Part 2

The MLGW Way….Forward

Memphis, TN
October 21, 2019

Contents

Tables

Figures

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Chapter 1 Introduction & Background

1.1 Description of Scope of Work

In May 2019, Memphis Light Gas & Water (MLGW) sought the services of qualified firm to assist in MLGW's initiative entitled: "The MLGW WAY….Forward". The initiative intended to focus on optimizing the efficiency of internal operations and evaluating infrastructure needs, and is to be governed by the MLGW Way Mission and Vision.

In conjunction with Baker Tilly, HDR was contracted to perform the services for Part 2 of the project. The scope of work generally entailed providing a condition assessment of MLGW's electric, gas, and water infrastructure, working in conjunction with MLGW engineering, operations, and construction staff to gauge existing programmatic and maintenance practices, and evaluate critical investment needs.

HDR was to provide regular feedback of findings to MLGW Management throughout the course of the engagement. Prepare a final report inclusive of completed analysis of processes reviewed, benchmarks of processes reviewed, and recommendations for changes. Ultimately this would culminate in a delivering a presentation of the final report to the MLGW Board and the Memphis City Council.

1.2 Goals of the Project

In December of 2018 the City Council rejected the MLGW Board approved rate plan that resulted in reductions to the O&M and Capital budgets to the tune of $40.9 million and $101.9 million respectively. This severally limited the capabilities for MLGW staff to implement reinvestment and rehabilitation efforts to an already ailing system.

The objective of this valuation is to assure that identified and scheduled investments are those that deliver the greatest value to MLGW and its customers, comply with regulatory requirements, optimize the use of scarce resources, and mitigate risks. All while understanding the critical balance of affordability and high level of service MLGW seeks.

With HDR's assessment and recommendations MLGW is hopefully that the Board and City Council will value a professional opinion of a national engineering firm and ultimately support an increase in expenditures to assure continuity of customer satisfaction and high quality performance.

1.3 Capital Project Planning

August 29, 2019 HDR was given a Notice to Proceed with a Final Deliverable and Board Presentation date of October 23, 2019. This allowed for an expedited timeframe of 8 weeks to perform a desktop reviews of reports and information, staff interviews, condition assessment, and report development.

1.3.1 Asset Review

Due to the expedited schedule a true condition assessment could not be implemented, especially in a utility of MLGW's size and complexity. In lieu of a condition assessment, HDR staff in conjunction with MLGW Engineering and Operations visited infrastructure deemed critical or in need of significant investment. An observatory review of the infrastructure was performed by HDR to gauge the need and magnitude of investment. This asset review allowed for HDR personnel to gain a general perspective of infrastructure condition and understanding of challenges faced by the staff through operations. In the subsequent chapters there are references to assets visited and those assessed across all lines of services.

1.3.2 Review of Capital and Programmatic Budgets

Continual investment in aging infrastructure such as MLGW's is critical to being able to provide a high level of service that MLGW seeks. The HDR team reviewed MLGWs last four years capital and compared those to similar utilities. In some cases, professional judgement based on HDR's experiences was utilized as a benchmark. The intent was to verify whether budgets and programs being invested were sufficient to maintain a utility of this size and complexity.
Additionally, maintenance practices were evaluated as this has a dramatic effect on how capital expenditures are planned and utilized. Utilities that choose to have "run to fail" mode of operation tend to have higher capital expenditures especially in aging infrastructure scenarios. "Maintain and Repair" operations tend to have staggered capital expenditures as the intent to reinvest in their current infrastructure. Blending of both styles can lead to budget shortfalls, strain on maintenance staff, and stalling in continued investment.

1.3.3 Gap Analysis

The HDR team looked for gaps in safety implementation and protection, operating programs, planning for regulatory changes, infrastructure resiliency potential, and level of protection. All these elements are evaluation of the effectiveness of mitigating risk. The evaluation is intended to be a qualitative assessment to highlight potential needs for investment and/or planning. Each chapter outlines potential gaps and risk registers are provided providing details to those captured for each service line.

Chapter 2 Gas

2.1 Overview of Assets Evaluated & Personnel Interviewed

2.1.1 Asset Performance/Condition Review

Memphis Light, Gas and Water (MLGW) provides natural gas to approximately 320,000 customers in a service territory that encompasses Shelby County. MLGW purchases natural gas from several transmission pipeline suppliers. Landfill facilities also inject renewable gas at key locations in the system.

The infrastructure of the system contains approximately 10 gate stations and 108 gas regulator stations that provide pressure reduction and flow control. The majority of the stations operate with obsolete equipment due to age of installation and advancements in technology. In emergency situations, finding replacement parts in a timely fashion can prove challenging or impossible. In these circumstances, it is difficult to maintain normal operating conditions within the set design parameters. This could compromise the performance of the system, lead to regulatory violations, or cause costly rushed replacement projects. Supervisory Control and Data Acquisition (SCADA) communications are provided at almost all of the gate stations, but only about 40 percent of the regulator stations have the ability to interface with SCADA. SCADA is instrumental for controlling operations and responding to issues within the gas system. Having the ability to immediately send signals significantly expedites the process of identifying and remediating any failures in the system. This speeds up the times to get equipment back in service and reduces chances of paying rush fees to get needed equipment on site.

Per MLGW's annual report for the calendar year 2018 that was submitted to the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), MLGW operates 200.35 miles of transmission pipelines and 4,518.19 miles of distribution pipelines. The system contains pipe installed from pre-1940 to the present. Based on direct assessments previously completed by MLGW, several aging pipelines have experienced coating holidays and disbandment, metal loss, and linear indications. This could be a result of older manufacturing methods and construction techniques (ex. puddle welding and wrinkle bends) utilized at the time of installation. The pipelines are composed of various materials including steel, cast iron, PVC, and Polyethylene. PVC and cast iron jeopardize the integrity of the system. Cast iron is leak prone due to its vulnerability to earth movement and graphitization. PVC becomes brittle and experiences degradation over time which leads to cracking.

MLGW has approximately 53 rectifiers and anode beds that protect the pipeline from corrosion. Due to rectifiers being outdated with broken components, many of the existing pipelines are showing signs of corrosion. This jeopardizes the integrity of each pipeline within the rectified system. If technicians receive faulty readings due to equipment (rectifier) malfunction, then the proper mitigation cannot be implemented to properly maintain the rectified system.

MLGW also owns and operates a Liquefied Natural Gas (LNG) storage facility that provides LNG truck loading service to the general public. The facility is a process plant that is composed of integrated specialized equipment. The electric components throughout the facility are obsolete, primarily the variable-frequency drives (VFD's) and programmable logic controllers (PLC's). MLGW has to send equipment out for repairs due to no replacement parts readily accessible. This is a high risk item because the control room operates 24 hours a day, 7 days a week, and 365 days a year. Interruptions to daily operations have severe cost and safety implications.

Several of the factors described above have been identified with a high level risk that could significantly impact the overall performance of the system. Continual improvements need to be devised and implemented to mitigate risk moving forward and ensure the integrity, safety, and reliability of the MLGW gas system.

2.1.2 Personnel Interview (Major Discussion Points)

HDR (Gerald Sullivan and Kevin Ortega) visited MLGW on 9/11/2019 and 9/12/2019. HDR interviewed several employees and toured numerous MLGW facilities (regulator stations, gate stations, etc.). The goal was to provide an independent third party assessment of MLGW's management systems and assets.

Interviews were conducted with the Gas Engineering and Operations Manager (Virgil Deanes, Jr.), Corrosion Control Supervisor (James Sarratt), Measurement & Pressure Regulations Supervisor (Mike Fasackerly), Gas System Integrity Supervisor (Russell Webb), Gas Engineering Supervisor (Richard Crick), and the LNG Plant Supervisor (David Hopkins). The Gas Engineering and Operations department has a strong understanding of their system and the condition of their assets. Interviews were focused around compliance with regulatory requirements, processes for data collection and information support, program identification and effectiveness, conformance with corporate initiative, and potential enhancements.

2.2 Review of Capital & Programmatic Budgets

2.2.1 Comparable to Industry Standards

The Gas Engineering and Operations department has put together a robust strategic plan for capital improvements (beginning budget year 2020) of the natural gas system which is outlined in the 2020 - 2024 "Master Plan" document. The "Master Plan" evaluates MLGW's transmission pipelines, distribution pipelines, gate stations, district regulators, corrosion control and regulatory compliance. Per MLGW's evaluation process, projects are identified and prioritized based on a Matrix Ranking system that factors in safety, regulatory concerns, reliability, impact to the customer, financial impact, and MLGW strategic initiatives. The plan implemented by Gas Engineering and Operations is centered on continual improvement.

Per regulatory requirements, MLGW has incorporated an elaborate Transmission Pipeline Integrity Management Program (TIMP) and Distribution Pipeline Integrity Management Program (DIMP). The TIMP and DIMP programs are structured to ensure the advancements of safe operating practices of company-owned and / or operated natural gas pipelines. The scope and applicability of each plan correlates with other MLGW programs and documentation. The prescriptive integrity management plans developed by MLGW are designed to meet the unique characteristics of the transmission and distribution systems which are comparable to other utility operators within the industry.

MLGW is organized and appears to have the resources to take on additional work, but the limiting factor is primarily budgetary restrictions. Based on the information submitted to HDR, the 2019 capital budget for the gas division was originally $38,710,000. However, the final budget for 2019 was revised to $26,000,000. The approximate 33 percent reduction in budget inhibits the ability of the gas division to efficiently execute projects. An example of a program that suffers due to the budget cuts is the regulator station replacement program.

2.2.2 Deficiencies

The regulator station replacement program is in place to update obsolete equipment. If there is equipment failure, MLGW will have a difficult time replacing specific parts because many suppliers no longer manufacture the outdated equipment. The program also includes the installation of SCADA communications. MLGW has identified approximately 19 regulator stations that require upgrades and 63 regulator stations that are in need of SCADA (partial or complete installations). MLGW initially set out to complete an average of four regulator stations per year. The goal was to have all the regulator stations and SCADA installations completed by the end of 2022. The average cost for updating each regulator station is approximately $175,000. A partial SCADA installation is approximately $7,500 and a complete SCADA installation is approximately $15,000. Due to budget cuts Gas Engineering & Operations will only be able to replace one regulator station per year. This will undoubtedly push back the targeted completion date. MLGW will fall behind because additional regulator stations will be identified for replacement as a result of continual assessment for capacity needs and obsolete equipment. This increases risk and compromises the reliability of the entire system.

2.3 Gap Analysis

2.3.1 Safety

Mandating the highest level of care and performance while building a culture that demands stringent safety standards is essential to MLGW. Not only is this important with respect to the current state of the natural gas industry as well as the current and potential compliance impacts on pipeline operators including MLGW, but it paves a path toward excellence in safety and reliability. Integrating a risk matrix (severity and probability) into the decision making process of prioritizing projects and programs helps MLGW to mitigate risk and improve safety, reliability, and efficiency. With the implementation of a plan guided by the risk matrix, resources can be properly allocated to eliminate projects with the highest risk first. The evaluation of this document is critical because every risk has an associated consequence on MLGW's operations and the surrounding community.

MLGW has implemented the use of a ranking matrix to assess the priority of each project. The lead design engineer and lead planning engineer are tasked with completing the evaluation utilizing the risk matrix. There are six categories that factor into the project prioritization. The categories are regulatory compliance, safety, reliability and operability of the system, customer impact, financial, and strategic corporate initiative. Rankings are assigned to each category. Select categories are weighted heavier than others such as, regulatory compliance and safety. This ensures that projects that are deemed out of compliance and / or contain unsafe situations get ranked higher in order to be addressed in a timely manner. A project will receive the highest final score if the strategic corporate initiative category ranks highest or the project addresses an issue that MLGW has received from PHMSA or the Tennessee Regulatory Authority.

The Gas Engineering and Operations department is already in the process of executing several critical programs primarily due to concerns with regulatory compliance. The associated projects were prioritized by the results of the risk matrix evaluation. An example of several programs are steel service replacements, casing mitigation, rectifier and anode bed replacements, PVC replacements, and cast iron replacements. Additional programs that are currently in place to address safety concerns and improve system reliability are regulator station replacements, RTU and SCADA communication installations, lead abatements, and vault replacements. The completion of each program will have a significant positive impact on system performance and operations. The risk matrix approach and methodology that has been adapted by MLGW defines a structured layout for executing projects now and into the future based on prioritized system needs governed by safety and reliability. This allows MLGW to make the best use of resources available.

To address safety concerns outlined within the DIMP plan, MLGW previously instituted a cast iron replacement program that would mitigate future leaks. This is a 30 year program that was put into effect in 1991. In 1991, MLGW had approximately 330 miles of cast iron pipe within the gas system. The program is set to be completed by the end of 2021 with the removal of all cast iron pipe. Since the beginning of the cast iron replacement program, the gas system now only contains close to 4 miles of cast iron pipe. MLGW plans on removing approximately 1 mile of cast iron pipe in 2020 and 3 miles of cast iron pipe in 2021 to complete the removal of the remaining cast iron pipe by the originally set completion date. The total cost of removal is forecasted to be about $17,000,000.

The cast iron replacement program demonstrates MLGW's ability to pinpoint a high risk problem and execute a solution on schedule. Throughout the program MLGW has continued to re-evaluate the program to ensure resources are allocated properly. With additional funding MLGW will be able to properly distribute resources and execute program goals in order to strategically enhance the integrity and performance of MLGW's gas system.

2.3.2 Programmatic Enhancements/Initiatives

There are several changes that MLGW can incorporate into their integrity plan to enhance the safety and efficiency of their gas system. The implementation of an in-line inspection (ILI) program would provide numerous benefits. ILI would allow MLGW to internally inspect a pipeline for anomalies. The use of ILI tools could provide cost savings over the long run, as well as establishing an enhanced platform for integrity testing in the future without the cost and system disruptions associated with other direct assessment methods or pressure tests. An internal inspection study would need to be completed for each transmission pipeline subjected to ILI. This would verify if ILI is feasible for specific sections of the pipeline. There are many reasons why a pipeline may not be internally inspected which include insufficient flow, too small of bend radius, changes in diameter, too many direction changes, etc. Retrofitting a pipeline can often be expensive. The use of ILI requires the analysis of the existing pipelines, replacement of features that restrict internal inspection and installation of launchers and receivers which adds cost and real estate concerns.

In addition to putting in place an ILI program, it would also be advantageous for MLGW to continue the development of the reclassify transmission pipelines as distribution pipelines program. MLGW has four main pipelines (approximately 62 miles) that have the potential to be re-classified as distribution pipelines. Due to age, condition, or operational requirements, these pipelines have been identified in the TIMP as high risk. The re-classification plan that is currently in place by MLGW will result in two remaining transmission pipelines. By re-classifying those pipelines as distribution MLGW will reduce the risks while providing a cost savings associated with inspection. In regard to transmission pipelines, MLGW allocates approximate $7,000 per mile (per year inspected) for external corrosion direct assessment (ECDA), $10,000 per year (per 3 digs) for ECDA digs, $50,000 per year for aerial patrolling of the transmission system, and $11.21 per 0.1 miles for leak survey. Re-classifying the potential 62 miles would save a significant amount on the continued cost of inspection in the future. Since there could be high costs associated with replacing sections of the existing pipelines that operate over 20 percent of the specified minimum yield strength (SMYS), it may be more profitable for MLGW to analyze their current system and put together cost saving analysis to see what pipelines make sense to change to distribution.

2.3.3 Future Regulatory Drivers

There are several changes that MLGW can incorporate into their integrity plan to enhance the safety and efficiency of their gas system. The implementation of an in-line inspection (ILI) program would provide numerous benefits. ILI would allow MLGW to internally inspect a pipeline for anomalies. The use of ILI tools could provide cost savings over the long run, as well as establishing an enhanced platform for integrity testing in the future without the cost and system disruptions associated with other direct assessment methods or pressure tests. An internal inspection study would need to be completed for each transmission pipeline subjected to ILI. This would verify if ILI is feasible for specific sections of the pipeline. There are many reasons why a pipeline may not be internally inspected which include insufficient flow, too small of bend radius, changes in diameter, too many direction changes, etc. Retrofitting a pipeline can often be expensive. The use of ILI requires the analysis of the existing pipelines, replacement of features that restrict internal inspection and installation of launchers and receivers which adds cost and real estate concerns.

2.3.4 Resiliency

2.3.5 Level of Service and Protection

In addition to putting in place an ILI program, it would also be advantageous for MLGW to continue the development of the reclassify transmission pipelines as distribution pipelines program. MLGW has four main pipelines (approximately 62 miles) that have the potential to be re-classified as distribution pipelines. Due to age, condition, or operational requirements these pipelines have been identified in the TIMP as high risk. The re-classification plan that is currently in place by MLGW will result in two remaining transmission pipelines. By re-classifying those pipelines as distribution MLGW will reduce the risks while providing a cost savings associated with inspection. In regards to transmission pipelines, MLGW allocates approximate $7,000 per mile (per year inspected) for external corrosion direct assessment (ECDA), $10,000 per year (per 3 digs) for ECDA digs, $50,000 per year for aerial patrolling of the transmission system, and $11.21 per 0.1 miles for leak survey. Re-classifying the potential 62 miles would save a significant amount on the continued cost of inspection in the future. Since there could be high costs associated with replacing sections of the existing pipelines that operate over 20 percent of the specified minimum yield strength (SMYS), it may be more profitable for MLGW to analyze their current system and put together cost saving analysis to see what pipelines make sense to change to distribution.

Project Risk Register

Project Name	MLGW Condition Assessment
Service Line - Gas	Gas Division
HDR Employee	HDR
Date	10/2/2019

	Impact				
Frequency	**1**	**2**	**3**	**4**	**5**
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Risk Severity	
Low - Monitor and periodically assess	1 to 4
Medium - Proactive mitigation actions necessary	5 to 10
High - full mitigation plan -escalate to manager	11 to 25

		Risk Statement				Probability	Impact						Date Last	Date Next
#	**Risk Category**	**Short Name**	**Description**	**Consequence**	**Type**	**(1,2,3,4,5)**	**(1,2,3,4,5)**	**Exposure**	**Mitigation**	**Contingency & Triggers**	**Risk Owner**	**Actions Taken**	**Review**	**Review**
Unique risk ID			Describe the risk, and capture the "likely cause" of the risk. Be detailed enough so that you can start forming mitigation plans.	Capture the result of the risk, should it happen. Relate to project critical success factors or MSD business objectives. If the consequences cannot be mitigated, you will have to dealt with them in a contingency plan.	Cost, Schedule, Regulatory, Other	Estimate of the probability the risk will occur (1 = highly unlikely, 5 = almost certain) .	Estimate of the amount of impact or severity of the risk.	Probability x Impact. Once all risks have been entered, sort by this column to identify your biggest risks.	Proactive plans to lower the probability or to lower the impact ahead of time. It may require a more detailed plan written up separately.	Identify what would have to be done if the risk were to become reality, and how you would recognize that action is required. This may require a more detailed plan documented separately.	Identify who is responsible for tracking this risk and its changes in probability and impact.	Identify what has been done, either to avoid or mitigate the risk		
Pipeline & Facilities														
1	Operational & Commissionning Risks	Regulator Stations	Capacity requirements and obsolete equipment (age and parts available for repair). Cost benefit analysis to repair or replace.	Failure could result in operating conditions outside of design parameters. Inability to provide pressure reduction and flow control for all five pressure systems. Section of main could be subjected to a temporary shutdown for assessment or repairs.	Active Risk	4	3	12	Implement a program to replace obsolete regulator stations. Identify stations for replacement by inoperability, reliability, and/or an inability to find replacement parts. Design replacements with dual runs to avoid temporary shutdowns due to annual repairs.	Operator would have to temporarily isolate the regulators. This would either require the use of a bypass or isolate the feed into the station. The bypass may require the installation of costly additional equipment. The regulators would be repaired or replaced. This would be recognized by gas operations reading a change in pressure. A relief valve would be triggered if installed within the regulator station.	Gas Division	Initial assessment of assets has been completed. There are a total of 109 regulator stations. MLGW have identified 19 regulator stations that require upgrades due to obsolete equipment. The program is long term with the goal of replacing 4 stations a year. There could be more once the upgrades are complete due to the continual assessment of all stations for both capacity needs and when the equipment will become obsolete.		
2	Operational & Commissionning Risks	Vault Replacement	Concerns with the structural integrity of the vault, obsolete equipment, coating and corrosion issues with equipment and vault walls / ceilings, ingress of water, and accumulation of mud and grit on the floor.	Failure in equipment would impact pipeline operations. Inability to provide pressure reduction and flow control. Unsafe working conditions which could lead to recordable incidents.	Active Risk	3	4	12	Complete vault integrity assessment of structural integrity and operational equipment.	Emergency repair of vault and operating equipment. Drainage and clearing of vault prior to work.	Gas Division	MLGW recently hired a consultant to complete a gas valve vault assessment report of all the vaults within the system. Reports with condition ratings were completed. Next step would be to take the reports and develop a replacement program. Additional funding required.		
3	Operational & Commissionning Risks	SCADA Communications	Not having RTU / SCADA can cause a delayed response time for emergency situations and gas system problems.	Potential damage to equipment and piping system due to delayed response. Decrease equipment life and increases costly repairs. Decreases system efficiency and performance while increasing operational costs.	Active Risk	4	2	8	Incorporate a program to install equipment to provide SCADA with communications to all the regulator stations.	Incorporate a program to install equipment to provide SCADA with communications to all the regulator and gate stations.	Gas Division	Initial assessment to identify regulator and gate stations without SCADA communications has been completed. There are 63 locations that SCADA doesn't have the ability to receive data from. MLGW plans on installing 34 complete installations in 2019.		
4	Operational & Commissionning Risks	Rectifier and Anode Bed	Equipment age and parts available for repair. Cost benefit analysis to repair or replace.	Equipment failure could result in an increase of corrosion and degradation of transmission and distribution piping systems, as well as, select services	Active Risk	3	5	15	Implement a program to replace several rectifiers and anode beds each year based on eqipment age and repair history. There is a total of 56 remote rectifier units.	Have several rectifiers, anode beds, and spare parts in storage in case of emergency repairs or replacements. The action would be recognizable if the CP readings are outside of industry standards or inconclusive	Gas Division	Corrosion control initial assessment has been completed. Over 3500 checkpoints for system anode and rectifier lines, 56 remote rectifier units, 3149 services, and 431 valves. Replacement program has not been implemented.		
5	Operational & Commissionning Risks	Steel Service Replacement	Result of DIMP analysis due to increase in underground leaks due to the failure of steel mechanical couplings.	Estimated that 40% of all underground leaks on MLGW's gas system occur on steel mechanical couplings on a service.	Active Risk	4	3	12	Develop long term program to address and replace underground couplings and steel services with PE pipe to eliminate leaks.	Mobilize crew to replace coupling and steel pipe with PE main. The action would be recognizable if a leak was reported or identified on a leak survey.	Gas Division	Initial assessment of potential leak points have been identified. There are estimated to be 140,000 steel taps and approx. 150,000 couplings. Replacement program has been implemented by MLGW. The project will be executed in 4 phases. Each phase will cover 4 years.		
6	Operational & Commissionning Risks	Pipeline Re-Classification	Failure to be compliant with regulatory requirements. Transmission requirements are more stringent than distribution.	Failure to be compliant could result in fines, citations, possible imprisonment, etc. Daily operations could be affected as well. The operator could be required to shut down or de-rate the line accordingly	Active Risk	2	2	4	Re-classify 4 pipelines (approximately 62 miles) that have the potential to be distribution pipelines. This will provide a cost savings as well because the inspection, patrol, and leak survey requirements are not as frequent. Additional regulatory rules are expected.	Verify the TIMP and DIMP plans are thorough and meet regulatory requirements. Failure to be compliant would be identified during internal or external audits.	Gas Division	MLGW has identified 4 pipelines that have the potential to be re-classified as distribution lines. The re-classification of GL-194 (31.89 miles) is co-dependent on the replacement of GL-001 and GL-212, which is proposed in the 2019 capital plan.		
7	Condition Assessment Risks	ILI Inspection	Regulatory requirements. Limited ability to inspect the internal conditions of the pipeline(s).	Lack of detailed information about defects within the pipeline segment including corrosion, cracks, deformations, etc. This could result in leaks or more severe issues. Other inspection methods may cause interruptions to the operation of the pipeline.	Active Risk	2	4	8	Install pig launchers and receivers on transmission pipelines. Retrofit existing pipelines to allow passage of in-line inspection tools if necessary.	Complete a direct assessment in which locations for examination for a given threat are selected based on a screening process. Conditions can be inferred based on the results. Another option would be to perform a hydrostatic pressure test. This test is designed to cause near critical defects to fail and defects that remain in the pipeline are not critical and safe to operate at the time of the test.	Gas Division	MLGW has installed a limited number of launchers and receivers. Majority of the transmission pipelines are not capable of in-line inspection. However, the new pipeline feeding the TVA plant is piggable.		
8	Operational & Commissionning Risks	Casing Replacement	Risk of corrosion or other damage to the carrier pipe or casing pipe. Casing is in electrical metallic contact with the carrier pipe especially if the annulus is waxed filled which is likely to deteriorate over time. Casing becomes filled or partially filled with electrolyte and an internal electrolytic couple develops.	Monitoring the condition of the casing. Provide supplemental cathodic protection to the casing. Removing electrolyte from inside the casing. Eliminating the metallic contact. Removal or replacement of the casing pipe. Replacing the carrier pipe. Implementing options for annular space metal corrosion mitigation. Coating or recoating the carrier pipe.	Active Risk	4	4	16	Develop long term program to remove casings. Prioritize casing projects by waxed filled, transmission main, and distribution main.	If the casing resulted in unsafe conditions due to corrosion defects, aged facilities, third party damages, or necessary relocations due to erosion problems the best solution would be to relocate the carrier pipe without casing if possible. The action would be recognizable by insufficient CP readings or gas detection from leak survey.	Gas Division	Casings within the gas system have been identified. Further investigation would be required to determine if casings are waxed filled or not. 3 casing mitigation projects have been identified through the TIMP plan. Address 1 project per year.		
9	Safety Risks	Lead Abatement	Health risk for personnel working on equipment with high levels of lead.	Exposure to high levels of lead may cause anemia, wekaness, and kidney and brain damage. Very high lead exposure can cause death.	Active Risk	2	2	4	Implementation of lead abatement program.	Personnel working in known areas with exposure to high levels of lead must wear proper personal protective equipment (respirator, gloves, goggles, etc.).	Gas Division	Implementation of lead abatement program is in process.		
10	Operational & Commissionning Risks	MAOP / Material Verification	Failure to produce common material for use in insepctions by US DOT PHMSA and applicable state pipeline safety agencies. Lack of traceable, verifiable and complete records.	Failure to be compliant could result in fines, citations, possible imprisonment, etc. Daily operations could be affected as well. The operator could be required to shut down or de-rate the line accordingly	Active Risk	2	4	8	Develop program for diligent, practicable processes to reconfirm MAOP by applying the concetps of traceable, verifiable, and complete records.	If no material records are available for a particular pipeline or facility then a hydrotest record would need to be obtained (establish MAOP).	Gas Division	Implementation of the "Gas Records Automation" (GRA) system should consolidate material records. If necessary, institute MAOP and material verification program		

#	Risk Category	Risk Statement				Probability	Impact						Date Last Review	Date Next Review
#	Risk Category	Short Name	Description	Consequence	Type	(1,2,3,4,5)	(1,2,3,4,5)	Exposure	Mitigation	Contingency & Triggers	Risk Owner	Actions Taken		
Unique risk ID			Describe the risk, and capture the "likely cause" of the risk. Be detailed enough so that you can start forming mitigation plans.	Capture the result of the risk, should it happen. Relate to project critical success factors or MSD business objectives. If the consequences cannot be mitigated, you will have to dealt with them in a contingency plan.	Cost, Schedule, Regulatory, Other	Estimate of the probability the risk will occur (1 = highly unlikely, 5 = almost certain) .	Estimate of the amount of impact or severity of the risk.	Probability x Impact. Once all risks have been entered, sort by this column to identify your biggest risks.	Proactive plans to lower the probability or to lower the impact ahead of time. It may require a more detailed plan written up separately.	Identify what would have to be done if the risk were to become reality, and how you would recognize that action is required. This may require a more detailed plan documented separately.	Identify who is responsible for tracking this risk and its changes in probability and impact.	Identify what has been done, either to avoid or mitigate the risk		
11	Operational & Commissionning Risks	Document Management	Loss of data or delayed reporting for emergency response, DIMP, TIMP, regulatory reports and protocols.	Inability to efficiently identify and evaluate potential risks / threats. Increase in resources and manpower. Lack of system knowledge. Damage to assets. Inaccurate reporting and compliance issues (potential fines and impact on daily operations).	Active Risk	4	3	12	Develop and incorporate uniform record management system. Ideally across the company, not only for gas division use.	Dedicate additional resources to filer, organize or re-collect data. Risk would be identified by having gaps in data and reporting.	Gas Division	The gas system integrity department is in the process of developing the "Gas Records Automation" (GRA). The plan is to turn records into useable data, create a single point for data entry, standardize tools to input data, create automatic workflows to eliminate duplicate data entry, and create useful dashboards to manage work and decisions.		
12	Operational & Commissionning Risks	PVC Replacement	Installation of PVC pipe prior to the early 70's (2", 3/4", and 5/8") is likely to cause failure. The failure could result in shearing at the service tee. PHMSA advised of the potential brittle-like cracking vulnerability of plastic pipe installed between the 60's and early 80's.	This could result in leaks or more severe issues affecting daily opertations and supply of gas to customers.	Active Risk	5	3	15	Identify remaining PVC pipe within the gas system and implement a removal program.	Emergency excavation to replace section of PVC due to leakage or similar.	Gas Division	Post 70's MLGW has replaced approximately 2 miles of 2" PVC and all the 3/4" and 5/8" PVC. MLGW has approximately 1.6 miles of 2" PVC remaining in the system. The current PVC replacement program spans 5 years and is targeted to be completed in 2022.		
13	Operational & Commissionning Risks	Cast Iron Replacement	Installation of cast iron pipe which can undergo graphitization and result in a soft and permeable material. This may allow gas to leak through the pipe wall. This also may result in the main being weaker and susceptible to breakage and fracture by loads.	Cast iron gas mains located in older, more densely populated urban environments can result in a gas leak being much more likely to migrate to a building and having a more significant safety impact.	Active Risk	5	3	15	Identify remaining cast iron pipe within the gas system and implement a removal program.	Emergency excavation to replace section of cast iron due to leakage or similar.	Gas Division	Cast iron replacement program is in progress and managed by the DIMP. Plan initially called for 330 miles of cast iron replacement. Program duration is 30 years and started in 1991 and expected to be completed in 2021. The remaining cast iron to be replaced consists of approximately 4 miles.		

Chapter 3 Electric

3.1 Overview of Assets Evaluated & Personnel Interviewed

3.1.1 Asset Performance/Condition Review

The condition review and asset performance was completed through a desktop analysis of information provided by MLGW, interviews with MLGW employees, and a visual look at a small sample of MLGW facilities.

3.1.2 Personnel Interview (Major Discussion Points)

There were two rounds of interviews completed with MLGW employees by the HDR electric team. The first round was during the week of August 26th. During this week Baker Tilly led the meetings in person and HDR was in the meeting as a phone participant. The schedule of meetings was as follows

- Tuesday August 27th – Wayne Ellis Manager of Substations
- Wednesday August 28th – Greg Deaton Manager of C&M, Paul Ferguson Manager of C&M
- Wednesday August 28th – Reggie Bowlin Manager System Operations
- Thursday August 29th – Wayne Jackson Manager of Distribution

During the week of August 26th, HDR was able to gain an understanding of the roles and responsibilities of each of the departments and how they interacted. Baker Tilly was focused primarily on processes for part one of the project and these discussion did not often align with asset performance/condition review. The primary message with all of these interviews was the inability to get contracts to complete work.

During the week of September 16th, HDR staff Clarissa Kotila and Justin Merkel met on site with MLGW electric personnel. The week started with a two hour kickoff meeting with Wayne Ellis, Neil Strongosky, Jon Mosteller, Greg Deaton, Paul Ferguson, Don Moore, Keith May, Wayne Jackson, Blake Daigle, and Don Roberts.

The discussion was informal and there was good input from the group. Topics discussed included:

- Engineering and construction standards
- What is the capital budget process and how are projects prioritized?
- The project life-cycle, identifying a project, engineering a solution and implementing the solution. What is the Process?
- Technology, how is AMI used, is there an OMS system, GIS system for mapping, SCADA system, and Distribution Automation.
- NERC – to what degree does MLGW follow NERC requirements on the transmission system?
- Reliability: trends, drivers and some of the low hanging fruit to address

- Vegetation Management is the number one cause of outages for MLGW. A three year cycle trim seemed to be the general consensus among the group for the ultimate system cycle trim.

During the afternoon of Tuesday, September 17th, HDR spent the afternoon traveling around the MLGW electric system with Don Moore and Keith May looking specifically for vegetation issues and getting an overall visual assessment of the overhead electric transmission and distribution system.

The morning of September 18th, HDR met with Wayne Ellis to tour substations. HDR wanted a representation of old, new, and middle-aged substations. The substations were #33, #76, #5 and #3.

Prior to meeting with Don Roberts in the reliability group, HDR met with Rodney Cleek to ask questions about the budgeting process. After an office visit with Don Roberts and Nick Smith, HDR viewed some underground replacement projects and some sample pole replacement projects.

After the HDR site visit Justin Merkel met via phone with Brad Gates to discuss street lighting.

3.2 Review of Capital & Programmatic Budgets

3.2.1 Comparable to Industry Standards (Benchmarking)

3.2.1.1 Vegetation management – as an industry standard vegetation management is best completed via cycle trimming. MLGW reliability numbers indicate trees are the number one cause of outages on the system. With cycle trimming the type of vegetation drives the cycle schedule. In the Memphis area the hot humid climate accelerates vegetation growth.

Figure 3-1. Growth cycle since last trim

The vegetation cycles are generally completed within a five year cycle; however the MLGW service territory vegetation requires a more frequent cycle trimming. Specifically Kudzu is problematic for electric lines with evidence of electric line conflicts throughout the MLGW service area.

Figure 3-2. Examples of Kudzu

The transmission corridors are in good condition from a vegetation management perspective. On the distribution system, corridors along streets and road are in much better condition than overhead power lines with back lot systems.

Vegetation next to the road can be accessed with machinery making it much more efficient to control vegetation. Back lot infrastructure is difficult to access due to fences and buildings and notification of landowners, therefore requiring manual labor to complete the cycle trim. In Figure 3-3 a comparison of the back lot (left photo) and street view (right photo) illustrates the differences in accessibility.

Figure 3-3. Back lot and street view of vegetation management

Pride of ownership is different among neighborhoods. In areas where vegetation in back lots are maintained, the Kudzu is kept at bay; however large trees create a canopy over the distribution line causing significant damage if a limb from the canopy falls into the power line. Figure 3-4 shows a recent break of a large limb that came down on the power line below, creating a pole replacement.

The attached riser still has damage which was probably not replaced during the emergency pole replacement due to lack of time.

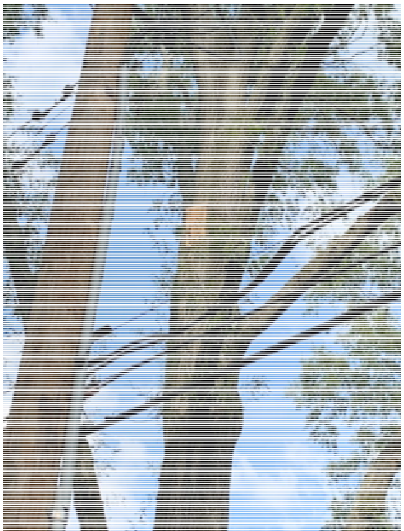

Figure 3-4. Tree canopy

3.2.1.2 The distribution system has a significant amount of open wire and insulated banked secondary feeding residential load. Utilities have programs to replace open wire secondary. Although the new standard for installing services and overhead secondary is bundled aerial conductor, MLGW appears to have an excessive amount of open wire or banked secondary. Because the secondary is lower than the primary, vegetation will grow into the secondary causing an outage as shown in Figure 3-5. Vegetation is likely to be reported as the cause of the outage by a trouble man. If the open wire secondary were replaced with insulated bundled service wire, the conductor can withstand incidental contact with vegetation without causing an outage. There are also issues with wind causing conductors to contact each other, causing an outage.

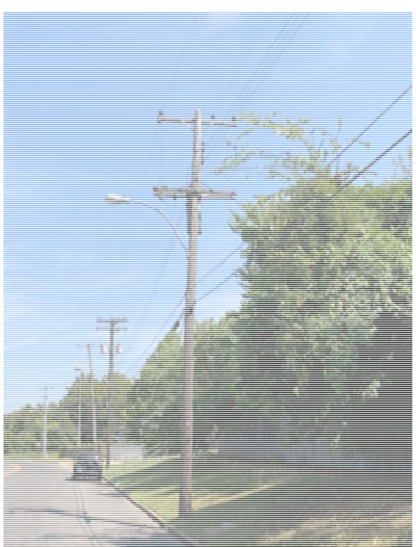

Figure 3-5. Open wire secondary

3.2.1.3 There is no regulation on distribution power transformers. Voltage is controlled by capacitor banks at the substation and out on the distribution system. There are pros and cons to this system. One advantage is the ability to tie distribution circuits together. Typical utility distribution systems have voltage regulation at the substation with a Load Tap Changer (LTC) or with feeder regulation on the circuits. It was noted that Substation #76 that was visited did have LTC on both transformers, but MLGW employees mentioned that it was a rare sight on their system and that for the most part they do not use LTC on their distribution transformers.

Voltage regulation must operate within +/- 5% of nominal voltage. Switched capacitor banks are located at points throughout the distribution system. HDR assumes that the capacitor banks were strategically placed by completing distribution power flow models. The capacitor banks are periodically inspected; however if a capacitor bank is not operating there is no indication of a failed capacitor or indication that the system voltage is out of tolerance.

3.2.1.4 Technology – MLGW uses Automated Metering Infrastructure AMI for metering and billing purposes. AMI can also be used to indicate problems out on the distribution system. During outage conditions, information can be fed to an outage management system (OMS) where crews can be dispatched to begin isolating an outage prior to customers calling and reporting the outage. The most important information that electric utility customers desire during an outage is the expected duration of the outage. AMI can help with these predictions by determining how many customers are effected by the outage event, and in combination with a good system model, be able to predict what isolation devices can be operated to restore power to most customers.

MLGW uses a customer call in system for outage notification. There are still many utilities that use a customer call as outage notification; however the trend is moving toward AMI information feeding an OMS or Automated Data Management System (ADMS). Further implementation of an OMS or ADMS system will inform MLGW personnel of how many customers are out of power, where the problem is occurring, correct the outage via automated or manual remote switching, and give real time data about the health of the distribution feeders.

An OMS/ADMS can be installed in a series of technology advancements. AMI is one of the advancements, accurate GIS mapping of the electric system, an real time electric system model, interaction with the transmission SCADA system, installing electronic relays on substation feeder breakers, installing intelligent switches at strategic locations throughout the distribution system, and a solid communication network. The OMS/ADMS is the computer system that brings all of the distribution technology together, manages data, reports and displays information, and in advanced distribution systems can perform switching to isolate system problems.

3.2.1.5 Throughout the distribution system, transformers remain on poles from discontinued services. MLGW records indicate 3,400 unused transformers remain in distribution plant but not used and useful. An investigation into the number of transformers that are not in service should be conducted to understand the magnitude of the unused transformers. Utilities typically remove transformers and services when there is a retired electric service and either place back into service or retire the unit. It was explained to HDR that transformers may remain in service due to new customers having to pay for the installation of the transformer and service where one previously existed. Transformers that remain on the system but are not in service, increase pole loading, are a liability for oil spills, add assets to the electric capital plant and provide no benefit to the system. **Error! Reference source not found.** is an example of an unused transformer with jumpers hanging loose and fuse doors open. There is also an example of an unused transformer and unused service. The Kudzu has completely engulfed the transformer and is weighting the service conductor, putting extra stress on the transformer pole. Vegetation would normally cause an outage but the service is not energized and an outage is not reported.

Figure 3-6. Examples of unused transformers

3.2.1.6 Substations

Utilities are facing a declining use per customer which changes the typical utility growth model. Assets have traditionally been replaced due to system capacity increases. Without the need for system capacity increases assets are needing replaced due to asset life. The largest cost items for electric utilities are substations, which can consume a large portion of the annual capital budget. The competition for budget dollars to replace aging infrastructure forces a higher utilization of the remaining infrastructure. MLGW has done a good job with laying out a plan to replace substation equipment due to capacity and asset life, which is in alignment with other electric utilities. However, unavailability of bus outages was mentioned which can also be indicative of a system that is losing some of the redundancy that used to be in place. With a decline in the redundancy, customer outage minutes will be directly affected as the load is not able to be shifted.

MLGW has also implemented a Substation Asset Group that reviews every maintenance report and decides if action is required to replace an asset or if it is able to remain in service. Overall, the substations are aging but they are maintained adequately and have useful life remaining. Breakers are available for replacement of failed breakers (when visiting Substation #33, several OCB, GCB and vacuum-type circuit breakers were observed within the substation fence inside the yard). However, if a breaker does fail, the requirement is to replace the foundation to meet seismic requirements which would take additional time. Wayne Ellis did mention that the plan is to get the breakers inside a building or warehouse so that they can be sheltered from the elements to prevent moisture and condensation inside the breaker control boxes.

Figure 3-7. Spare breakers sitting inside the substation fence at Station #33

Figure 3-8. Main Bus Tie breaker at Station #33.

Substation vegetation is also a general concern noted at all sites visited. Weeds and vegetation inside the substation fence were common. A programmatic approach is recommended for weed-spraying inside substations.

Figure 3-9. Substation #3 – vegetation

A substation mobile trailer is in the budget for 2020 which will alleviate problems mentioned several times during meetings and site visits, which is the unavailability of bus outages for maintenance or other work. Some bus PTs and switches have not been tested in several years due to this fact. Sometimes when the field crews go out to replace failed equipment, they will operate the switches and the switches will fail to open or break (interrupt the circuit).

Substation #33 is a 161/115kV substation. Both 161kV and 115kV are in a main-and-transfer bus scheme. Right now, there is a tie OCB on the main bus. For a breaker failure of the tie OCB, it would cause a large disruption until the circuits could be switched over to the transfer bus. To avoid such a large disruption, it might be advantageous to consider a series breaker where two breakers are used in series in place of the tie breaker. If there is a breaker failure of one of the series breakers, it will only trip the other series breaker and not the entire adjacent bus and transformer.

Substation #76 is a 115kV Substation on the high voltage side but all clearances were built out for 161kV which is indicative of proper planning and recognizing that the high side voltage could be increased in the future. The Substation is not heavily loaded right now – at the site visit it was noticed that both transformers were loaded to 16 MVA each while the lowest rating for each is 25 MVA so the substation has room for load growth as well. The switchgear in Substation #76 did have some rust on the floor due to a previous water leak which seems to be an issue with the switchgear buildings that have been previously purchased.

Figure 3-10. Substation #76 – Rust from water incursion inside the switchgear building

Substation #5 had some work being done during the site visit. It was noted that the single-phase transformers are all planned for replacement in 2020 – one of the transformers had visible oil staining on the foundation. There are also a few feeder breakers that are completely disconnected and sitting on the existing foundation. Those breakers that are bad could be removed and replaced since from the talks during the site visit, Substation #5 is a critical substation where it is difficult to obtain bus outages.

Figure 3-11. Substation #5 – Relay Panel Line-up

Substation #3 did have newer relaying installed but physical outdoor equipment was noted to have sections of cable tray, and even cable risers outside the control enclosure were exposed to elements where rodents could enter the cable tray and eventually nest in the control enclosure. It is advised to replace the cover for the cable trench that is broken and seal off the cable trench against rodent incursion. Substation #3 also had 115kV underground cables and it was mentioned that the expertise to replace those cables has left the company so if they fail in service, it could be an expensive fix and would likely affect customers.

Figure 3-12. Substation #3 Switchgear Line-up

Figure 3-13. Substation #3 – cable trench issue

3.2.1.7 Electromechanical substation controls

The MLGW substations are primarily protected and controlled with electromechanical relaying and controls. While parts are available now for electromechanical relays, as time goes on parts will be less readily available which will eventually lead to longer outages due to relay failures. Electric utilities with voltages of 115 kV and higher have electronic controls and microprocessor relays on their breakers, lines, feeders, capacitor banks and transformers. This allows the substations and assets to be continually monitored by feeding real time data to the SCADA system. It also allows remote access to relays for settings changes or interrogation of the relay after system interruptions. Converting from electromechanical relays to micoprocessor relays is not an easy conversion. Considerable engineering design and planning needs to go into the conversion process due to existing control cables, space in control enclosures for replacement and cutover while keeping the substation in service as much as possible,. There is also expertise in both engineering and field technicians to implement, test and maintain these new controls. MLGW has a plan to install Satec devices to allow an interface between the SCADA equipment and the electromechanical controls. The interface is a step toward modernization; however replacement of the electromechanical controls will need to occur to implement a modern substation and give better visibility of the electric system to operators.

To fully implement a Distribution Automation system and provide for self-healing system capabilities which is the path forward for MLGW and many other utilities, the electromechanical feeder relays at many substations will need to be replaced with microprocessor relays. Once microprocessor relays are in place, communication back to SCADA will require some investment in communication systems (right now JMUX system is existing for transmission line relaying). As part of communication systems to implement Distribution Automation, it is also imperative to ensure that NERC CIP requirements for system access (physical and cyber, including routable protocol) are in place and being monitored on a regular basis as required by NERC CIP standards.

3.2.1.8 Street Lighting

Most utilities are in the process of either developing a plan or implementing a conversion from High Pressure Sodium (HPS) to Light Emitting Diode (LED) technology. MLGW is in the process of developing a plan for this retrofit and will be implementing LED pilot projects before implementing a major system retrofit.

Roadway fixtures are primarily semi cutoff fixtures. Most utilities are moving to dark sky compliant fixtures that are full cutoff with no light above the horizontal plane. During the tour of the distribution system HDR witnessed several day burners on the lighting system.

3.2.1.9 Distribution Pole Replacement Program

MLGW has a pole inspection and replacement program. At the time of the HDR field visit there were approximately 3,500 poles left to replace from the inspection cycle. Approximately 800 poles were replaced during other maintenance such as car vs. pole, storms, outages, new services, etc. The reliability engineering group is producing the pole replacement list but the poles are not being scheduled and replaced. To expedite the process, steel trusses/stubs were scheduled to be installed as a faster and less expensive option for reinforcing poles with ground line rot. Stubbing does extend the life of the pole, as long as the pole top has solid wood and cracks and checks still meet tolerances. Figure 3-14 is an example of a steel truss/stub

Figure 3-14. Steel truss/stub

3.2.1.10 Underground Cable Replacement

The reliability group has identified cable replacement projects that target specific areas with known problematic cable. Within these targeted areas places with faulted cable are being replaced first. The duration for an underground cable outage is normally longer than an overhead conductor outage. In addition to this, once a cable segment fails additional failures tend to happen in the same segment within a short period of time. MLGW has identified a plan for replacement; however, the plan has not been implemented or partially implemented. Figure 3-15 shows an example of unfinished cable replacement that has been in this condition for over six months. There was no active construction in the area or crews progressing the project.

Figure 3-155. Unfinished underground cable project

3.2.2 Deficiencies

- Implementation of reliability driven projects. Pole replacement and underground cable replacement have been identified but implementation of the programs is marginally successful.
- Vegetation management in back lots. Vegetation management is good in transmission corridors. On the distribution system the lines that are accessible from the street and can be maintained with mechanized equipment are in much better condition than back lot overhead systems where manual vegetation removal is required.
- Lack of a detailed technology plan for, DA, AMI, OMS, relay upgrades, SCADA, and other technology. Technology can be expensive and difficult to implement. A comprehensive plan should be put together and updated annually during the budgeting process. The plan should include the type of technology that will be implemented in the future within specific departments along with human resources needed to support technology. An oversight committee should be developed to determine that technology is compatible and can be shared across the entire organization. In some instances that could mean collaborating with Gas and Water.
- Capacitor bank maintenance and voltage monitoring needs evaluated. With the number of distribution capacitor banks on the system, there should be emphasis

placed on a comprehensive capacitor maintenance plan in addition to monitoring voltage throughout the distribution system.

- Strict adherence to the budget. Historically 80% of the electric budget is spent. The system is not getting upgraded as prioritized in the capital plan. Projects that are funded but not completed may be essential to increased system reliability. The projects that are prioritized and survive the capital budgeting process are the projects that should be completed. If a project is not able to be completed during a fiscal year, money should be released from the project and a project that is next in line for priority should be completed. The plan should be made more visible so that there is an understanding of where capital spends are, and it should be mandatory for department managers to forecast each month throughout the year.

3.3 Gap Analysis

3.3.1 Safety

During HDR's time at MLGW there was evidence of a positive safety culture. It was mandatory to have proper PPE for entering substations. The workers that were witnessed had proper PPE and were operating safely. Several crews were witnessed as HDR completed the on-site tour of the system. In instances where crews were working along the road, signage was in place to give safe warning and protect workers, and MLGW workers were wearing PPE. The cone policy while parking was consistently adhered to.

To truly understand the safety culture would take much more time than the few days that HDR was with MLGW, but it was clear that the safety message is coming from the executive level.

While on the tour HDR did notice a couple of observations in substations:

- Public Safety – implementing fence and gate grounding for existing substations which do not have it right now (for example, Substation #3 did not have fence or gate grounding observed).
- Operator Safety – consideration for implementing switch grounding mats for manual switch operating handles to improve operator safety. Switch grounding mats were not observed at any of four substations visited (but they may exist at other substations that HDR was not able to visit during this trip).

Another public safety worthy of note is the unfinished underground projects. While visiting the area of underground replacement, there were sidewalks that were covered with plywood, barricades, warning cones, and other obstructions that citizens in these areas needed to contend with. These materials are trip hazards and in some cases barricades to energized parts. Since there is no active construction, MLGW personnel are not continually monitoring these temporary barricades and tripping hazards that exist on sidewalks.

3.3.2 Programmatic Enhancements/Initiatives

3.3.2.1 Substation Infrastructure Replacement

Breaker and transformer infrastructure should continue to be replaced. Predictive testing along with consequence of equipment failure should be used to prioritize the replacement list. If possible replacing electromechanical with microprocessor relays should be completed at the same time. When replacing transformers, LTC's should be investigated and considered for install.

3.3.2.2 Communication Network-

A communication network for all MLGW facilities should be reviewed and a plan to upgrade or install communication systems for better control and information should be installed.

3.3.2.3 Pole inspection and replacement

The pole inspection and replacement program should continue with an elevated effort to complete replacement of identified poles within a scheduled time frame. Pole replacement reduces the average age of the system pole plant.

3.3.2.4 Underground cable replacement

The underground replacement should continue with an elevated effort to complete the identified circuits within a scheduled time frame.

3.3.2.5 Grid Modernization Initiative

Develop a collaborative plan that incorporates the current and future technology needs across the electric departments. The plan should include skillsets of estimated number of human resources needed to support specific departments. Capital investment plan should be assembled and prioritized to spend appropriate levels of funding for technology in each electric department. OMS, ADMS, AMI, Communication, GIS, Intelligent switches, intelligent voltage compensation devices, and electronic relays, are investments that should be in the modernization initiative.

3.3.2.6 Targeted Undergrounding

In areas that have backyard overhead systems that are difficult to access, this may be a long term solution for accessibility and vegetation management if the facilities are moved to the front lot. If MLGW chooses to relocate facilities through a programmatic approach, stringent guidelines need to be established and communicated. There are many unforeseen costs such as customer service entrances, trenching, landscaping, asphalt, and concrete repair. It is likely that the costs outweigh the benefits for targeted undergrounding, and reestablishing easements with an aggressive vegetation removal program may be more effective and receptive by the public. Targeted undergrounding is a public process and community forums soliciting input from neighborhoods are an important part of the project planning.

3.3.2.7 Program Management

In order to complete work project planning is the largest percentage of time allocated for a project. Engineering must be completed in advance of the construction to understand the complexity of the project. Proper engineering produces job packages including permitting, materials, and coordination with other entities which produces a better cost estimate, will identify resources and material needed, and will produce a schedule for when the work can be completed. At MLGW the substation group has adopted this philosophy and has a dedicated project coordinator that is tasked with schedule and budget for the substation group of projects. The substation group has projects scheduled for an entire year. Program Management of the major electric projects will assist in adhering to the budget with project planning, resource allocation, project timing, and coordination with other departments and entities.

3.3.3 Future Regulatory Drivers

Rates dependent on throughput will cause upward pressure on rates as electric use per customer declines. System throughput is the traditional rate model and end of life assets would normally be replaced through capacity upgrades.

Investments are needed on the system but there is less throughput and revenue to fund the investments needed. Adding renewable generation such as roof top solar or other distributed generation sources further reduces the system throughput and further reduces the revenue for system upgrades. One method to recover rates needed for system improvements is to increase the monthly meter charge to cover the local distribution charges for maintaining a reliable electric grid and reducing the local delivery charge. The cost of energy supply delivered primarily by TVA would still be a fee based on energy delivered.

Regulations from the federal government requiring the conversion from gas and diesel to electric vehicles could have a large impact on infrastructure.

3.3.4 Resiliency

Resiliency is the ability to restore or bounce back from a major event. MLGW currently has limited visibility of the distribution system. Visibility of the system will assist on both ends of a major event. When going into the event, knowing where devices are or automatically opening devices to prevent a cascading series of substation due to low voltage will minimize the infrastructure that is impacted by an event. Following an event, visibility of the electric system will allow faster recovery times by being able to see results of the entire system from one location.

TVA is the primary electric supply for MLGW service territory. A review of TVA resiliency would mitigate concerns of how the TVA system would respond to a major event.

Continued system planning and maintenance will improve the resiliency of the MLGW electric system.

3.3.5 Level of Service and Protection

Expectations for increased reliability will continue to increase as well as the demand for information. Duration of power outages and instantaneous information about customer electricity is expected. To provide this level of service, the MLGW grid must advance technologically to meet this expectation.

Reduced revenue due to a declining use per customer will put more strain on the electric system and force a higher utilization of the existing assets. Investment in technology is required to have more visibility of the electric system and give better information as to where improvements can be made to improve the overall performance of the electric system.

Project Risk Register

Project Name MLGW Condition Assessment
Service Line - Electric
HDR Employee
Date

Frequency	Impact 1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Risk Severity	
Low - Monitor and periodically assess	1 to 4
Medium - Proactive mitigation actions necessary	5 to 10
High - full mitigation plan -escalate to manager	11 to 25

#	Risk Category	Risk Statement Short Name	Description	Consequence	Type	Probability (1,2,3,4,5)	Impact (1,2,3,4,5)	Exposure	Mitigation	Contingency & Triggers	Risk Owner	Actions Taken	Date Last Review	Date Next Review
Unique risk ID			Describe the risk, and capture the "likely cause" of the risk. Be detailed enough so that you can start forming mitigation plans.	Capture the result of the risk, should it happen. Relate to project critical success factors or MSD business objectives. If the consequences cannot be mitigated, you will have to dealt with them in a contingency plan.	Cost, Schedule, Regulatory, Other	Estimate of the probability the risk will occur (1 = highly unlikely, 5 = almost certain) .	Estimate of the amount of impact or severity of the risk.	Probability x Impact. Once all risks have been entered, sort by this column to identify your biggest risks.	Proactive plans to lower the probability or to lower the impact ahead of time. It may require a more detailed plan written up separately.	Identify what would have to be done if the risk were to become reality, and how you would recognize that action is required. This may require a more detailed plan documented separately.	Identify who is responsible for tracking this risk and its changes in probability and impact.	Identify what has been done, either to avoid or mitigate the risk		
Condition Assessment Risks														
CA1	Substation	Transformer Capacity	Monitoring of capacities does not occur. A large load (s) could be added to the system without MLGW knowledge. Load reconfigured on the distribution system	Low voltage could occur on Feeders causing customer equipment damage. Overloading of substation transformers could result in failure of the transformer		2	4	8	Continued monitoring of transformer loading capacities across the system. Load forecasting based upon growth studies in specific geographical areas. Analysis includes N-1 failures of transformers. New loads exceeding 1 MVA added to the system need to get to system planning for analysis. Feeder reconfiguration either temporarily or permanent need to be analyzed in a system model.	Electric Planning needs to set specific criteria for maximum loading of substations and feeders. When loading approaches the maximum capacity set by planning.	Electric Planning			
CA2	Substation	Asset life	Substation equipment needs to be maintained, and components need to be replaced periodically to extend asset life.	Depending on the equipment that fails a long duration outage could occur if substation equipment fails.		3	4	12	Monitor equipment with oil analysis on transformers, conducting breaker timing for breakers, and other maintenance.	Have spare equipment identified for locations that are defined as critical. Electric Planning should be able to assist with determining these components.	Substation Maintenance			
CA3	Distribution	Open Wire Secondary	Open Wire secondary is predominant on MLGW electric system. Vegetation can easily get into the secondary, the secondary conductors slap together due to wind causing numerous outages.	The consequence is small due to the number of customers impancted, but due to the large amount of this conditon it makes the overall consequence to the system higher.		5	2	10	Begin replacing open wire with bundled aerial conductor when crews are working on a segment. Proactively start replacing with a programmatic approach.	Develop a targeted replacement plan using reliablity data to support where the highest numbers are located.	Distribution Reliablity/Asset Management			
CA4	Transmission/Distribution	Wood Pole Replacement	Wood poles on the system have been inspected and rated. Poles that have been identified for replacement has not occurred.	Poles will be undergoing an inspection. Poles from the previous inspection tagged for replacement or stubbing has not occurred.		5	2	10	Build a pole replacement plan to change out the decayed poles. Another option is to have Equipment in place to automatically isolate the system when poles fail.	Need to replace poles at least at the rate that they are rated as replacement each year.	Distribution Reliablity/Asset Management			
CA5	Distribution	Underground Replacement	Undergound 1960-1980 failed underground cable	if a cable segment fails the outage is generally long in duration before it can be fixed.		5	2	10	Install loops to get customers in quicker, Replace cable on a two or three failure policy. If the failure exceeds X number of times it is automatically replaced.	Replace underground cable to reduce underground outages . Criteria for replacement and a replacement schedule should be identified by distribution reliability replaced by the construction group	Distribution Reliablity/Asset Management			
Operational & Commissionning Risks														
OC1	Technology	Grid Modernization	Tecnology needs to be periodically upgraded	Not implemented technolgy and updating the system and deffering pushes off the steep learning curve for employees to implement too many technolgy changes at one time.		2	5	10	Periodically implement technology when equipment ugrades or procedures are needed.	Need a grid modernization plan for how to implement technolgy and identify the steps that need to be taken to get to the end plan.	All MLGW			
OC2	Transmission/Distribution	Vegetation Management	Vegetation caused outages	Vegetation is the leading cause of outages on MLGW system		4	3	12	Reduce the cycle trim to a 3 year cycle. Look at a more aggressive approach to vegietation in back lots.		Vegetation Management			
OC3								0						
OC4								0						
OC5								0						
Safety Risks														
S1								0						

Chapter 4 Water

4.1 Overview of Assets Evaluated & Personnel Interviewed

4.1.1 Asset Performance/Condition Review

Memphis Light Gas and Water (MLGW) currently provides potable water supply to approximately 254,000 customers and accounts in Shelby County Tennessee. Major commercial customers supplied by MLGW are Federal Express, Army Corps of Engineers and St Jude Children's Hospital among others. In 2018, the average daily demand of the MLGW system was approximately 119 million gallons per day (MGD) with a maximum day demand of over 141 MGD.

The purpose of the study was to assist MLGW by reviewing the existing water infrastructure, assessing its condition and operating approach to assist in determining whether long term capital needs are appropriate and necessary. To accomplish this, HDR visited eight pumping stations along with other Water Division facilities and completed the following tasks

- Reviewed available System Data provided by MLGW to understand capital requests and related financial information
- Assessed the current condition of major operating systems at the most critical infrastructure
- Reviewed the reliability and resiliency of MLGW's supply, production and distribution networks
- Provided comparative data from other utilities of similar size
- Recommended measures to improve performance or delivery
- Identified any concerns about maintaining the Level of Service to customers.

This study was prepared as a companion and update to several relevant documents and presentations including the 2018 Water Emergency Response Plan and the 2019/2020 Budget Presentation. Data developed during that study has been relied upon in several instances and reference to that document will be made herein.

4.1.1.1 MLGW Production Facilities

A short profile of each pumping station is provided below which serves as a basis for HDR's understanding of the infrastructure. Customer demand is met through potable water production at one of these facilities

Wilson Mallory (Mallory) Pumping Station (formerly Parkway Pumping Station) which was completed in 1924 and modernized in 1971 to upgrade the aeration facility and electrify the high service pumps. A recent upgrade project initiated in 2016 includes rehabilitation of structural, mechanical, pumping, and control systems. Mallory supplies the City Zone and has a current rated plant capacity of 35 MGD. Mallory is supplied by a nearby wellfield generally along Parkway Avenue and Ayers Street. Water from Mallory

James Sheahan (Sheahan) Pumping Station was completed in 1932 and modernized in 1972 to electrify of all high-service pumps and construct additional aerator capacity. A new laboratory area is under construction along with other plant upgrades. Sheahan serves the City Zone and the current plant capacity is 35 MGD and Sheahan is supplied by a wellfield generally located generally along Getwell and Park Avenues.

Thomas H. Allen (Allen) Pumping Station was completed in 1953 and has not had any significant modernization of that facility. A significant rehabilitation project was designed with an anticipated implementation date of 2019; however, bid prices exceeded the available funds and the work was placed on hold. Allen supplies the City Zone and has a current plant capacity of 30 MGD with Allen being supplied by wells along Havana, Person, Prospect, Benton and Marquorie Streets.

C.M. McCord (McCord) Pumping Station was completed in 1958 and upgraded in 1973 resulting in a 15 MGD capacity increase which included an addition to the aeration facility and two (2) - 15 MGD pumps. McCord serves the City Zone and has a current station capacity of 35 MGD and McCord is supplied by wells along Kenwood, Ivanhoe, Bragg, Woodfield Park and Elmore Roads.

Ira J. Lichterman (Lichterman) Pumping Station was completed in 1965 and upgraded in 1975 resulting in a 15 MGD capacity increase which included an addition to the aeration facility and two (2) - 15 MGD pumps. Lichterman supplies the City Zone and has a current station capacity of 30 MGD. Lichterman is supplied by wells generally located along Ridgeway, Hickory Hill, Winchester and Raines Roads.

Justin J. Davis (Davis) Pumping Station was completed in 1971 and upgraded in 1999 resulting in a pumping station capacity increase from 15 MGD to 30 MGD which included an addition to the aeration facility and new pumps. Davis supplies the City Zone and is supplied by a wellfield along Shelby Drive and Sewanee Road.

Ray Morton (Morton) Pumping Station was completed in 1982 and has not had a major facility modernization. It currently has a rated capacity of 30 MGD. Morton supplies the City Zone and is supplied by wells located along Hawkins Mill, Allen and Egypt Central Roads.

Patricia Walker Shaw (Shaw) Pumping Station was completed in 1990 and upgraded in 1997 resulting in a pumping station capacity increase from 15 MGD to 30 MGD. Shaw is currently the primary supply of water into the East County Upper System. Shaw is supplied by wells generally located along Houston Levee and Pisgah and Humphrey Roads.

LNG Pumping Station was completed in 1967. LNG currently supplies water locally as well as into the North County Zone. The current station capacity is 1.1 MGD. LNG is supplied by wells along Mill- Arlington Road.

Robert E. Palmer (Palmer) Pumping Station was completed in 1970. It currently supplies water generally into the South County Upper System and has a rated station capacity of 5.5 MGD. Palmer is supplied by wells located along Holmes Avenue.

Each of these facilities has a history of producing high quality finished water. However, the aging equipment and condition of each facility have led to concerns about the resiliency and remaining service life of assets, the investment needs and the priority of any needed improvements. MLGW has undertaken this study to more acutely assess the current condition of each facility, understand any necessary upgrades and identify any areas of efficiency or optimization that might delay or offset investment.

4.1.1.2 MLGW Groundwater Supplies

MLGW's 10 pumping stations are supplied by 123 active wells located across Memphis. These wells typically withdraw groundwater from the Memphis Sands (aka 500 Foot Sands) aquifer located in the Memphis formation (typical depth of 400'-500'). The Memphis Sands water is characterized as a generally soft, calcium bi-carbonate type with low dissolved solids concentrations. Lichterman Pumping Station also has wells that tap the deeper Fort Pillow formation (typical depth 1,200'). Figure 4-1 provides additional information.

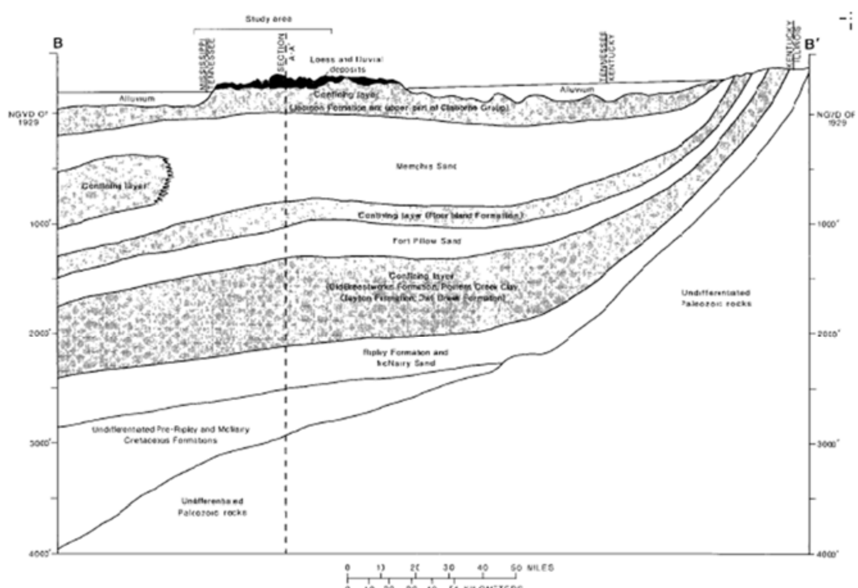

Figure 4.--Principal aquifers and confining layers, south to north, through the Mississippi embayment along line B-B'.

Figure 4-1. USGS Aquifer Description

Dissolved solids concentrations are highly variable within the aquifer. These values are typically lower as the aquifer moves east away from the Mississippi River as Figure 4-2 indicates.

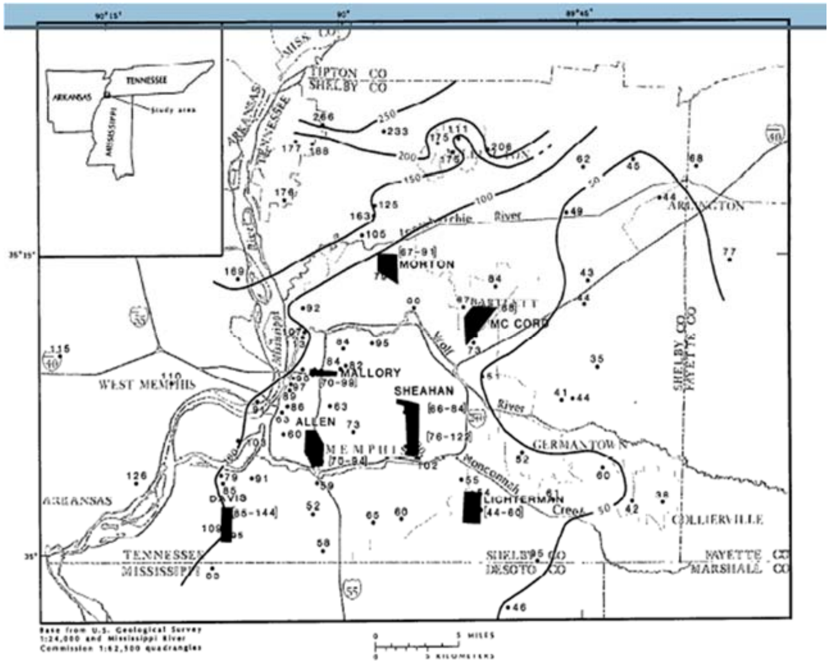

Figure 4-2. USGS Aquifer Description

MLGW performed a condition review of each of the wells in 2018 as part of the Water Emergency Response Plan. As part of that study, each well was given a current condition assessment score of 1-4 along with other performance indicators and general information being recorded. A composite of the wells with ratings 1, 2 or 3 (Score of 1 being considered best, score of 4 being out of service with long term issues) is provided in Appendix A but their relationship to the age of the infrastructure is summarized below in Table 4-1.

Well Condition Classification	Typical Age of Wells (Years)	Current Well Yield (MGD)
1	13	61.1
2	29	83.6
3	47	85.8

Table 4-1. MLGW Composite Well Ages

It should be noted that MLGW has internally assessed typical well life (initiation to abandonment) to be approximately 36 years. This is based upon historical life of the well after its first failure/rehabilitation (24 years). Final well abandonment and closure are site and utility-specific with a dependence on the type of well, aquifer and geologic formation. To highlight the current situation, 43% of all MLGW's active wells, regardless of condition classification, are older than the typical 36 year abandonment milestone.

The condition and reliability of the well supplies to the pumping stations is one of the observed deficiencies to the MLGW water system. MLGWs own internal assessments have identified the need for up to 36 new wells to restore or replace the specific capacity of the wells that have been lost to condition or time. This lack of available supply is a significant limiting factor on MLGW water production. To illustrate the limitation, Table 4-2 provides a breakdown of the current reliable groundwater supply to each pumping station based upon the MLGW and HDR assessments,

Pumping Station (Capacity)	Well Classification 1-2			Well Classification 3			Reliable Well Supply	
	No	Avg Age	Capacity (MGD)	No	Avg Age	Capacity (MGD)	Active Wells	Capacity (MGD)
Mallory (35 MGD)	9	28	18.0	4	46	7.4	13	19.9
Sheahan (35 MGD)	9	24	18.5	10	47	16.4	19	24.9
Allen (30 MGD)	7	11	13.4	4	31	7.4	10	15.8
Lichterman (30 MGD)	5	29	8.2	14	51	21.2	19	18.0
Morton (30 MGD)	12	30	24.6	0	0	0	12	22.1
Davis (30 MGD)	7	13	13.6	5	47	6.6	12	15.5
McCord (35 MGD)	8	13	15.9	8	48	7.0	16	17.8
Shaw (30 MGD)	16	24	32.6	0	0	0.0	16	29.3
LNG (1.1 MGD)	0	0	0.0	2	50	2.4	2	1.2
Palmer (5.5 MGD)	0	0	0.0	3	56	5.1	3	2.6
Totals	**73**	**22**	**144.8**	**50**	**47**	**73.5**	**123**	**167.1**

Table 4-2. Well Age and Capacity by Pumping Station

As noted in Table 4-2, the total available well supply from the most reliable (Class 1-2) wells is 144.8 MGD or 55% of the rated capacity of the pumping stations. This supply capacity is supplemented by the Class 3 (lowest reliability) wells which have a capacity of 73.5 MGD. By overlaying some reliability factors (90% for Class 1-2/50% for Class 3), an estimation of the system-wide reliable well supply appears to be approximately 167.1 MGD (or 64% of pumping station capacity) based upon the information provided by MLGW and HDR's limited field assessments.

Pumping Station Infrastructure Findings

Since 1870, MLGW (then the Memphis Water Company) has been providing high-quality drinking water to customers. Between 1870 and 1907, groundwater was treated at the Auction Avenue plant which was supplemented with the 1907 addition of the Central Avenue plant. In 1924, both the Auction and Central Ave plants were abandoned with the completion of the Parkway Pumping Station (now Mallory Pumping Station). Over the next 70 years, MLGW would construct other Pumping Stations to match the growing community. However, as the per capita water use has declined in recent years along with industrial and residential migration, the need for new facilities has been mitigated. The most recent capacity expansion at the MLGW facilities occurred at the Davis Station in 1999.

To further illustrate the age of the production infrastructure, Figure 4-3 provides a timeline of construction for pumping stations and the related capacity. Where expansions or upgrades occurred, the additional capacity is shown in the year of implementation. Milestones for 50-year and 75-year service anniversaries are included.

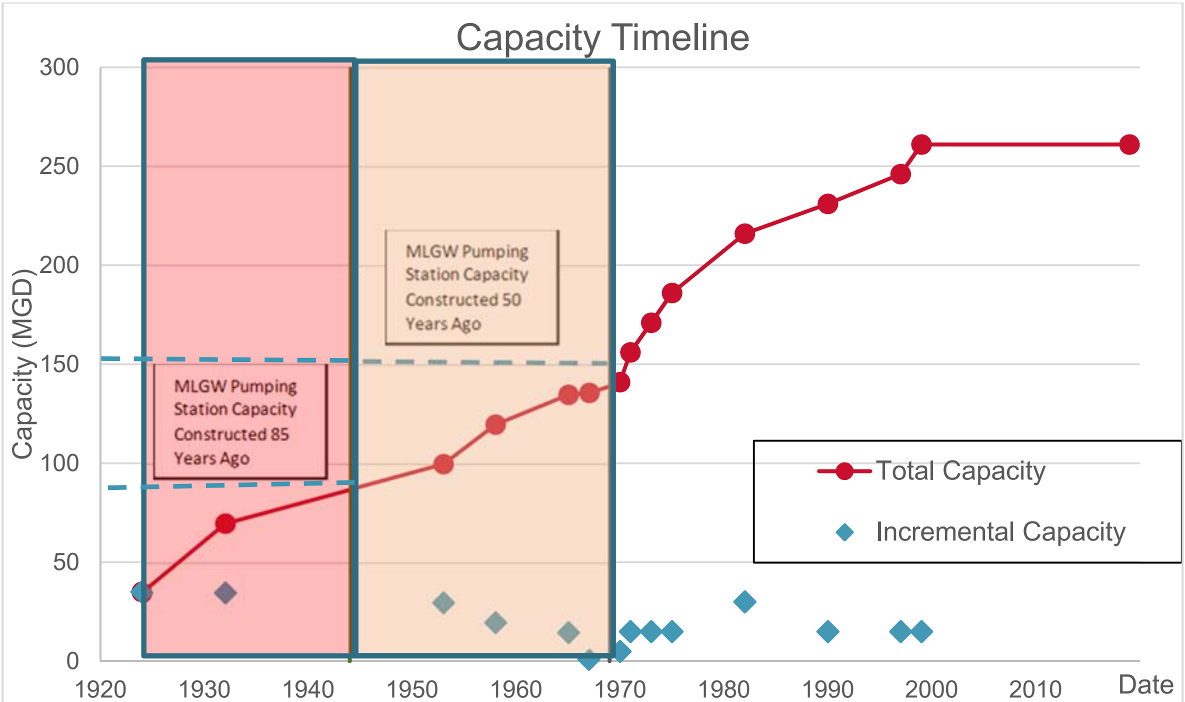

Table 4-3. Timeline of Capacity Development at MLGW

This figure reflects that over half of the production capacity was constructed more than 50 years ago and over 25% is over 85 years old. This is significant when you consider that all original structures and much of the original mechanical equipment is still in service.

One of the focal points of the review of the Water Division is to understand the current conditions of its major infrastructure and to assess or confirm the need for investment. In order to gain a first-hand understanding of the current conditions, senior HDR engineers visited the MLGW pumping stations and key distribution facilities during the period of September 17-19, 2019. Appendix B to this report provide the observations of our team for each major process or system at these facilities. A brief summary of findings is provided on the following pages for the pumping stations that were visited.

1. Mallory Pumping Station

The oldest pumping station in the MLGW system, Mallory was originally constructed and put in service in 1924. A major facility upgrade was completed in 1971 was completed which electrified the high service pumps (formerly steam driven) and modernized the filters. Mallory supplies water into the western portion of the urban core including key customers such as St Jude, City Hall and several hospital facilities. Specific observations at Mallory included

- All facility construction is original to 1924
- Aerators have been seismically mitigated and media has been recently replaced

- Filters (8) are suitably sized but media is 50 years old. Air scour should also be considered to clean the media.
- Filter control valves recently replaced along with coating rehabilitation throughout areas of the plant.
- High service pumps appear to be original (electrified in 1971). 4 HSP with 2 out-of-service currently. One out of service for mechanical repair and other has electrical issues.
- HSP suction and discharge piping have been recently painted and several lengths of pipe replaced
- West Reservoir (10 MG storage) currently unbaffled and has a backwash recovery chamber constructed in its center. Decant pump station needs to be replaced.
- New backwash recovery facility being planned for corner of North Parkway and Dunlap
- Chemical storage and feed systems are in good condition.
- Electrical service and gear is beyond service life and specific elements exhibit corrosion and hazard.

2. Sheahan Pumping Station

Sheahan was originally constructed in 1932 and supplies the water operations center and the water quality laboratory. The second station constructed in the MLGW system, Sheahan's last major facility upgrade was completed in 1971 which electrified the high service pumps (formerly steam driven) and modernized the filters. Sheahan is centrally located within the MLGW system but is currently hydraulically limited in its area of supply. Plant currently operating on 2 of 4 high service pumps which is a critical limiting factor. Other specific observations at Sheahan include

- All facility structures are original to 1932 and are not seismically-mitigated
- Aerators media has not been recently replaced
- Filters (8) are suitably sized and media was replaced in 2007. However, media has been found in reservoir and underdrain condition is unknown. Air scour should also be considered to clean the media.
- Filter control valves are in variable conditions. Several have newer actuators but no valves appear to have been replaced in recent years.
- High service pumps appear to be original (electrified in 1971). 4 HSP with 2 out-of-service currently for discharge valving and VFD/electrical issues.
- Chemical storage and feed systems are in good condition.
- HSP Roof recently rehabilitated
- BW recovery tank in center in finished water reservoir similar to Mallory.

3. Allen Pumping Station

Allen was originally constructed in 1953 and has a design capacity of 30 MGD. Allen is considered to be an important station because of its ability to serve many areas of the MLGW system as a primary or back-up supply. Based on field observations, Allen's overall condition is likely the worst in the MLGW system. Recent attempts at an upgrade have encountered budget issues. Specific observations at Allen include

- Numerous facility structural issues including roof needs, several crack repair issues and facility is not seismically-mitigated
- Aerators media has not been recently replaced
- Filters (8) are suitably sized and media appears to be original from 1953. Media has been found in reservoir and underdrain condition is unknown.
- Filter control valves are in variable conditions. A handful have newer actuators but no valves appear to have been replaced in recent years. Filter control improvements (new operating consoles and SCADA) project stopped in the middle of implementation.
- High service pumps (5) currently operate but VFD cabinets have safety and performance concerns.
- Chemical storage and feed systems are in good condition.
- No backwash recovery facilities were noted

4. McCord Pumping Station

McCord was originally constructed in 1958 and expanded in 1973. Based on available information, MLGW recognizes the capacity at McCord to be 35 MGD. However, a review of McCord filters indicated that capacity would be limited to 17.6 MGD under typical regulatory guidelines for drinking water mixed media filters (5 GPM/SF with one filter out of service). McCord is not considered to be a critical station due to its limited area of supply. This station is positioned near Bartlett and supplies a local area in the central part of the MLGW system. Based on field observations, McCord's overall structural condition is acceptable but it has more equipment service issues than other MLGW facilities. Specific observations at McCord include

- Aerators media has not been recently replaced
- Filter media was replaced in 2006 but a portion of underdrain is apparently broken.
- Filter control valves generally have newer actuators and several have been replaced in recent years.
- Filter controls are outdated equipment that no longer has factory support. Improvements (new operating consoles and SCADA) project are programmed but have not been implemented.

- Only 2 of the 5 high service pumps currently operate. The deficiencies include discharge valves, VFD cabinets and mechanical needs.
- Chemical storage and feed systems are in good condition.
- Backwash recovery facilities were noted

5. Lichterman Pumping Station

Lichterman was originally constructed in 1965 and expanded in 1975. Based on available information, MLGW recognizes the capacity at Lichterman to be 30 MGD. However, a review of Lichterman filters indicated that capacity would be limited to 17.6 MGD under typical regulatory guidelines for drinking water mixed media filters (5 GPM/SF with one filter out of service). This is concerning as Lichterman is considered to be a critical and workhorse station due to its area of supply and ability to supply other areas. This station supplies the southeast part of the MLGW system and serves as a key back-up to Davis and Sheahan as well as supplying the South Central system. Based on field observations. Specific observations at Lichterman include:

- Aerators media has not been recently replaced but structure is seismically mitigated
- Polymer is injected at Lichterman to assist in filtration
- Filter media was replaced in 2008.
- Filter control valves generally have newer actuators and several have been replaced in recent years.
- Filter controls are outdated equipment that no longer has factory support. Improvements (new operating consoles and SCADA) project are programmed but have not been implemented.
- All 5 high service pumps currently operate. However, deficiencies include discharge valves and VFD cabinets are present.
- Chemical storage and feed systems are in good condition.

6. Davis Pumping Station

Davis was originally constructed in 1971 and expanded in 1999. Based on available information, MLGW recognizes the capacity at Davis to be 30 MGD. However, a review of Davis filters indicated that capacity would be limited to 19.4 MGD under typical regulatory guidelines for drinking water mixed media filters (5 GPM/SF with one filter out of service). Like Lichterman, this is a concern as Davis is considered to be a critical station due to its supply of TVA, President's Island and several industrial areas. This station supplies the southwest part of the MLGW system and serves as a back-up to Allen. Based on field observations. Specific observations at Davis include:

- Aerators media has not been recently replaced but structure is seismically mitigated
- Filter media appears to be original.
- Filter control valves and actuators have not been replaced in recent years.
- Filter controls upgrades are being implemented to comply with NERC/FERC standards.

- Four of five high service pumps currently operate but different hydraulic designs which reduces their range and efficiency. Deficiencies also include discharge valves and VFD cabinets.
- Chemical storage and feed systems are in good condition.
- Recovery basin approach being reviewed to minimize wastewater fees paid to city

7. Morton Pumping Station

Morton was originally constructed in 1982 and has a design capacity of 30 MGD. Morton is considered to be an important station as it provides service to the growing North County Upper System around Millington. Morton also can provide back-up supply to McCord and Mallory. A review of Morton filters indicates that capacity would be limited to 22.4 MGD under typical regulatory guidelines for drinking water mixed media filters (5 GPM/SF with one filter out of service). If all filters are online, the 30 MGD capacity is achievable. Specific observations at Morton include:

- Aerator media has been recently replaced and structure has been seismically braced.
- Media was replaced in 2005 but underdrain condition is unknown.
- Filter control valves are in variable conditions. Many leak. A few have newer actuators. Several valves were laying in the yard awaiting installation.
- Filter control units are original and have not been replaced.
- Three high service pumps (out of 4) currently operate but VFD cabinets have safety and performance concerns.
- Chemical storage and feed systems are in good condition.
- Backwash recovery facilities are in good condition.

8. Shaw Pumping Station

Shaw originally constructed in 1990 and expanded in 1997. It has a design capacity of 30 MGD. Shaw is considered to be a critical station because of its ability to serve the East County system and serve as a limited back-up to Lichterman. Like Morton, a review of the filters indicates that capacity would be limited to 22.4 MGD under typical regulatory guidelines for drinking water mixed media filters (5 GPM/SF with one filter out of service). If all filters are online, the 30 MGD capacity is achievable. Specific observations at Shaw include:

- Aerator media has not been recently replaced
- Filters media appears to be original from 1990. Media has been found in reservoir and underdrain condition is unknown.
- Filter control valves are in variable conditions. A handful have newer actuators but several are noted as leaking. Filter control improvements (new operating consoles and SCADA) has not started at Shaw.

- Three high service pumps (out of 8) currently operate but VFD cabinets have safety and performance concerns.
- Chemical storage and feed systems are in good condition.
- No backwash recovery facilities were noted

As noted previous, more complete descriptions of the current conditions at each major component at these 8 pumping stations is provided in **Appendix B**. During the field visits, HDR focused on the 8 major stations noted above and could not visit the LNG or the Palmer facility with the time available. Adequate description of their condition is provided on the 2018 Water Emergency Response Plan to provide an understanding of their criticality and current performance.

Distribution System Infrastructure Findings

As part of HDR's review, we have investigated elements of the transmission and distribution network to determine their performance and reliability. Limited site visits to key booster pump stations were included to gain an understanding of the infrastructure. The flowing section summarizes the information that was collected regarding the various system elements

4.2 Booster Pump Stations

- Observations based on review of a typical booster pump station (Germantown)
- There are a total of 19 booster pump stations.
- Booster Pump Stations don't have back up power supply and limited overhead storage could result in low pressures during power outages
- Multiple (eight) booster pump stations have only one pump in operation or by design
    - No redundancy component at this booster pump stations
    - Per operations the redundancy for these BPS is typically provided by an alternative BPS is the system.
- 12 booster pump stations have at least 1 pump with a VFD
    - Remaining BPS don't have a VFD equipped and pump with a constant speed directly into the distribution system.
    - Addition of VFDs would allow for pumps to be controlled by discharge pressure with the pumps automatically adjusting flow via VFD
        - This would reduce wasted energy or over pressurization in the system.
- Combined with all pumps at 100%, the booster pump stations have a max pumping of capacity 90 MGD (just the perspective on the quantity of pumping)

4.3 Elevated Storage Tanks

- 15 elevated storage tanks throughout the system. provided a total of 5.2 MG of storage (~5% of average day demand)
- Majority of finished water is stored at the pumping stations in underground reservoirs.
    - Minimal amount of elevated storage necessitates that high service pumps at Pumping Stations are reliable to distribute finished water into the system
- Two of the elevated tanks have recently had an investigation completed
    - Baker Tank
        - Investigation Completed in September 30, 2016
        - Per Report, Interior needs recoated in the next 2-3 years with spot clean & top coat the interior recoating
        - ANSI/OSHA related deficiencies
    - Doc Gallagher Tank

- Investigation Completed in March 15, 2019
- Per Report, refurbishment work be performed within the next 4-5 years on the interior and within the next 3-5 years on the exterior to prevent the loss of steel cross-section.

4.4 Distribution System

- Continue the ongoing practice of removing lead service lines from the system.
- Need to develop a main replacement program, aging infrastructure and additionally a large amount of cast iron pipe in the system.
- Currently, there are only two distribution mains crossing the Loosahatchie River
  - Additional connectivity was discussed by the staff for resiliency purposes.
- Main breaks, in Dec. 2017 through 2018 there were a total of 407 main breaks
  - Average age – 60 years old for the main
  - 371 of the breaks are cast iron, 91%
  - 222 of the mains are listed as temperature change breaks
- Main breaks, Jan – Aug 15th of 2019
  - 177 Main breaks
  - Average age in 60 years old
  - 155 of the breaks are in cast iron, of 87%
- General Customer Complaints
  - 2017 - General Customer Complaints - 292
  - 2018 - General Customer Complaints - 276
  - 2019 - General Customer Complaints - 169 (7/31/19)

    Total 737
  - Note: MLGW Laboratory analyze approximately over 40,000 State and Federal Regulatory compliance sampling and reporting annually, as well as approximately 3000 lead and copper testing within the last 3 years.
- Per CIP Presentation, the below is the request for capital funds
  - Distribution System (2019) - $13,153,888
    - Revenue Extension ($3,403,888)
    - Lead Service Replacement ($5,000,000)
    - Excludes: Purchase of Meters, Misc. Emergency Construction and CIAC

- See the distribution capital table below
  - Key notes include:
    - No money allocated for booster pump stations over the next 5 years
    - No money for a valve actuation and replacement program, even when many staffers noted that the assumption at MLGW is to assume it can't hold
    - For new mains, the total over the 5 years would be $12,719,000 (seems small)
    - Lead service replacement is expected to continue through 2024
      - In 2018, replaced 752 at 11,178 feet of service
        - In 2019 through July, replaced 258 at 3,322 feet of service

DISTRIBUTION SYSTEM	2019 BUDGET	2019 REVISED BUDGET	2020 BUDGET	2021 PROJECTION	2022 PROJECTION	2023 PROJECTION	2024 PROJECTION
Apartments	$ -	$ -	$ 50	$ 51	$ 52	$ 54	$ 55
Booster Stations	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Emergency Maintenance	$ 3,137	$ 3,100	$ 3,212	$ 3,265	$ 3,330	$ 3,397	$ 3,465
General Power Service	$ 2,928	$ 2,900	$ 3,546	$ 3,617	$ 3,690	$ 3,764	$ 3,839
New Water Main	$ 7,399	$ 1,500	$ 3,089	$ 2,594	$ 2,339	$ 2,349	$ 2,349
Lead Service Replacement	$ -	$ -	$ 2,500	$ 2,500	$ 2,500	$ 2,500	$ 2,500
Planned Maintenance	$ -	$ 2,500	$ 3,000	$ 3,000	$ 3,000	$ 3,000	$ 3,000
Relocate at Customer Req	$ 75	$ 75	$ 282	$ 288	$ 293	$ 299	$ 305
Residential S/D	$ 66	$ 66	$ 246	$ 251	$ 256	$ 261	$ 266
Residential Svc in S/D	$ 122	$ 122	$ 338	$ 345	$ 352	$ 359	$ 366
Residential Svc not S/D	$ 276	$ 276	$ 318	$ 324	$ 330	$ 337	$ 344
Street Improvements	$ 2,415	$ 1,000	$ 2,820	$ 2,350	$ 2,350	$ 2,350	$ 2,350
Previously Capitalized Items - Meters	$ 5,291	$ 5,291	$ 572	$ -	$ -	$ -	$ -
Contributions in Aid of Construction	$ (3,957)	$ (4,005)	$ (2,975)	$ (3,034)	$ (3,095)	$ (3,157)	$ (3,200)
TOTAL - DISTRIBUTION SYSTEM	**$ 17,752**	**$ 12,825**	**$ 16,999**	**$ 15,551**	**$ 15,398**	**$ 15,512**	**$ 15,638**

Figure 4-3. Distribution System Details

4.4.1 Personnel Interview (Major Discussion Points)

HDR personnel visited MLGW for 3 days during the week of September 17th. The site visits enabled our team to gain a better understanding of the MLGW water infrastructure as has been previously identified in this report. The visits also allowed HDR professionals to ask questions and have open dialogue with MLGW staff about the current physical conditions of their facilities, their operations approach, workforce issues, procurement of services, prioritization process for capital expenditures and other relevant topics. This section of the report offers a summary of our HDR's impression of those conversations. It is offered in a composite format and the information does not reflect the views of any one individual. Topics of discussion included:

Age and Condition of Infrastructure – HDR perceived a general consensus among the MLGW staff that the condition of the cumulative assets were deteriorating and that maintenance needed to be increased to accommodate the condition and age. Specific concerns included wells, filters, valves and pumps as detailed below.

Wells – Need to replace wells, especially at Davis, Lichterman and Allen is clearly a concern based upon the perceived criticality of those locations. Recent program to have Layne drill up to 7 new wells per year has been partially successful but slowed by electrical implementation issues.

Filters – Media condition at Lichterman, Davis and Shaw is an issue that needs further observation. Each of these facilities has media that is very old by industry standards and also has some of the highest facility output s in the system. The presence of media in several finished water reservoirs is a concern.

Valves – In general, staff does not have a high level of confidence in yard valves to hold. The in -plant valves are in various conditions and many are leaking. Replacing valves to restore control over the facilities is necessary.

Pumps – Two types of high service pumps are currently present at each plant. Older centrifugal pumps (DeLaval) that have typically been operating since installation. Maintenance on these is more difficult as manufacturer is out of business for years. In-house capabilities don't appear to have the training or skills to service and parts are hard to find and often have to be machined. Newer VT pumps are outside on reservoir and more accessible if less durable. Hydraulics are an issue in some locations. Annual pump replacement program was discussed on a couple occasions.

Loss of Experience and Human Capital – Leadership at all levels is critical to utility performance. A common discussion topic has been the impact of retirement and departures on the culture of MLGW. This is a theme that is nationwide and not just local, however, the particular nature of MLGW assets makes this issue different for you than other utilities. MLGW's mechanical and electrical infrastructure is much older than most peer utilities so maintenance and repair are more important skills to your organization. The loss of expertise in these areas is apparent with so many pumps out of service in addition to valve conditions, etc. Additional maintenance capacity and expertise will be needed to regain the overall asset condition needed to provide a reliable level of service (LOS). The only alternative to this is additional capital investment to replace these systems.

Ability to Contract for Services – This issue is related to the loss of experience. HDR does not have first-hand knowledge of the contracting and procurement processes within MLGW. From our industry experience, we are aware of the need for more detailed procedures and the general impact on timeliness. The general concern with MLGW is the time between request, authorization and implementation.

Work Order Systems – Maintenance staff had clear concerns about the effectiveness and user-interface on the maintenance work order system. Again, HDR did not observe this first-hand but understands that properly prioritizing work is important with limited resources. The other concern is that completed maintenance tasks are not being recorded in the MLGW asset database and important information is being lost or never entered.

Operator controls – MLGW's operating approach is unique and innovative based on HDR's experience in the industry. Establishing control over the production facilities through SCADA links and remote operation is not a new concept and is a very efficient way to operate a system with so many production assets. However, this function is typically performed by a licensed treatment plant operator(s) in other communities and HDR recommends that this practice be considered by MLGW.

4.5 Review of Capital & Programmatic Budgets

HDR has been provided financial statements and fiscal information related to the water utility. Our review of capital budgets has primarily evolved from a review of the MLGW's Combined Financial Statements between 2015-2018. From these statements, Table 4-4 provides a summary of relevant information regarding the Water Utility's capital budget.

Capital Budget [1]	**2015[2]**		**2016[2]**		**2017**		**2018**		**4- Year Total**	
	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual	Budget	Actual
Overhead Storage					$ 0	$ 0	$ 1,700	$ 1,753		
Wells					$ 4,600	$ 3,276	$ 7,867	$ 3,361		
Pumping Stations					$9,810	$10,398	$ 8,035	$ 974		
Underground Reservoirs					$ 220	$ 0	$ 815	$ 0		
Other Misc					$ 160	$ 114	$ 145	$ 0		
Production System Subtotal	$15,642	$2,018	$15,627	$7,763	$14,790	$13,788	$18,562	$ 7,771	$ 64,621	$ 31,340
Buildings and Structures	$ 2,821	$ 960	$3,124	$2,273	$ 1,672	$1,268	$ 3,347	$ 1,681	$ 10,964	$ 6,182
Distribution System	$13,289	$7,785	$21,385	$20,429	$29,834	$30,873	$30,196	$24,163	$ 94,704	$ 83,250
General Plant	$2,205	$ 931	$ 2,401	$ 1,660	$3,966	$1,663	$ 3,018	$1,687	$ 11,590	$ 5,941
Water Division Total	**$32,938**	**$11,618**	**$41,278**	**$31,039**	**$48,754**	**$45,022**	**$53,616**	**$32,340**	**$176 586**	**$120 019**

[1] All Dollars in 1,000s
[2] 2015/16 Cost centers were different – pumping station based – rather than asset category as in 2017/18

Table 4-4. Capital Budgets 2015-2018

As evidence in Table 4-4, MLGW has a gap between budgeted capital expenditures and actual capital expenditures over the last few years. This is especially present in the Production System assets where less than 50% of the budgeted capital amounts are reaching implementation.

4.5.1 Comparable to Industry Standards

The water industry is made up of a diverse group of utilities that each have different sources, treatment process, distribution networks, etc. and also have different cultures, metrics for success and financial performance. The organic growth of the MLGW system over the last 70 years has resulted in a unique utility that features:

- 10 different production and treatment facilities across Memphis with localized wellfields
- Centralized operations of production facilities (unmanned stations) which reduces the number of licensed operators.
- Multi-utility management structure that can apply best practices from gas and power industries.
- Single City pressure zone that is supplied by 8 Pumping Stations

However, HDR has reviewed several peer utilities in the region to determine where comparative information may be extracted for use. The peer utilities selected are St. Louis Water Division, Louisville Water Company, New Orleans Water and Sewerage, Greater Cincinnati Water Works and Columbus (OH) Division of Water.
These utilities were selected for several reasons including:

- Similar age of many key assets (production facilities were built around same time)
- Similarity of distribution network age and materials
- Regional compatibility from regulatory to economic factors
- Service area population

There are also notable differences including the source of supply and method of water purification. This difference is mitigated somewhat by understanding that surface water plants have more assets and expense at each plant but have far fewer plants than MLGW. As noted, distribution networks exhibit similarities. The comparative information on budget and capital expenses for these utilities is provided in Table 4-5

Utility	Production Capacity	Water Delivered to Mains (MG)	Average Daily Pumpage	Maximum Daily Pumpage	No. of Customers	Service Area Size	Operating Expense ($000s)	Water Revenue ($000s)	Capital Expenditures ($000s)	Projected Capital Budget ($000s)	
	MG	2018	2018	2018		(miles of main)	2018	2018	2018	2019	2020
Louisville Water Company	240	43,570	119	152	316,482	4,233	137,624	191,998	111,000	105,000	-
Greater Cincinnati Water	260	44,184	121	157.2	240,336	3,176	75,980	147,519	83,790	85,864	89,063
City of St. Louis	380	43,500	119	-	92,188	-	50,036	55,779	-	-	-
New Orleans	250	54,140	146	-	135,000	1,834	106,761	$109,900	72,487	48,343	115,000
Columbus	255	48,800	134	-	278,139	3,541	113,447	198,982	87,500	149,473	165,440
Memphis	261	43,500	119	144	254,000	3,943	50,600	103,000	32,340		

Table 4-5. Comparable Utility Details

4.5.2 Deficiencies

As noted previously, it is difficult to extract directly comparative information directly between two or three utilities. For this reason, we have tried to obtain information from utilities in the same region and of somewhat similar size. From this, HDR has drawn some loose comparisons with the MLGW system and its financial details including:

- Per customer revenue is lower than all comparable utilities
- Per customer operating and maintenance expenses are lower than all comparable utilities
- Capital investment as a percentage of revenue is lower than all comparable water utilities
- Capital investment as a percentage of customer base is lower than all comparable utilities

4.5.3 Over Allocation

HDR did not find an over-allocation of budget or capital amounts in the Water Division. As previously noted, the actual capital invested at production facilities showed significant variation for the budgeted amount over multiple fiscal cycles. The need for consistent investment and implementation of equipment replacement or new construction at the wells and pumping stations is apparent and justifiable.

4.6 Gap Anaylsis

Sections 4.4 and 4.5 have focused on the findings of HDR's review of MLGW's existing infrastructure and operations approach along with the budget, financial and capital investment results. The assessment that we have provided in those sections is essentially a "snapshot in time" and is based upon the information provide to us by MLGW. HDR has not tried to ascertain the accuracy of the information provided beyond the comparative provided herein. It is likely that additional investigation might reveal more information regarding our findings and could identify additional areas of concern. However, our review period was limited and our charge was to adhere to our schedule to assist MLGW in their budgeting.

For the purposes of gap identification, HDR has provided a risk register to catalog the findings, identify the severity of the issue, the likelihood of occurrence and the potential mitigating measures available to MLGW. The Risk Register shown in Figure 4-4 identifies 24 items within the Water Division for review and consideration. Several items are inter-related and may require an integrated response.

4.6.1 Safety

A handful of the items on the Risk Register include safety issues that should be examined and considered for capital programming. These items are varying in their degrees of severity. One item that was identified at multiple locations was the operating conditions of the variable frequency drives. The drives generate a significant amount of heat during operation and standard practice is to provide an air conditioned space for these (either the entire room or the VFD cabinet itself). MLGW has several locations where VFDs are used but air conditioned space is not provided so the cabinet doors have simply been opened with a fan running on them to help cool the gear. This is a performance and safety concern. The VFD performance is negatively

impacted by heat but dust can also create problems. An electrical/instrumentation room with proper environmental controls is necessary and should be a high priority.
HDR identified other items and suggest coordinated safety review with MLGW's safety lead to review other observations. HDR site visits were not focused on safety issues and the items previously identified were found incidentally.

4.6.2 Programmatic Enhancements/Initiatives

Based on a review of available utility documentation regarding past performance together with our site visits and discussions with MLGW staff, HDR has identified five (5) key program initiatives that should be considered for implementation. Each of these is identified below with a brief description. More details can be offered if MLGW is interested in moving forward.

Implementation Assessment – Based on our review of Financial Statements over the last 4 years, the Water Division has not expended its capital construction budget in any year. In 3 of the 4 years, the gap between budget and actual expenditures is significant. As the need for significant capital investment is apparent, this gap has been hard to fully understand. From our comparative information, HDR believes a $60-70 million dollar capital budget is justifiable. However, fully understanding the obstacles to successfully delivering that level of investment and identifying fresh ways to deliver improvements is very important before asking rate payers to support it. Alternative delivery methods may be helpful in accomplishing.

Distribution Delivery Master Plan – MLGW staff is currently updating their hydraulic model and this is a key tool for planning. HDR recommends that MLGW commission a Distribution Master Plan to assess the hydraulic delivery efficiency and identify additional ways to convey water from one area of the City Zone to another. Key elements of a DSMP would include:

- Asset review for detailed condition assessment
- Criticality assessment of mains to determine the key transmission mains, the alternative routes, the impact of service interruptions and assets that can be considered for de-commission without loss of service
- Intra-zone Infrastructure review to identify needs for improving transmission of water within the City Zone to improve reliability and reduce the reliance on local Pumping Stations.
- District Metering Assessment to add master metering at strategic location within the distribution system to better understand flow patterns, help account for non-revenue water by zone and generally increase the data acquisition over the network.

Completion of SCADA upgrades – SCADA upgrades are an obvious priority and the completion of them is critical to optimize control and operations at the Pumping Stations. Electrical upgrades should be upgraded with the SCADA where feasible.

Workforce Initiatives/Training – MLGW Water Division workforce size is somewhat smaller than comparable utilities that were reviewed. This is attractive from an operating cost perspective but can leave MLGW vulnerable to changes or sudden increases in workload (maintenance mostly). MLGW benefits from its centralized operations approach that results in only 4 licensed operators being necessary. From our discussions, HDR believes that MLGW's mechanical maintenance capabilities has been diminished in recent years. We have heard about operations and maintenance approaches from years past but less about the current approach. Difficulties with training, advancement and hiring have been frequent topics of discussion. A Water Division focused review on position

Well Development/Rehabilitation Program – The number of aging and under-performing wells has been previously discussed. MLGW has previously produced a high-level wellfield assessment and has attempted to replace s a few wells on the past 2 years. However, well replacement through new well development needs to occur at a faster rate to avoid the risk of critical supply reduction. Well inspection frequency also needs to increase.

4.6.3 Future Regulatory Drivers

MLGW has done a good job of responding to developing regulatory initiatives. This includes the recent focus on lead in the drinking water which MLGW has a service line replacement program. As a groundwater, MLGW is most affected by changes to the Lead and Copper Rule (LCR). In response to the Flint Michigan issue (among others), USEPA has recently issued proposed revisions to the LCR that include 6 proposed initiatives:

- Identify the Areas Most Impacted – Requiring a lead service inventory
- Strengthening treatment requirements – Review of utility corrosion control approach
- Replacing lead service lines – Annual goal for replacement in systems above 10 ppb
- Increasing sampling reliability – New testing protocols
- Improving risk communication – public notification of exceedance within 24 hours
- Protecting children in schools – Requirements to test schools and child care facilities

A fact sheet for these revisions is provided in Appendix B.
There are a few other regulatory activities that could impact Memphis. These are summarized below. A more detailed analysis of each of these can be offered upon request.

- ***Manganese*** has been put on the Contaminant Candidate List 4 (CCL4) which could transform it from a secondary to a primary contaminant for the purposes of regulation. This arises largely out of new information from Canadian studies about the harm that long-term exposure can have on impacted populations.
- ***Perfluorinated Compounds*** such as PFAS and PFOA which are chemical by-products generated during the industrial manufacturing process. These compounds can be found in groundwater or surface water and are very difficult to treat. This is a nationwide issue and groundwater fields near industrial centers, airports, military facilities and other manufacturing sites should be sampled or the facility inventoried to assure that these compounds are not part of their discharges.
- ***Legionella*** outbreaks in recent years have brought the issue back into public view and likely will lead to a renewed regulatory consideration. Legionella is not source dependent and flourishes in low residual environments such as household plumbing, especially low-flow, high water age locations. Low frequency distribution maintenance (flushing) can also be helpful to Legionella.

4.6.4 Resiliency

Resiliency is a critical part of system operations and has been coming under increasing scrutiny nationwide as utilities are trying to fortify their infrastructure against adverse events. HDR talked at length with MLGW staff during our site visit to understand how resiliency is being applied within the Water Division. Each utility can interpret this differently because their infrastructure is different and the findings from our review are provided below.

- Number of plants that MLGW operates is a mitigating factor against the possibility of a system-wide outage. Multiple plants reduce the risk associated with the shutdown of a single plant

- Current resiliency of individual pumping stations is more concerning than the cumulative resiliency of the MLGW system. HDR has prepared a snapshot review of the limiting factors or reliable production capacity at each pumping stations based upon 1) current well capacity 2) recent filtration criteria and 3) current high service pump capacity. Table 4-6 provides our assessment of the reliability of each pumping station compared with its average and maximum daily production for 2018.

	PLANT DETAILS (MGD)									
	Mallory	**Sheahan**	**Allen**	**Lichterman**	**Morton**	**Davis**	**McCord**	**Shaw**	**LNG**	**Palmer**
AVG DAY	11.6	9.8	12.8	16.1	13.0	14.4	14.5	17.7	0.5	3.6
PEAK DAY	15.6	15.4	15.0	22.2	15.7	18.4	16.3	21.3	0.6	4.8
RATED PLANT CAPACITY	35.0	35.0	30.0	30.0	30.0	30.0	35.0	30.0	1.1	5.5
AVG DAY (%)	**33.2**	**28.1**	**42.6**	**53.6**	**43.4**	**48.0**	**41.4**	**58.9**	**46.4**	**66.0**
PEAK DAY (%)	**44.6**	**44.1**	**50.2**	**73.9**	**52.4**	**61.4**	**46.5**	**71.1**	**58.4**	**86.4**
WELL RELIABILITY CLASS 1-2	18.0	18.5	13.4	8.2	24.6	13.6	15.9	32.6	-	-
WELL RELIABILITY CLASS 3	7.4	16.4	7.4	21.2	-	6.6	7.0	-	2.4	5.1
ASSESSED WELL RELIABILITY [1]	*19.9*	24.9	*15.8*	18.0	*22.1*	*15.5*	17.8	29.3	1.2	*2.6*
FILTER CAPACITY W/ OOS	35.0	35.0	30.0	*17.6*	22.5	19.4	17.6	22.5	1.2	5.5
HSP ON-LINE CAPACITY [2]	35.0	*15.0*	30.0	30.0	25.0	30.0	*15.0*	*21.0*	*1.1*	5.5
FACILITY RELIABLE CAPACITY [3]	19.9	15.0	15.8	17.6	22.1	15.5	15.0	21.0	1.1	2.6
RELIABILITY / RATED CAPACITY	0.6	0.4	0.5	0.6	0.7	0.5	0.4	0.7	1.0	0.5
AVG DAY (%)	**58.4**	**65.5**	**80.9**	**91.4**	**58.9**	**92.8**	**96.5**	**84.1**	**46.4**	**139.6**
PEAK DAY (%)	**78.5**	**102.8**	**95.2**	**125.9**	**71.1**	**118.8**	**108.5**	**101.6**	**58.4**	**182.8**

Table 4-6. Pumping Station Reliability Review

- Results shown in Table 4-6 show that MLGW is relying upon the availability of system-wide capacity for reliability purposes rather than keeping each pumping station fully capable of rated capacity. This is not a common strategy. It can certainly be useful in the near term to ease the impact of renewal costs. However, each Pumping Station needs to be hydraulically interconnected in an effective manner throughout the City Zone. It is not clear that this is the case based on discussions with staff.
- Level of investment for replacement work or upgrades at each facility needs to increase to improve localized reliability. This is the clearest path to assuring a reliable supply to customers. A prioritized master capital investment plan can provide the roadmap.

Project Risk Register

Project Name	MLGW Condition Assessment
Service Line - Water	Drinking Water Utility
HDR Employee	Tippey, Anderson, Guffey
Date	Sept 30, 2019

	Impact				
Frequency	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Risk Severity	
Low - Monitor and periodically assess	1 to 4
Medium - Proactive mitigation actions necessary	5 to 10
High - full mitigation plan -escalate to manager	11 to 25

#	Risk Category	Risk Statement: ASSET AFFLIATION	Risk Statement: Description	Risk Statement: Consequence	Type	Probability (1,2,3,4,5)	Impact (1,2,3,4,5)	Exposure	Mitigation	Contingency & Triggers	Risk Owner	Actions Taken	Date Last Review	Date Next Review
Unique risk ID			Describe the risk, and capture the "likely cause" of the risk. Be detailed enough so that you can start forming mitigation plans.	Capture the result of the risk, should it happen. Relate to project critical success factors or MSD business objectives. If the consequences cannot be mitigated, you will have to dealt with them in a contingency plan.	Cost, Schedule, Regulatory, Other	Estimate of the probability the risk will occur (1 = highly unlikely, 5 = almost certain) .	Estimate of the amount of impact or severity of the risk.	Probability x Impact. Once all risks have been entered, sort by this column to identify your biggest risks.	Proactive plans to lower the probability or to lower the impact ahead of time. It may require a more detailed plan written up separately.	Identify what would have to be done if the risk were to become reality, and how you would recognize that action is required. This may require a more detailed plan documented separately.	Identify who is responsible for tracking this risk and its changes in probability and impact.	Identify what has been done, either to avoid or mitigate the risk		
Condition Assessment Risks														
CA1	Priority	Pumping Stations	Pumps age and out of service. During site visits, roughly 25% of all high service pumps were currently out of service and another 20% were under duress or hydraulically challenged. Pumps are typically original installation and subject to increasing maintenance.	Without a programmed upgrade or replacement, more frequent service interruptions are forseeable from current pumps as more maintenance or repair issues arise.		4	3	12	Defined High Service Pump Replacement or Installation of new HSP on sutiable reservoirs					
CA2	Priority	Pumping Stations	Related pump systems (vacuum prime, VFDs, etc.) are exhibiting increased maintenance or outright failure	Critical system components are in various states of performance. Some systems are the reason for pump being out of service. Deteriorating conditions will result in more pump issues		5	3	15						
CA3	Priority	Pumpng Stations	A significant percentage of filter control and isolation valves at many pumping stations are inoperable or leaking. Valve holding and control are impacted leading to concerns about facility control	Valve reliability issues will impact operations and require additional manpower and maintenance to overcome the increasingly frequent service and delivery issues at pumping stations		4	3	12						
CA4		Facility Resiliency	Resilient facility capacity, specifically at Shaw, but generally at all facilities does not match the rated capacity. This results in gaps between expectation and reality for a pumping station output.	Out of service wells or equipment places impacts the delivery capacity of the pumping station and places additonal service burden on remaininging equipment increasing the probability of		4	3	12						
CA5		Equipment Repair	All pumping stations still rely upon original installation pumps to deliver capacity. These pumps are between 30-80 years old. Historically, MLGW has performed many repairs in-house and staff indicates outside vendors are expensive and custom-type repairs. Loss of internal expertise to perform appears to lead to greater mechancial vulnerability and more pumps out of service.	Older assets are more expensive to service and require repair more frequently. This will lead to increasing maintenance costs system-wide and impact the ability to meet other asset needs.		4	3	12						
CA6		Maintenance Tracking	Regular practices were discussed during our visits. One possible impediment to the prioritized repair of faciliteis is the absence of an effective CMOM platform. System ticketing of repairs, etc. is not user-friendly or customized to the water application leading to reduced usefulness and adherence to the tool.	Communication regarding the necessary maintenance work and its prioritization may not be getting identified, tracked and performed as expected within the organization.		3	3	9						
CA7		Pumping Stations	Media in filters at most facilities is overdue for repalcement. Several have lost media. This is a regulatory and water quality risk.	Filter media is key part of treatment approach and needs to be replaced roughly every 15-20 years to assure that it is serving as expected and preventing contaminant intrusion.		3	3	9						
CA8		Puumping Stations Electrical	Nearly all Pumping Stations utilize original construction electrical switchgear. This equipment has evidence of corrosion and can potnetially impact performance and safety. From our experience, availability for 2.4 KV parts can be challenging requiring a premium surcharge on equipment.	Not an immediate risk but more program-level. System maintenance and replacement costs are likely higher than more common equipment.		4	2	8						
CA9		Booster Pumping Stations	Noted during inspection that 8 booster pump stations had only one pump in service. Some of these utilize nearby BPS for back-up. This cuts the reliability...	Potential impacts to the reliability of delivery in distribution system. A model review is needed to determine severity of interruption.		4	2	8						
Operational Risks														
OC1		Well Capacity	No of operating wells at most of the plants has been reducing in recent years as several were taken out of service and not replaced. Capacity and reliability risk if replacement pace does not increase. As an example, Lichterman has 1 operating well with one in development. All others are 30+ years old. Mechanical failure could take the pumping station off line.	Source of supply adequacy is crucial to delivering services to the community. Multiple active and sound wells are needed to avoid disruption of delivery capacity in the event of contaminant intrusion or mechanical issue.		4	4	16						

		Risk Statement				Probability	Impact						Date Last	Date Next
#	Risk Category	ASSET AFFLIATION	Description	Consequence	Type	(1,2,3,4,5)	(1,2,3,4,5)	Exposure	Mitigation	Contingency & Triggers	Risk Owner	Actions Taken	Review	Review
Unique risk ID			Describe the risk, and capture the "likely cause" of the risk. Be detailed enough so that you can start forming mitigation plans.	Capture the result of the risk, should it happen. Relate to project critical success factors or MSD business objectives. If the consequences cannot be mitigated, you will have to dealt with them in a contingency plan.	Cost, Schedule, Regulatory, Other	Estimate of the probability the risk will occur (1 = highly unlikely, 5 = almost certain) .	Estimate of the amount of impact or severity of the risk.	Probability x Impact. Once all risks have been entered, sort by this column to identify your biggest risks.	Proactive plans to lower the probability or to lower the impact ahead of time. It may require a more detailed plan written up separately.	Identify what would have to be done if the risk were to become reality, and how you would recognize that action is required. This may require a more detailed plan documented separately.	Identify who is responsible for tracking this risk and its changes in probability and impact.	Identify what has been done, either to avoid or mitigate the risk		
OC2		Key Facility Resiliency	Collective water resiliency of all pump stations considered togther meets today's needs but lack of facility -level resiliency at key stations (Shaw) is problematic - Shaw has 2 back-up generators, 3 high service pumps (out of 6) out of service a limted back-up approach.	Some key MLGW pumping stataions (Shaw most notably) have only a partial back-up in the event of total failure at the pumping station. Impact on residents in this service zone could be significant dependig on the nature of the event. Collective processing and pumping capabilities won't be useful.		4	3	12						
OC3		Growth Area Supplies	Ability to reliably serve new areas (Riverport, North County) if key facilities (Allen, Davis, Morton) are offline is not known.	Memphis demand growth areas don't match up with areas of excess treatment and pumping capacity. Infrastructure.is needed to provide resilient supplies to these areas of futre growth.		4	3	12						
OC4		Standard Processes	Need valve operation plan for maintenance staff - exercising valves is critical to understanding reliability and effectively controlling the system.	Valve operation is important to understand which valves can be relied upon in difficult times. Without it, small issues can become big problems.		4	2	8						
OC5		Renewal Processes	Valves determined to be critical for control of the pumping stations or distribution system should be funded and installed. Prioritize by criticality.	Same as above for valves that are determine to be unreliable or inoperable.		3	2	6						
OC6		Renewal Processes	Electrical maintenance plan including replacement of equipment and frequency	MLGW is highly dependent on electrical and instrumentation systems (central operations) and knowing the condition, operating deficiencies and probability of failure is important		3	2	6						
OC7		Operational Approach	Use of Central operations requires SCADA/plants to be sound and working - digital system component life is 10 years - must invest to assure performance.	Mistakes - communication or technological - can result in loss of service to customers		3	3	9						
OC8		Operational Approach	Pumping station production is operated by a system operations technician and not a licensed operator. Operators visit plants daily to confirm or adjust chemicals, etc. Typically one person is responsible for treatment and production in our experience.	Coordination of activities is important under this approach. Lack of coordinated approach can lead to mistakes in operations.		3	2	6						
OC9		Operations Capacity	Workforce risks evidenced by previous maintenance risk items. The number, age and condition of the numerous plants requires a pro-active maintenance approach. Staff levels do not appear to match this need.	Resources need to match the needs to assure viability of the utility. Run to fail approach will minimize immediate costs and cover lack of staffing but will result in more severe and expensive service failures that will be harder to recover from.		3	3	9						
Safety Risks														
S1		Electrical Safety	VFD Cabinets at Most plants are not housed in air conditioned spaces. Heat generated during use is now being mitigated buy opening cabinets and blowing a fan on gear. Safety tape is located nearby	Obvious safety and equipment failure risk. Potential safety risks include Arc Flash. Electronic gear can easily be damaged from particluates caught up in cooling fan		4	3	12						

4.6.5 Level of Service and Protection

Level of Service (LOS) to the customers is a direct reflection of the quality of the product and the reliability of the service. Our review of water quality data provided by MLGW and discussions with staff have not indicated any current issues that require new initiatives. A couple of notable observations include:

- MLGW is currently investigating some wellfield issues with results yet to be finalized. The findings from this investigation will be addressed in future capital plans
- Filter media upgrades need to be a prioritized capital improvement at plants with media older than 25 years. This physical barrier is important and helps assure a high level of water quality delivered to the end user.

Reliability of supply is the second element to meeting LOS expectations. HDR's review of reliability of supply has found a mixed bag of information. Avoided maintenance and capital investment has allowed the individual pumping stations and some booster pump stations to become more vulnerable to a service interruption (partial or entire facility). However, the presence of ten plants mitigates the overall system impact to a single event. In effect, the system has collective reliability while individual areas (some critical) exhibit significant vulnerability.

The remedy to this is a prioritized capital investment plan that identifies:

- Long term assets to be maintained
- Assets that can be decommissioned once investments are made and full reliability restored locally.
- Implementation strategy to assure program delivery and asset renewal

Maintaining LOS is a struggle in today's utility environment but smart and programmed capital investment for facility renewal is needed to avoid the negative consequences that arise from service outages.

Chapter 5 Recommendations

Major investments in infrastructure rehabilitation, renewal, and replacement were limited by the desire to keep rates at or below industry averages. In the face of limited resources, MLGW staff still continue its excellent record of regulatory compliance and day-to-day operation and maintenance of electrical, gas, and water infrastructure. However, the result of deferred investment on infrastructure renewal and replacement in the aging systems has now created urgent needs for investment to meet MLGWs continued reliably utility service.

This report recommends taking immediate action to begin implementing improvements to the systems. To do so will require a significant investment in more capital expenditures. If the board and the city are unwilling to accept such investments many important projects and programs will be deferred. Doing so will almost certainly result in infrastructure failures, an increase to the overall implementation cost, and ever more likelihood of a failure that could result in serious consequences for residents, customers, and businesses in Memphis.

Neglecting the essential system is no longer an option – serious failures are or on the brink of occurring at an increasingly rapid pace and schedule. The ability to successfully apply temporary repairs rather than permanent fixes diminishes significantly with each passing day.

We believe that the recommendations presented in this document are essential to maintaining reliable facilities that will allow MLGW to fulfill its responsibility for safely delivering services that create and sustain superior customer experiences and make MLGW a trusted provide of exceptional customer value in the communities we are privileged to serve.