artifacts: WwAMP - Condition Assessment Activities – Vertical Assets (Appendix F); WwAMP – Governance Business Processes (Appendix M)

Purpose

The purpose of this Tactical Recommendation is to perform asset condition assessment activities on all vertical assets based on priorities defined over a three-year period. Condition assessment priorities for linear assets are documented by LSIP.

Benefits

The benefits of this Tactical Recommendation include promoting better understanding of deterioration rates by vertical asset types, enhancing the management and prioritization of maintenance tasks, and supporting identification of asset renewal needs.

Context and Background

Condition assessment scheduling is based on non-inspected "active" WRRF and SPS and CSO assets listed in the Risk Register for Vertical Assets that received a tabletop analysis for identifying condition. Chapter 4 – Asset Profile and Chapter 5 – Asset Risk of the WwAMP describes the approach and process to identifying assets for condition assessment and developing asset risk scores for vertical assets. Those that had a consequence of failure (COF) score equal to 4 or 5 were classified as "Priority #1 Condition Assessment" and scheduled to be assessed in Year 1. The remaining non-inspected assets were classified as "Priority #2 Condition Assessment" and scheduled based on location and workload leveling over the three years. *Condition assessment activities for linear assets are documented in LSIP.*

The recommended condition assessment schedule details are contained in the Condition Assessment Activities – Vertical Assets spreadsheet included in Appendix F. The spreadsheet indicates the recommended approach to assessing asset condition as either "visual" or "detailed." The recommended approach is based on the level of assessment performed as part of the WwAMP development on similar asset types. In general:

All high COF assets were labeled as Priority #1 Condition Assessment. Priority #1 assets are to be addressed in Year 1.

The remaining assets that have a high likelihood of failure (LOF) score were labeled as Priority #2 Condition Assessment. Priority #2 assets are to be addressed in Year 1, Year 2 and Year 3.

Figure 9-3 shows the distribution of condition assessment counts per year based on 2020 assessment data for WRRF process areas and the SPS.

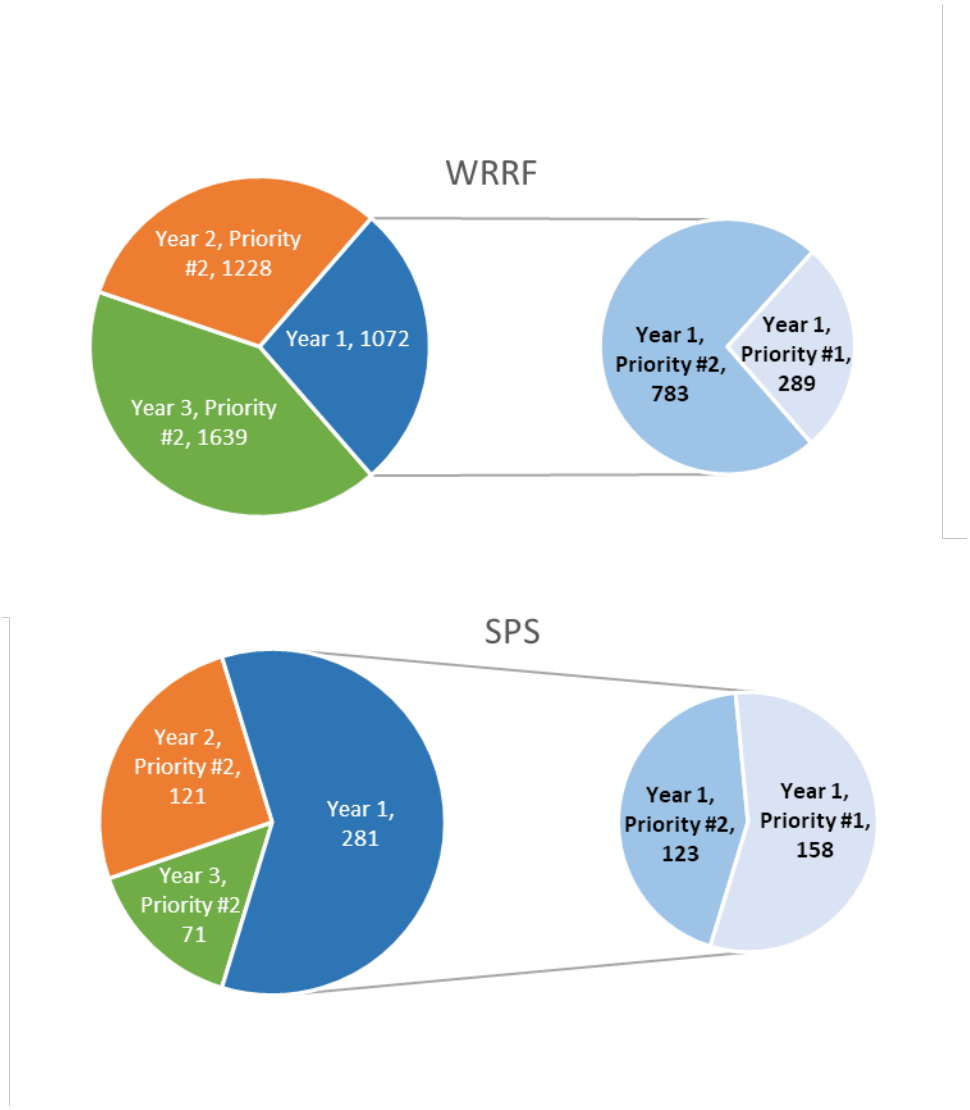


Figure 9-3: Count of Condition Assessments for WRRF and SPS by Priority (based on 2020 data)

Figure 9-4, Figure 9-5, and Figure 9-6 show the distribution of visual and detailed condition assessments (by WRRF process area and SPS facility). *Assets that received a visual condition assessment in 2020 are not reflected.* Asset types recommended for detailed assessments include DRIVE-ELEC, FAN, MCC, MOTOR, and PUMP. A detailed assessment requires the asset to be actively running and/or involves special instrumentation in addition to visual inspection. Examples of detailed assessment condition properties include infrared delta-T; insulation resistance; vibration analysis; volt and amp balance; and functionality of valves, control lights, and switches. Table 9-11 provides a summary of the vertical asset condition assessments.

Table 9-11 Summary of Vertical Asset Condition Assessments

Asset Type	Year 1 – Priority 1&2		Year 2 – Priority 2		Year 3 – Priority 2	
	Visual	Detailed	Visual	Detailed	Visual	Detailed
WRRF – Primary	836	38	-	-	-	-
WRRF – Secondary	97	60	879	58	-	-
WRRF – Dewatering	5	10	288	3	-	-
WRRF - Incineration	-	-	-	-	751	70
WRRF – Common Support	24	2	-	-	813	5
SPS – Blue Hill	50	5	-	-	-	-
SPS – Bell Isle	103	5	-	-	-	-
SPS – Conner Creek	20	9	42	-	-	-
SPS - Fischer	-	-	-	-	15	-
SPS – Freud	35	1	34	2	-	-
SPS – Fairview	16	9	43	-	-	-
SPS – Oakwood	16	12	-	-	-	-
SPS - Woodmere	-	38	-	-	56	-

Figure 9-4 includes all Priority #1 and a portion of Priority #2 assets recommended for performing visual and detailed condition assessments in the Primary process area for the WRRF. This is driven by the fact that the Primary process area assets have a high COF.

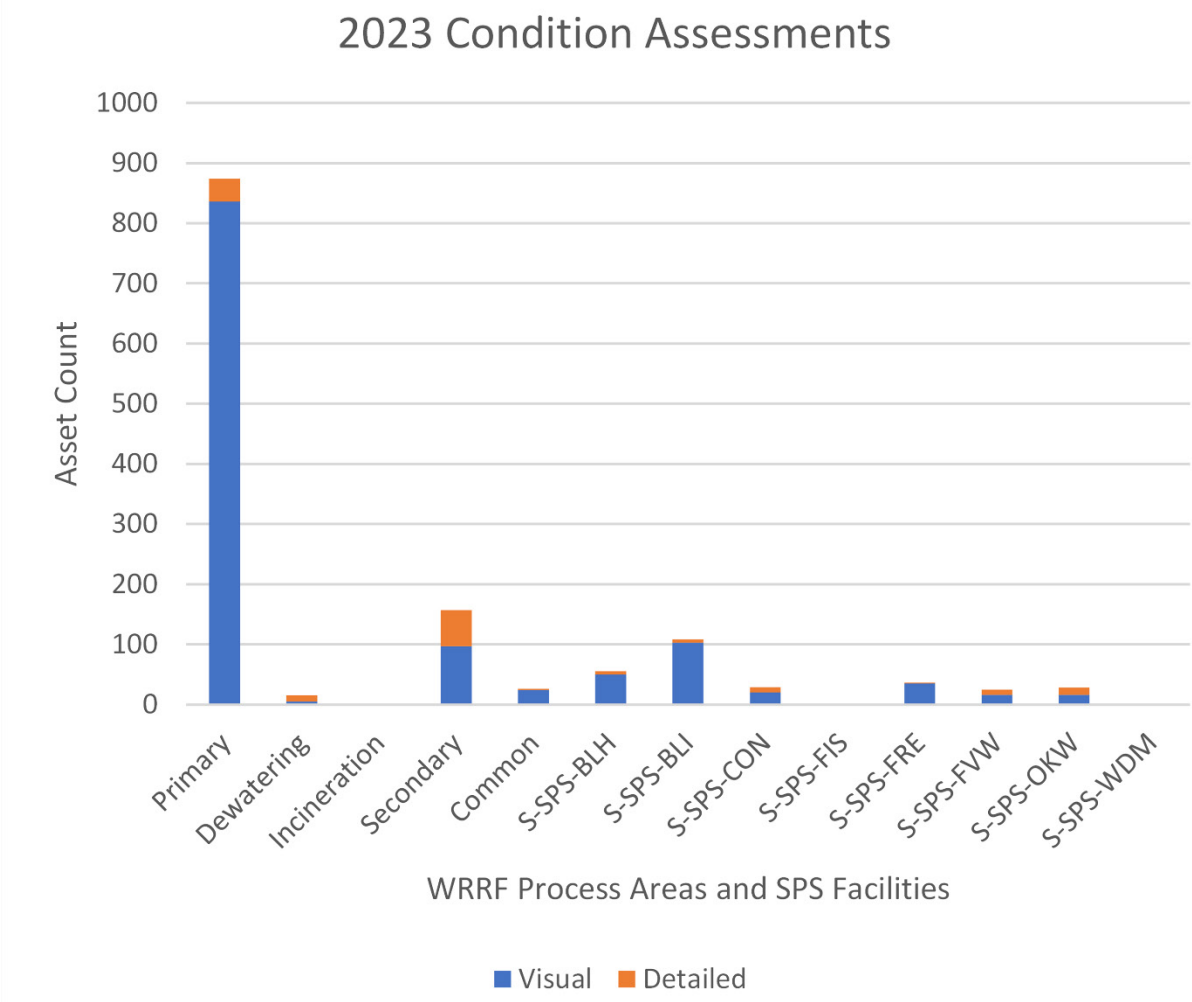


Figure 9-4: Priority #1 & #2 Condition Assessments – Year 1 (based on 2020 data)

Figure 9-5 indicates the Priority #2 assets for performing visual and detailed condition assessments in the Secondary process area for the WRRF. This is driven by the fact that the Secondary process area assets have a high LOF.

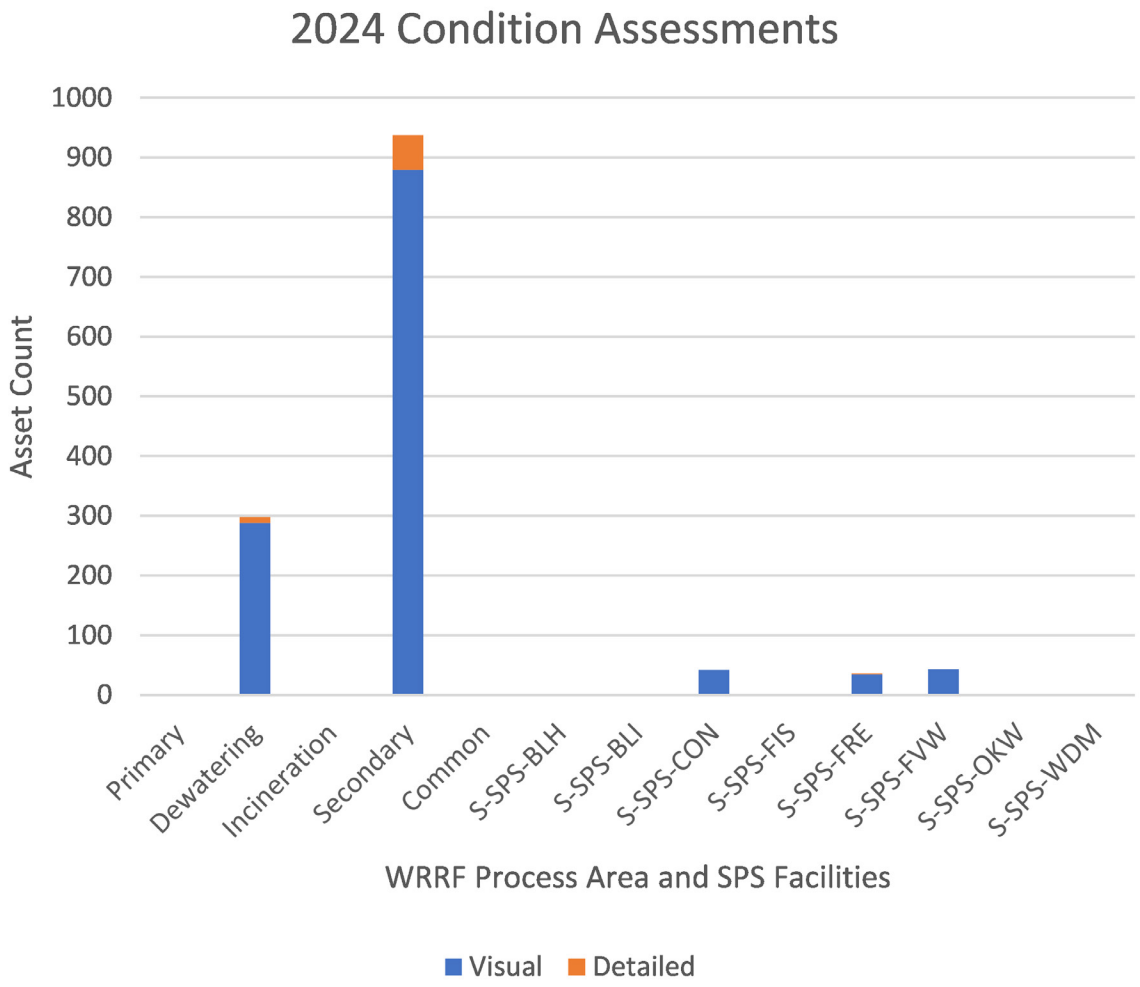


Figure 9-5: Priority # 2 Condition Assessments – Year 2 (based on 2020 data)

Figure 9-6 indicates the Priority #2 assets for performing visual and detailed condition assessments in the Incineration and Common Support process areas for the WRRF. This is driven by the fact that the incineration and common support process area assets have a high LOF but lower compared to Secondary process area assets so were identified for being addressed in Year 3.

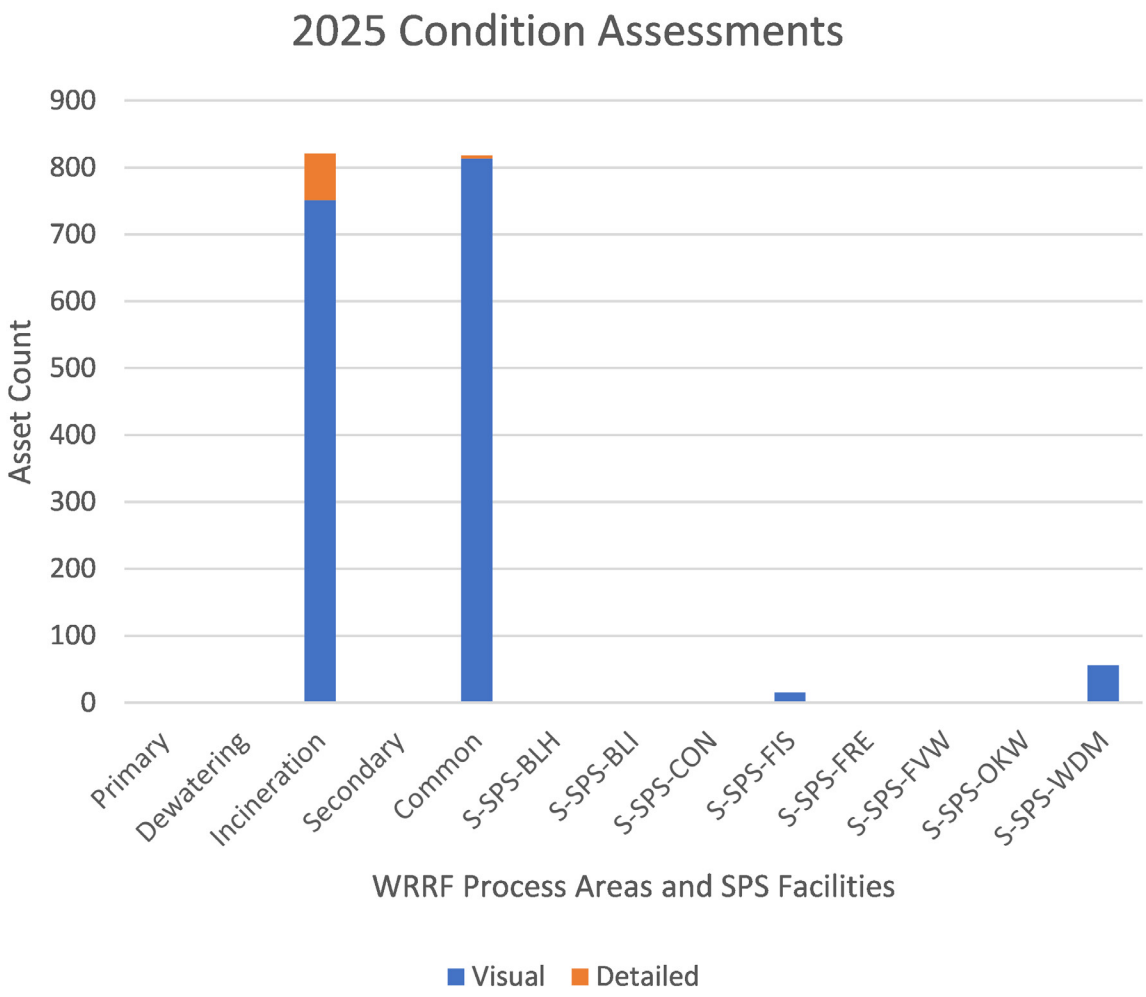


Figure 9-6: Priority # 2 Condition Assessments – Year 3 (based on 2020 data)

Table 9-12 details tasks needed to support implementation and Table 9-13 describes resources required.

Table 9-12: Tasks to Support Implementation

Year and Task
Year 1 – Perform Priority #1 and Priority #2 Condition Assessments – Year 1 • Review and confirm the condition assessment schedule for Year 1, as reflected in Condition Assessment Activities – Vertical Assets. • Implement the condition assessment activities for Year 1.
Year 2 – Perform Priority #2 Condition Assessments – Year 2 • Review and confirm the condition assessment schedule for Year 2, as reflected in Condition Assessment Activities – Vertical Assets. • Implement the condition assessment activities for Year 2.

Year and Task
Year 3 – Perform Priority #2 Condition Assessments – Year 3 • Review and confirm the condition assessment schedule for Year 3, as reflected in Condition Assessment Activities – Vertical Assets. • Implement the condition assessment activities for Year 3.

Table 9-13: Resource Requirements for Tactical Recommendation WW5: WwAMP - Condition Assessment of Non-Inspected Vertical Assets

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
400 hours (5 staff at 80 hours each; over a two-week period)	$0	400 hours (5 staff at 80 hours each; over a two-week period)	$0	500 hours (7 staff at 70 hours each; over a two- week period)	$0

9.2.6 WW6:WwAMP - Asset Risk for Vertical Assets

GLWA Owner: Local Asset Management Team

Alignment to SAMP Improvement Initiatives:

- R5 – Asset Risk Identification and Analysis

Supporting Artifacts: WwAMP - Risk Register for Vertical Assets (Appendix G); WwAMP Governance Business Processes (Appendix M)

Purpose

The purpose of this Tactical Recommendation is to further develop the asset risk profile included in the Risk Register for Vertical Assets, using improved condition data.

Benefits

The benefits of this Tactical Recommendation include refining the Risk Register for Vertical Assets results to prioritize staff decision-making around O&M and capital planning and consequently mitigate asset risk.

Context and Background

The vertical asset risk scores relied on tabletop analysis for determining history of reliability and approximately 54% of the vertical asset condition scores. The results are presented in Appendix G - Risk Register for Vertical Assets and described in Chapter 5 – Asset Risk Determination of the WwAMP. The COF scores were initially set by GLWA staff at

the process level through tabletop analysis and then adjusted through multiple staff workshops. Using the data from the Risk Register for Vertical Assets, risk mitigation strategies were subsequently identified. As GLWA continues to collect asset data to identify LOF and COF, risk mitigation strategies can be continuously refined. Current risk mitigation strategies reflected in the Risk Register for Vertical Assets include the following:

Asset Replacement - replacement projects can be grouped by location and/or asset type and specific replacement programs can be developed to effectively maximize asset life while minimizing the risks associated with failure.

O&M Improvement - evaluation of development, utilization, and performance tracking for O&M.

Contingency Attenuation - minimizing the risk associated with asset failure can be asset or system specific, depending on an array of variables. Examples of strategy in this treatment group include decrease in response times, changes in operations that affect resiliency, upgraded equipment that eliminate or safeguards the asset, and improved system design, to name a few.

Each risk mitigation strategy is "triggered" by a respective numerical setpoint for affected criteria scores, which is reflected in the Risk Register for Vertical Assets. The set point represents the numerical value that is no longer acceptable in accordance with GLWA's risk tolerance levels. A risk mitigation strategy should improve (or lower) the score below the set point. This is important to GLWA as the occurrence of risk events tend to cost more to manage once they occur, compared to implementing risk mitigation strategies to prevent them from occurring. The description of reduction in asset risk score per risk mitigation strategy is presented in Table 9-14. A detailed decision-making flowchart for identifying risk mitigation strategies within the Risk Register for Vertical Assets is presented in Figure 9-7, which can be applied in subsequent years by the Local Asset Management Team. This methodology supports Section 5.5 – Risk Treatment and Appendix F –WwAMP - Condition Assessment Activities – Vertical Assets.

Table 9-14: Risk Mitigation Strategy Triggers and Effects

Set Point Trigger	Set Point Value	Risk Mitigation Strategy	Effect
Condition Score	>4.0	Asset Replacement	Reduction of Condition score
History of Reliability Score	>3.5	O&M Improvement	Reduction of History of Reliability score
Consequence of Failure Score	>3.5	Contingency Attenuation	Reduction of COF score

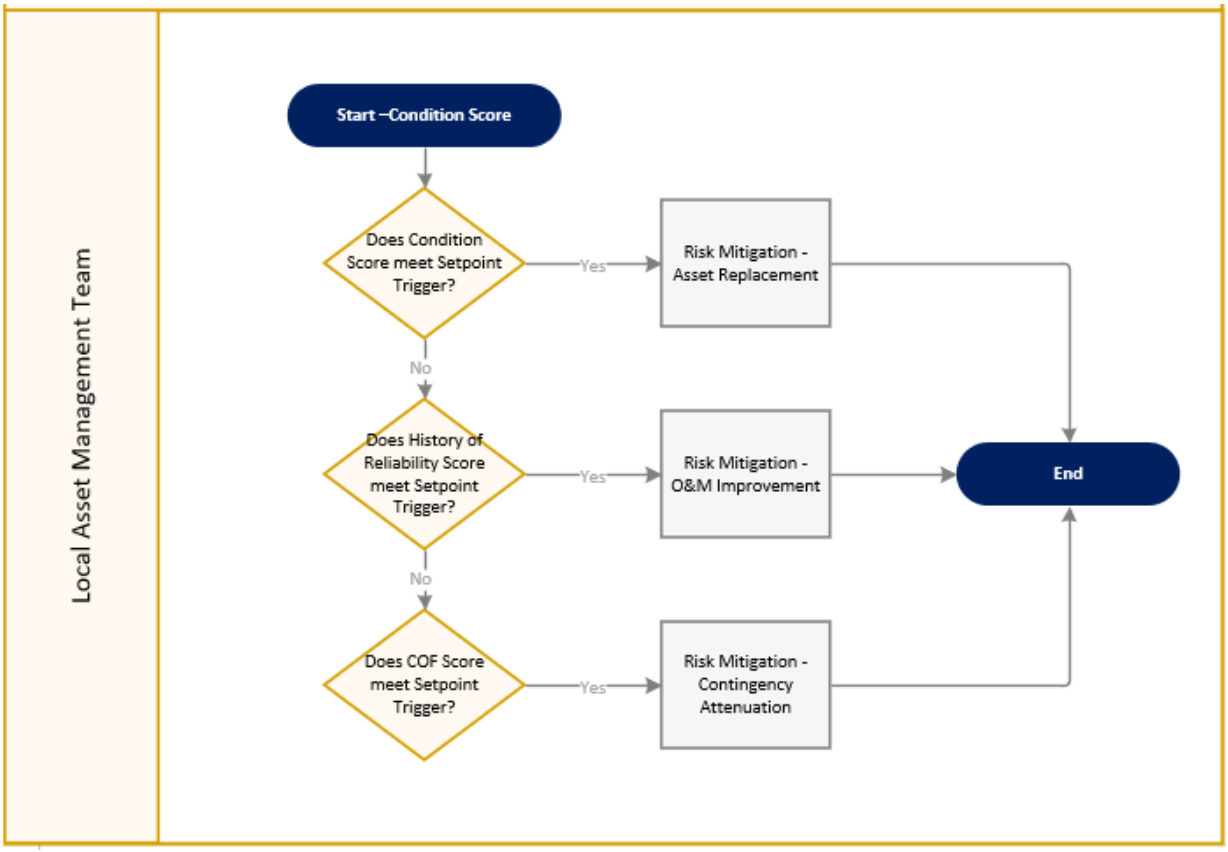


Figure 9-7: Risk Mitigation Strategy Decision-Making Flowchart

Figure 9-8 shows the wastewater assets risk scores. Figure 9-9 shows the wastewater asset risk scores with risk mitigation strategies in place.

Figure 9-8 indicates the volume of asset risk scores (based on 2020 data) for each possible pairing of COF (1 to 5) and LOF (1 to 5) scores. The volume of assets is represented by the bubble size and labeled with the number of assets. Green, yellow, and red chart backgrounds correspond to GLWA wastewater risk tolerance: low, medium, and high, respectively.

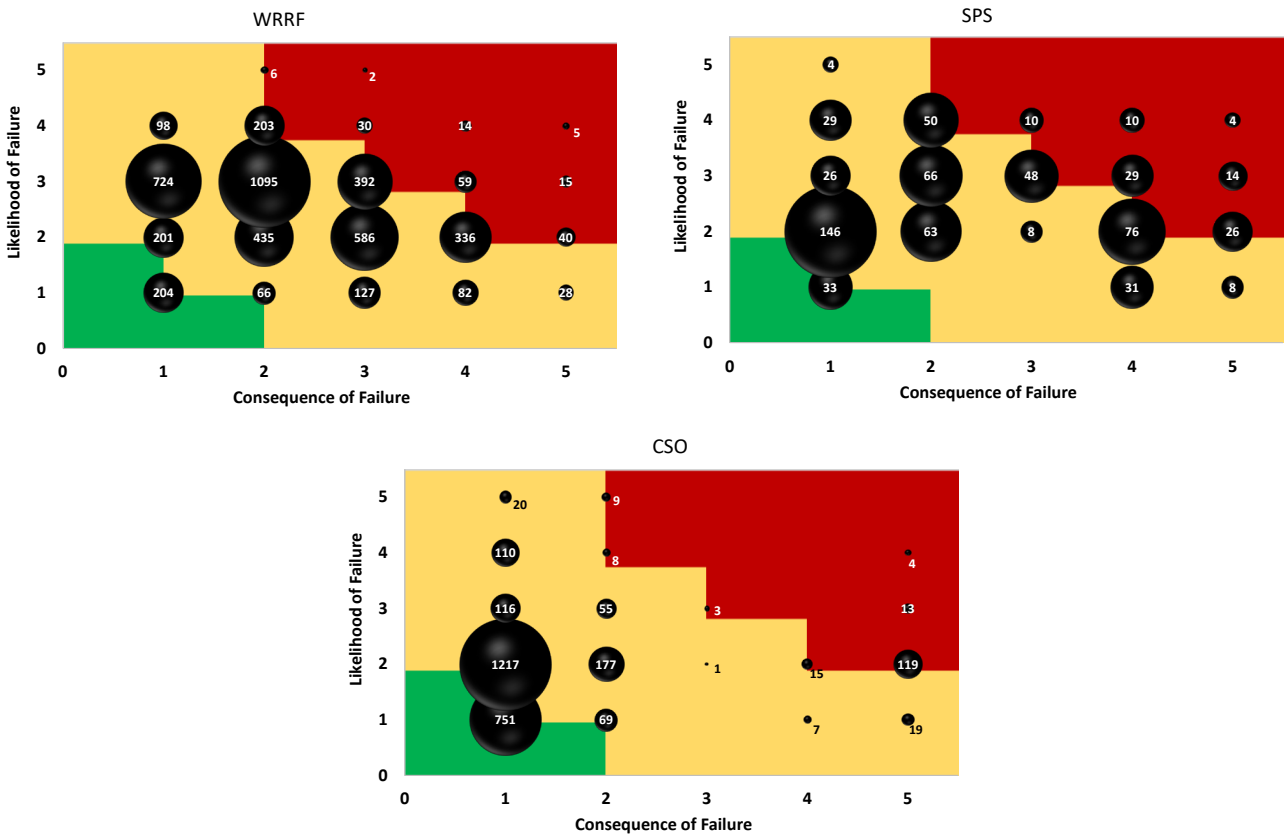


Figure 9-8: Vertical Assets Risk (based on 2020 data)

Figure 9-9 shows vertical asset risk scores (based on 2020 data) with risk mitigation. Asset replacement was recommended for all assets that received a visual or detailed condition score equal to 4 or higher. The physical condition score represents 70% of the LOF score. As condition scores are updated, asset replacement for risk mitigation can be continuously evaluated using the risk register tool. History of reliability score (HoR, 30% of LOF) was adjusted to a score of 2 for all assets recommended for improved O&M strategies. O&M strategy for risk mitigation was applied to all assets with an HoR score of 3.5 or higher.

Assets with tabletop-analysis condition scores of 4 or higher are recommended for visual or detailed assessments over the next three years before scheduling asset replacement. This is evident by the reduction in LOF scores for CSO, which received visual and detailed assessments, as compared to WRRF and SPS, which received tabletop-analysis physical condition scores for most assets.

Assets with a COF score of 3.5 or higher that received a visual or detailed assessment were recommended for contingency attenuation for risk mitigation. Contingency attenuation refers to minimizing the risk associated with asset failure. Examples of strategy in this treatment group include development of an asset contingency plan or system redundancy.

Due to the variability in contingency attenuation, COF scores with risk mitigation were adjusted conservatively to a score of 3. As with asset replacement for risk mitigation, assets that received a tabletop-analysis for condition were recommended for a visual or detailed assessment before considering planning a project to reduce asset consequence.

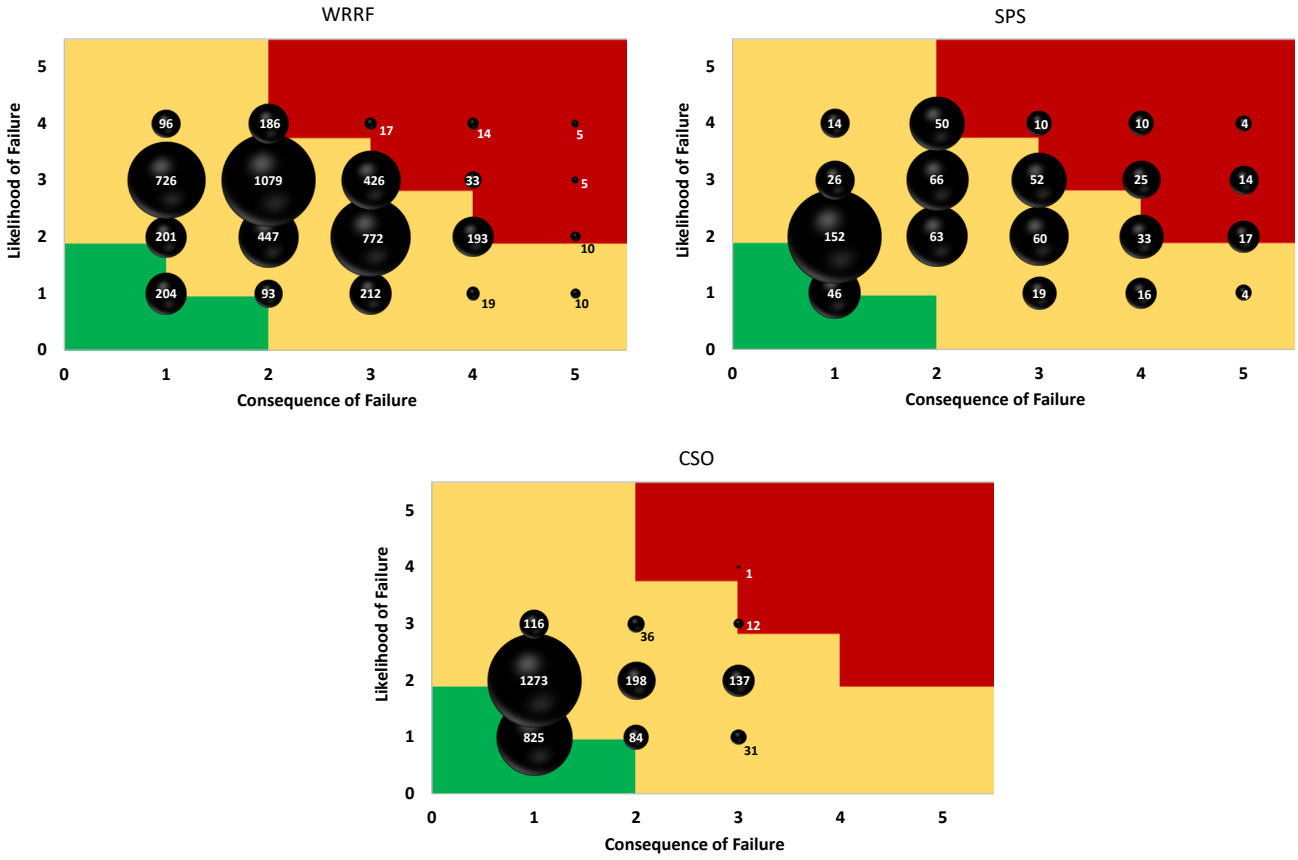


Figure 9-9: Vertical Asset Risk (based on 2020 data) with Risk Mitigation

Table 9-15 details the tasks needed to support implementation, while Table 9-16 describes resource requirements.

Table 9-15: Tasks to Support Implementation

Year and Task
Year 1 – Refine Risk Register for Vertical Assets with Updated Condition Data • Incorporate Year 1 condition assessment data from condition assessment activities (Tactical Recommendation WW5: WwAMP – Condition Assessment of Non-Inspected Vertical Assets) into the Risk Register for Vertical Assets. • Update History of Reliability scores in the Risk Register for Vertical Assets with any new available data. • Use results from the Risk Register for Vertical Assets to schedule/plan asset replacements using the Scheduled Replacement Program (SRP) model.

Year and Task
Year 2 – Assess Risk Mitigation Strategies and Refine • Re-evaluate risk mitigation strategies included in the Risk Register for Vertical Assets and update as needed. • Incorporate Year 2 condition assessment data from condition assessment activities (Tactical Recommendation WW5: WwAMP – Condition Assessment of Non-Inspected Vertical Assets) into the Risk Register for Vertical Assets. • Update History of Reliability scores in the Risk Register for Vertical Assets with any new available data. • Use results from the Risk Register for Vertical Assets to schedule/plan asset replacements using the SRP model.
Year 3 – Revisit Risk Register for Vertical Assets Criteria and Refine • Incorporate Year 3 condition assessment data from condition assessment activities (Tactical Recommendation WW5: WwAMP – Condition Assessment of Non-Inspected Vertical Assets) into the Risk Register for Vertical Assets. • Update History of Reliability scores in the Risk Register for Vertical Assets with any new available data. • Use results from the Risk Register for Vertical Assets to schedule/plan asset replacements using the SRP models (Tactical Recommendation WW10: WwAMP – Scheduled Replacement Program Implementation).

Table 9-16: Resource Requirements for Tactical Recommendation WW6: WwAMP - Asset Risk for Vertical Assets

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
50 hours (2 staff at 25 hours each to update the Risk Register for Vertical Assets)	$0	60 hours (5 staff at 2 hours each over one, 2-hour meeting; 2 staff at 25 hours each to update the Risk Register for Vertical Assets)	$0	50 hours (2 staff at 25 hours each to update the Risk Register for Vertical Assets)	$0

9.2.7 WW7: WwAMP - Maintenance and Reliability Work Management Processes for Vertical Assets

GLWA Owner: Wastewater Operations

Alignment to SAMP Improvement Initiatives:

- M2 – Formalized Work Management Policy
- M3 – Improved Planning and Scheduling Function

Supporting Artifacts: WwAMP – Governance Business Processes - Appendix M

Purpose

The purpose of this Tactical Recommendation is to define improved work management processes based on maintenance and reliability industry standards for vertical assets that can be implemented and support O&M staff as part of the roll-out of NexGen. Work management is defined as all activities starting from identifying needed work through completing and documenting work performed.

Benefits

The benefits of this Tactical Recommendation include defining efficiencies in performing work and maximizing the value provided by NexGen. The work management process should be used to configure NexGen workflow routing and data fields to support needed data capture. Formal business processes and procedures for planning and scheduling of work will be implemented sometime after NexGen goes live; NexGen will need to be updated to support these activities at a later date (2023).

Context and Background

This Tactical Recommendation was identified during the Maintenance & Reliability Maturity Assessment conducted in 2019 that revealed work management processes were not optimized or standardized across similar work groups. The current O&M strategies are described in Chapter 6 – O&M Strategies of the WwAMP.

Table 9-17 details tasks needed to support implementation and Table 9-18 describes resources requirements.

Table 9-17: Tasks to Support Implementation

Year and Task
Year 1 – Develop Improved Maintenance and Reliability Work Management Processes • Document improved work management process that includes work identification, work planning, work scheduling, work execution, work completion, and work analysis with representatives from vertical asset work groups. These work management processes should be defined through a series of facilitated workshops to discuss and document the workflow. • Update NexGen configuration to support improved work management processes. • Train plant personnel on the defined work management processes.
Year 2 – Improve Planning and Scheduling Activities • Evaluate current planning and scheduling activities and identify workflow improvements as needed. • Assess planning and scheduling staff resources and adjust as necessary (hire, assign, etc.) • Train planners and schedulers on any newly identified activities.
Year 3 • None

Table 9-18: Resource Requirements for Tactical Recommendation WW7: WwAMP - Maintenance and Reliability Work Management Processes for Vertical Assets

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
300 hours (30 staff involved in 10 hours of business process development and training)	$100,000 (to work with GLWA to develop business processes and update NexGen configuration and facilitate training)	100 hours (10 staff at 10 hours each that includes five, 2-hour meetings/ training sessions)	$50,000 (to work with GLWA to evaluate Planning and Scheduling activities, organizational support, and facilitate training)	0 hours	$0

9.2.8 WW8: WwAMP - Implement Maintenance and Reliability Improvements for Vertical Assets

GLWA Owner: Wastewater Operations

Alignment to SAMP Improvement Initiatives:

- M2 – Formalized Work Management Policy
- M3 – Improved Planning and Scheduling Function

Supporting Artifacts: Failure Modes and Effects Analysis (FMEA) Pilot – Approach and Results (Appendix I); Planned Maintenance Optimization (PMO) Report and Tool - (Appendix J); WwAMP – Governance Business Processes (Appendix M)

Purpose

The purpose of this Tactical Recommendation is to apply various reliability improvement methods designed to direct O&M resources to conducting the most effective tasks in maintaining critical asset reliability and minimizing overall operational risk. These methods include, but are not limited to, Failure Modes and Effects Analysis (FMEA) and Planned Maintenance Optimization (PMO).

Benefits

The benefits of this Tactical Recommendation include focusing resources on high-value activities with objectives of achieving workflow efficiencies and using data to minimize the risk of asset failures.

Context and Background

This Tactical Recommendation was identified during the Maintenance & Reliability Maturity Assessment conducted in 2018 that revealed work management processes did not include industry recommended maintenance reliability activities. The current O&M strategies are described in Chapter 6 – O&M Strategies of the WwAMP.

Table 9-19 details tasks needed to support implementation and Table 9-20 describes resources required.

Table 9-19: Tasks to Support Implementation

Year and Task
Year 1 – Implement FMEA and PMO Activities • Review, approve & implement FMEA and PMO outputs from pilot projects across the WRRF. The results of the pilot FMEA and PMO are reflected in Appendices I and J of the WwAMP. • Evaluate the impact of the FMEA and PMO changes by monitoring the occurrence of asset failures and make decision on expanding PMO analysis and the development of FMEAs to other asset types.
Year 2 – Expand FMEA and PMO and Develop Predictive Maintenance Strategy • Expand FMEA and / or PMO activities to other asset types beyond the pilot (if approved). • Develop Root Cause Analysis for high COF assets. • Define a Predictive Maintenance (PdM) strategy. • Define a PdM team and provide training and certification.
Year 3 – Implement Predictive Maintenance Strategy • Implement the PdM strategy defined in Year 2.

Table 9-20: Resource Requirements for Tactical Recommendation WW8: WwAMP - Implement Maintenance and Reliability Improvements for Vertical Assets

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Est Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Est Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Est Consultant Cost ($)
60 hours (5 staff at 12 hours each; over six, 2-hour meetings)	$0	400 hours (10 staff at 40 hours each; over twenty, 2-hour meetings/trainings)	$0	800 hours (10 staff at 80 hours each)	$0

9.2.9 WW9: WwAMP - Maintenance and Reliability Performance Measurement and Improvement for Vertical Assets

GLWA Owner: Local Asset Management Team; Wastewater Operations

Alignment to SAMP Improvement Initiatives:

- S3 – Improved Performance Reporting
- O6 – Future AM Assessments and Benchmarking

Supporting Artifacts: Tier 1-3 Performance Indicators (PIs) – Chapter 3 of the WwAMP

Purpose

The purpose of this Tactical Recommendation is to develop a Maintenance and Reliability Program performance monitoring system.

Benefits

The benefit of this Tactical Recommendation is that it will enable GLWA to monitor the impact of maintenance and reliability improvement activities using identified performance indicators (Tactical Recommendation WW2: WwAMP- Service Levels).

Context and Background

This Tactical Recommendation was identified during the Maintenance & Reliability Maturity Assessment conducted in 2018 that revealed work management processes did not include industry recommended maintenance reliability activities. The current O&M strategies and performance tracking are described in Chapter 6 – O&M Strategies of the WwAMP.

Table 9-21 details tasks needed to support implementation and Table 9-22 describes resources required.

Table 9-21: Tasks to Support Implementation

Year and Task
Year 1 – Develop Maintenance and Reliability Performance Tracking Platform with Tier I PIs • Identify and develop a performance tracking technology platform using the defined Tier I PIs (Tactical Recommendation WW2: WwAMP – Service Levels). • Identify staff responsible for monitoring Tier 1 PIs. • Define follow-up actions for staff responsible for monitoring performance.
Year 2 - Develop Maintenance and Reliability Performance Tracking Platform with Tier 2 and Tier 3 PIs • Incorporate Tier 2 PIs into performance tracking platform. • Identify staff responsible for monitoring Tier 2 PIs. • Define follow-up actions for staff responsible for monitoring performance. • Incorporate Tier 3 PIs into performance tracking platform. • Identify staff responsible for monitoring Tier 3 PIs. • Define follow-up actions for staff responsible for monitoring performance.
Year 3 – Perform Maintenance and Reliability Maturity Assessment • Repeat the Maintenance & Reliability Maturity Assessment and compare to 2018 results to identify improvements that have occurred.

Table 9-22: Resource Requirements for Tactical Recommendation WW9: WwAMP - Maintenance and Reliability -Performance Measurement and Improvement for Vertical Assets

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
40 hours (2 staff at 10 hours each to assist with set up technology platform, 5 staff at 4 hours each over two, 2-hour meetings)	$100,000 (to develop performance tracking platform with Tier 1 metrics and facilitate governance monitoring responsibilities)	40 hours (2 staff at 10 hours each to assist with set up technology platform, 5 staff at 4 hours each over two, 2-hour meetings)	$50,000 (to incorporate Tier 2 and Tier 3 metrics into performance tracking platform)	40 hours (10 staff at two, 2-hour meetings)	$10,000 (to facilitate and prepare Maintenance & Reliability Maturity Assessment)

9.2.10 WW10: WwAMP - Scheduled Replacement Program Implementation

GLWA Owner: Local Asset Management Team

Alignment to SAMP Improvement Initiatives:

- G4 – Scheduled Replacement Program

Supporting Artifacts: Scheduled Replacement Program (SRP) Models (WRRF, SPS, CSO, and linear assets) (Appendix K); WwAMP – Governance Business Processes (Appendix M)

Purpose

The purpose of this Tactical Recommendation is to implement results identified in the SRP models to identify projected funding needed to support long-term renewal needs for WRRF, SPS, CSO, and wastewater system linear assets.

Benefits

The benefits of this Tactical Recommendation include improved understanding of long-term renewal and financial needs projected into the future to maintain the asset profile.

Context and Background

As part of the development of Chapter 7 – Renewals of the WwAMP, two SRP models were developed to help understand the long-term renewal needs: one for the WRRF and SPS

assets, and one for linear assets. A life cycle model for CSO facilities was already in existence. GLWA has since transferred results from the assessment on linear assets to a new Info Asset Planner (IAP) SRP model.

The current SRP tools are spreadsheet-based. Spreadsheets are very useful for building and proving new models but can become challenging to use over time due to manual data entry requirements. A single commercial-off-the-shelf (COTS) software can assist with the consolidation of SRP results and presentation of funding needs for the entire set of wastewater system assets in a standardized manner.

Table 9-23 details tasks needed to support implementation and Table 9-24 describes resources required.

Table 9-23: Tasks to Support Implementation

Year and Task
Year 1 – Update SRP Models with Year 1 Condition Assessments • Update existing SRP models with results from Year 1 condition assessment data (Tactical Recommendation WW5: WwAMP – Condition Assessment for Non-Inspected Vertical Assets). • Document the data management issues and opportunities.
Year 2 –Update SRP Models with Year 2 Condition Assessments and Assess SRP Model Options • Update existing SRP models with results from Year 2 condition assessment data (Tactical Recommendation WW5: WwAMP – Condition Assessment for Non-Inspected Vertical Assets). • Document the data management issues and opportunities. • Discuss COTS options and receive demonstrations from vendors and feedback from peer group organizations.
Year 3 – Update SRP Models with Year 3 Condition Assessments and Identify and Secure New SRP Software (if needed) • Update existing SRP models with results from Year 3 condition assessment data (Tactical Recommendation WW5: WwAMP – Condition Assessment for Non-Inspected Vertical Assets). • Prepare Request for Qualifications for COTS software acquisition, configuration, and training (if needed).

Table 9-24: Resource Requirements for Tactical Recommendation WW10: WwAMP - Scheduled Replacement Plan Implementation

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
50 hours (5 staff at 2 hours each; over two, 1-hour meetings and 2 staff at 40 hours of working with SRP models)	$0	50 hours (5 staff at 2 hours each; over two, 1-hour meetings and 2 staff at 40 hours of working with SRP models)	$0	100 hours (4 staff at 4 hours each to participate in two, 2-hour meetings and 84 hours (2 staff at 42 hours each to develop RFP)	$0

9.2.11 WW11: WwAMP - Capital Improvement Program (CIP) Process Improvement

GLWA Owner: Enterprise Asset Management Group

Alignment to SAMP Improvement Initiatives:

- R1 – Shift to Asset Risk-Driven Funding and CIP Prioritization

Supporting Artifacts: WwAMP Governance Business Processes – Appendix M

Purpose

The purpose of this Tactical Recommendation is to refine the existing CIP development process to incorporate results of condition assessment, reliability analysis, risk assessment and long-term renewals planning as inputs into the CIP identification process.

Benefits

The benefit of this Tactical Recommendation includes more precise identification of capital needs using industry standard capital planning identification data inputs.

Context and Background

The approach to identifying this Tactical Recommendation is based on understanding of the existing CIP business process and inputs considered/not considered.

Table 9-25 details tasks needed to support implementation and Table 9-26 describes resources required.

Table 9-25: Tasks to Support Implementation

Year and Task
Year 1 – Refine the CIP Process to Incorporate Results of Asset Management Analyses • Facilitate a series of business process mapping workshops to define the CIP development process that includes new practices such as condition, risk, SRP, IAP, reliability analysis, service levels.
Year 2 – Initiate Use of Asset Management Analyses Results into CIP Process • Formally implement the new CIP development process that reflects inputs identified in Year 1.
Year 3 • None

Table 9-26: Resource Requirements for Tactical Recommendation WW11: WwAMP - Capital Improvement Program Process Improvement

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
60 hours (6 staff to participate in five, 2-hour meetings)	$50,000 (to facilitate process improvement meetings)	0 hours (new inputs do not require additional time to the existing CIP process)	$0	0 hours	$0

9.2.12 WW12: WwAMP - Replacement Cost Database for Vertical Assets

GLWA Owner: Enterprise Asset Management Group

Alignment to SAMP Improvement Initiatives:

- D10 – Asset Costing Improvements

Supporting Artifacts: Financial System

Purpose

The purpose of this Tactical Recommendation is to incorporate modern equivalent asset replacement costs to help monitor and report the current value of the assets.

Benefits

The benefit of this Tactical Recommendation is that it makes more accurate asset costs for use in preparing long-term renewal forecasts. Creating a simple and structured vertical asset replacement cost database can help improve confidence in funding projections and making decisions.

Context and Background

One of the data gaps that was identified in the development of the WwAMP is a lack of robust and up-to-date replacement cost information of the vertical asset base. As a result, the long-term renewal projections could be under- or over-estimating the renewal needs of the system. The assets in WAM already have a defined hierarchy, but the cost database does not extend to all assets.

Table 9-27 details tasks needed to support implementation and Table 9-28 describes resources required.

Table 9-27: Tasks to Support Implementation

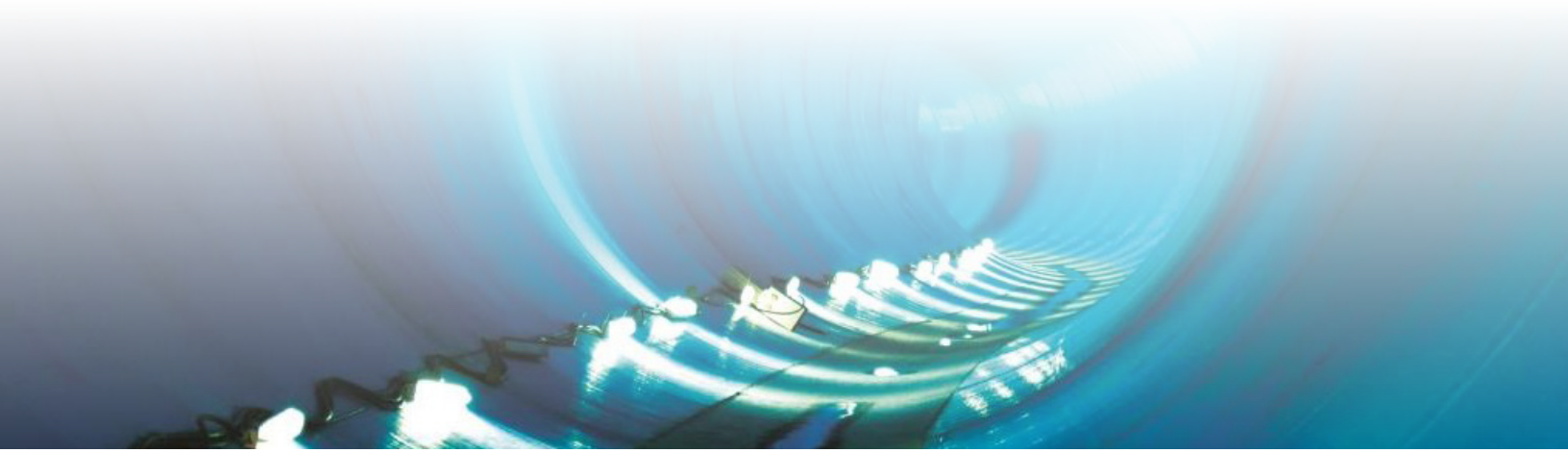
Year and Task
Year 1 – Improve Asset Cost Data on Existing Assets in WAM/NexGen • Review asset hierarchy and confirm lowest level to record/track replacement costs. • Identify existing cost information (project actuals, tender schedules of rates and prices, project estimates). • Identify owners, maintainers, and users of the cost data. • Confirm key fields and attributes (e.g., sizes) to track. • Develop Excel-based data collection template to record cost information. • Populate data collection template from sources and inflate to current dollars. • Consolidate data into a single flat Excel file (the database). • Analyze collected data and establish unit prices. • Review and refine data fields, attributes, and collection templates.
Year 2 – Identify Process to Maintain Cost Data • Establish a process for maintaining the cost database with defined roles and responsibilities, including a combination of annual escalation, updates from project actuals, and a major refresh process when annual escalation becomes no longer valid.
Year 3 – Expand Asset Cost Database and Processes to all Assets • Extend asset cost database to assets that are not currently in WAM/NexGen (e.g., civil assets) to achieve more complete coverage of the asset base.

Table 9-28: Resource Requirements for Tactical Recommendation WW12: WwAMP - Replacement Cost Database for Vertical Assets

Year 1		Year 2		Year 3	
Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)	Estimated GLWA Staff Resources (Hours)	Estimated Consultant Cost ($)
100 hours (2 staff at 50 hours each)	$50,000 (to support GLWA staff with the task activities)	24 hours (4 staff at three, 2-hour meetings)	$0	40 hours (2 staff at 20 hours each)	$0

Appendix A – Acronyms

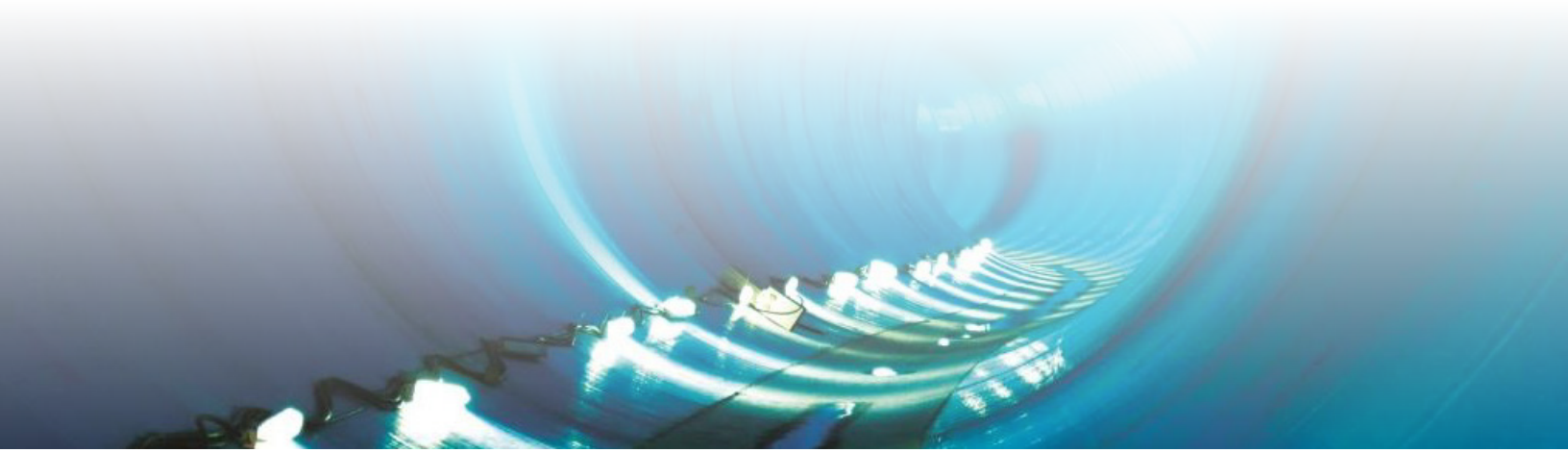
See SAMP for Glossary of Terms.



Acronym	Definition
ACES	Asset condition evaluation system
AHU	Air handling unit
AM	Asset management
AMP	Asset management plan
AMPU	Am program update
AWWA	American Water Works Association
CBOD	Carbonaceous biochemical oxygen demand
CIP	Capital improvement program
CM	Corrective maintenance
CMMS	Computerized maintenance management system
COF	Consequence of failure
COTS	Commercial-off-the-shelf
CSO	Combined sewer overflow
DWSD	Detroit water and sewerage department
EAM	Enterprise asset management
EAMG	Enterprise Asset Management Group
EGLE	Environment, Great Lakes, and Energy
EM	Emergency maintenance
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FMEA	Failure modes effects analysis
GIS	Geographic information system
GLWA	Great Lakes Water Authority
HoR	History of reliability
HVAC	Heating, ventilation, and air conditioning
I&E	Improvements and extension
IAP	Info asset planner
IT	Information technology
IWOP	Interim wet weather operating plan
LOE	Level of effort
LOF	Likelihood of failure
LSIP	Linear system integrity program
MDEQ	Michigan Department of Environmental Quality
MSI	Multi-sensor inspection
MTBF	Mean time between failure
NA	Not applicable

Acronym	Definition
NASSCO	National Association of Sewer Service Companies
NPDES	National pollution discharge elimination system
NWI	Northwest Interceptor
O&M	Operations and maintenance
OEM	Original equipment manufacturer
P&S	Planning and scheduling
PACP	Pipeline assessment certification program
PdM	Predictive maintenance
PFAS	Per- and Polyfluoroalkyl Substances
PI	Performance indicators
PM	Preventive maintenance
PMIS	Project management information system
PMO	Planned maintenance optimization
ROP	Regional operating plan
RPN	Risk priority number
RTB	Retention treatment basins
RUL	Remaining useful life
SAMP	Strategic asset management plan
SCREAM	System condition risk enhanced assessment model
SDF	Screening & disinfection facilities
SOAP	Solomon Oldach Assessment Process
SPS	Sewage pump stations
SRP	Scheduled replacement program
SSO	Source separated organics
TP	Total phosphorous
TRC	Total residual chlorine
TSS	Total suspended solids
USGS	United States Geological Survey
WAM	Work and asset management
WE&RF	Water Environment & Reuse Foundation
WRRF	Water Resource Recovery Facility
WSAA	Water Services Association of Australia
WwAMP	Wastewater asset management plan
WwAMT	Wastewater asset management team

Appendix B – WwAMP Development Participants



The initial wastewater asset management plan (WwAMP) was developed over a period of time from 2020 to 2022 through a series of collaborative workshops and meetings held between Jacobs and GLWA staff. A list of staff involved in the development of the initial WwAMP is presented in Table B-1. A list of meetings held is presented in Table B-2.

Table B-1: WwAMP Development Participants

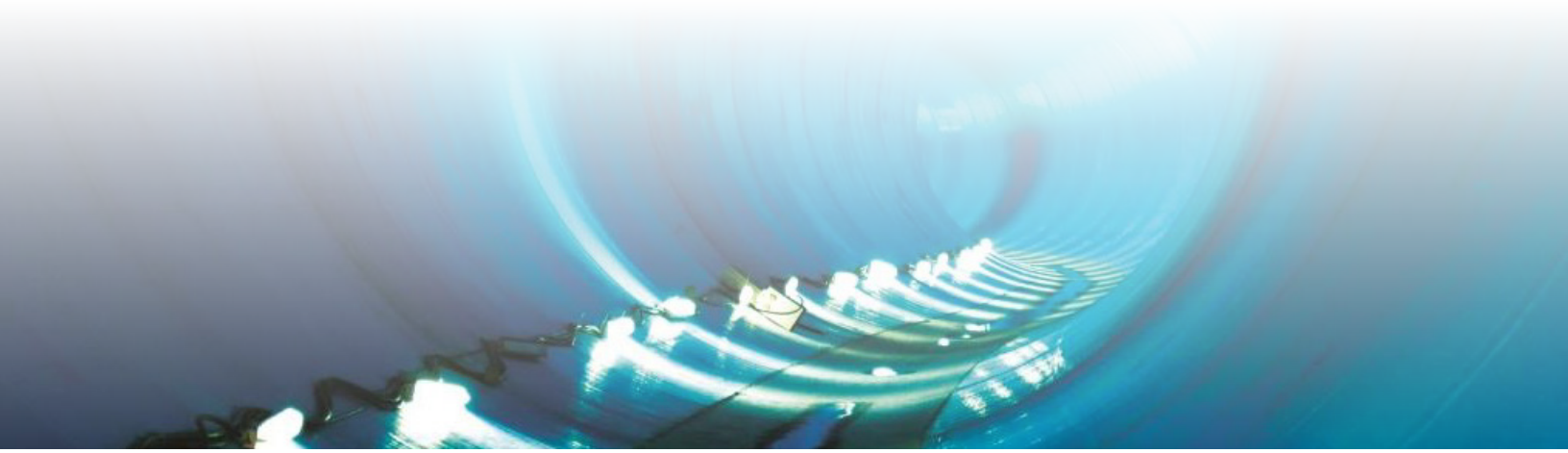
#	Name	Area
1	Ian Thompson	CIP
2	Christopher Nastally	CSO
3	Joe Burchi	EAMG
4	Jody Caldwell	EAMG
5	Fadel Farhat	EAMG
6	William Fritz	EAMG
7	Kyle Hines	EAMG
8	Ashley Jacqmain	EAMG
9	Kaisra Osman	EAMG
10	David Taylor	EAMG
11	Paula Anderson	Facilities
12	Thomas Hall	Field Services
13	Todd King	Field Services
14	Robert Arbaugh	Finance
15	Guy Belew	Finance
16	Verne Houlton	IT
17	Jenny Wein	IT
18	Roger Willingham	IT
19	Bryon Wood	IT
20	Shondell Daniel	System Control Center
21	Biren Saparia	System Control Center
22	Debra Anderson	Transformation
23	Tamika Mitchell	Transformation
24	Daniel Alford	Wastewater
25	Chad Cogar	Wastewater
26	Jonathan Farrugia	Wastewater
27	Melissa Frierson	Wastewater
28	Majid Khan	Wastewater

#	Name	Area
29	Jeffrey Smith	Wastewater
30	Raymond Zdonkiewicz	Wastewater
31	Major Gresham	Wastewater Maintenance Manager
32	Lamarr Beden	Wastewater Operations Team Lead
33	Richard Muntz	Wastewater Operations Team Lead
34	Annette Vines	Wastewater Team Lead
35	Eric Griffin	Water – Energy, Research & Innovation
36	Katherine Miracle	Water – Field Services
37	Latonia Wilson	Water – Field Services
38	Justin Woods	Water – Field Services
39	Terry Daniel	Water Operations
40	Jerrod Wade	Water Operations
41	Jeff Dorsey	Water Treatment
42	Ed Merriweather	Water Treatment
43	Anthony Troy	Water Treatment
44	Alpesh Patel	WRRF - Engineer
45	Erica Moore	WRRF - Incineration
46	John Clark	WRRF - Maintenance
47	Bobby Davis	WRRF - Maintenance
48	John Lokosis	WRRF - Maintenance
49	John Miller	WRRF - Maintenance
50	Melvin Murphy	WRRF - Maintenance
51	Kenneth Paylor	WRRF - Maintenance
52	Joseph Rowland	WRRF - Maintenance
53	Peter Sissen	WRRF - Operations
54	Zanetta Stewart	WRRF - Operations
55	Robert Kowal	Retired

Table B-2: WwAMP Development Meetings

Meetings	# of Group Meetings	Timeframe
WwAMP PAW – Asset Hierarchy (Workshop 1)	7 (Primary; Secondary; Dewatering; Incineration; Sewer Pump Stations; Common Support; CSO)	October 2020 – November 2020
WwAMP PAW – Asset Risk (Workshop 2); Risk Results	7 (Primary; Secondary; Dewatering; Incineration; Sewer Pump Stations; Common Support; All Results)	October 2020 – August 2021
Work Management and Performance Metrics	3	October 2020-February 2021
WwAMP PAW – FMEA/PMO (Workshop 3)	6 (Primary; Secondary; Dewatering; Incineration; Sewer Pump Stations; Common Support)	November 2020
Asset Drivers	1	February - March 2021
WwAMP PAW (Workshops Round 4)	4 (Primary (Part A and B); Dewatering; Common Support)	February – March 2021
Condition Assessment Results Review	1	April 2021
WwAMP Tactical Recommendations Review	5	May 2021 – May 2022
Asset Renewals (SRP Model)	4 (SPS and WRRF)	June 2021 – April 2022
PMO/FMEA Report Out	7 (Overview, Primary; Secondary; Dewatering; Incineration; Sewer Pump Stations; Common Support)	July 2021 - March 2022
WwAMP Draft Review	2	March 2022
WwAMP Governance Business Process Review	3	May – June 2022
PMO Tool Training	1	June 2022

Appendix C – WwAMP Asset Data and Information Improvement Summary



C.1 PURPOSE

This WwAMP Asset Data and Information Improvement Summary for the Great Lakes Water Authority (GLWA) presents the data updates obtained for the latest WwAMP, including the revised asset hierarchy; condition assessment information for selected assets; operations and maintenance (O&M); and capital renewal needs. The intent is to capture the most essential information to reveal the current status of WwAMP assets, but also to support optimization of the operating context and direction within which the assets must perform in alignment with the Strategic Asset Management Plan (SAMP) for GLWA.

GLWA recognizes that asset data collection, management, quality control, and effective utilization is a continuous process and is ever evolving as data needs evolve. The following asset data and information improvement summary is the result of an assessment performed in 2020 as part of development of the WwAMP. This data gap summary recognizes GLWA updates data as part of day-to-day operations and the data gaps listed here may not represent existing gaps. Chapter 9 of the WwAMP includes a Tactical Recommendation that outlines improvements for GLWA to pursue to improvement wastewater asset data quality.

C.2 APPROACH

Once available data was collected from GLWA through a WAM data export performed in June 2020, Jacobs reviewed the data in detail to determine alignment with SAMP objectives. Specifically, Jacobs reviewed SAMP Section 6.3.6, which states that GLWA can consider asset management plans (AMPs) successful when:

- Through development of AMPs, team members are learning, the AMPs are being used, and they are living, useful documents
- GLWA can demonstrate improvement in achievement of service levels
- GLWA can demonstrate improvement in accomplishment of performance indicators
- GLWA can demonstrate responsible management of the grouping of assets covered in the AMP, including risk management
- GLWA can demonstrate decreased lifecycle cost of owning, operating, and maintaining assets, i.e., expectations of the grouping of assets are being met in the most effective and efficient manner
- GLWA can demonstrate that due regard is being given to the long-term stewardship of the grouping of assets covered in the AMP
- GLWA is making well-informed decisions on a daily basis and can develop defendable business cases

- GLWA can justify the near- and long-term funding requirements for the grouping of assets
- GLWA has confidence that regulatory compliance will be achieved in groupings of assets
- AMPs are widely understood and supported at GLWA, appropriate resources are available for their development, and AMPs form the basis for funding decisions for asset capital and O&M needs

C.3 Results

C.3.1 Asset Inventory

The asset inventory comprises a list of all assets, organized into a hierarchy, with an appropriate set of attributes such as type, status, make, model, material, size/capacity, date of installation.

C.3.2 Vertical Asset Data Gaps

A vertical asset register was created for the WwAMP based on WAM export data. The WwAMP vertical asset register was focused on asset type, asset status, process area or facility, parent/child asset relationships, and missing asset records for existing assets found in the field or noted by GLWA staff. The data gaps presented below represent changes made to data from the WAM export data in the vertical register.

Vertical Assets Data Gaps – Identified	Count of Records in Risk Register		
	WRRF	CSO	SPS
Incorrect Asset Type	522	122	101
Incorrect Asset Status	322	-	-
Incorrect Process Area	64	-	-
Incorrect Asset Description	12	-	-
Incorrect Parent/Child Relationship	52	-	-
Missing Asset Record in WAM	160	19	68
Total Records in Risk Register	5418	3167	810

Data collection and updates are perpetual GLWA tasks, and updates to wastewater asset data, subsequent to the WwAMP data exports, have been noted by GLWA. It is noted that improving asset data is an ongoing task and improvements have been performed by GLWA that might have addressed data gaps included.

Data gaps and inaccuracies remain for the water resource recovery facility/sewer pump stations (WRRF/SPS) assets in WAM. These include:

- Status, type and missing records for the electrical and mechanical assets
- Attributes such as make, model, size/capacity for the electrical and maintenance assets
- Errors in parent/child asset relationships
- The inventory of civil assets is completely missing.

C.3.3 Linear Asset Data Gaps

During the development of the WwAMP there has been improvement of data for linear assets, and it is believed that no major data gaps remain.

C.4 Asset Condition

C.4.1 Vertical Asset Data Gaps:

During the development of the WwAMP, approximately 1,000 assets had a visual condition assessment. The following gaps were identified:

- There are 3,939 WRRF assets and 446 SPS assets (based on current counts) that do not have condition grades.
- The condition of civil assets is completely missing.

C.4.2 Linear Asset Data Gaps

Approximately 72% of the linear system has CCTV inspection and the resulting condition grades. The remaining non-inspected assets are a key data gap. There are many reasons why the standard CCTV program could not inspect assets, often related to access, and closing the data gap is likely to require alternative approaches that may have a significantly higher unit cost of inspection. The LSIP program is working to address these gaps.

C.5 Asset Valuation

C.5.1 Vertical Asset Data Gaps

- WRRF/SPS electrical and maintenance assets (i.e., assets in WAM) replacement costs have been escalated from 2013 costs using construction price indices. The

escalation method is a good tool in the short term but after 10 years that can be a significant divergence between escalated costs and real costs.

- WRRF/SPS civil assets are completely missing.

C.5.2 Linear Asset Data Gaps

Linear asset replacement costs are missing from GLWA data. Development of a replacement cost database will be developed as part of the LSIP.

C.6 Asset Risk

C.6.1 Vertical Asset Data Gaps

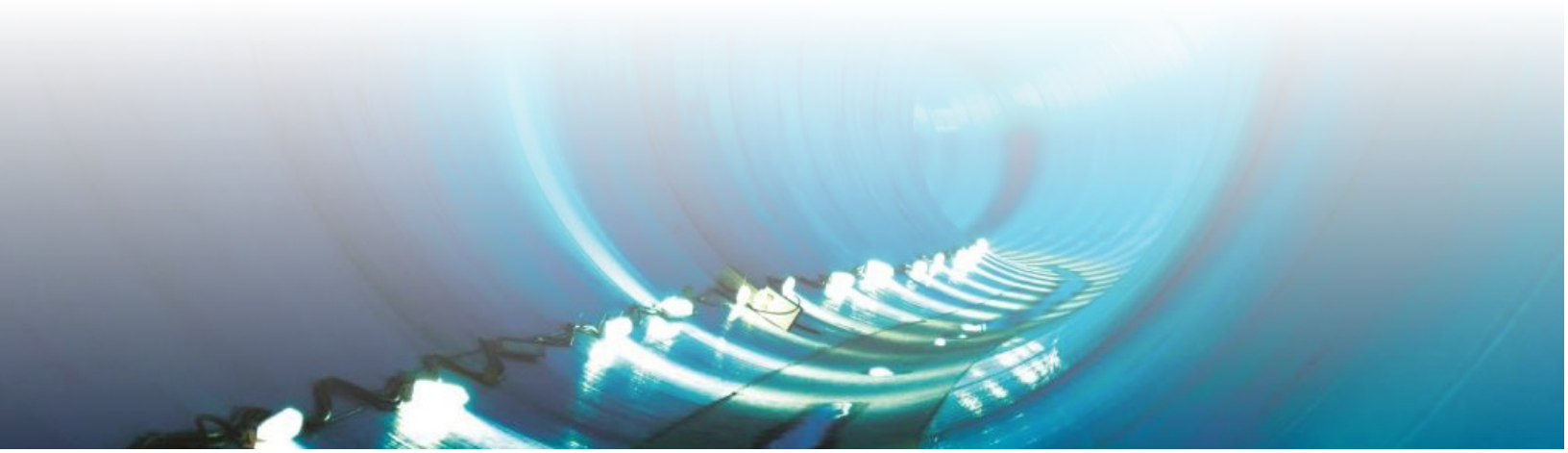
The likelihood of failure (LOF) matrix for vertical assets includes five weighted categories: Remaining Useful Life (RUL), Performance, History of Reliability, Physical Condition, and Adherence to Operations and Maintenance (O&M) Strategy. RUL, Performance, and Adherence to O&M Strategy were designated a weight of zero due to missing data. The table below lists the zero-weighted categories and the data needed to score each category.

LOF Category	Category Description
RUL	Estimation of the remaining useful life, calculated by subtracting the age of the asset from the expected service life, divided by the expected service life.
Performance	Ability of an asset to meet average and peak flow requirements with appropriate utilization and function.
Adherence to O&M Strategy	Complete, up-to-date, written, and performed O&M strategy and standard operating procedures, reviewed at least three cycles.

C.6.2 Linear Asset Data Gaps

The data improvements discussed above will improve the quality of the risk scores. There are no major data gaps for linear assets.

Appendix D – Work and Asset Management (WAM) Data Gaps Spreadsheet

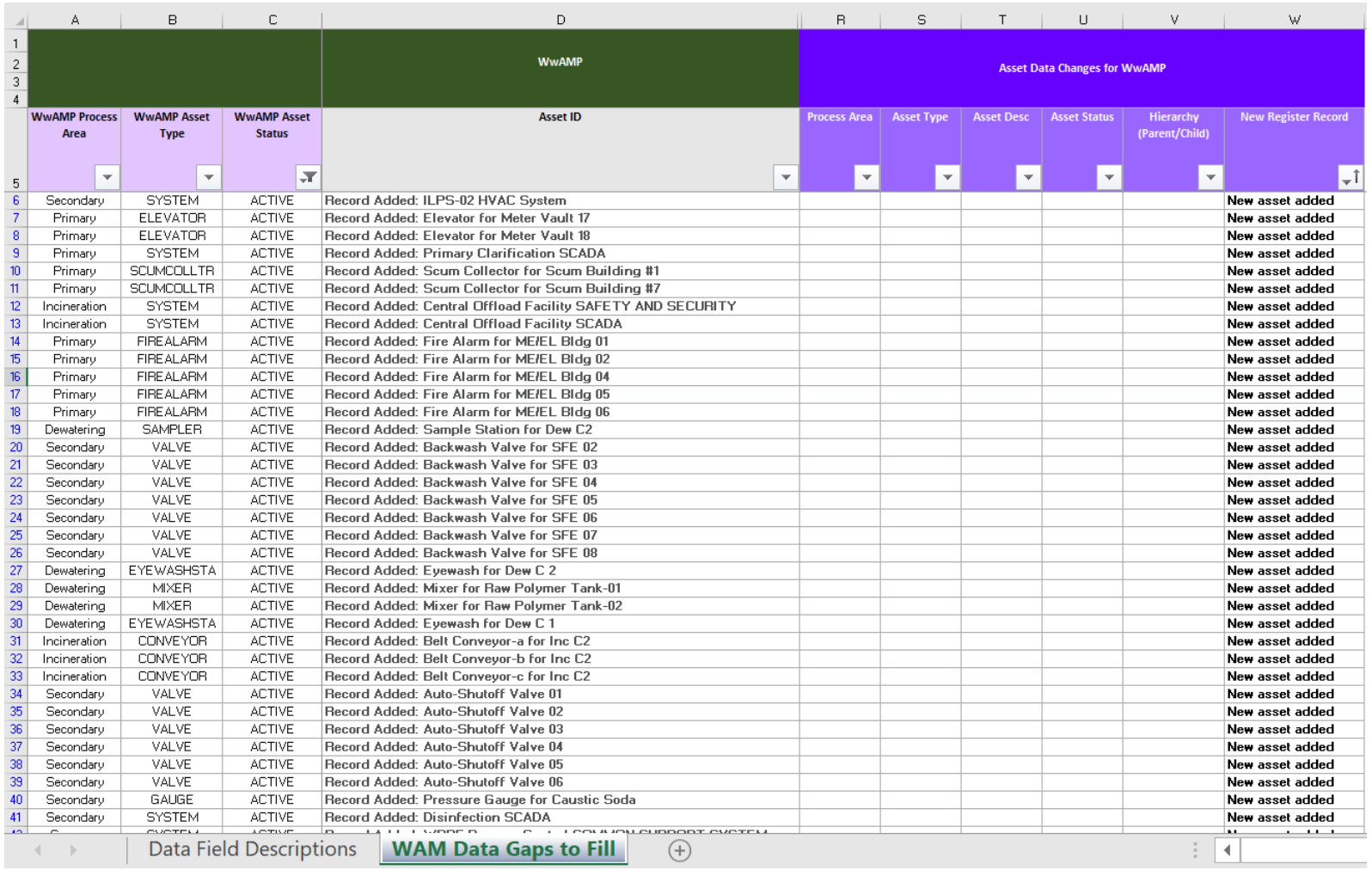


The Work and Asset Management (WAM) Data Gaps is an MS Excel file that was provided to GLWA as part of initial WwAMP development on March 15, 2022. Images of that file and two worksheets contained therein, are presented in Figure D-1 and Figure D-2.

	A	B
1	Data Field	Description
2	WwAMP Process Area	WwAMP Process Area/Facility used for grouping of assets. Based on WAM Data Export, revised during workshops and GLWA reviews
3	WwAMP Asset Type	WwAMP Asset Type used for grouping of assets. Based on WAM Data Export, changes based on asset descriptions and GLWA workshops
4	WwAMP Asset Status	WwAMP Asset Status used for reporting. Based on WAM Data Export, revised during workshops and GLWA reviews
5	Asset ID	Based on WAM Data Export. In addition to asset IDs from WAM, asset records with "Newly added" in the prefix were added to account for assets discovered through workshops that were not in WAM and to allow for parent assets that were not included in the hierarchy (and parent/child relationships in WAM).
6	Hierarchy Sort Order	When sorted low-to-high, Risk Register is sorted with children directly below parent assets
7	Level 1	Enterprise (GLWA)
8	Level 2	Fund (Wastewater)
9	Level 3	Unit (WRRF/SPS/CSO)
10	Level 4	Facility (Process Area or PS Facility)
11	Level 5	Process
12	Level 6	Installation
13	Level 7	Equipment
14	Level 8	Component
15	Level 9	Subcomponent
16	WAM Area	Original WAM Data Export
17	WAM Asset Type	Original WAM Data Export
18	WAM Asset Status	Original WAM Data Export
19	Process Area	Assets were reassigned a process area solely based on input frpm GLWA
20	Asset Type	Asset type changed when the asset description did not match the WAM assigned asset type. Risk Register records that solely functioned as a parent asset were assigned asset type "Non-asset."
21	Asset Desc	Asset descriptions were edited based on GLWA input and in the event a change in hierachy location neccessitated a change in the description.
22	Asset Status	Asset status was changed based on GLWA input.
23	Hierarchy (Parent/Child)	Edits to parent-child relationship were made to refelct GLWA input and maintain consistency.
	New Register Record	Assets were identified through GLWA review that were not included in the WAM Data Export, those are identifed as "New Asset Added." Assets were identified through GLWA review that had been replaced with a

Data Field Descriptions | WAM Data Gaps to Fill

Figure D-1: WAM Data Field Descriptions

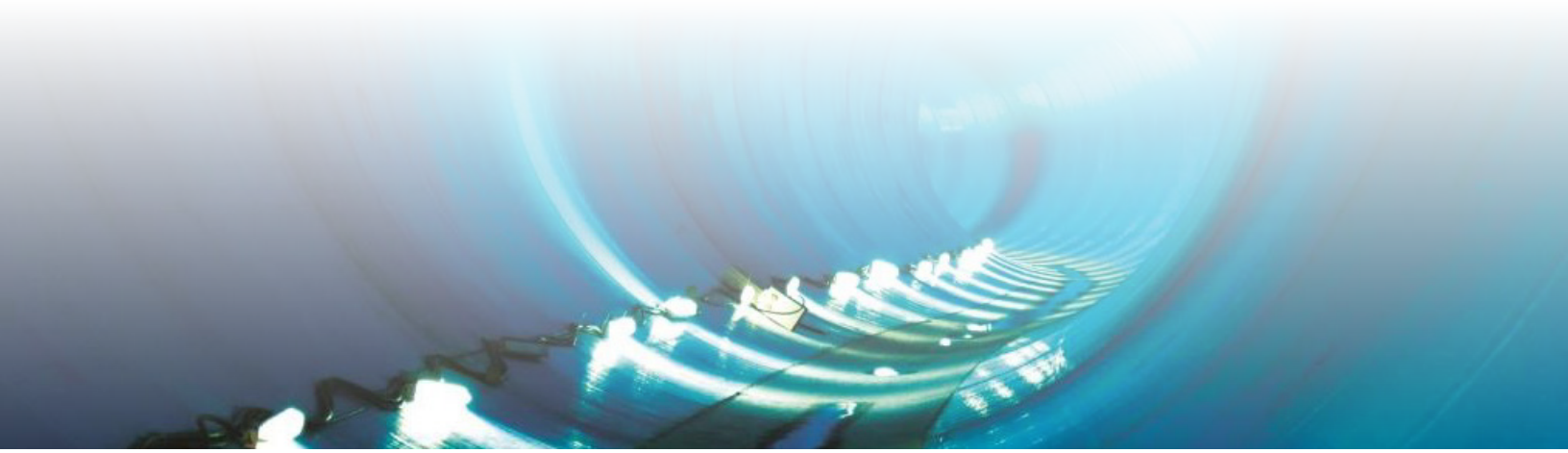


	A	B	C	D	R	S	T	U	V	W
1				WwAMP	Asset Data Changes for WwAMP					
2										
3										
4										
5	WwAMP Process Area	WwAMP Asset Type	WwAMP Asset Status	Asset ID	Process Area	Asset Type	Asset Desc	Asset Status	Hierarchy (Parent/Child)	New Register Record
6	Secondary	SYSTEM	ACTIVE	Record Added: ILPS-02 HVAC System						New asset added
7	Primary	ELEVATOR	ACTIVE	Record Added: Elevator for Meter Vault 17						New asset added
8	Primary	ELEVATOR	ACTIVE	Record Added: Elevator for Meter Vault 18						New asset added
9	Primary	SYSTEM	ACTIVE	Record Added: Primary Clarification SCADA						New asset added
10	Primary	SCUMCOLLTR	ACTIVE	Record Added: Scum Collector for Scum Building #1						New asset added
11	Primary	SCUMCOLLTR	ACTIVE	Record Added: Scum Collector for Scum Building #7						New asset added
12	Incineration	SYSTEM	ACTIVE	Record Added: Central Offload Facility SAFETY AND SECURITY						New asset added
13	Incineration	SYSTEM	ACTIVE	Record Added: Central Offload Facility SCADA						New asset added
14	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 01						New asset added
15	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 02						New asset added
16	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 04						New asset added
17	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 05						New asset added
18	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 06						New asset added
19	Dewatering	SAMPLER	ACTIVE	Record Added: Sample Station for Dew C2						New asset added
20	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 02						New asset added
21	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 03						New asset added
22	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 04						New asset added
23	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 05						New asset added
24	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 06						New asset added
25	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 07						New asset added
26	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 08						New asset added
27	Dewatering	EYEWASHSTA	ACTIVE	Record Added: Eyewash for Dew C 2						New asset added
28	Dewatering	MIXER	ACTIVE	Record Added: Mixer for Raw Polymer Tank-01						New asset added
29	Dewatering	MIXER	ACTIVE	Record Added: Mixer for Raw Polymer Tank-02						New asset added
30	Dewatering	EYEWASHSTA	ACTIVE	Record Added: Eyewash for Dew C 1						New asset added
31	Incineration	CONVEYOR	ACTIVE	Record Added: Belt Conveyor-a for Inc C2						New asset added
32	Incineration	CONVEYOR	ACTIVE	Record Added: Belt Conveyor-b for Inc C2						New asset added
33	Incineration	CONVEYOR	ACTIVE	Record Added: Belt Conveyor-c for Inc C2						New asset added
34	Secondary	VALVE	ACTIVE	Record Added: Auto-Shutoff Valve 01						New asset added
35	Secondary	VALVE	ACTIVE	Record Added: Auto-Shutoff Valve 02						New asset added
36	Secondary	VALVE	ACTIVE	Record Added: Auto-Shutoff Valve 03						New asset added
37	Secondary	VALVE	ACTIVE	Record Added: Auto-Shutoff Valve 04						New asset added
38	Secondary	VALVE	ACTIVE	Record Added: Auto-Shutoff Valve 05						New asset added
39	Secondary	VALVE	ACTIVE	Record Added: Auto-Shutoff Valve 06						New asset added
40	Secondary	GAUGE	ACTIVE	Record Added: Pressure Gauge for Caustic Soda						New asset added
41	Secondary	SYSTEM	ACTIVE	Record Added: Disinfection SCADA						New asset added

Data Field Descriptions | WAM Data Gaps to Fill

Figure D-2: WAM Data Gaps to Fill

Appendix E – Asset Condition Assessment Methodology



E.1 Linear Assets

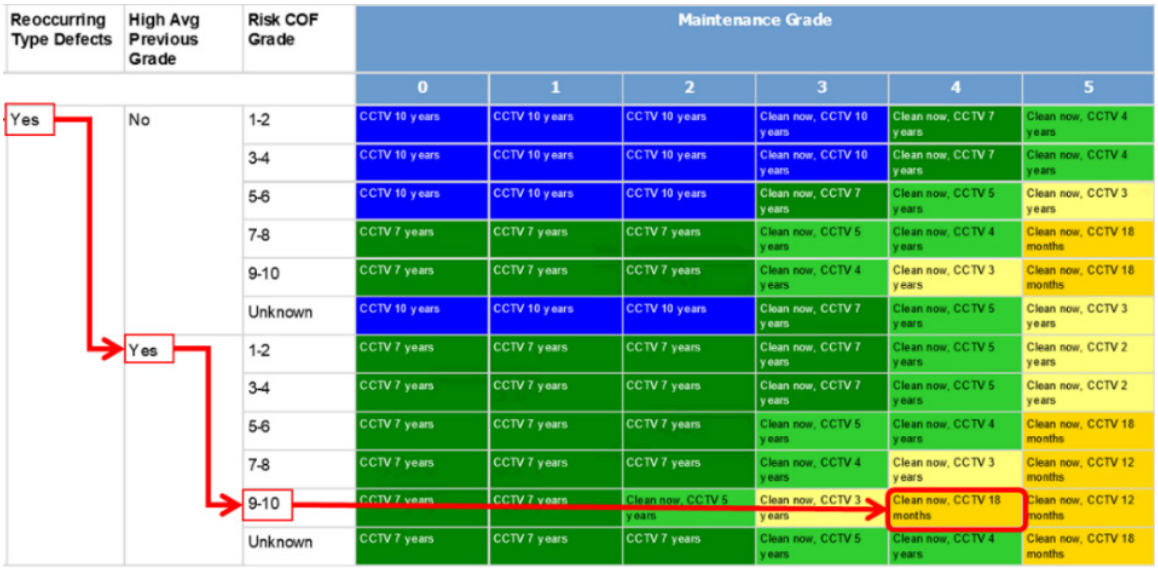
The SCREAM model utilizes pipe defects recorded in CCTV inspection data to assign a maintenance action or structural repair action listed in E-1.

Table E-1: Description of Recommended Action Types

Scheduled Action Category	Scheduled Action	Timeline for Action
Maintenance Action	Cleaning	As soon as possible
	CCTV inspection	18 months – 10 years
	CCTV inspection with Multi-Sensor	18 months – 10 years
Structural Repair Action	CCTV inspection	12 months – 10 years
	Priority 1 Rehabilitation List Priority 2 Rehabilitation List Priority 3 Rehabilitation List	As determined through development of rehabilitation plan (LSIP)

Pipes assigned a structural repair action are included in forecasting renewal needs and prioritized for rehabilitation by COF as Priority 1 (highest consequence), Priority 2 (next highest consequence), and Priority 3 (lowest relative consequence).

The maintenance action and structural repair action logic is diagramed in Figure E-1 and Figure E-2, respectively.



Reoccurring Type Defects	High Avg Previous Grade	Risk COF Grade	Maintenance Grade					
			0	1	2	3	4	5
Yes	No	1-2	CCTV 10 years	CCTV 10 years	CCTV 10 years	Clean now, CCTV 10 years	Clean now, CCTV 7 years	Clean now, CCTV 4 years
		3-4	CCTV 10 years	CCTV 10 years	CCTV 10 years	Clean now, CCTV 10 years	Clean now, CCTV 7 years	Clean now, CCTV 4 years
		5-6	CCTV 10 years	CCTV 10 years	CCTV 10 years	Clean now, CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 3 years
		7-8	CCTV 7 years	CCTV 7 years	CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 4 years	Clean now, CCTV 18 months
		9-10	CCTV 7 years	CCTV 7 years	CCTV 7 years	Clean now, CCTV 4 years	Clean now, CCTV 3 years	Clean now, CCTV 18 months
		Unknown	CCTV 10 years	CCTV 10 years	CCTV 10 years	Clean now, CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 3 years
	Yes	1-2	CCTV 7 years	CCTV 7 years	CCTV 7 years	Clean now, CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 2 years
		3-4	CCTV 7 years	CCTV 7 years	CCTV 7 years	Clean now, CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 2 years
		5-6	CCTV 7 years	CCTV 7 years	CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 4 years	Clean now, CCTV 18 months
		7-8	CCTV 7 years	CCTV 7 years	CCTV 7 years	Clean now, CCTV 4 years	Clean now, CCTV 3 years	Clean now, CCTV 12 months
		9-10	CCTV 7 years	CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 3 years	Clean now, CCTV 18 months	Clean now, CCTV 12 months
		Unknown	CCTV 7 years	CCTV 7 years	CCTV 7 years	Clean now, CCTV 5 years	Clean now, CCTV 4 years	Clean now, CCTV 18 months

Figure E-1: SCREAM Maintenance Action

Latest Inspection Type	High Defect Acceleration	Risk COF Grade	Structural Grade					
			0	1	2	3	4	5
CCTV	No	1-2	CCTV 10 years	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 3 years	Priority 3
		3-4	CCTV 10 years	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 3 years	Priority 3
		5-6	CCTV 10 years	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 3 years	Priority 3
		7-8	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 3 years	CCTV 18 months	Priority 1
		9-10	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 3 years	CCTV 18 months	Priority 1
		Unknow n	CCTV 10 years	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 3 years	Priority 3
	Yes	1-2	CCTV 10 years	CCTV 10 years	CCTV 10 years	CCTV 4 years	CCTV 12 months	Priority 3
		3-4	CCTV 10 years	CCTV 10 years	CCTV 10 years	CCTV 4 years	CCTV 12 months	Priority 3
		5-6	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 4 years	CCTV 12 months	Priority 2
		7-8	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 3 years	CCTV 12 months	Priority 1
		9-10	CCTV 10 years	CCTV 7 years	CCTV 4 years	CCTV 18 months	Priority 2	Priority 1
		Unknow n	CCTV 10 years	CCTV 10 years	CCTV 7 years	CCTV 4 years	CCTV 18 months	Priority 2

Figure E-2: SCREAM Structural Repair Action Logic

Overdue re-inspections for pipes with COF grade 5 are prioritized followed by uninspected pipes for PM. Pipes recommended for rehabilitation are prioritized with one year for planning.

E.2 Vertical Assets

Condition assessments on vertical assets were performed by Jacobs between July and August 2020 for 875 assets. The condition assessment process used by Jacobs is based on research published in the International Infrastructure Management Manual (IIMM) 2006 edition. Preliminary risk scores were developed to identify high risk assets on which to perform condition assessment activities.

E.2.1 Preliminary Risk Score Development

The approach for WRRF and SPS assets started with developing preliminary risk scores through various activities, including 2020 GLWA staff workshops and a tabletop analysis for COF (described below). Preliminary risk scores prioritized assets for condition assessments, resulting in necessary condition grades for calculating LOF scores (described below).

This preliminary risk score activity was used as a first step in the further development of risk scores (see Appendix H).

Separate from the COF scoring exercise, a MTBF analysis was derived from work order data, staff institutional knowledge, and industry trends to estimate LOF. The assigned COF was multiplied by the estimated LOF to produce a preliminary risk score.

As part of the preliminary risk score development, a tabletop analysis for COF was performed. GLWA staff individually assigned an overall COF score to Level 5 Process assets

based on the COF criteria in described in Table E-2: Regulatory Compliance, Impact to Service Levels, Financial Impact, Health and Safety, Public Impact, Environmental Stewardship, and Public Trust. COF was scored on a scale from 1 to 5, where 5 is the most severe.

Table E-2: Vertical Asset COF Matrix

Category	Wt. (%)	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5
Regulatory Compliance	14.3	• Failure will not cause regulatory/permit violation, enforcement infraction, or unregulated discharge • No effect on mandated/enforceable program • Failure does not result in significant fine	• Failure may have some local impact • Failure will impact ability to meet expected future requirements • Failure will lead to non-compliance event in the near future	• Failure will cause moderate regulatory or permit violation, enforcement infraction, or unregulated discharge or will cause other non-compliance, permit violations, or significant regulatory scrutiny • Failure will impact mandated or enforceable program	• Failure will cause major regulatory or permit violation, enforcement infraction, or unregulated discharge, or will cause other non-compliance, permit violations, or significant regulatory scrutiny • Failure will impact mandated or enforceable program	• Failure will cause extreme regulatory/permit violation, enforcement infraction, or unregulated discharge, or will cause other non-compliance, permit violations, or significant regulatory scrutiny • Failure will impact mandated or enforceable program
Impact to Service Levels	14.3	No impact on service levels, facility service level, or processes	Failure will have minor impact to facility level of service or processes for a day or less	Failure will have minor impact to facility service level or processes for up to a week or major impact for a day or less	Failure will have minor impact to facility service level or processes for up to a month or major impact for up to a week	Failure will have minor impacts to facility service level or processes for over a month or major impacts for more than a week
Financial Impact	14.3	Less than $10,000	$10,000 to less than $50,000	$50,000 to less than $250,000	$250,000 to less than $1,000,000	Greater than $1,000,000
Health & Safety	14.3	Failure (or immediate resolution of the failure) results in use of first aid supplies but no lost time **OR** Failure results in a near miss to one or more team members or the public	Failure (or immediate resolution of the failure) results in an injury requiring treatment away from the workplace **OR** Results in a team member reassignment to light duty **OR** Results in a major near miss to several team members or significant members of the public	Failure (or immediate resolution of the failure) leads a team member lost time event **OR** Leads to a treatable injury to a member of the public **OR** Leads to an Occupational Safety and Health Administration violation	Failure (or immediate resolution of the failure) will result in injury for one or more team members or members of the public **OR** Leads to permanent loss of ability to perform job for one or more team members	Failure (or immediate resolution of the failure) will result in measurable team member or public health events, including exposure to contaminants or hazardous materials **OR** Will result in death or permanent disability for one or more team members
Public Impact	14.3	Failure leads to no measurable impact on City, regional, or neighborhood growth plans	Failure will have minor impact on City, regional, or neighborhood growth **OR** Will have minor but measurable impact on economic development OR Will have minor but measurable impact on quality of life or aesthetics	Failure will have moderate impact on City, regional, or neighborhood growth **OR** Will have moderate impact on economic development **OR** Will have moderate impact on quality of life or aesthetics	Failure will restrict planned City, regional, or neighborhood growth **OR** Will have major impact on economic development **OR** Will have major impact on quality of life or aesthetics	Failure will restrict planned City, regional, or neighborhood growth **OR** Will have extreme impact on economic development **OR** Will have extreme impact on quality of life or aesthetics
Environmental Stewardship	14.3	No harm to resident biota or their habitat **OR** Release of non-harmful substances **OR** • If release of harmful substances, it does not exceed reportable quantities • Cleanup achieved with commonly available materials	• Failure results in minor short-term reversible impacts in a localized area • Ecosystem function not significantly impaired • No remediation required	Failure results in significant but reversible impacts on the environment **OR** Temporary loss of ecosystem function **OR** Any remediation required	Failure results in non-reversible impacts to the environment **OR** Significant remediation in a localized or broad area	Failure results in environmental damage with permanent loss to ecosystem, including severe degradation of watershed or loss of habitat **OR** Failure results in significant death to state priority or federally endangered species
Public Trust	14.3	• Few customer complaints • No media coverage • No impact on GLWA image or relationships	Failure results in several complaints made to GLWA OR Minor local media inquiries **OR** Minor impact on GLWA image or relationships	Failure results in moderate local media coverage or editorial comment **OR** National media inquiries **OR** Complaints elevated to the Board level	Failure results in significant local media coverage or editorial **OR** Citizen satisfaction survey indicates unacceptable performance	Intervention from external authorities (state or federal) **OR** Daily local negative news stories and national news coverage **OR** Lasting damage to GLWA image, existing relationships, and public confidence

Averaged GLWA staff COF scores for each Level 5 Process was used to assign a COF score to each child asset (Level 6, Level 7, Level 8) through a tabletop analysis known as Solomon Oldach Assessment Process (SOAP). SOAP holds that a child asset failure will not have a greater consequence than a parent asset failure. The SOAP relationship rules are listed and described in Table E-3.

Table E-3 SOAP COF Relationship Rules

Asset COF Parent/Child Relationship	Relationship Criteria
$COF_{CHILD} = COF_{PARENT}$	Equipment failure causes immediate system functional failure (no time to react to failure)
$COF_{CHILD} = COF_{PARENT} - 1$	Equipment failure may contribute to eventual system functional failure (have time to react to failure) **OR** Equipment failure does not cause system functional failure but repair will cause a long duration disruption to system operation
$COF_{CHILD} = COF_{PARENT} - 2$	Equipment failure does not cause system functional failure but repair will cause a short duration disruption to system operation
$COF_{CHILD} = 1$	Equipment failure has minimal or no impact on system operation*
*Lowest criticality score to be assigned is no less than 1	

SOAP was applied to each of the seven (7) GLWA COF criteria. During the review and feedback workshops, process-specific staff input was used to modify COF criteria scores to better reflect consequence of failure experienced during operation for specific assets.

E.2.2 Condition Assessment Activities

The basis for assessing the condition of assets is the development of a set of asset specific questions that focus on the visual and measurable indicators of an assets condition. For this condition assessment, only visual indicators were used. For each asset type assessed, a set of assessment criteria or assessment questions and answers was assigned. All assessment questions were assigned 2 to 5 answers that describe the level of degradation observable for the question. The answer which represents the best condition is assigned a score of 1 and the answer representing the worst observable condition is assigned a score of 5. The score for each answered question rolls up to an overall condition score. In the event a question did not apply to a particular asset the question is answered as NA (not applicable). In this case, the question was not scored, and questions weights were recalculated to accurately average the condition score.

Visual assessment can be very effective when the assets are assessed repeatedly on a regular schedule using the same asset type question sets, trends will appear that can be used for future repair and replacement planning and to identify potential issues with maintenance procedures.

Assets that receive poor visual condition assessment scores are noted and recommended for additional investigation in order to better understand asset risk. Additional investigations could include detailed condition assessments, manufacturer assessments, or detailed look into asset work orders.

Once the overall asset condition scores were calculated and averaged, the assets were grouped into one of 5 asset Condition Categories. Table E-4: Condition Category lists the condition category groups assets and the applicable range of scores.

Table E-4: Condition Categories

Min Score	Max Score	Condition Score Category
1.00	1.49	Condition 1
1.50	2.49	Condition 2
2.50	3.49	Condition 3
3.50	4.49	Condition 4
4.50	5.00	Condition 5

Each condition category has been found to have specific indications as to the assets remaining useful life and future maintenance requirements. The percent of service life remaining and general maintenance recommendations for each category are shown in Table E-5: Condition Description and Remaining Service Life.

Table E-5: Condition Description and Remaining Service Life

Condition Score Category	Description	Remaining Useful Life
1	Indicates the asset is new or in like new condition. Continuation of current maintenance practices and operating procedures is recommended	>90%
2	Indicates the asset is in good condition. Some minor additional maintenance may be required, continue the current maintenance and operating procedures	75%
3	Indicates the asset is in fair condition. Asset has one or more issues requiring immediate attention. The current maintenance and operating procedures or intervals may need to be modified or adjusted to avoid recurrence of identified issues.	50%
4	Indicates the asset is in poor condition. Planning for rehabilitation or replacement should begin. Review of current maintenance practices and procedures is recommended. If this is a critical asset a predictive maintenance program should be evaluated to prevent reaching this condition in the future.	30%

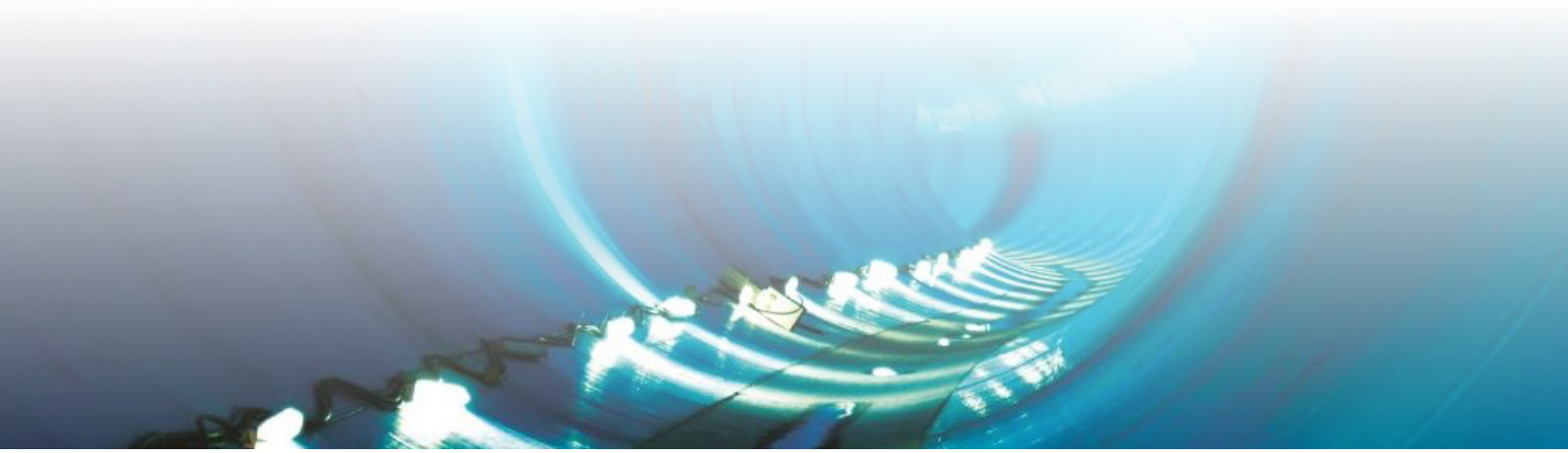
Condition Score Category	Description	Remaining Useful Life
5	Indicates the asset is in very poor condition. Failure of the asset is imminent or has already occurred. Greater than 50% of the asset is requires replacement. If this is a critical asset a predictive maintenance program should be evaluated to prevent reaching this condition in the future.	5% or less

Survey Flags were also used for this assessment to identify an asset status and drive a predefined assessment score. The Survey Flags used in the assessment were:

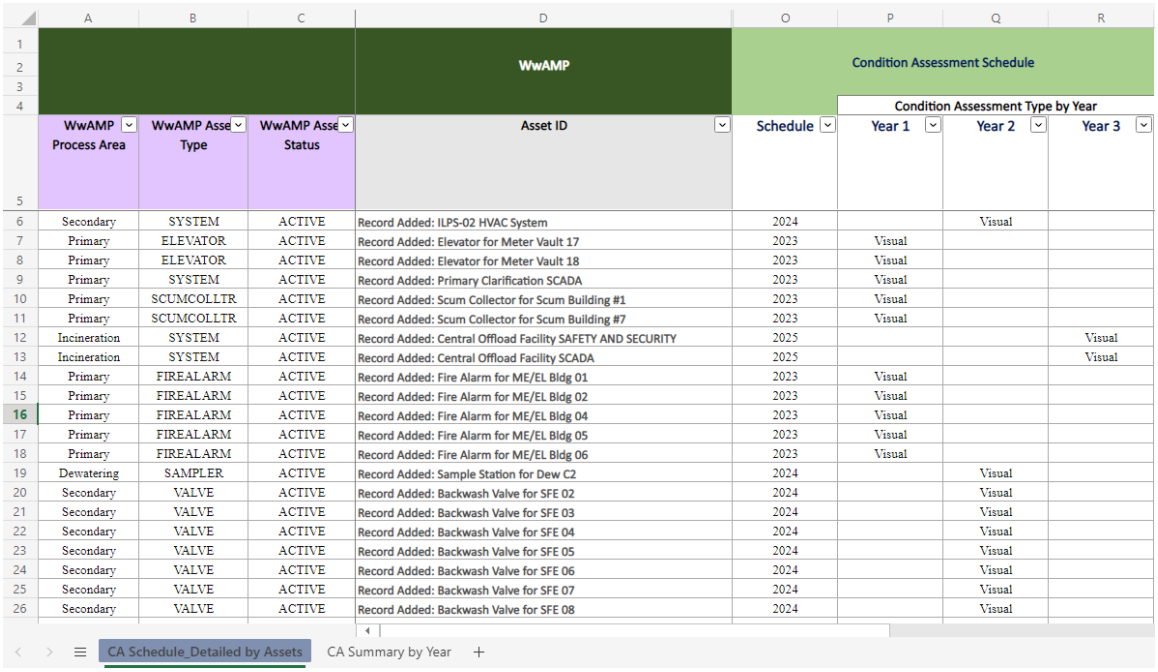
- **Not Functional** – Condition Score 5, for assets that were not available for service or offline at the time of inspection but in otherwise good condition.
- **Partially Evaluated** – Condition Score 3, for assets that could not be fully assessed because of accessibility

No complete plant or process was assessed; therefore, the results are representative of plant conditions and not inclusive of all plant assets. No predictive testing or performance testing was performed as part of this assessment.

Appendix F – WwAMP Condition Assessment Activities – Vertical Assets



The Condition Assessment Activities – Vertical Assets spreadsheet is an MS Excel file that was provided to GLWA as part of the initial WwAMP development on June 10, 2022. A representative image of that file with key column headings is presented in Figure F-1.

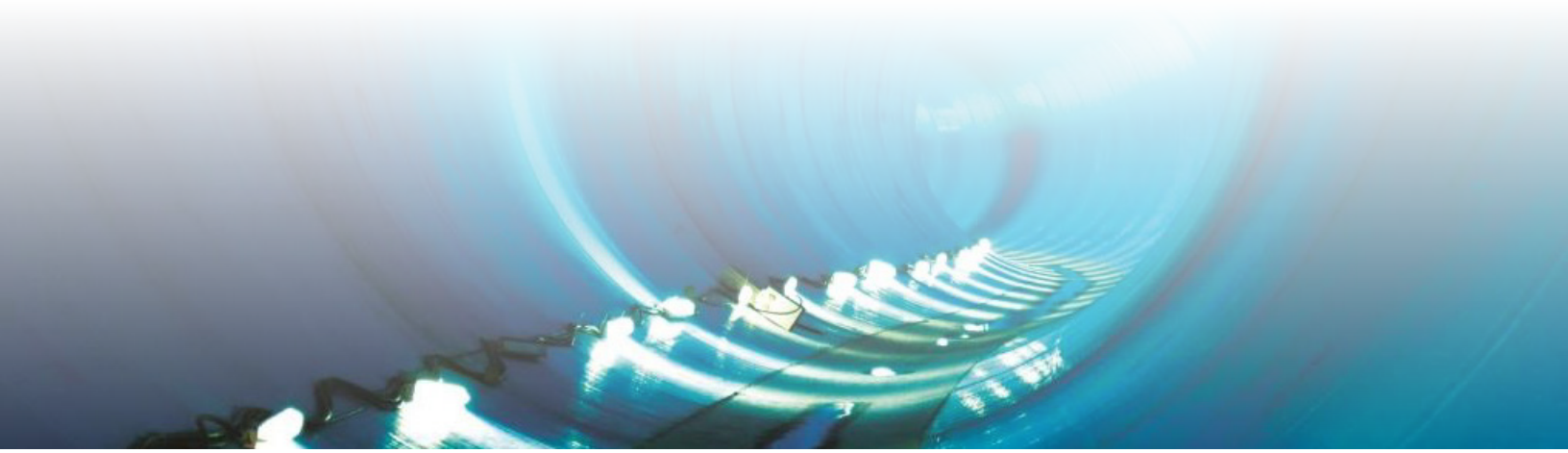


	A	B	C	D	O	P	Q	R
1								
2				WwAMP	Condition Assessment Schedule			
3								
4						Condition Assessment Type by Year		
5	WwAMP Process Area	WwAMP Asse Type	WwAMP Asse Status	Asset ID	Schedule	Year 1	Year 2	Year 3
6	Secondary	SYSTEM	ACTIVE	Record Added: ILPS-02 HVAC System	2024		Visual	
7	Primary	ELEVATOR	ACTIVE	Record Added: Elevator for Meter Vault 17	2023	Visual		
8	Primary	ELEVATOR	ACTIVE	Record Added: Elevator for Meter Vault 18	2023	Visual		
9	Primary	SYSTEM	ACTIVE	Record Added: Primary Clarification SCADA	2023	Visual		
10	Primary	SCUMCOLLTR	ACTIVE	Record Added: Scum Collector for Scum Building #1	2023	Visual		
11	Primary	SCUMCOLLTR	ACTIVE	Record Added: Scum Collector for Scum Building #7	2023	Visual		
12	Incineration	SYSTEM	ACTIVE	Record Added: Central Offload Facility SAFETY AND SECURITY	2025			Visual
13	Incineration	SYSTEM	ACTIVE	Record Added: Central Offload Facility SCADA	2025			Visual
14	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 01	2023	Visual		
15	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 02	2023	Visual		
16	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 04	2023	Visual		
17	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 05	2023	Visual		
18	Primary	FIREALARM	ACTIVE	Record Added: Fire Alarm for ME/EL Bldg 06	2023	Visual		
19	Dewatering	SAMPLER	ACTIVE	Record Added: Sample Station for Dew C2	2024		Visual	
20	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 02	2024		Visual	
21	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 03	2024		Visual	
22	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 04	2024		Visual	
23	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 05	2024		Visual	
24	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 06	2024		Visual	
25	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 07	2024		Visual	
26	Secondary	VALVE	ACTIVE	Record Added: Backwash Valve for SFE 08	2024		Visual	

CA Schedule_Detailed by Assets | CA Summary by Year

Figure F-1: WwAMP Condition Assessment Activities – Vertical Assets Spreadsheet

Appendix G – WwAMP Risk Register for Vertical Assets

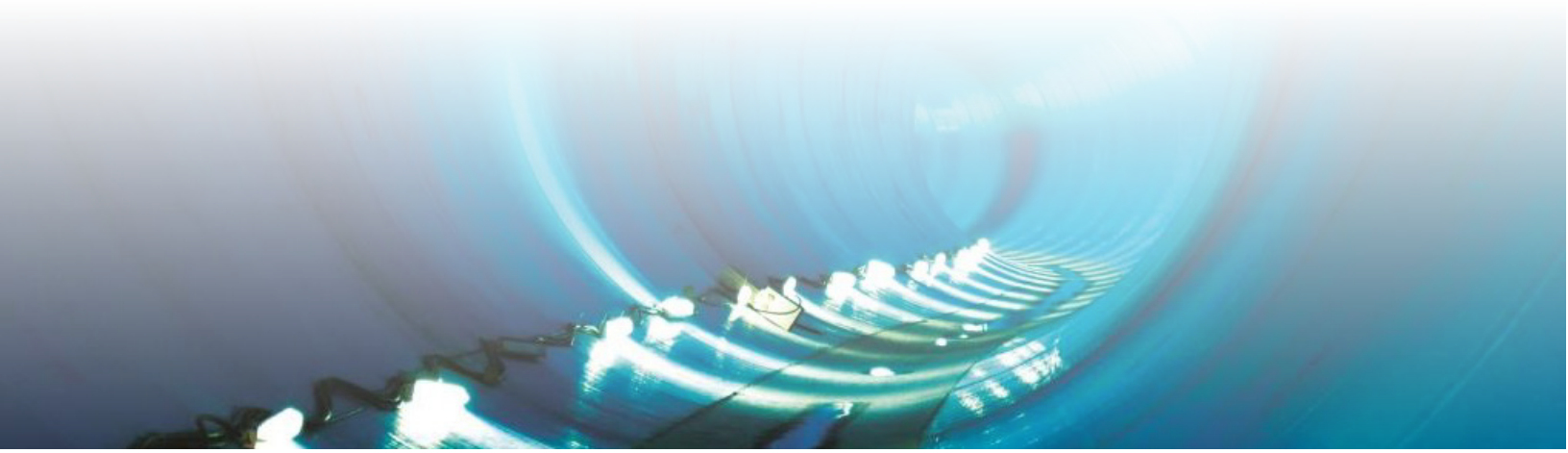


A representative image of the Risk Register for Vertical Assets, along with key column headings, is presented in Figure G-1.

BEFORE EVALUATING ASSET RISK & TREATMENTS 1. Clear all filters. 2. Sort by WwAMP Asset Status. 3. Filter for "ACTIVE" status only.				LOF Criteria Weights 30%	 70%			
WwAMP Process Area	WwAMP Asset Type	WwAMP Asset Status	WwAMP COF (includes final round of GLWA feedback)	History of Reliability	Physical Condition	Calculated Asset LOF Score (weighted criteria)	Calculated WwAMP Risk (LOF x COF)	2020 Condition Assessment Tier
S-SPS-OKW	PUMP	ACTIVE	1.00	1.00	5.00	3.80	3.80	3 - Detailed
S-SPS-OKW	MOTOR	ACTIVE	1.00	1.00	5.00	3.80	3.80	3 - Detailed
S-SPS-OKW	PUMP	ACTIVE	1.00	1.00	5.00	3.80	3.80	3 - Detailed
S-SPS-OKW	PUMP	ACTIVE	1.00	1.00	5.00	3.80	3.80	3 - Detailed
S-SPS-OKW	MOTOR	ACTIVE	1.00	1.00	5.00	3.80	3.80	3 - Detailed
S-SPS-OKW	PUMP	ACTIVE	1.00	1.00	5.00	3.80	3.80	3 - Detailed
S-CSO-OKW	FANVENT	ACTIVE	1.00	1.00	5.00	3.80	3.80	2 - Visual
S-CSO-OKW	PUMP	ACTIVE	1.00	1.00	5.00	3.80	3.80	3 - Detailed
Primary	TANK-PRESS	ACTIVE	2.00	3.36	5.00	4.51	9.02	2 - Visual
Primary	TANK-PRESS	ACTIVE	2.00	3.36	5.00	4.51	9.02	2 - Visual
Primary	TANK-PRESS	ACTIVE	2.00	3.36	5.00	4.51	9.02	2 - Visual
Primary	COMPRESSOR	ACTIVE	3.00	3.12	5.00	4.43	13.30	2 - Visual
Primary	GATE	ACTIVE	2.00	2.48	5.00	4.24	8.49	2 - Visual
Secondary	BOILER	ACTIVE	2.00	3.62	5.00	4.59	9.17	2 - Visual
Secondary	BOILER	ACTIVE	2.00	3.62	5.00	4.59	9.17	2 - Visual
Secondary	PUMP	ACTIVE	2.00	3.39	5.00	4.52	9.04	2 - Visual

Figure G-1: Risk Register for Vertical Assets Spreadsheet

Appendix H – Risk Scoring Methodology



Total asset risk is the product of LOF and COF. The following equation is used to calculate total asset risk:

Total Asset Risk = LOF x COF

The following sections detail the COF and LOF scoring categories, criteria, and data used for linear and vertical assets, based on 2020 data extract from WAM. CSO assets are discussed separately from the rest of the vertical (WRRF and SPS) assets due to differences in desktop analysis approaches for COF and are further explained in the GLWA 2021 CS-299 CSO Facilities Assessment.

H.1 Linear Assets

Linear total risk results are summarized in Chapter 5.

H.1.1 COF Scoring

The WwAMP linear asset COF matrix includes four weighted categories: Financial Impact, Health and Safety (employee), Public Impact, and Environmental Stewardship. Category scores were determined by developed criteria on a scale from 1 to 5, with 5 the most severe. Table H-1 describes the data used to assign the category scores in the linear COF matrix. The linear COF matrix with category scoring criteria descriptions is shown in Table H-2.

Table H-1: Linear Asset COF Data Sources

Category	Data Input	Data Source
Financial Impact	Pipe Replacement Cost	Cost to replace the pipe, estimated based on pipes length, diameter and look-up tables in the SCREAM tool.
Health & Safety (Employee)	Buried Depth of Pipe	Average depth of pipe from upstream and downstream manhole inverts in GIS.
	Pipe Diameter	Pipe diameter in CCTV inspection data, GIS diameters used as backup.
Public Safety	Distance from pipe to railroad, building, or street	Calculated in GIS using pipe, railroad, building, and street GIS layers.
Environmental Stewardship	Distance from pipe to waterbody	Calculated in GIS using pipe GIS layer and USGS wetland GIS data.

Table H-2: WwAMP Linear Asset COF Matrix

Category	Weight	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5
Financial Impact (Replacement Cost)	0.25	$500,000 or less	$500,001 to $1,000,000	$1,000,001 to $2,500,000	$2,500,001 to $5,000,000	Greater than $5,000,000
Health & Safety	0.25	Buried depth is less than 20 feet	Buried depth is 20 feet or greater **AND** Diameter is less than 60 inches	Buried depth is 20 feet or greater **AND** Diameter is 60 to less than 120 inches	Buried depth is 20 feet or greater **AND** Diameter is 120 to less than 193 inches	Buried depth is 20 feet or greater **AND** Diameter is 193 inches or greater
Public Impact	0.25	Proximity to RR, building or street is greater than 50 feet	Proximity to street types 'Minor Collector' or 'Local' is 50 feet or less	Proximity to street types 'Minor Arterial' or 'Major Collector' is 50 feet or less **OR** Proximity to railroad is 5 to 50 feet **OR** Proximity to building is 5 to 50 feet	Proximity to street type is 50 feet or less **OR** Proximity to railroad is 5 feet or less	Proximity to street types 'Interstate' or 'Other Freeways and Expressways' is 50 feet or less **OR** Proximity to Building is 5 feet or less
Environmental Stewardship	0.25	Proximity to waterbody is greater than 1,000 feet	Proximity to waterbody is greater than 500 feet, up to 1,000 feet	Proximity to waterbody is greater than 50 feet, up to 500 feet	Proximity to waterbody is greater than 10 feet, up to 50 feet	Proximity to waterbody is 10 feet or less

H.1.2 LOF Scoring

The WwAMP linear asset LOF matrix includes five, weighted categories: RUL, Performance, Reliability, Physical Condition, and II. Category scores were determined by developed criteria on a scale from 1 to 5, with 5 the most severe. Table H-3 describes the data used to assign the category scores in the linear LOF matrix. The linear LOF matrix with category scoring criteria descriptions is shown in Table H-4.

Table H-3: Linear Asset LOF Data Sources

Category	Data Input	Data Source
RUL	Structural Condition Grade	Calculated in SCREAM using • Structural Condition Grade and Decay Curves, *for pipe with inspection.* • Install Date, *for pipes without inspection.* • RUL average of pipes with same material, *for pipes without install date or inspection.* • RUL equal to 50 years, *for all lined pipes in GIS.*
	Decay Curves	
	Install Date	
	Pipe asset data attribute: Lined	
Performance	Maintenance Condition Grade	The maintenance condition grade calculated in SCREAM, based on CCTV inspection, maintenance-related defects.
Reliability	Sag Condition Grade	The sag condition grade calculated in SCREAM, based on CCTV inspection, sag-related defects.
	Pipe Diameter	A combination of diameter and pipe slope determined if the slope was below the minimum slope per the Ten-State Standards.
	Pipe slope	
Physical Condition	Structural Condition Grade	The structural condition grade calculated in SCREAM, based on CCTV inspection, maintenance-related defects.
II	II Score	The II score (0-100) calculated in SCREAM, based on CCTV inspection, II-related defects.

Table H-4: WwAMP Linear Asset LOF Matrix

Category	Weight	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5
RUL	0.2	Greater than 80%	Greater than 50%, up to 80%	Greater than 20%, up to 50%	Greater than 5%, up to 20%	5% or less
Performance	0.15	Maintenance Condition Grade = 0, 1	Maintenance Condition Grade = 2	Maintenance Condition Grade = 3	Maintenance Condition Grade = 4	Maintenance Condition Grade = 5
Reliability	0.1	Sag Condition Grade = 0 **AND** Slope less than min = 'No'	Sag Condition Grade = 1 **OR** Slope less than min = 'No'	Sag Condition Grade = 2	Sag Condition Grade = 3	Sag Condition Grade = 4, 5
Physical Condition	0.4	Structural Condition Grade = 0, 1	Structural Condition Grade = 2	Structural Condition Grade = 1 **OR** Structural Grade = 99	Structural Condition Grade = 4	Structural Condition Grade = 5
II	0.15	SCREAM II Score is 0 **OR** 99	SCREAM II Score is greater than 0 and less than 10	SCREAM II Score is 10 to less than 15	SCREAM II Score is 15 to less than 30	SCREAM II Score is 30 or greater

H.1.3 Risk Score Utilization

Linear total asset risk scores using 2020 data, were plotted on a Risk Severity Heat Map in Chapter 5. The heat map shows the quantity of pipe miles that reside at each product combination of COF and LOF. For example, if a significant portion of assets have a total asset risk score of 10, with COF = 2 and LOF = 4, renewal could be an appropriate risk treatment. Additionally, if the factors were reversed and COF = 4 and LOF = 2, improving resiliency could be a risk treatment strategy. Understanding where the bulk of assets fall on the heat map is informative for targeting O&M strategies.

H.2 WRRF and SPS Assets

Total asset risk results are summarized in Chapter 5.

H.2.1 Preliminary Risk Score Development

The approach for WRRF and SPS assets started with developing preliminary risk scores through various activities including 2020 GLWA staff workshops and a tabletop analysis for COF (described below). Preliminary risk scores prioritized assets for condition assessments, resulting in necessary condition grades for calculating LOF scores (described below).

Separate from the COF scoring exercise, a MTBF analysis was derived from work order data, staff institutional knowledge, and industry trends to estimate LOF. The assigned COF was multiplied by the estimated LOF to produce a preliminary risk score.

H.2.2 COF Scoring

As part of the preliminary risk score development, a tabletop analysis for COF was performed. GLWA staff individually assigned a COF score to Level 5 Process assets utilizing the vertical asset COF matrix. Table H-5 describes the criteria for the seven weighted categories: Regulatory Compliance, Impact to Service Levels, Financial Impact, Health and Safety, Public Impact, Environmental Stewardship, and Public Trust. Each category was scored on a scale from 1 to 5, where 5 is the most severe.

Table H-5: Vertical Asset COF Matrix

Category	Wt. (%)	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5
Regulatory Compliance	14.3	• Failure will not cause regulatory/permit violation, enforcement infraction, or unregulated discharge • No effect on mandated/enforceable program • Failure does not result in significant fine	• Failure may have some local impact • Failure will impact ability to meet expected future requirements • Failure will lead to non-compliance event in the near future	• Failure will cause moderate regulatory or permit violation, enforcement infraction, or unregulated discharge or will cause other non-compliance, permit violations, or significant regulatory scrutiny • Failure will impact mandated or enforceable program	• Failure will cause major regulatory or permit violation, enforcement infraction, or unregulated discharge, or will cause other non-compliance, permit violations, or significant regulatory scrutiny • Failure will impact mandated or enforceable program	• Failure will cause extreme regulatory/permit violation, enforcement infraction, or unregulated discharge, or will cause other non-compliance, permit violations, or significant regulatory scrutiny • Failure will impact mandated or enforceable program
Impact to Service Levels	14.3	No impact on service levels, facility LOS, or processes	Failure will have minor impact to facility level of service or processes for a day or less	Failure will have minor impact to facility service level or processes for up to a week or major impact for a day or less	Failure will have minor impact to facility service level or processes for up to a month or major impact for up to a week	Failure will have minor impacts to facility service level or processes for over a month or major impacts for more than a week
Financial Impact	14.3	Less than $10,000	$10,000 to less than $50,000	$50,000 to less than $250,000	$250,000 to less than $1,000,000	Greater than $1,000,000
Health & Safety	14.3	Failure (or immediate resolution of the failure) results in use of first aid supplies but no lost time **OR** Failure results in a near miss to one or more team members or the public	Failure (or immediate resolution of the failure) results an injury requiring treatment away from the workplace **OR** Results a team member reassignment to light duty **OR** Results in a major near miss to several team members or significant members of the public	Failure (or immediate resolution of the failure) leads a team member lost time event **OR** Leads to a treatable injury to a member of the public **OR** Leads to an Occupational Safety and Health Administration violation	Failure (or immediate resolution of the failure) will result in injury for one or more team members or members of the public **OR** Leads to permanent loss of ability to perform job for one or more team members	Failure (or immediate resolution of the failure) will result in measurable team member or public health events, including exposure to contaminants or hazardous materials **OR** Will result in death or permanent disability for one or more team members
Public Impact	14.3	Failure leads to no measurable impact on City, regional, or neighborhood growth plans	Failure will have minor impact on City, regional, or neighborhood growth **OR** Will have minor but measurable impact on economic development **OR** Will have minor but measurable impact on quality of life or aesthetics	Failure will have moderate impact on City, regional, or neighborhood growth **OR** Will have moderate impact on economic development **OR** Will have moderate impact on quality of life or aesthetics	Failure will restrict planned City, regional, or neighborhood growth **OR** Will have major impact on economic development **OR** Will have major impact on quality of life or aesthetics	Failure will restrict planned City, regional, or neighborhood growth **OR** Will have extreme impact on economic development **OR** Will have extreme impact on quality of life or aesthetics
Environmental Stewardship	14.3	No harm to resident biota or their habitat **OR** Release of non-harmful substances **OR** If release of harmful substances, it does not exceed reportable quantities Cleanup achieved with commonly available materials	Failure results in minor short-term reversible impacts in a localized area Ecosystem function not significantly impaired No remediation required	Failure results in significant but reversible impacts on the environment **OR** Temporary loss of ecosystem function **OR** Any remediation required	Failure results in non-reversible impacts to the environment **OR** Significant remediation in a localized or broad area	Failure results in environmental damage with permanent loss to ecosystem, including severe degradation of watershed or loss of habitat **OR** Failure results in significant death to state priority or federally endangered species
Public Trust	14.3	Few customer complaints No media coverage No impact on GLWA image or relationships	Failure results in several complaints made to GLWA **OR** Minor local media inquiries **OR** Minor impact on GLWA image or relationships	Failure results in moderate local media coverage or editorial comment **OR** National media inquiries **OR** Complaints elevated to the Board level	Failure results in significant local media coverage or editorial **OR** Citizen satisfaction survey indicates unacceptable performance	Intervention from external authorities (state or federal) **OR** Daily local negative news stories and national news coverage **OR** Lasting damage to GLWA image, existing relationships, and public confidence

Averaged GLWA staff COF scores for each Level 5 Process was used to assign a COF score to each child asset (Level 6, Level 7, Level 8) through a tabletop analysis known as Solomon Oldach Assessment Process (SOAP). SOAP holds that a child asset failure will not have a greater consequence than a parent asset failure. The SOAP relationship rules are listed and described in Table H-6.

Table H-6: SOAP COF Relationship Rules

Asset COF Parent/Child Relationship	Relationship Criteria
$COF_{CHILD} = COF_{PARENT}$	Equipment failure causes immediate system functional failure (no time to react to failure)
$COF_{CHILD} = COF_{PARENT} - 1$	Equipment failure may contribute to eventual system functional failure (have time to react to failure) or Equipment failure does not cause system functional failure but repair will cause a long duration disruption to system operation
$COF_{CHILD} = COF_{PARENT} - 2$	Equipment failure does not cause system functional failure but repair will cause a short duration disruption to system operation
$COF_{CHILD} = 1$	Equipment failure has minimal or no impact on system operation*
*Lowest criticality score to be assigned is no less than 1	

SOAP was applied to each of the seven (7) GLWA COF criteria. During the review and feedback workshops, process-specific staff input was used to modify COF criteria scores to better reflect consequence of failure experienced during operation for specific assets.

H.2.3 LOF Scoring

The WwAMP vertical asset LOF matrix includes five weighted categories: RUL, Performance, History of Reliability, Physical Condition, and Adherence to O&M Strategy. Due to an absence of meaningful initial data, the matrix categories RUL, Performance, and Adherence to O&M Strategy were designated a weight of zero. Categories were scored on a scale from 1 to 5, where 5 is the most severe. Physical Condition and History of Reliability data was based on industry trends and input from GLWA staff.

Table H-7 describes the data used to assign the category scores in the LOF matrix. Physical Condition scores were based on condition grade results from one of the tiered condition assessment classifications described in Table H-8.

Table H-7: WRRF and SPS Asset LOF Data Sources

Category	Data Input	Data Source
History of Reliability	Corrective Workorders	WAM workorders and industry trends
Physical Condition	Condition Grade	Condition grade results from Tier 1 or Tier 2 CAs

Table H-8: WRRF and SPS Condition Assessment Classification Tiers

Tier	Classification	Description
1	Tabletop Analysis	Based on available maintenance history, industry trends, and institutional knowledge from GLWA staff.
2	Visual Assessment	Field inspection using visual assessment.

The vertical LOF matrix with category scoring criteria is shown in Table H-9.

Table H-9: Vertical Asset LOF Matrix

Category	Weight	Score = 1	Score = 2	Score = 3	Score = 4	Score = 5
RUL	0.0	81% to 100%	51% to 80%	21% to 50%	6% to 20%	0% to 5%
Performance	0.0	Sufficient capacity to meet average and peak flow requirements. Appropriate utilization and function.	Under-utilized or oversized, causing O&M issues.	Meets current functional demand but has limited degradation availability.	-	Unable to meet current average capacity needs. Functionally failed.
History of Reliability	0.30	No unscheduled corrective work order events within 12 months.	-	1 to 3 unscheduled corrective work order events within 12 months.	-	More than three unscheduled corrective work order events within 12 months.
Physical Condition	0.70	Very good. Condition Grade 1. New or nearly new. Only normal maintenance required.	Good. Condition Grade 2. Minor wear.	Fair. Condition Grade 3. Major wear impacting level of service.	Poor. Condition Grade 4. Unable to meet level of service life. Failure imminent.	Very poor. Grade 5. Requires complete rehabilitation or replacement. Failed.
Adherence to O&M Strategy	0.0	Complete, up-to-date, written, performed, and reviewed at least 3 cycles.	Complete, written, up-to-date, performed, and reviewed at least one time.	Developed but not fully vetted.	Written, but outdated.	No written procedures, or procedures are not being used.

H.2.4 Risk Score Utilization

The WRRF and SPS asset risk determination involved multiple series of staff workshops, multiple tabletop analysis, prioritization of high-risk assets for further assessment, and several iterations of asset risk score calculations. Figure H-1 illustrates the general risk process flow.

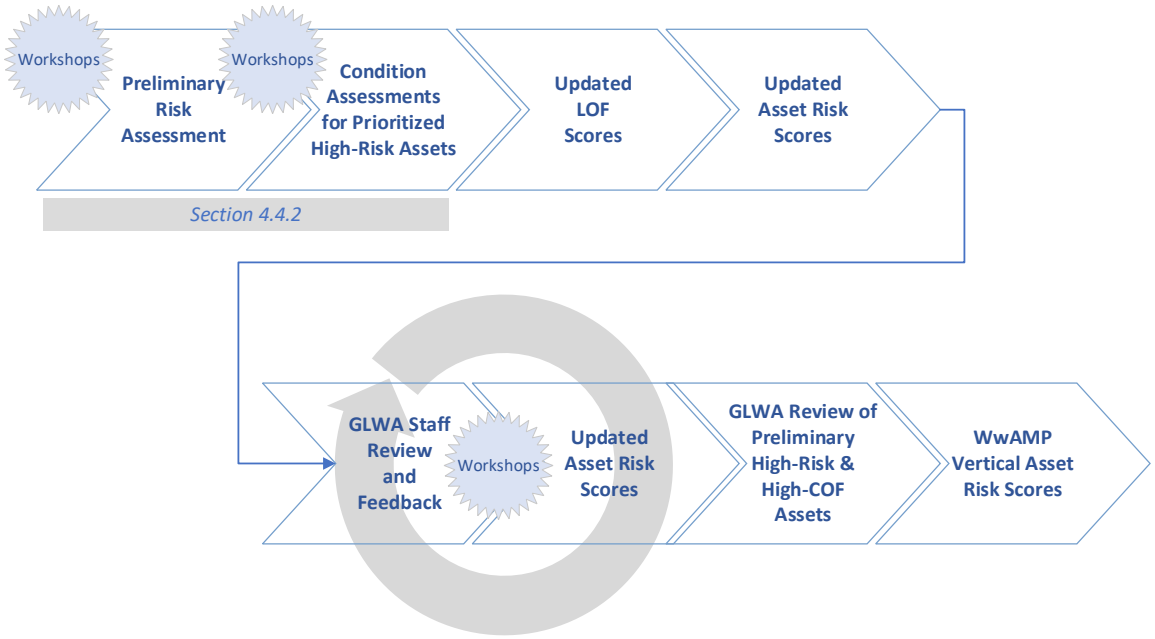


Figure H-1: Vertical Asset Risk Process Flow Diagram

The continuous feedback loop from GLWA staff also provided updates to the vertical asset register, including updates to asset statuses, asset types, asset descriptions, modifications to the asset hierarchy, and the addition of missing asset records.

Vertical total asset risk scores were plotted on a Risk Severity Heat Map in Chapter 5. The heat map shows the quantity of assets that reside at each product combination of COF and LOF. For example, if a significant portion of assets have a total asset risk score of 10, with COF = 2 and LOF = 4, renewal could be an appropriate risk treatment. Additionally, if the factors were reversed and COF = 4 and LOF = 2, improving resiliency could be a risk treatment strategy. Understanding where the bulk of assets fall on the heat map is informative for targeting O&M strategies.

H.3 CSO Assets

H.3.1 COF Approach

As part of the 2021 CS-299 CSO Facilities Assessment, all CSO assets were reviewed for COF either independently or as a group of the same asset types at the same CSO facility. Starting with Level 4 (Facility) through Level 8 assets, COF scores were assigned, respectively, utilizing the vertical asset COF matrix (Table H-5). Desktop analysis (SOAP methodology) was not needed.

As described above, the vertical COF matrix includes seven weighted categories: Regulatory Compliance, Impact to Service Levels, Financial Impact, Health and Safety, Public Impact, Environmental Stewardship, and Public Trust. Each category was scored on a scale from 1 to 5, where 5 is the most severe.

H.4 LOF Approach

The WwAMP vertical asset LOF matrix described above (Table H-9) includes five, weighted categories: RUL, Performance, History of Reliability, Physical Condition, and Adherence to O&M Strategy. Categories were scored on a scale from 1 to 5, where 5 is the most severe.

Table H-10 describes the data used to assign the category scores in the LOF matrix. Physical Condition scores were based on condition grade results from one of the tiered condition assessment classifications described in Table H-11.

Table H-10: CSO Asset LOF Data Sources

Category	Data Input	Data Source
History of Reliability	Corrective Workorders	WAM workorders and industry trends
Physical Condition	Condition Grade	Condition grade results from Tier 2 or Tier 3 condition assessments

Table H-11: CSO Condition Assessment Tiers

Tier	Classification	Description
2	Visual Assessment	Field inspection using visual assessment.
3	Detailed Assessment	Field inspection using predictive testing methods including thermal imaging, spot vibration testing, amperage balance, voltage balance, and insulation resistance testing.[1]
[1]Additional details about CSO condition assessments can be found in the 2021 CS-299 CSO Facilities Assessment.		

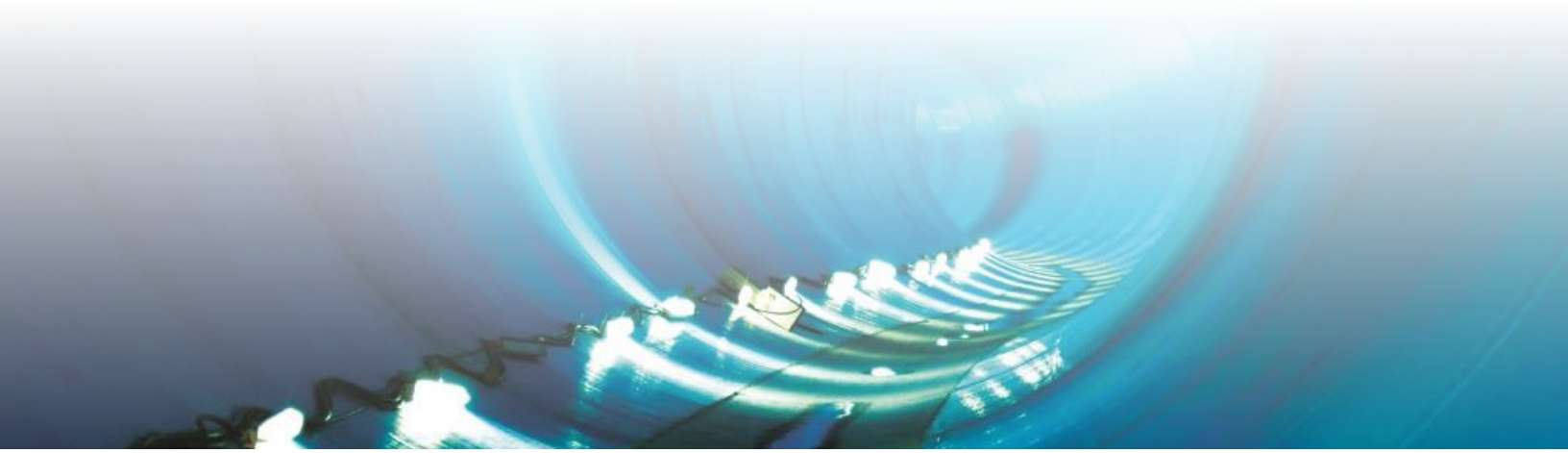
The LOF scores presented in the 2021 CS-299 CSO Facilities Assessment are slightly different due to different weights applied to categories in the vertical asset LOF matrix.

H.4.1 Risk Score Utilization

Vertical total asset risk scores were plotted on a Risk Severity Heat Map in Chapter 5. The heat map shows the quantity of assets that reside at each product combination of COF and LOF. For example, if a significant portion of assets have a total asset risk score of 10, with COF = 2 and LOF = 4, renewal could be an appropriate risk treatment. Additionally, if the factors were reversed and COF = 4 and LOF = 2, improving resiliency could be a risk treatment strategy. Understanding where the bulk of assets fall on the heat map is informative for targeting O&M strategies.

The total asset risk scores presented in the 2021 CS-299 CSO Facilities Assessment are slightly different due to different weights applied to categories in the vertical asset LOF matrix.

Appendix I – Failure Modes Effects Analysis (FMEA)Pilot: Approach and Results



Failure Modes and Effects and Analysis (FMEA) is a key operations and maintenance strategy that can result in efficiencies and thorough evaluation of asset operations and maintenance needs.

I.1 Overview of FMEA Theory

The FMEA was developed by the U.S. Military in the 1940s as a method for evaluating machinery to better understand the potential failures and appropriate mitigation strategies to manage risk.

An FMEA analysis deconstructs an asset into its various sub-components and then defines the various ways the component may fail, or failure modes. A failure mode is simply a simple action statement comprised of a noun and verb that describes a resultant condition driven by a cause of causes of the specified failure mode. For example, a failure mode may be defined as "bearing seizes" with associated causes of "lack of lubrication" or "misalignment of drive shaft", etc. Failure modes identified are those failures that are "likely" to occur.

Each combination of failure mode and cause of failure is scored using a Risk Priority Number (RPN). The RPN is a quantitative ranking of the risk associated with each failure mode and cause. The RPN scoring factors are listed in Table I-1, and used in the following equation:

RPN = Severity x Occurrence x Detectability

Table I-1: FMEA Scoring Factors

Factor	Description	Scale
Severity	COF	1 (low) to 5 (high)
Occurrence	Likelihood of cause occurring	1 (low) to 5 (high)
Detectability	Ability of the cause being detected under normal operation	1 (high) to 5 (low)

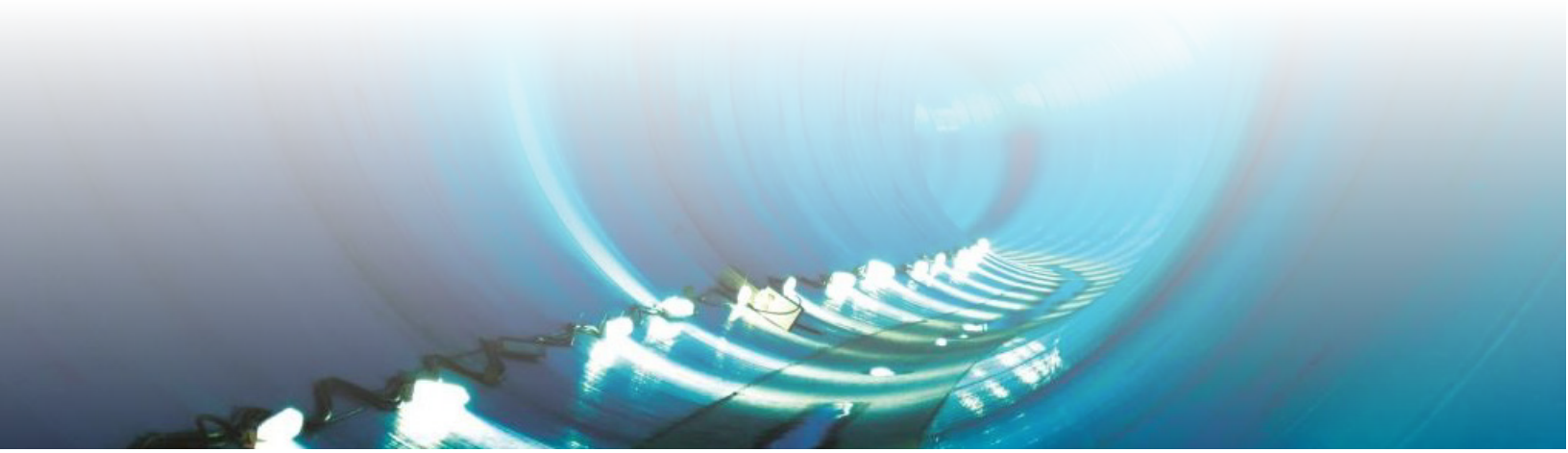
Mitigation strategies are assigned to address each failure mode and failure cause and are designed to manage the risk of asset failure. Strategies include:

- PM
- PdM
- Operator inspections
- Operational practices
- Redesign of either asset or system
- No action, or Run To Failure

I.1.1 FMEA PROCESS FOR GLWA

- For the GLWA WRRF reliability initiative, it was determined to pilot the FMEA approach on a single asset from each of the four major areas to include Primary, Secondary, Dewatering, and Incineration.
- The assets selected for FMEA were assets identified as high-risk during the comprehensive risk ranking of all WRRF assets with input from the WRRF maintenance team on asset performance history.
- The assets selected are as follows:
    - Primary - PS-1 Primary Pump
    - Secondary – Clarifier Drive
    - Dewatering – Belt Filter Press
    - Incineration – ID Fan Variable Frequency Drive
- The process used at GLWA for completing the FMEAs included the following activities:
    - Walk down of each asset by Jacobs Consultant to ensure a detailed understanding of the asset environment, operating context, and overall condition of the asset.
    - Photographs of the asset for reference during the analysis.
    - Review of manufacturer's O&M manual to ensure full understanding of OEM recommended actions and details of the machine.
    - Conduct of the FMEA by Jacobs Consultant.
    - Presentation and review of FMEA results and recommended actions.
    - Update of the FMEA based on feedback from the WRRF team.

Appendix J – Planned Maintenance Optimization (PMO) Report and Tool



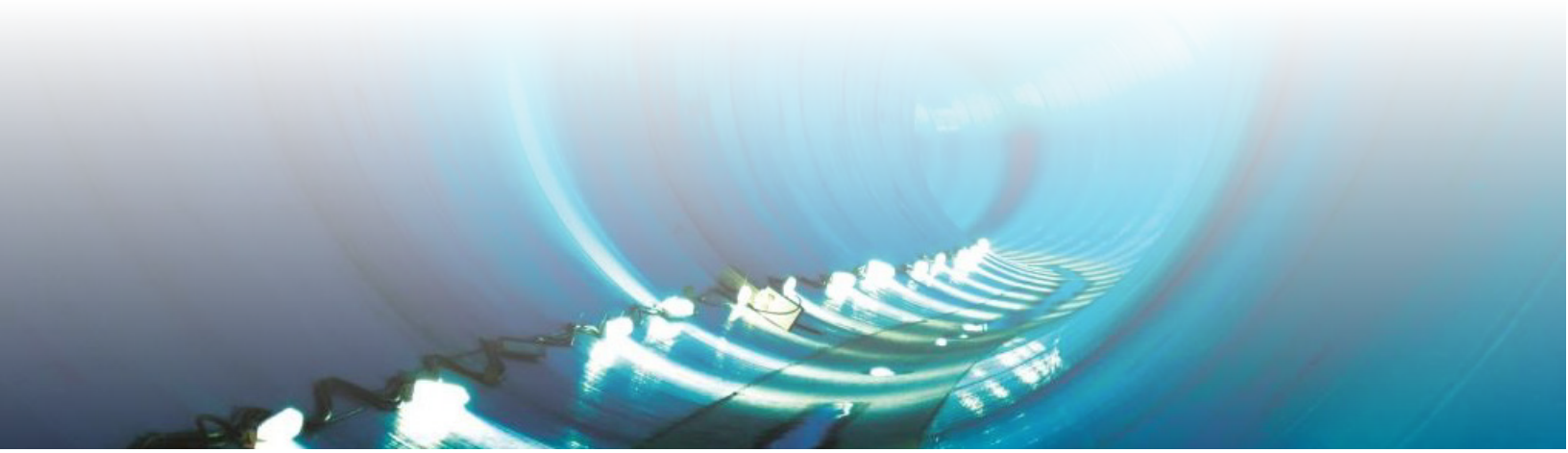
Planned Maintenance Optimization (PMO) is a key operations and maintenance strategy that can result in efficiencies and thorough evaluation of asset operation and maintenance needs.

Planned Maintenance Optimization (PMO) evaluates the PM strategy across the asset population as it compares to the criticality of the assets. PMO also aims to redistribute the performance of PM from low-value activities to high-value activities in order to achieve greater value per hour of PM completed. PMO achieves this by working to identify and remove duplicate PM tasks. This includes increasing or decreasing PM intervals, applying the use PdM where beneficial, improving work instructions, improving operator inspections, and achieving greater overall efficiency and safety. By careful analyzing PM tasks, PMO can streamline PM without increasing the risk of failure. Thus, PMO has the potential to significantly reduce overall annual PM hours and improve delivered level of service and performance.

GLWA's PMO goals include the following:

- Delete maintenance tasks that provide little value
- Extend or reduce PM interval based on type of task, equipment usage, environment, and industry guidelines
- Improve PM scheduling
- Add PM/PdM, where beneficial
- Take credit for current PdM activities
- Make use of and improve operator rounds
- Reassign PM tasks to Operations Department that would be better served by having the Operations Department perform the task
- Make use of installed instrumentation and monitoring
- Strengthen work packages (task instructions, parts, and tools)

Appendix K – Scheduled Replacement Program (SRP) Models (WRRF, SPS, CSO Facilities, and Linear Assets)



K.1 VERTICAL ASSETS

In developing life cycle models for vertical assets, three related datasets are required inputs: asset inventory, asset condition, and asset cost Information. Selection of asset types at an appropriate level in the asset hierarchy is critical to understanding the true life cycle behavior of a complete asset base (rather than considering only end-of-life replacement), and to developing reasonable confidence in cost estimates.

K.1.1 MODEL INPUTS & DATA AVAILABILITY

The WAM data set was used as the basis for compiling the necessary inventory, condition and replacement cost information for life cycle model development. The SRP represents primarily mechanical, electrical, instrumentation, building and process equipment. A combination of desktop and visual condition assessments provided condition score ratings on a scale of 1 to 5, as described in Table K-1.

Table K-1: Condition Score Ratings Key

Score	Descriptor	Description
1	Excellent	• New or recently rehabilitated infrastructure • Well maintained and in excellent condition
2	Very good	• Infrastructure is in the early stage of its useful life • Acceptable condition with some deterioration • May require some minor maintenance
3	Good	• Infrastructure is in the mid-stage of its useful life • May show slight signs of deterioration • May require maintenance
4	Fair	• Infrastructure in later stage of its useful life • May show minor deterioration • May require ongoing monitoring and major maintenance or rehabilitation
5	Poor	• Infrastructure in end-stage of its useful life • May show major deterioration or condition may be critical • May require extensive monitoring, rehabilitation and/or replacement

K.1.2 Estimating Costs

Replacement costs used in the model were source from the following data sources:

- WRRF and SPS WAM data – with some uncertainty around the date for the costs estimates as well as items included, an additional 40% project markup was applied to the costs to account for additional engineering, installation, and general contingency
- 2013 CSO SRP with costs escalated to 2021 values; most of these were from vendor quotes and this was about 25% of the total asset count
- Current vendor quotes, quotes from recent pricing GLWA received
- Prices from recent Jacobs projects

K.1.3 SRP Strategy

For the purpose of this SRP, 95 individual asset types were reviewed and assigned a life cycle investment profile. Each asset type was assigned one of nine asset categories, as follows:

- Building Structural/Architectural
- Building Mechanical
- Process Structural
- Electrical Systems
- Instrumentation/Control
- Process Mechanical
- Health and Safety Equipment
- Site Works
- Linear

Asset information (inventory, condition, and replacement costs) was processed via the life cycle model based on the appropriate asset type for each entry in the inventory. In vertical life cycle models, three life cycle behavior profiles were developed that match the investment requirements of the various asset types.

The profiles were tuned for each asset type to model asset behaviors with respect to mid-life and end-of-life intervention frequency. These behaviors were then reviewed by GLWA staff to confirm alignment with GLWA policies and experience.

K.1.3.1 Profile 1

For larger, high-value assets with unique mid-life interventions, each asset was modelled separately, and available condition data was used to forecast the intervention. Figure K-1 illustrates the approach.

Asset Type	Midlife Intervention Trigger	Midlife Intervention	Midlife Intervention Frequency (years)	End-of-Life Trigger	End-of-Life Frequency (years)	Comments/ Assumptions
Pump, Centrifugal	Failure of motor and wearing of impeller.	Replace motor and impeller.	**20**	Alignment issues, plugging, and decreased capacity.	**40**	For pumps that are used frequently, midlife interventions for wear parts become more frequent.

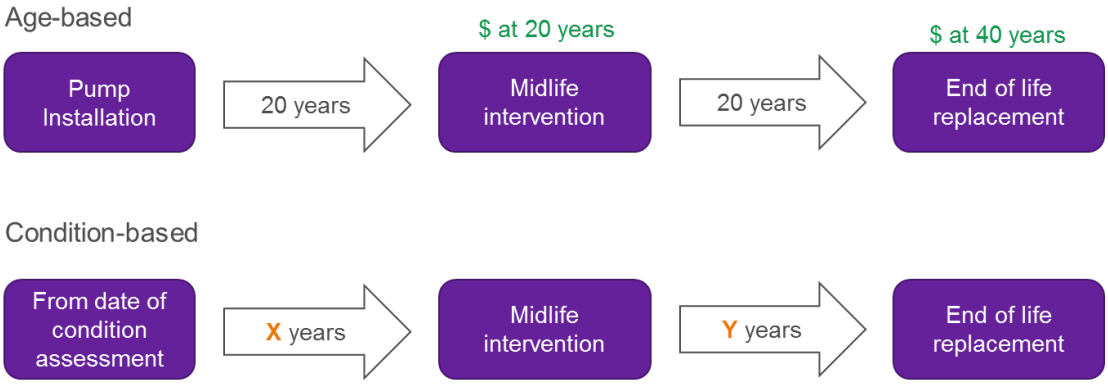


Figure K-1. Modelling Profile 1 Example

Condition deterioration curves consistent with industry practices were used to forecast the timing of midlife interventions and asset replacement, as shown in Figure K-2. While updated curves could be developed by GLWA in the long term, it is noted that a significant effort would be required for data collection and analysis; an industry scan of deterioration curves every 3 to 5 years is recommended as other SRP data improvement enhancements are undertaken.

Figure K-2: Condition-based deterioration curves

K.1.3.2 Profile 2

For smaller, low value assets with significant quantities, assets were pooled into cohorts and modelled together. Figure K-3 illustrates the approach where yearly funding is allocated to replace the asset cohort.

Asset Type	Midlife Intervention	End-of-Life Trigger	End-of-Life Frequency (years)	Comments/ Assumptions	Summary of Historical Data Analysis
Analyzer	N/A	Deterioration of reading accuracy, increased frequency of calibration.	**10**	Technology typically does not change.	N/A

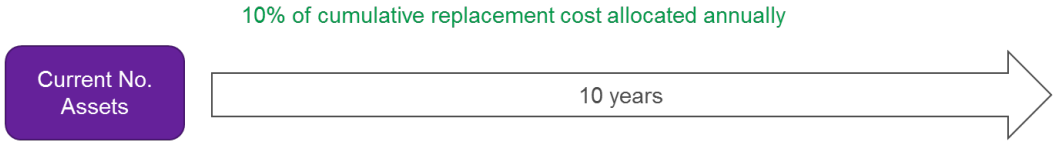


Figure K-3: Modelling Profile 2 example

K.1.3.3 Profile 3

For extremely long-lasting assets such as buildings, it was noted through discussion with the Project Team that the nominal lifespan was not a good indicator of realistic replacement practices. For these assets, expenditures throughout the operational phase were typically targeted towards regular inspection and minor interventions (crack sealing) which allowed Halton to extend the lifespan of the asset almost indefinitely. Rather than setting a distinct time-period on the anticipated useful life of such assets, costs for distributed interventions were allocated over the nominal lifespan as shown in Figure K-5.

Asset Type	Nominal End-of-Life Frequency (years)	Comments/ Assumptions
Misc. Structural	**60**	5% of replacement value, spent to extend the asset life over the nominal lifespan in 5 year increments

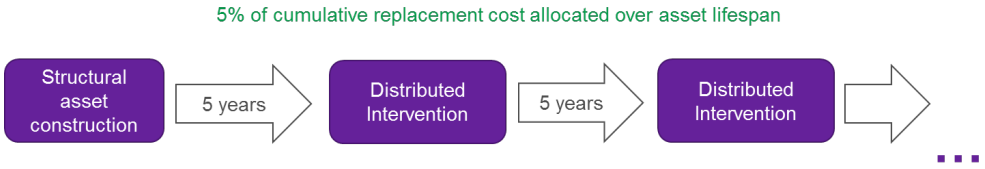


Figure K-5 Modelling Profile 3 example

K.1.4 MODEL DEVELOPMENT

This SRP model was developed in Microsoft Excel to forecast capital expenditures over the next 50 years for the asset inventory, following the logic sequence outlined in Figure K-6.

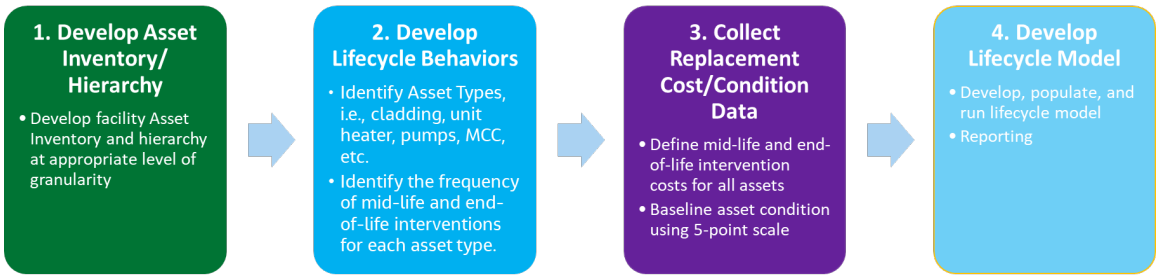


Figure K-6. Vertical SRP model logic sequence

Within the model, data for each inventory item was separated into five subsets, as discussed below.

Asset Hierarchy: includes details on the inventory item including system, facility type, facility name and aliases, process, asset type, TCA asset category and SAP or TCA asset identifier, as shown in the example in Figure K-7.

Asset Hierarchy			Asset Hierarchy						
			Calculate Life Cycle Expenditures						
Level 1: Process Area	Level 2: Level 4	Funtional Group	Asset	Concatenated	Asset Information Source	Status	Asset ID	Asset Category	Asset Type
Primary	PUMP STATION #1 SYSTEM, WWTP (PARENT ASSET FOR ALL PUMP STATION #1 PROCESS ASSETS)		*CA: PUMP, LIFT, MAIN; M.L.P.#1: PUMP STATION #1 *CA: # 1 PUMP STATION BASEMENT			Active	E00000000904673	Process Mechanical	PUMP – MAIN LIFT

Figure K-7: Example Asset Hierarchy – WRRF Main Lift Pump

Historical Data: includes condition and age data, and the condition data source. The data collection method was also included as an indicator of data reliability, based on four possible categories in order of descending reliability: performance testing, visual inspection, workshop, age-based. An example model entry is shown in Figure K-8.

Historical Data						Cost Data		
Year of Construction	Condition Grade	Date of Condition Assessment	Notes	Data Source(s)	Data collection method	Cost Data Source	Cost Base Year	Asset Replacement Cost Estimate ($)
2004	3	2020					2021	$ 1,197,849

Figure K-8: Example Historical Data and Cost Data entry - WRRF Main Lift Pump

Projection Data: includes the SRP modelling profile based on the asset type, including midlife and end-of-life investment frequency, deterioration curve classification, remaining useful life estimate and intervention cost as a % of replacement cost. Where there was no condition data, age was used to predict the next intervention. If the asset had already reached the end of its theoretical useful life based on age, then it was identified for replacement in 2022. An example model entry is shown in Figure K-9.

Condition-based Projection Data													
LCM Strategy	Strategy 1 Analysis Basis	Mid-Life Frequency (yrs.)	End-of-Life Frequency (yrs.)	Remaining Life Age Based	Type Lookup	Life Remaining from date of condition assessment (condition-based)	Mid-Life Cost/ Replacement Cost	Mid-Life Intervention Cost with Markup (Current Dollars)	Strategy 2, annual allocation (Annual$/ Replacement$)	Strategy 3 - distributed intervention (Intervention$/ Replacement$)	Strategy 3 - intervention frequency (years)	Replacement Cost (End-of-Life Cost) with Markup	Inflated Replacement Cost (End-of-Life Cost), with Markup (Current Dollars)
Strategy 1 (m	Condition-based	15	80	63	6	40	20.0%	$335,398	N/A	N/A	N/A	$ 1,676,989	**$ 1,676,989**

Figure K-9: Example Projection Data entry - 5 Halton Hills Reservoir

Cost Data: includes the replacement cost for the given asset and an escalated (present day) replacement cost. The final escalated end-of-life cost includes a project delivery markup.

Model Results: Direct outputs of the SRP model profiles show significant peaks and troughs in the forecast expenditures. Such peaks are often artificial and caused by many assets being forecast for replacement in a particular year. The useful life of different asset types could be represented by a range of probability distributions to model the likelihood of failure. In practice, developing and maintaining such curves for different asset types and failure modes is impractical, and a five-year moving average was applied to the projections of all asset

types to represent the variability in actual life compared to the nominal useful life, and thereby produce a profile which better reflects realistic investment needs.

K.2 Linear Assets

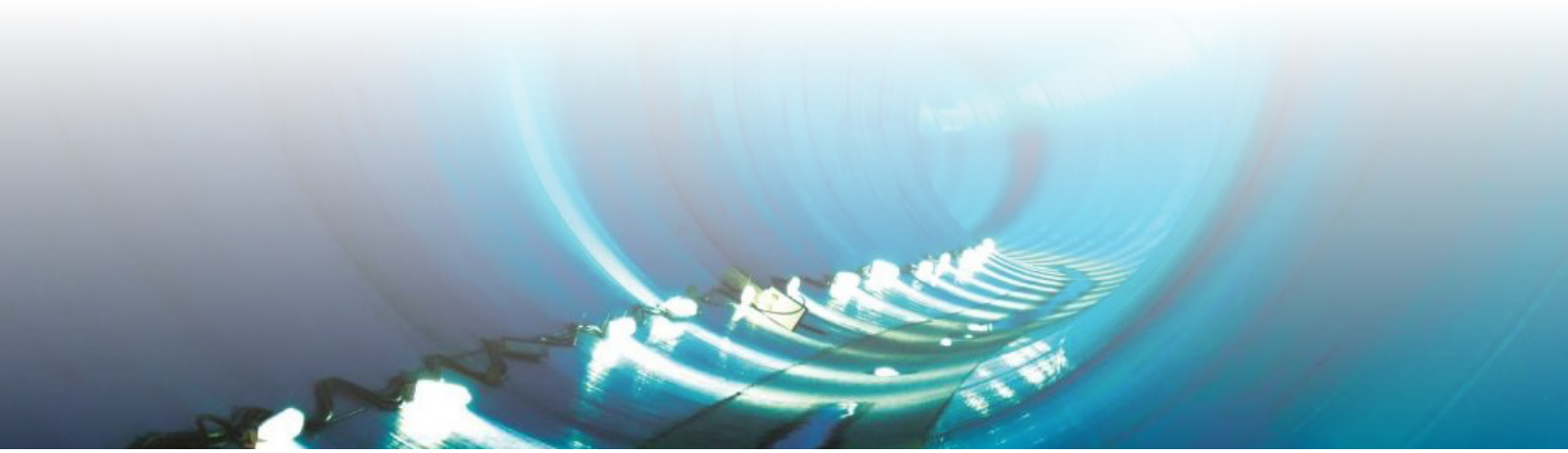
K.2.1 Balancing of Rehab Dates and Estimating Costs for Uninspected Pipes

When SCREAM schedules rehabilitation dates using the RUL of a pipe, five problems can occur:

- The scheduled date doesn't take into account the risk COF of the pipe.
- A scheduled date doesn't isn't created for pipes that have not been inspected.
- Pipes are often scheduled in the same year, leading to big spikes to rehab. This happens because some RULs are estimated using similar pipes. For example, when a pipe's material isn't known or an appropriate remaining life curve is not available, the average RUL for pipes with the same attributes (diameter, basin and material) are applied. Many pipes may end up with the same RUL.
- Finally, uninspected pipes can outlive their RUL curve and end up with an RUL of 0 because the install date was more than the curve (over 100 years ago, for example). Not all of these pipes are in bad shape. To address this, for uninspected pipes that are within 20 years of the end of the curve, we use averages from similar inspected pipes.

To address this gap, there is a balancing process. Balancing shifts some rehab work to occur sooner, depending on the COF.

Appendix L – WwAMP Continuous Improvement Plan Tracker



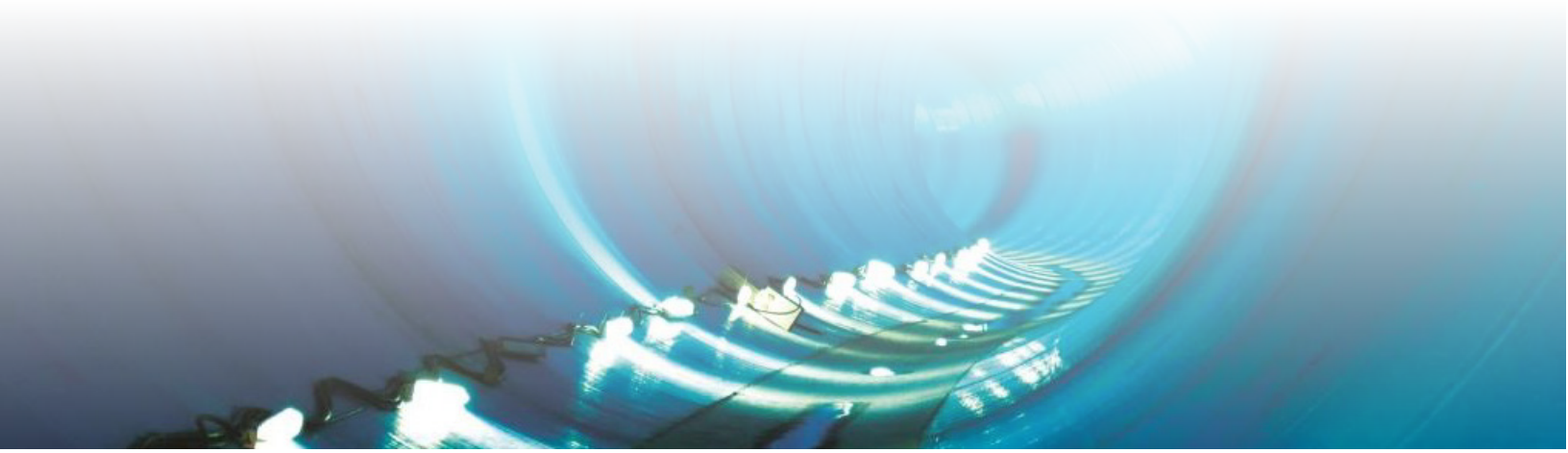
The Continuous Improvement Plan Tracker is an MS Excel file that was provided to GLWA as part of the initial WwAMP development on June 10, 2022. A representative image of that file with key column headings is presented in FigureL-1.

Wastewater Continuous Improvement Plan Tracker

Tactical Recommentation #	Tactical Recommendation Title	Affected WW Assets	Related SAMP II	GLWA Owner	YEAR 1			YEAR 2			YEAR 3		
					Actions	Estimated Labor Hours (Total	Estimated Consultant Cost ($)	Actions	Estimated Labor Hours (Total GLWA)	Estimated Consultant Cost ($)	Actions	Estimated Labor Hours (Total GLWA)	Estimated Consultant Cos
WW1	Asset Management Roles & Responsibilities	All	•P1 - Dedicated Asset Management (AM) Team Members within Business Units (BU) •O6 - Future AM Assessments and Benchmarking	Enterprise Asset Management Group	**Year 1- Define Asset Management Champion Roles and Responsibilities** IDiscuss the role and responsibilities of the Asset Management Champion and assess potential to incorporate into the existing asset management governance structure. IDevelop the Asset Management Champion job description with clearly defined responsibilities. IIdentify owners of the Key Artifacts listed in Table 9-1 (supporting tools and datasets) and document responsibilities for managing these. IImplement the new roles (Asset Management Champion, owners of supporting tools and datasets).	40	0	**Year 2 – Assess and Refine Asset Management Champion Roles and Responsibilities** IReview the successes and challenges of the Asset Management Champion as part of an annual meeting and refine job description as needed. IDiscuss and document succession planning strategy for the Asset Management Champion and owners of Key Artifacts and implement.	10	0	**Year 3 – Perform Maturity Assessment Check-In** IReview the Asset Management Assessment and Benchmarking activity performed in 2018 during SAMP development and compare to other maturity assessment methods within the industry. The results of the Maturity Assessment performed during SAMP development are documented in the "Asset Management Assessment Summary – April 18, 2019." IConduct asset management maturity assessment and compare results to the maturity assessment documented in the "Asset Management Assessment Summary – April 18, 2019."	60	50,000

Figure L-1: Continuous Improvement Tracker

Appendix M – WwAMP Governance Business Processes



M.1 Overview

The Wastewater Continuous Improvement Plan is comprised of a series of Tactical Recommendations starting in FY22/23, that were identified to achieve significant milestones for improving the way Great Lakes Water Authority (GLWA) manages its wastewater system assets that include linear (pipe) and vertical assets (water resource recovery facility (WRRF); sewer pump stations (SPS) and combined sewer overflow (CSO) facilities. Current asset management activities are identified in the Wastewater Asset Management Plan (WwAMP).

The Wastewater Continuous Improvement Plan aims to service levels a number of key gaps including refinement of service levels based on stakeholder expectations, performing targeted condition assessment activities to improve GLWA's condition assessment program, and refining operations and maintenance (O&M) practices that focus on improving data quality, business processes, and use of technology.

M.2 Purpose of Asset Management Governance Business Processes

The purpose of documenting the related asset management business processes is to support staff with performing wastewater asset management continuous improvement activities. These business processes focus primarily on vertical assets and is complemented by a separate set of business processes for linear assets under GLWA's Linear System Integrity Program (LSIP).

M.3 Business Processes

Seven (7) business processes are described herein (Sections 1.3.1 – 1.3.7). A list of these business processes is reflected in Table M-1 along with responsible owner, or lead of the business processes, and a listing of key responsibilities.

Table M-1: Wastewater Asset Management Plan Asset Management Governance Business Processes

Responsible Owner	Business Process - Key Responsibilities	Frequency
EAMG	1. **WwAMP Management** – incorporate updates to each section of the WwAMP every 3 years (major update); annually (July) (minor updates) and as identified	• Every 3 Years • Annually • As identified
EAMG	2. **WwAMP - Continuous Improvement Plan Implementation** – ensure adherence to routine meeting schedule with identified Tactical Recommendation owners.	Monthly

Responsible Owner	Business Process - Key Responsibilities	Frequency
Local AM Team	**3. WwAMP - Asset Audit Program** - implement the improvements to data listed in the Asset Data and Improvement Summary (Appendix C) and WAM Data Gaps (Appendix D)	Annually
Local AM Team	**4. WwAMP - Condition Assessment Program – Vertical and Building Assets** – implement visual and detailed condition assessments in alignment with the priorities listed in the WwAMP - Condition Assessment Activities – Vertical Assets (Appendix F)	• Annually • Failure Event • Monthly
Local AM Team	**5. WwAMP - Risk and Criticality Assessment Program** - follow the asset risk management and data management activities in alignment with Tactical Recommendation WW6 – Asset Risk for Vertical Assets and Tactical Recommendation WW3 – Asset Data and Information for WAM/NexGen	• New asset driver affecting COF • Annual review of COF • New O&M optimization activity • New condition data
Operations and Maintenance Supervisors	**6. WwAMP - Strategic Maintenance and Reliability Program** 7. Manage and run the PMO Tool and use as needed following review of the Performance Indicator Report from NexGen **8.** Manage Failure Modes Effects Analysis (FMEA) development and usage following review of the Asset Failure Report from NexGen – identify and prioritize and implement development of additional FMEAs beyond the pilot activities completed in 2022.	Weekly
Finance/ Maintenance Director	**9. WwMP - Asset Replacement and Retirement Program –d**etermine projects for Capital Outlay or CIP	As Identified
EAMG	**10. WwAMP - Scheduled Replacement Program (SRP) –** update data in the SRP models on an annual basis and obtain refined future financial outlooks that can be used in the CIP Planning Process as inputs. *Note: This tool is reflected as part of the WwAMP - Asset Replacement and Retirement Program Business Process.*	Annually

M.3.1 WwAMP Management

Table M-2 describes the WwAMP Management Business Process. Figure M-1 depicts this process visually. This business process is to be updated as it changes over time.

Table M-2 Business Process Description – WwAMP Management

WwAMP Management	
Objective	To update the Wastewater Asset Management Plan (WwAMP) with up to date and accurate information and obtain comprehensive analysis of the asset management activities and projection of future continuous improvement actions.
Description of Process	**Trigger: Every 3 Years, Annually, or As Identified** 1. **EAMG** – Review WwAMP and identify needed updates 2. **EAMG** - Assign sections to update with deadline 3. **Local AM Team/O&M Supervisors/Finance** – Prepare updated content 4. **EAMG** – incorporate edits 5. **EAMG** - Post for review by identified GLWA staff 6. **EAMG** – Facilitate meeting to discuss trends and results 7. **Local AM Team/O&M Supervisors/Finance** – participate in meeting 8. **EAMG –** Update the WwAMP following the meeting as needed 9. **EAMG-** post WwAMP and inform wastewater staff of its availability
Roles	
Process Sponsor	EAMG
Process Users	• Local AM Team; • O&M Supervisors • Finance
Timing	
Starting Event	Every three years, annually, or as identified
Ending Event	Updated WwAMP - posted

Business Process: Wastewater Asset Management Plan (WwAMP) Management

GLWA

EAMG

Start – Every 3 Years

Start – Annually (every July)

Start – As identified

Email

1 Review existing WwAMP and identify contents that need to be updated

2 Assign sections to update with deadline (as needed)

4 Incorporate edits

5 Post for review by identified GLWA staff

6 Facilitate meeting to discuss trends and results (as needed)

8 Update WwAMP following meeting (as needed)

9 Post WwAMP and inform wastewater staff of its availability

End

Note:

- Major update every 3 years
- Minor update annually
- Updates as identified

Local AM Team

Sharepoint; Email notification

3 Prepare updated content

Sharepoint; Email notification

Email Meeting Invite

7 Participate in meeting

Verbal input t meeting

O&M Supervisors

3 Prepare updated content

7 Participate in meeting

Finance

3 Prepare updated content

7 Participate in meeting

M.3.2 WwAMP Continuous Improvement Plan Implementation

Table M-3 describes the WwAMP Continuous Improvement Plan Implementation Business Process. Figure M-2 depicts this process visually. This business process is to be updated as it changes over time.

Table M-3 Business Process Description – WwAMP Continuous Improvement Plan Implementation

WwAMP - Continuous Improvement Plan Implementation	
Objective	To support implementation of the WwAMP Continuous Improvement Plan through a defined business process.
Description of Process	**Trigger: Monthly** 1. **EAMG** – Review WwAMP Continuous Improvement Plan Tracker 2. **EAMG** – Remind staff to update Tactical Recommendations status in the WwAMP Continuous Improvement Tracker 3. **Local AM Team/O&M Supervisors/Finance** – Prepare updated content 4. **EAMG** – review and finalize edits 5. **EAMG** - Post for review by identified GLWA staff 6. **EAMG** – Facilitate meeting to discuss progress per Tactical Recommendation/issues 7. **Local AM Team/O&M Supervisors/Finance** – participate in meeting 8. **EAMG –** Update the WwAMP – Continuous Improvement Plan Tracker with updates following the meeting as needed 9. **EAMG-** post WwAMP- Continuous Improvement Plan Tracker and inform wastewater staff of its availability
Roles	
Process Sponsor	EAMG
Process Users	• Local AM Team • O&M Supervisors • Finance
Timing	
Starting Event	Monthly
Ending Event	Updated WwAMP – Continuous Improvement Plan - posted

Business Process: Wastewater Asset Management Plan (WwAMP) Continuous Improvement Plan Implementation

GLWA

EAMG

Start – Monthly

1 Review Continuous Improvement Plan Tracker based on last month

2 Remind staff to update Tactical Recommendations and status in the Continuous Improvement Plan Tracker

WwAMP _ Continuous Improvement Plan Tracker

4 Review and finalize updates

5 Post for review by identified GLWA staff

6 Facilitate meeting to discuss progress per Tactical Recommendation/ issues

8 Update WwAMP - Continuous Improvement Plan Tracker with update following meeting as needed

WwAMP _ Continuous Improvement Plan Tracker

9 Post WwAMP - Continuous Improvement Plan Tracker and inform wastewater staff of its availability

End

Note: Established as a routine agenda item for WwAMT meeting

Local AM Team

Sharepoint; Email notification

3 Prepare updated content

Sharepoint; Email notification

Verbal input t meeting

7 Participate in meeting

Email Meeting Invite

O&M Supervisors

3 Prepare updated content

7 Participate in meeting

Finance

3 Prepare updated content

7 Participate in meeting

M.3.3 WwAMP - Asset Audit Program

Table M-4 describes the WwAMP - Asset Audit Program Business Process. Figure M-3 depicts this process visually. This business process is to be updated as it changes over time.

Table M-4 Business Process Description – WwAMP - Asset Audit Program

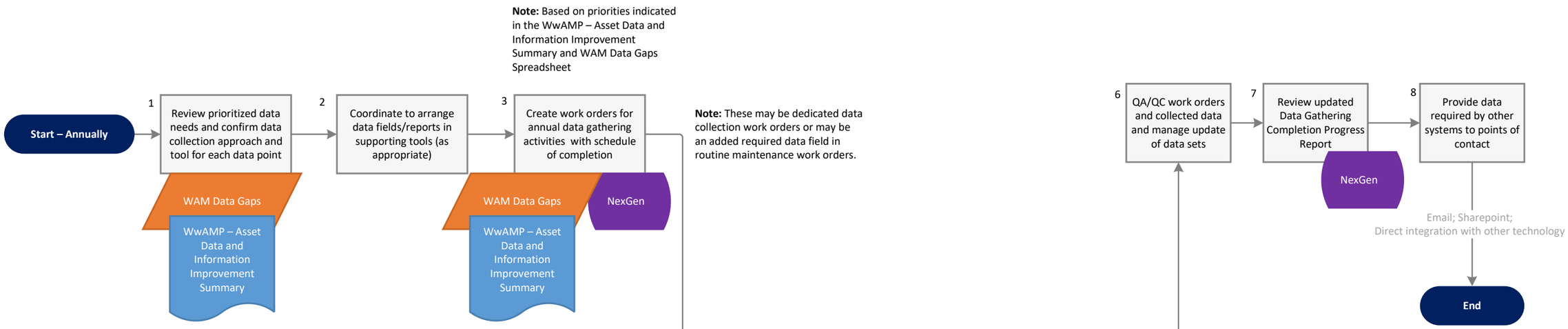
WwAMP - Asset Audit Program	
Objective	To methodically and systematically gather missing data on assets (to address quality or completeness issues) and improve the datasets used by GLWA to inform asset management decision-making.
Description of Process	1. **Local AM Team:** Review prioritized data needs and confirm data collection approach and tool for each data point 2. **Local AM Team:** Coordinate to arrange data fields/reports in supporting tools 3. Local AMG: Create work orders for annual data gathering activities with schedule of completion 4. **O&M Supervisors**: Receive work order and plan and schedule (includes use of Contractors) 5. **O&M Supervisors:** Manage performance of work and log data in NexGen 6. **Local AM Team:** QA/QC work orders and collected data and manage update of data sets 7. **Local AM Team:** Review updated Data Gathering Completion Progress Report 8. **Local AM Team:** Provide data required by other systems to points of contact
Roles	
Process Sponsor	Local AM Team
Process Users	• Local AM Team; • O&M Supervisors
Timing	
Starting Event	Annually
Ending Event	Updated datasets

Business Process: Wastewater Asset Management Plan (WwAMP) - Asset Audit Program

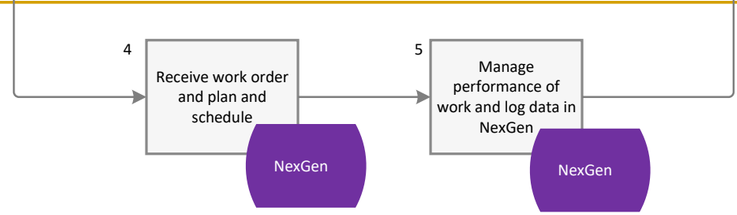
GLWA

This business process should be revisted/included in at the time of NexGen configuration so that configuration supports this programmatic asset management activity.

Local AM Team



O&M Supervisors



M.3.4 WwAMP - Condition Assessment Program – Vertical and Building Assets

Table M-5 describes the WwAMP Condition Assessment Program Business Process. Figure M-4 depicts this process visually. This business process is to be updated as it changes over time.

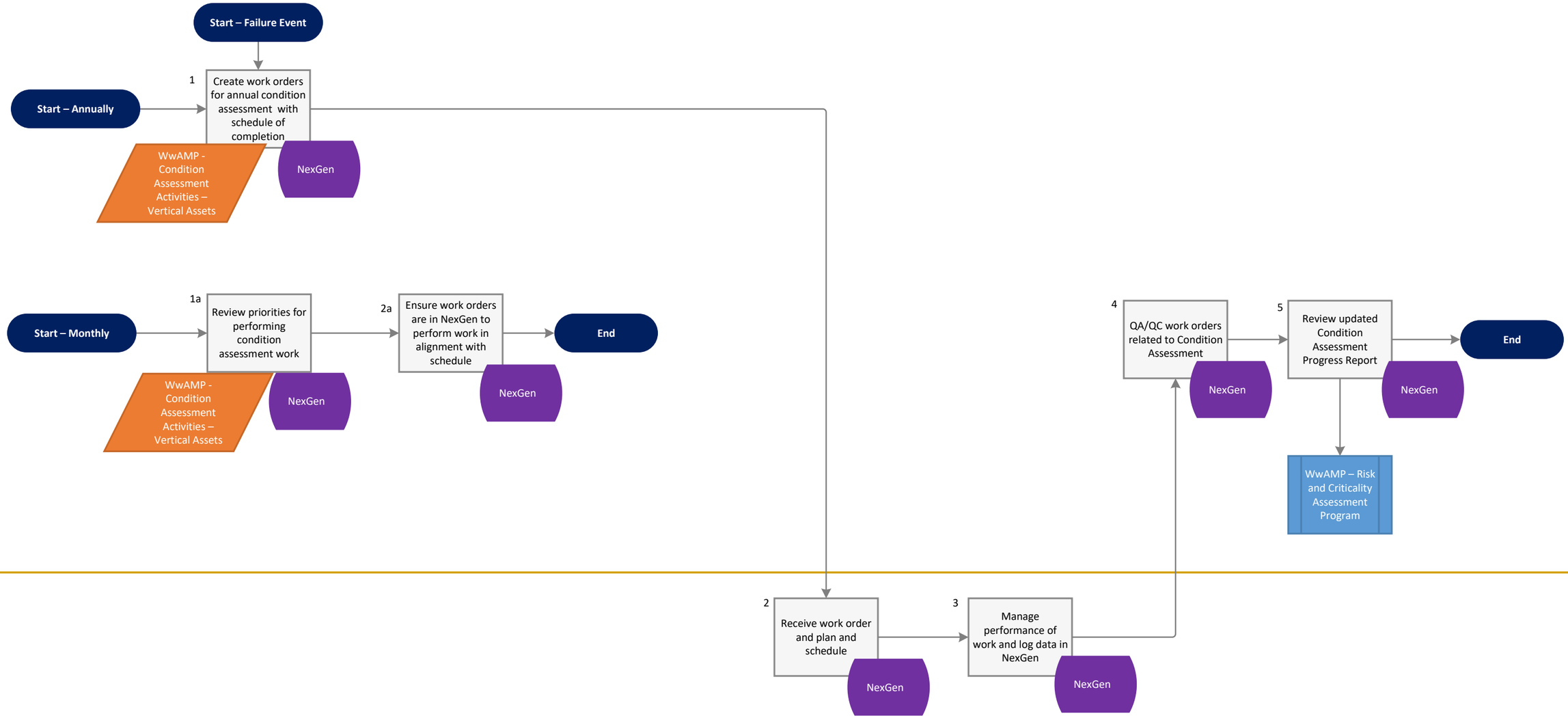
Table M-5 Business Process Description – WwAMP Condition Assessment Program – Vertical and Building Assets

WwAMP – Condition Assessment Program – Vertical and Building Assets	
Objective	To methodically and systematically gather condition assessment information on wastewater system assets and improve the datasets and analytical tool used by GLWA to track or use asset condition data.
Description of Process	**Trigger:** Annually, Monthly, or Failure Event 1. **Local AM Team:** Create work orders for annual condition assessment with schedule of completion 2. **O&M Supervisors:** Receive work order and plan and schedule 3. **O&M Supervisors:** Manage performance of work and log data in NexGen 4. **Local AM Team:** QA/QC work orders related to Condition Assessment 5. **Local AM Team:** Review updated Condition Assessment Progress Report 6. **Trigger:** Monthly 7. **Local AM Team:** Review priorities for performing condition assessment work 8. **Local AM Team:** Ensure work orders are in NexGen to perform work in alignment with schedule
Roles	
Process Sponsor	Local AM Team
Process Users	• Local AM Team • O&M Supervisors
Timing	
Starting Event	• Annually • Monthly • Failure Event
Ending Event	Updated Condition Assessment Progress Report

Business Process: Wastewater Asset Management Plan (WwAMP) Condition Assessment Program – Vertical and Building Assets

GLWA *This business process should be revisted/included in at the time of NexGen configuration so that configuration supports this programmatic asset management activity.*

Local AM Team



O&M Supervisors

M.3.5 WwAMP - Risk and Criticality Assessment Program

Table M-6 describes the WwAMP - Risk and Criticality Assessment Program Business Process. Figure M-5 depicts this process visually. This business process is to be updated as it changes over time.

Table M-6 Business Process Description – WwAMP - Risk and Criticality Assessment Program

WwAMP - Risk and Criticality Assessment Program	
Objective	To maintain and accurate risk register and use the results to trigger identification of risk mitigation strategies so that the overall risk profile associated with wastewater assets is formally managed.
Description of Process	**Trigger:** EAMG: communicates change on criticality to the Local AM Team (any GLWA staff can identify a change and funnel communication to the EAMG) **Trigger:** Annual review of COF criteria **Trigger**: O&M Supervisors communicates change in maintenance that impacts the LOF to the Local AM Team **Trigger:** Local AM Team: New condition data has been generated 1. **Local AM Team**: Log updates to the WwAMP – Risk Register 2. **Local AM Team:** Review and refine identified risks 3. **Local AM Team/O&M Supervisors:** Identify risk mitigation strategy and candidate Risk Owner 4. **Local AM Team**: Communicate risk, mitigation strategy and Risk Owner to the EAMG 5. **EAMG:** Review to approve risk, mitigation strategy and Risk Owner 6. **Local AM Team:** Inform Risk Owner of assignment 7. **Risk Owner/GLWA Staff**: Receive and acknowledge mitigation strategy assignment 8. **Risk Owner/GLWA Staff:** Implement mitigation strategy and report progress to the Local AM Team 9. **Local AM Team:** Update the Asset Risk Register 10. **Local AM Team:** Review performance metrics to track effectiveness of the mitigation strategy 11. **EAMG:** Do mitigation strategies need to be adjusted? 12. **EAMG:** Inform Local AM Team a new mitigation strategy is warranted (return to step 3)
Roles	
Process Sponsor	Local AM Team
Process Users	• Local AM Team • Risk Owner/GLWA Staff • EAMG
Timing	
Starting Event	Whenever an asset driver that impacts consequence of failure of criticality of an asset; or when condition score information is updated
Ending Event	Updated WwAMP-Risk Register

Business Process: Wastewater Asset Management Plan (WwAMP) - Risk and Criticality Assessment Program

GLWA *This business process should be revisted/included in at the time of NexGen configuration so that configuration supports this programmatic asset management activity.*

EAMG

Note: Any GLWA staff can communicate a change to asset criticality criteria to the EAMG to funnel communications to the Local AM Team

Start –New Asset Driver Affecting Consequence of Failure (criticality)

Start –Annually – Scheduled review of the COF criteria

1 Communicate change to the Local AM Team

5 Review to approve risk, mitigation strategy and Risk Owner

12 Inform Local AM Team a new mitigation strategy is warranted

11 Do mitigation strategies need to be adjusted? — Yes / No → **End**

O&M Supervisors

Start – If new O&M Optimization Activity affecting Likelihood of Failure

1 Communicate change to the Local AM Team

Email

3 Identify risk mitigation strategy and candidate Risk Owner

Email

Local AM Team

WwAMP – Condition Assessment Program – Vertical and Bldg Assets

Start – New Condition Data

Notification in NexGen

Email

1 Log data into the Risk Register

Asset Risk Report - Risk Register

2 Review and refine identified risks

Asset Risk Report - Risk Register

In-person meeting

3 Identify risk mitigation strategy and candidate Risk Owner

Asset Risk Report - Risk Register

4 Communicate risk, mitigation strategy and Risk Owner to the EAMG

6 Inform Risk Owner of assignment

Email

9 Update the Asset Risk Register

Asset Risk Report - Risk Register

10 Review performance metrics to track effectiveness of the mitigation strategy

Email/Face to Face Meeting

Risk Owner/GLWA Staff

Note: The Risk Owner is a generic term for any GLWA staff responsible for implementation of an identified Risk Mitigation Strategy.

7 Receive and acknowledge mitigation strategy assignment

8 Implement mitigation strategy and report progress to the Local AM Team

M.3.6 WwAMP - Strategic Maintenance and Reliability Program

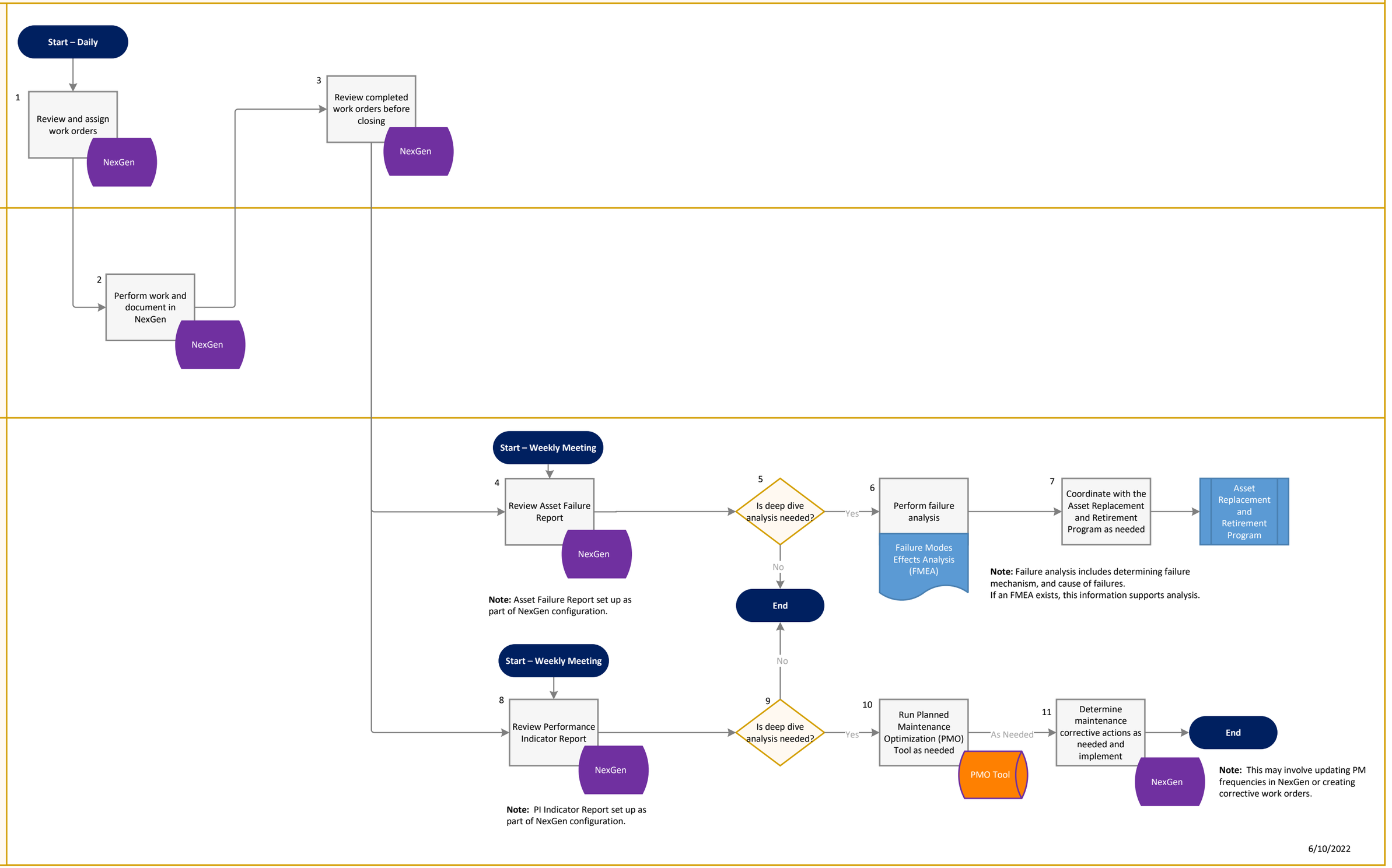
Table M-7 describes the WwAMP Strategic Maintenance and Reliability Program Business Process. Figure M-6 depicts this process visually. This business process is to be updated as it changes over time.

Table M-7 Business Process Description – WwAMP Strategic Maintenance and Reliability Program

WwAMP – Strategic Maintenance and Reliability Program	
Objective	To implement strategic maintenance and reliability program best practices starting with development of Failure Modes Effects Analysis (FMEA) and running Planned Maintenance Optimization (PMO) analyses.
Description of Process	**Trigger:** Daily 1. **O&M Supervisors:** Review and assign work orders 2. **Maintenance Staff:** Perform work and document in NexGen 3. **O&M Supervisors:** Review completed work orders before closing 4. **Trigger:** Weekly 5. **Team Leader:** Review Asset Failure Report 6. **Team Leader:** Is deep dive analysis needed? 7. **Team Leader:** Perform failure analysis 8. **Team Leader:** Coordinate with the Asset Replacement and Retirement Program as needed 9. **Trigger:** Weekly 10. **Team Leader:** Review Performance Indicator Report 11. **Team Leader:** Is deep dive analysis needed? 12. **Team Leader:** Run Planned Maintenance Optimization (PMO) Tool as needed 13. **Team Leader:** Determine maintenance corrective actions as needed and implement
Roles	
Process Sponsor	Team Leader
Process Users	• O&M Supervisors • Team Leader • Maintenance Staff
Timing	
Starting Event	• Daily • Weekly
Ending Event	• Coordination with the WwMP – Asset Replacement and Retirement Program • Updated work orders in NexGen

Business Process: Wastewater Asset Management Plan (WwAMP) - Strategic Maintenance and Reliability Program

GLWA *This business process should be revisted/included in at the time of NexGen configuration so that configuration supports this programmatic asset management activity.*



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M.3.7 WwAMP - Asset Replacement and Retirement Program

Table M-8 describes the WwAMP - Asset Replacement and Retirement Program Business Process. Figure M-7 depicts this process visually. This business process is to be updated as it changes over time.

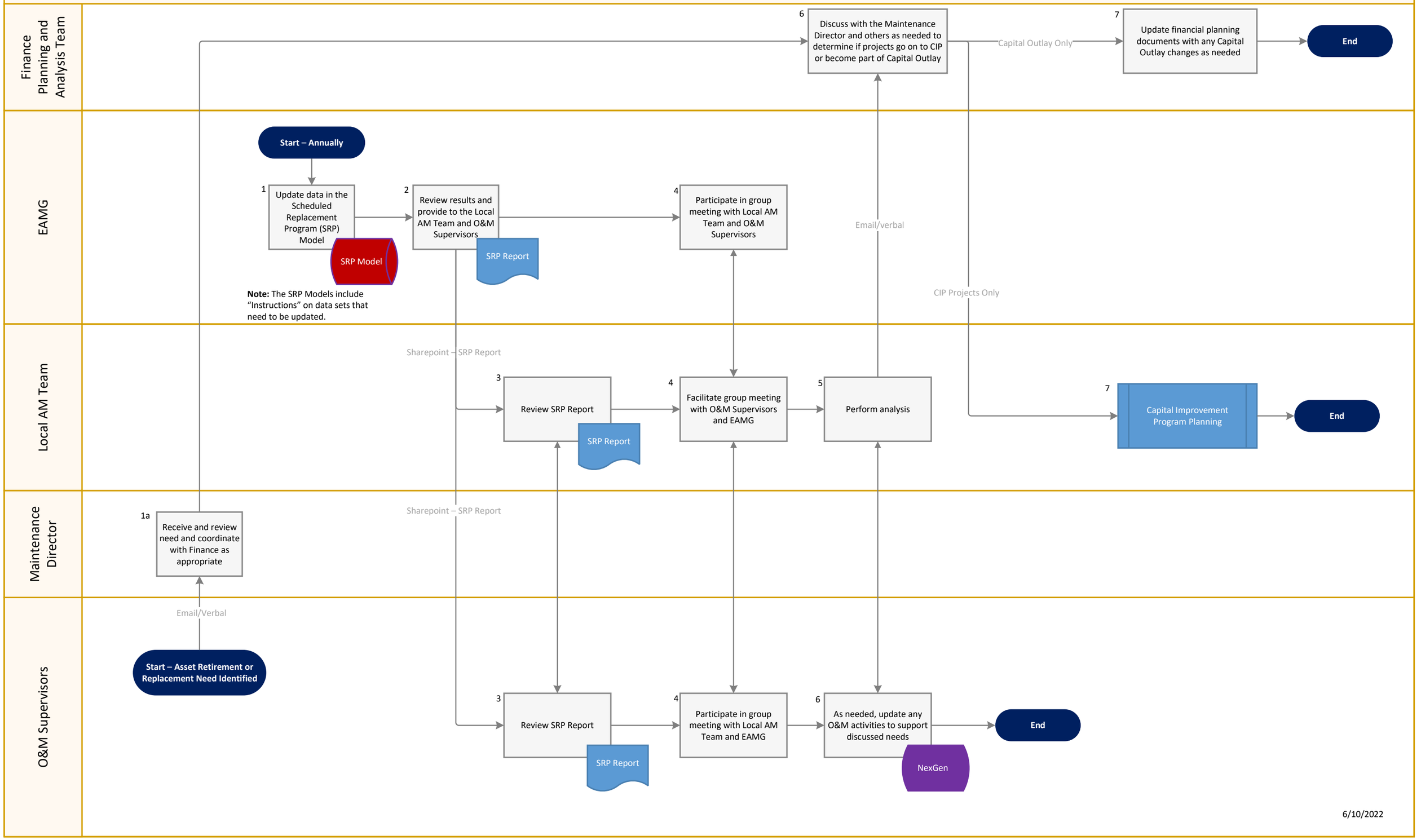
Table M-8 Business Process Description – WwAMP - Asset Replacement and Retirement Program

WwAMP –Asset Replacement and Retirement Program	
Objective	To identify assets that need replacement or retirement.
Description of Process	**Trigger:** Annually 1. **EAMG:** Update data in the Scheduled Replacement Program (SRP) Model 2. **EAMG:** Review results and provide to the Local AM Team and O&M Supervisors 3. **Local AM Team and O&M Supervisors**: Review SRP Report 4. **Local AM Team:** Facilitate meeting 5. **EAMG and O&M Supervisors**: Participate in meeting 6. **Local AM Team:** Perform analysis 7. **Finance:** Discuss with the Maintenance Director and others as needed to determine if projects go on to CIP or become part of Capital Outlay 8. **O&M Supervisors**: As needed, update any O&M activities to support discussed needs 9. **If Capital Outlay - Finance**: Update financial planning documents with any Capital Outlay changes as needed 10. **If CIP** – Local AM Team – move project through CIP Process **Trigger:** As Identified by O&M Supervisors – need for asset replacement or retirement 1a. **Maintenance Director:** Receive and review need and coordinate with Finance as appropriate *Continue to step 6 (above)*
Roles	
Process Sponsor	EAMG
Process Users	• Local AM Team • O&M Supervisors • EAMG • Financial Planning and Analysis Team • Maintenance Director
Timing	
Starting Event	• As Identified • Annually

WwAMP –Asset Replacement and Retirement Program	
Ending Event	• Asset Replacement and Retirement forecast • Updated Capital Outlay Budget (potential) • Updated CIP (potential) • Updated O&M change (potential)

Business Process: Wastewater Asset Management Plan (WwAMP) - Asset Replacement and Retirement (R&R) Program

GLWA *This business process should be revisted/included in at the time of NexGen configuration so that configuration supports this programmatic asset management activity.*



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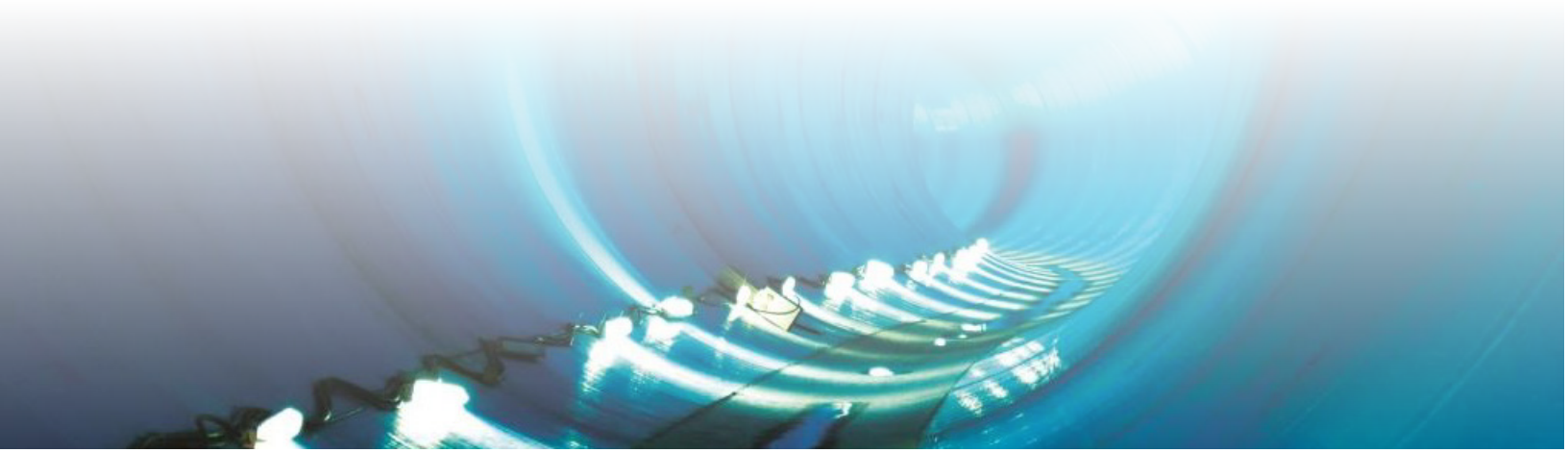
Appendix N WwAMP Continuous Improvement Plan Staffing Plan



The Continuous Improvement Plan Staffing Plan is presented in Table N-1 and is a listing of estimated staff resources required to implement the WwAMP Continuous Improvement Plan. The staffing plan is contained within and excerpted from the Continuous Improvement Plan Tracker (Appendix L) and Chapter 9 of the WwAMP.

Table N-1: Continuous Improvement Plan Staffing Plan

Tac Rec #	Year 1		Year 2		Year 3	
	Est Labor Hours (GLWA)	Description	Est Labor Hours (GLWA)	Description	Est Labor Hours (GLWA)	Description
WW1	40	5 staff at four, 2-hour meetings	10	5 staff at one, 2-hour meetings	60	10 staff at three, 2-hour meetings
WW2	200	10 staff at 10 hours each; 50 hours of one staff to facilitate compilation of metrics; 50 hours of one staff create initial baseline of data	20	5 staff, 2, 2-hour meetings	50	10 staff at 5 one-hour meetings
WW3	150	5 staff at 10 hours each to participate in five, 2-hour meetings; 100 hours for 2 staff (50 hours each) to address gaps	400	4 staff at 100 hours each	20	5 staff at 4 hours each; over two, 2-hour meetings
WW4	40	10 staff at four, 1-hour meetings	60	10 staff at three, 2-hour meetings – one meeting per task activity	50	5 staff at 10 hours each; over five, 2-hour meetings
WW5	400	5 staff at 80 hours each; over a two-week period	400	5 staff at 80 hours each; over a two-week period	500	7 staff at 70 hours each; over a two- week period
WW6	50	2 staff at 25 hours each to update the Risk Register for Vertical Assets	60	5 staff at 2 hours each over one, 2-hour meeting; 2 staff at 25 hours each to update the Risk Register for Vertical Assets	50	2 staff at 25 hours each to update the Risk Register for Vertical Assets

Tac Rec #	Year 1		Year 2		Year 3	
	Est Labor Hours (GLWA)	Description	Est Labor Hours (GLWA)	Description	Est Labor Hours (GLWA)	Description
WW7	300	30 staff involved in 10 hours of business process development and training	100	10 staff at 10 hours each that includes five, 2-hour meetings/ training sessions	0	NA
WW8	60	5 staff at 12 hours each; over six, 2-hour meetings	400	10 staff at 40 hours each; over twenty, 2-hour meetings/trainings	800	10 staff at 80 hours each
WW9	40	2 staff at 10 hours each to assist with set up technology platform; 5 staff at 4 hours each over two, 2-hour meetings	40	2 staff at 10 hours each to assist with set up technology platform; 5 staff at 4 hours each over two, 2-hour meetings	40	10 staff at two, 2-hour meetings
WW10	50	5 staff at 2 hours each; over two, 1-hour meetings and 2 staff at 40 hours of working with SRP models	50	5 staff at 2 hours each; over two, 1-hour meetings and 2 staff at 40 hours of working with SRP models	100	4 staff at 4 hours each to participate in two, 2-hour meetings and 84 hours 2 staff at 42 hours each to develop RFP
WW11	60	6 staff to participate in five, 2-hour meetings	0	NA	0	NA
WW12	100	2 staff at 50 hours each	24	4 staff at three, 2-hour meetings	40	2 staff at 20 hours each
TOTAL	**1,490 hrs**		**1,564 hrs**		**1,710 hrs**	