Asset Management Practices for Buried Piping at Nuclear Power Facilities

A Project and Report for the Civil and Environmental Engineering Department at Virginia Tech

Luke Mayotte

11/20/2013

Committee:

Dr. Sunil Sinha

Dr. Michael Garvin

Dr. Gerardo Flintsch

Contents

A. Introduction 3

I. Asset Management 3

II. Nuclear Power 6

B. Motivation for Research 8

C. Research Plan and Hypothesis 9

D. Research Method 10

I. Overview 10

II. Establishment of Recommended Practice 11

a) Literature Review 12

b) Literature Recommended Practice Summary 28

c. Verification of Recommended Practice 30

III. Establishment of Industry POCs 32

IV. Collection of Industry Response 32

V. Qualitative Industry Analysis 32

a. NPP "A" Review 33

b. NPP "B" Review 35

C. NPP "C" Review 37

d. Review of Industry Practice Results 40

VI. Conclusions 41

F. Final Conclusions and Impact 42

G. Future Research 44

Appendices:

A. Research Objectives and Schedule
B. Bibliography
C. Contact List
D. Sample Asset Management Questionnaire for POCs
E. Overview of Current Buried Piping Asset Management Practices and Recommendations/Requirements

Abstract: Infrastructure asset management is a system for managing assets that promotes optimization of time, resources, and technology to achieve maximum effective life of the asset for minimum cost. The nuclear power industry has begun to implement such programs at their facilities for buried piping system in order decrease leak occurrences and establish effective management practices for extended life. This report looks at what asset management strategies have been required and recommended for nuclear power plants and what asset management practices are already in place within the industry. Three sources of relevant industry guidance were reviewed and three industry contacts were established to determine practice. All results were compared to a known framework for asset management to determine what practices and recommendations could be considered asset management. It was determined that, while some areas of asset management are lacking, overall industry practice and requirements fulfill the majority of an effective asset management program. Areas for future research are outlined.

A. Introduction

I. Asset Management

Asset Management has become an important area of study influencing U.S. infrastructure management and development. As U.S. infrastructure begins to age, it has become necessary to re-evaluate how it is cared for and decision making processes regarding upkeep. Given the state of U.S. infrastructure, having effective management practices will be critical to maintaining and improving level of service while mitigating cost.

Asset Management is defined by the Environmental Protection Agency as a “continuous process that guides the acquisitions, use, and disposal of infrastructure to optimize service delivery and minimize costs over the asset’s entire life.” (Sinha 2013) In essence, it is the consideration of optimizing the sustainable life of an asset from commissioning to decommissioning. When a piece of infrastructure is commissioned, it is at the peak of its performance and level of service. As it ages, this level of service will inevitably drop, either physically by means of corrosion, wear, and degradation, or through its usefulness as demand changes and the asset’s service level remains the same or begins to decline. Eventually, this piece of infrastructure will reach a failure point, again either through physical or useful means. While some assets are designed to run to failure, in the case of some major U.S. infrastructure, this is not an option. We rely heavily on our infrastructure systems and they must be maintained. This is where rehabilitation and/or replacement come into play for asset management.

To prevent failure of an asset it must either be continually rehabilitated, or preemptively replaced before it reaches failure. The decision of what method (repair, replace, or run to failure) will be the most cost, time, and resource effective is the essence of asset management.

The decision maker must be able to effectively determine when to act and what actions will be the most beneficial to economic prosperity, environmental stewardship, and social responsibility. The combination of data collection, information processing, and decision making optimization allow for the effective and efficient management of a system of assets, and effective optimization of available resources. Figure 1. shows the basic structure of effective asset management as described above (Sinha 2013). As part of a thorough asset management program, a framework must be established around which to structure asset management The elements of an effective asset management program, as describe in (Sinha 2013) include; asset inspection and evaluation; condition assessment; asset deterioration modeling; decision support; means and methods of repair/replace/renew/maintain activities; and prioritization for future analysis. These elements work in a continuous feedback loop, centered around a structured asset management program, optimally based with a Global Information Systems (GIS) software for enhanced awareness and easily updated and prioritized information. The structure for this asset management framework can been seen in Figure 2.

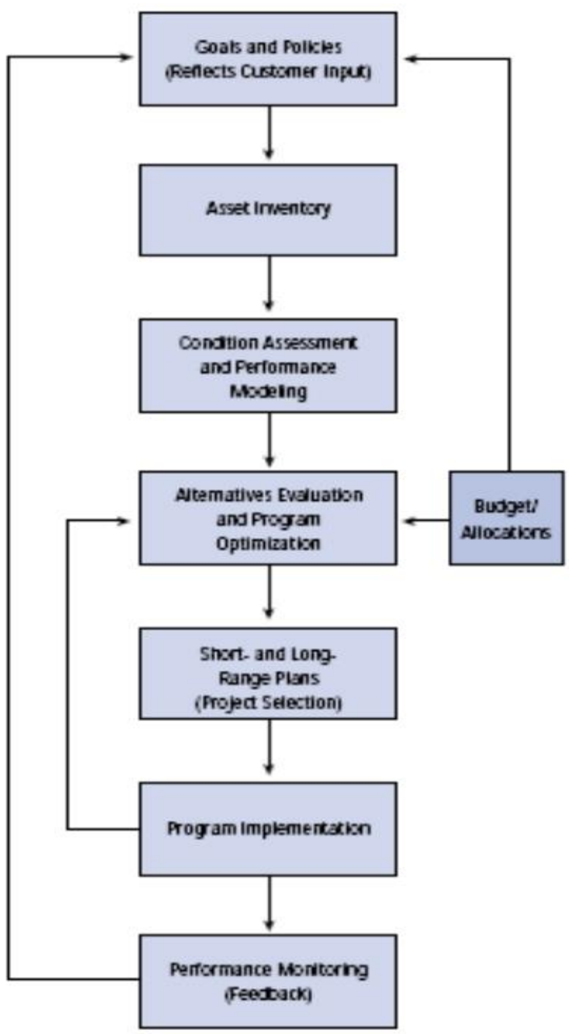

Figure 1. Asset Management Structure. Adopted from *Asset Management Primer*, Federal Highway Administration 1999

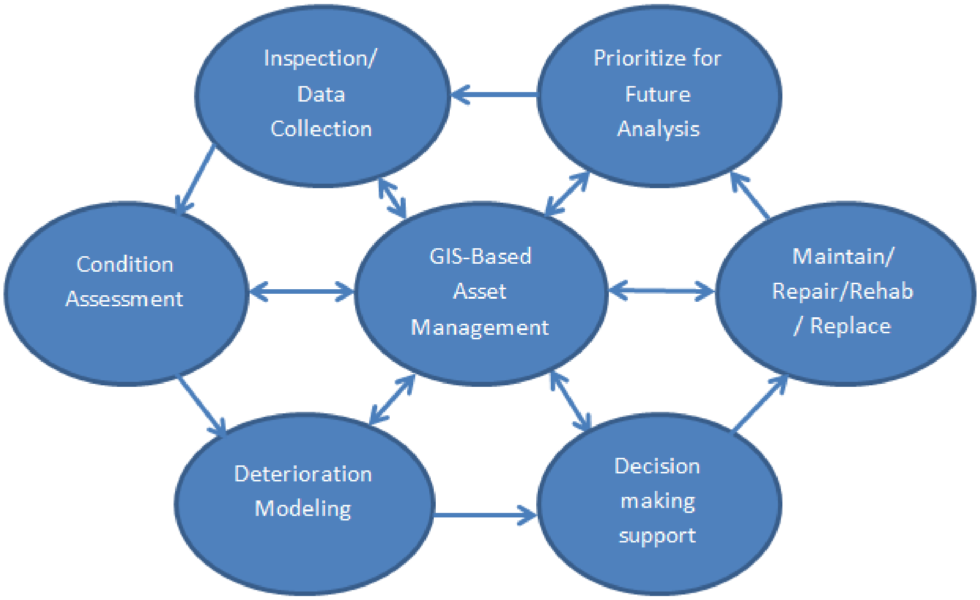

Figure 2: Framework for an Effective Asset Management Program. Adopted from (Sinha 2013)

Each aspect of the feedback loop has a purpose and is composed of individual items. Inspection and data collection may be composed of elements from new and established inspection techniques, continuous monitoring technology, and data collection strategies and software. Condition assessment will be composed of analysis of the collected data and inspection results in order to assign a condition to each asset. These condition ratings will generally be on a scale, establishing which assets are at the highest risk of failure, and which are at less risk.

Deterioration modeling is then used to determine the possible modes of failure and predict timeframe, using elements such as finite element analysis, failure mechanism determination, and laboratory testing. These elements are used for decision support as to the proper and most prudent action to take, in addition to elements such as life cycle cost analysis, budgetary consideration, and the possible consequences of failure. While the decision as to what action to take to effectively maintain assets cannot be made for the user, these elements are essential to help the user/manager weigh options and make an informed, prudent, and savvy asset management decision. When a decision to maintain/repair/rehabilitate/replace an asset has been effectively made, the program must also contain proper means and methods as to how to proceed with these actions. This includes the use of standardized and approved practices, while continuing to adopt and utilize newer, approved technologies and practices. After a supported management decision has been made and action taken there must be process feedback in order to prioritize future actions. This includes recounting the asset management process and considering how to proceed in the future (Sinha 2013).

Each asset will need to be considered in this asset management loop, and the greater the amount of information available for each asset, the better the practice will become. Managers will be able to reference past action and pair them with the other decision making support systems discussed to continue to improve processes and make the system more effective. Through these means, the user will be able to reduce waste and optimize infrastructure management actions.

II. Nuclear Power

One aspect of U.S. infrastructure that has begun to show signs of the need for enhanced asset management practices is nuclear power. While nuclear power plants (NPPs) are highly regulated due to the extreme consequences of failure, it has become evident that some aspects of asset management for NPPs are not as comprehensive, due to the less critical nature of some systems.

NPPs in general are a complex network of systems, components and processes. The development of nuclear power can be traced as far back as the Manhattan Project and WWII, attempting to harness the power of energy released in a fission reaction for extremely powerful weapons. When WWII ended, this area of research gave way to new developments in using these same fission reactions to provide power through steam generation. The achievement of a safe and sustained reaction by means of control rods and cooling would release great amounts of energy in the form of heat. This heat could then be utilized to produce steam, moving power-generating turbines. Between the 1950s and 1980s, breakthroughs in nuclear research gave way to the development of over 10 kinds of NPPs, including graphite reactors, light water reactors, heavy water reactors, and fast breed reactors (among other), each with their own sub-sets of variations. (Wood 2007; Lish 1972)

While the intricacies of these stations vary greatly, the principle components are essentially the same. Each contains at least one of the following components:

- Contained Reactor Vessel
- Primary Coolant/Feed water system
- Steam Turbine and Generator
- Residual Heat Removal System
- Coolant Purification System
- Spent Fuel Storage
- Radioactive Waste Handling Facility
- Closed Loop and Nuclear Service Water Systems
- Emergency System

- Ventilation System

Within these major systems of NPPs, constant asset management is essential, because the consequence of failure is extreme. All essential systems require redundancy with emergency backup in order to prevent loss of control of the fission reaction or escape of radioactive materials (Lish 1972). That being said, it has recently come into focus that numerous subsystems have lacked the same amount attention the critical systems receive. Beneath the ground at every NPP is buried piping, sometimes miles in length, generally associated with the Closed Loop and Nuclear Service Water Systems, but also feeding over 40 systems such as fire protection, fuel and lubrication oil, off gasses, and hydrogen among others (NRC 2011; EPRI 2010).

A significant issue facing nuclear power today is the management of these buried (beneath soil) and underground (within a subsurface housing) utilities; specifically the piping and tanks containing closed loop cooling water and service water. These vital components of the overall system are crucial to ensuring that cooling water is supplied to secondary and tertiary cooling systems, such as residual heat removal and cooling of turbine bearing oil (Lish 1972). While many features of a power plants are readily accessible for inspection and maintenance, these equally important utilities are buried out of sight or contained in subsurface vaults. Therefore, the corrosion and degradation of these utilities is not easily observed or monitored, and the results of these challenges are beginning to reveal themselves.

The majority of these secondary systems contain normal or below nominal levels of radiation and present little to no threat to the environment if a leak occurs. However, there is a small percentage of piping systems that do transport water containing slightly elevated levels of the radioactive isotope tritium, and are therefore present a more notable concern. Though the Nuclear Regulatory Commission has deemed thus far that such leaks have not presented a notable threat to health and public safety, it is still an area of concern for safe overall plant operation (NRC 2013).

The control and monitoring of this piping is challenging for a number of reasons. One of the primary contributors, and the most obvious, is the location of the pipes. In order for these pipes to be properly located and inspected or repaired, they must be either unearthed or located within a vault, tunnel or trench. The surrounding site itself may also present additional challenges given the unique geotechnical, chemical, of structural considerations of each facility.

Additional challenges in properly managing the aging of these utilities is presented by the variation of piping and pipe protection material. Pipes are generally composed of one, or several materials, ranging from concrete, steel, PVC, asbestos, iron, or copper, and can range in size from a diameter of 2 inches to 10 feet. The various methods of protection may also alter the rate of degradation to varying degrees. The two main types of protection are Primary Protection and Cathodic Protection. The primary protection will generally be a coating or layer that is designed to prevent corrosion and will wear with time and earth disturbance. Cathodic protection historically has been provided by one of two mechanisms. A sacrificial anode made of a material with higher reactivity than the pipe material may be attached to the pipe and will degrade over time, creating an electrochemical corrosion cell electrically preventing the corrosion of the pipe material. Alternatively, a direct current will be channeled through the material serving the same purpose of protecting the piping material from corrosive electro-chemical reactions (EPRI 2010).

The mechanism of degradation for these utilities is twofold. The outside diameter of the pipe (OD) is exposed to the soil and groundwater which lead to its degradation. The inside of the pipe, or inner diameter (ID) is exposed to moving medium, whether it be water, fuel etc., and also contributes to the gradual degradation of the pipe. Because the piping system or tanks in question lie either beneath soil or within a subsurface housing such as a vault or tunnel, generally the only way to observe the amount of corrosion and degradation is through either destructive evaluation or non-destructive evaluation. Destructive evaluation would consist or removal of a piping system or segment for inspection and testing to determine failure point. Non-Destructive testing is far more common due to its lack of interference with system function, though methods for accurate non-destructive evaluation of piping systems are limited and additionally cumbersome, including excavation of the piping segment and in-place visual analysis and ultrasonic evaluation.

The partial or complete shutdown of the plant is a costly and time consuming process. Additionally, in the event that a leak is detected in one of these pipes, the ability of the managers to locate and repair the leak is not quick, easy, or inexpensive. These facts, coupled with the negative potential impacts of radioactive material being released into the groundwater if leaks go undetected, present the need for a comprehensive and effective asset management plan to ensure the safe and effective function of nuclear underground utilities at optimal cost.

B. Motivation for Research

The issue of groundwater contamination due to leakage in buried piping began as early as the 1980's, but was more formally recognized in September 2006 with the NRC's release of the Liquid Radioactive Release Task Force Report. This came as a response to reports of tritium contamination in groundwater at over 7 NPPs between 2004 and 2007 (NRC 2006). When this issue gained notoriety it quickly became evident that immediate and practical solutions needed to be put in place. The number of reported leaks from 2004 to 2009 grew at a significant rate, partially due to the increased level of attention and inspections these underground pipelines were receiving. In 2009, NRC Chairman Gregory Jaczko officially tasked the NRC with addressing the management practices of buried piping. According to the NRC, nearly all NPPs instituted formal programs relating to the management of buried and underground piping systems and the level of attention directed towards pipe health, protection systems, and reporting has steadily grown (EPRI 2009, NRC 2011).

Along with individual management programs, the industry as a whole has begun to implement regulation, directed primarily from the NRC. From 2009 to 2011 several new initiatives and programs were implemented in part by the NRC, the Electric Power Research Institute (EPRI), Nuclear Strategic Issue Advisory Committee (NSIAC), and the Nuclear Energy Institute (NEI). These included the Buried Piping Integrity Initiative (NSIAC), The Buried Pipe Integrity Group (BPIG, EPRI), the Aging Management Program, and Guidelines for the Management of Buried Piping Integrity (EPRI) among others. The majority of these regulations and programs are directed towards the management of Safety related piping, attempting to provide a reasonable level of certainty that hazardous leaks can be avoided, prevented, or mitigated. These initiatives have subsequently led to the monitoring of implementation and research, provided by EPRI, NEI, NSIAC, into new and better methods of aging management, included inspection, maintenance, repair, monitoring and record keeping (EPRI 2009; NRC 2010, NEI 2010).

In order for NPPs to maintain operation, they must undergo a License Renewal Process, requiring them to maintain compliance with current regulations. These regulations are those dictated by the NRC, and are based on the research and recommendations of the EPRI, NEI, and NSIAC. Among its many responsibilities, The Institute of Nuclear Power Operations (INPO) is responsible for the evaluation of the regulations that are set forth by the NRC, and provides feedback to the NSIAC and NEI. Additionally, American Nuclear Insurers (ANI) conducts inspections of NPPs and reports findings and recommendations to the NEI. This collaborative effort enables the NRC to enact regulations based on research, field testing, and evaluation of current practices.

As the industry continues to implement its plans to improve management practices, it is evident that effective asset management is necessary to optimize available resources and preserve the aging infrastructure. A framework for asset management as previously presented in this paper has the potential to affect such a program if implemented, but before that can occur, it is necessary to understand what the state of current practice is. With all of the new management direction and recommendation being provided by the industry, the question is presented; what elements of asset management are being required and recommended by the industry, and what elements of asset management are already in practice within the industry?

C. Research Plan and Hypothesis

The goal of this Project and Report was to evaluate current asset management practices both recommended by the oversight and research organizations such as the NEI, NRC, and EPRI, as well as current industry practices at actual NPPs. While it is clear that this issue is of great importance to the NRC and other oversight organizations it is not clear exactly what elements of asset management are currently in practice and in literature. The plan for research was to first evaluate some of the primary documents set forth for guidance and regulation of buried piping management programs in the nuclear industry and identify what aspects of asset management they address from the viewpoint of the asset management framework presented in the report. After the review of literature, the next step was to establish what industry practices are currently in use with regards to asset management for buried piping, again from the viewpoint for the framework presented in this report. After both the recommended/required and industry practice asset management strategies were determined, the final goal was to draw conclusions as to where recommendations and current practice differ, and what aspects of asset management may be lacking all together.

For this project, the hypothesis was made that both industry guidance and regulation, as well as the current practices would have elements of the framework for asset management presented in this paper. Since the NRC has placed such recent emphasis on this issue, it was presumed that NPPs would have established written and approved guidelines for managing and monitoring buried piping, and that industry guidance for management would also contain significant strategies for asset management. Since this issue has not been an area of significant importance to regulatory organizations such as the NRC for the extent of the life of these power plants (as much as 40 years, in some cases) it will take time and resources to completely change the way asset management is handled at these facilities, and so it was also hypothesized that asset management programs and strategies will not completely coincide with the framework for asset management utilized in this study.

D. Research Method

I. Overview

This project consisted of five general research objectives, each with individual sub-tasks. See Tables A.1 and A.2 in Appendix A for a breakdown of research goals and sub-tasks, and a detailed schedule for the project. The following goals were completed:

- R1 Establishment Recommended Practice
- R2 Establish Industry Points of Contact
- R3 Collection of Industry Responses
- R4 Establishment of Industry Practice
- R5 Analysis and Conclusions.

II. Establishment of Recommended Practice

In order to establish the recommended practice, a literature review of applicable buried pipe management programs presented by the NRC, EPRI, and NEI was conducted. The following documents were selected for review:

- NEI Underground Pipe and Tank Integrity Initiative
- EPRI Recommendations for an Effectively Program to Control the Degradation of Buried and Underground Piping
- EPRI Life Cycle Management Planning Sourcebooks – Volume 2: Buried Large-Diameter Piping

Though many documents exist concerning the management of buried and underground piping, these are some of the primary guiding resources of recommended industry practice. An additional source of literature, the NRC Generic Aging Lessons Learned (GALL) Report was considered for analysis, as it is the primary document for license renewal requirements for NPPs, but all information from the GALL report was covered as part of the EPRI Life Cycle Management Planning Sourcebook for Buried Large Diameter Piping.

These documents were respectively reviewed and their programs were evaluated from the perspective of the framework for an effective asset management program presented in section A of this report (See Figure 2). In order to compare the guiding documents to the framework for asset management, each of the 6 categories of the framework were considered when reviewing the guidance. To establish that the reviewed material did indeed fulfill one of the six categories, the guidance documents were looked at from a qualitative perspective. In order to meet the requirement, the guidance needed only display some evidence of the discussed categories for asset management, and not necessarily discuss them by name or conform perfectly to the framework.

That being said, there is a significant amount of flexibility within this evaluation method. The goal of this research was to investigate and evaluate asset management recommendations, regulations, and practices of the industry, and not to evaluate an overall asset management program as it conforms to the framework. The framework serves only as a reference for determining asset management practices, and not as a set requirement of either "yes" conforming to the framework, or "no" not conforming to the framework.

When this literature review was completed, it was additionally verified by an Industry expert to establish that these documents are the guiding resources for recommended industry practice.

a) Literature Review

1. NEI 09-14 Rev. 1, Guidelines for the Management of Underground Piping and Tank Integrity

Review

Starting in 2009 with the Buried Piping Initiative, and subsequently with the 2010 Underground Piping and Tanks Integrity Initiative, the NEI has begun implementing a plan for the evaluation, trend documenting, and standardization of management practices. The guiding document for the establishment of a management plan was the Guidelines for the Management of Underground Piping and Tank Integrity. This document establishes the requirement for fulfilling the Underground piping and Tank Integrity Initiative established by NEI and NSIAC based on a five step milestone process for all NPPs:

1) Procedures and Oversight
2) Prioritization
3) Condition Assessment Plan
4) Plan Implementation
5) Asset Management Plan

Milestone 1 is the establishment of procedures and oversight. This milestone was set for June 2010 and contained several criteria. First is for all NPPs to ensure they understand their roles and responsibilities including the accountability of senior level leadership. Subsequently, a document would be developed delineating program guidelines and implementation procedures. It states that EPRI, NEI and others would provide support for the establishment of this program as well as oversight for the distribution and implementation of the program in the industry, documenting progress, commitment, experience and learning, and progress with technology development.

The second milestone for the initiative, set for December 2010, is the prioritization of all buried piping segments by individual NPPs. This segment was formerly known as Risk Ranking, though at the time of distribution not all utilities had Risk Ranking programs to start the prioritization process. The purpose of this prioritization is to determine the risk and consequence of failure, and prioritize piping segments for future consideration. This ranking is based on several criteria including:

- Age
- Relevant industry operating experience
- Pipe flow rate
- Tank volume
- Contents
- Soil condition and chemistry

- Plant operating history
- Leakage history
- Internal corrosion consideration
- Coating and lining
- Wet or alternately dry

This information will be compiled in a database and a means to update later risk ranking programs would be established.

The third milestone is the establishment of a condition assessment plan by Dec 2012. All NPPs are required to have a plan to establish the integrity of all buried piping. This plan needs to include the identification off all piping segments, potential inspection techniques, a schedule for inspection based on the prioritization/risk ranking, and assessment of all cathodic protection systems where applicable.

After the establishment of this plan is the fourth milestone; Implementation of the condition assessment plan beginning no later than June 2013 and completed by June 2014. This inspection plan will establish a baseline for future inspections and determine the current condition of all piping segments.

Once this inspection process is completed, results are documented and used to establish an asset management plan, set forth in the fifth and final phase. This asset management plan is instructed to be implemented prior to 31 Dec 2014 and should be comprised of the following elements:

- Inspection Plans
- Planned Maintenance Activities
- Plans for Repairs
- Anticipated Replacements

The development of this plan is through the categorization of each buried line based on prioritization, contents, important to plant function, cathodic protection condition, inspection results and operator experience and listed in the following categories:

- Components to be repaired or replaced with a planned schedule
- Components requiring periodic inspection or monitoring with a planned schedule
- Components with low risk, able to run to failure and be replaced as needed (NEI 2010)

<u>Evaluation</u>

When considering the framework for asset management presented in this document, this NEI document can be seen to contain some elements of an effective asset management program. While it does not provide great detail as to the specific aspects of each asset management category, it does acknowledge that further guidance for administering these steps can be found within EPRI and other supporting literature. The categories in which this document displays sound asset management practices include:

- Inspection and Data collection
- Condition Assessment
- Decision Making Support
- Prioritization for Future Analysis

Inspection and Data collection, in addition to condition assessment were the essence of the majority of this plan, and were therefore included. Also included was decision support, due to the implementation of the asset management plan in the fifth step. This asset management plan, though not following the exact framework used as the standard for this report, took into account not only condition and risk of the pipe, but also decision support techniques and prioritization for future analysis

The areas of the asset management framework that were not specifically discussed in the establishment of this program were deterioration modeling for enhanced decision making and specific instruction for implementation of Maintain/Repair/Replace/Rehabilitate actions, though it was noted that safety related (containing or effecting radioactive material) piping and tanks are governed by technical specifications and ASME code. Finally, though an overall asset management plan was discussed in the literature, the GIS system for asset tracking and monitoring was not acknowledged, and the plan for asset management implementation was brief and not detailed. See Figure 2.1 for representation of NEI's program fulfilment of effective asset management elements (Green is fulfilled, yellow = partially fulfilled, blue is not fulfilled).

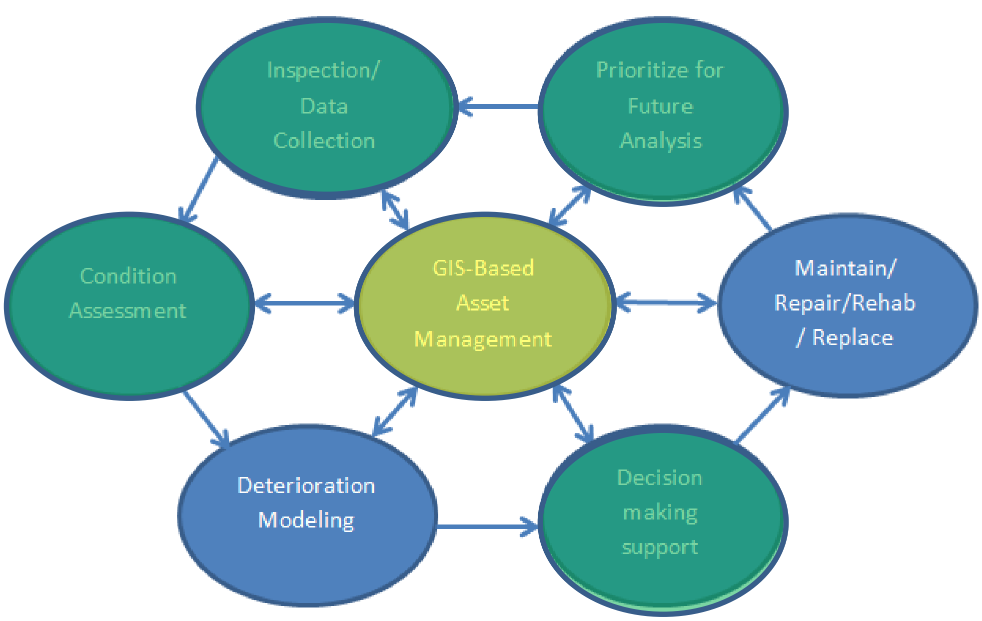

Figure 2.1: Asset Management Program evaluation for NEI 09-14 [Rev 1] - Guideline for the Management of Underground Piping and Tank Integrity.

2. EPRI Recommendations for an Effectively Program to Control the Degradation of Buried and Underground Piping and Tanks

Review

While little academic literature is applicable specifically to the field of aging management in the area of buried and underground utilities specifically for NPPs, The EPRI has compiled recommendations and procedures delineated by the NSIAC and NEI to NPP owners. These guidelines are intended to aid in the creation of an asset management program specified in NEI 09-14 [Rev 1] that will be used to attempt to reduce the number and type of leaking pipes to an acceptable minimum. The program set forth by the EPRI is similar in nature to the NEI 09-14 [Rev 1], though its purpose is for guidance, aiding regulation compliance, rather than for regulation itself.

There are six elements to the EPRI program which help NPP operators to prioritize inspections, make run-or-repair decisions, choose repair techniques, and take action to reduce and mitigate piping failure. The six steps are as follows in Figure 3:

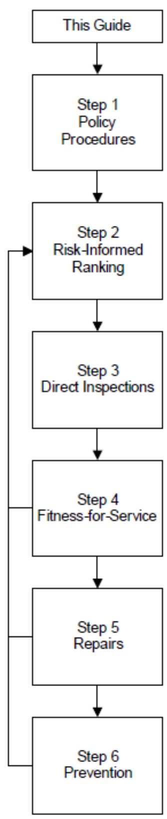

Figure 3: EPRI Recommendations for an Effective Program to Control the Degradation of Buried and Underground Piping procedure flowchart

These steps are similar to the process dictated by NEI 09-14 [Rev 1]. In fact, this document displays how it relates to the procedures set forth in NSIAC's Underground Piping and Tank Integrity Initiative. See Figure 4.

NSIAC Action	Recommendation Step	Implementation Dates	
		Buried Pipe	**Underground Piping & Tanks**
Procedures and Oversight	Section 1 - Procedures and Oversight	June 30, 2010	Dec 31, 2011
Risk Ranking / Prioritization	Section 2 - Risk Ranking	Dec 31, 2010	June 30, 2012
Inspection Plan / Condition Assessment Plan	Section 3 - Inspection	June 30, 2011	Dec 31, 2012
Plan Implementation	Section 3 - Inspection Section 4 - Fitness-for-Service Section 5 - Repairs	June 30, 2013	June 30, 2014
Asset Management Plan	Section 6 - Prevention, Mitigation and Long-Term Strategy	Dec 31, 2013	Dec 31, 2014

Figure 4: EPRI allignment with NSAIC Underground Piping and Tank Integrity Initiative (EPRI 2010)

Step 1) Policies and Procedures

Much like the NEI 09-14 [Rev 1], this step establishes the objectives, roles and responsibilities, training, schedule for implementation, reporting procedures, continuous feedback, and budget for implementation. It discusses the need for the program, background concerning the programs origin and the program's relationship to NEI 09-14 [Rev 1].

Step 2) Risk Ranking

This step establishes the use of risk ranking as the likelihood of failure vs. the consequence of failure based on several criteria, including but not limited to pipe and soil characteristics, type and condition of the protection system, prior inspections, history of leaks, and analysis of failure modes. Consequence assessment is based on nuclear safety (plant safety), radiological impact, industry safety, environmental damage, and cost. The process followed for the risk ranking procedure is shown in Figure 5. Included in this risk ranking is a full inventory and in-place drawing compilation of all relevant piping segments, which are then confirmed through field survey. The scope is then modified to exclude all inconsequential piping segments that are listed as run-to-failure.

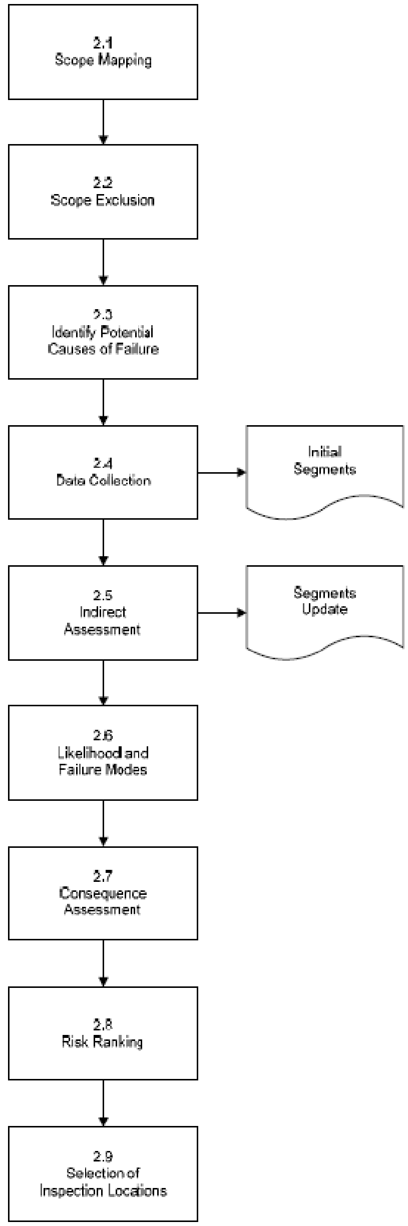

Figure 5: EPRI Risk Ranking Procedures (EPRI 2010)

The remaining piping segments are then considered for their possible causes of failure, including:

- Corrosion
- Erosion
- Internal loading
- External loading
- Mechanical defect
- Occlusion

When all possible potential causes of failure are established, data collection can begin for each piping segment. The collection of this data is based on the potential causes of failure, and will be specific to each piping segment. Each system line will be broken into segments of similar failure probability based on potential cause and data will be collected concerning the potential for these failures to occur. Special consideration is given to prestressed concrete cylinder piping (PCCP), metal piping, tanks, and consequences of failure. Indirect assessments are then conducted for the surrounding area of each pipe segment to evaluate the potential for each failure mechanism to occur. This includes items such as soil analysis, cathodic protection checks, pipe fluid checks, and guided wave inspection. Based on these inspections, a likelihood of failure is established, being either low, medium, or high. Based on these factors and consequence of failure, a risk-ranking is established. The actual ranking of assets can be conducted one of two ways. The primary method employed by the EPRI guidance is the use of qualitative Risk Analysis or use a Risk Matrix shown in Figure 6, comparing the likelihood of failure to the consequence. Additionally, use of software for risk ranking is recommended, though not required.

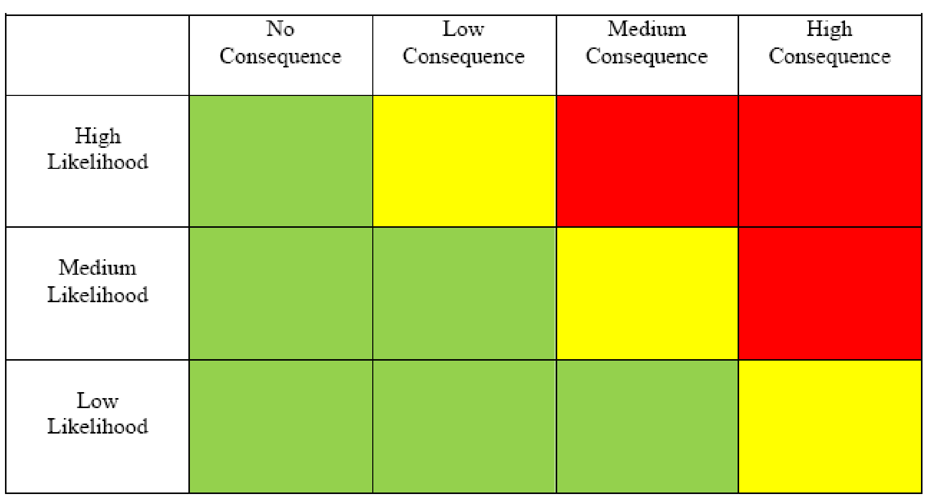

Figure 6: EPRI Example Risk Matrix (EPRI 2010)

Also described is the selection of inspection locations, which should be determined using the risk ranking results, operator experience, and industry experience. Locations that are commonly corroded due to external conditions, such as entering or exiting soil, entering or exiting water, or contact with dissimilar metals should be considered. Additionally any areas with history of corrosion issues should be evaluated.

Step 3) Inspection

Inspections of piping systems are conducted via one of four primary mechanisms shown in Figure 7. Entry or Excavation Non-Destructive Examination (NDE) is the first, and most commonly recognized form of evaluation. Classic NDE requires that the pipe be excavated and inspected, or, if the pipe diameter is large enough, a person or automated machine may enter the pipe to perform an inspection. When conducting this type of evaluation, visual and failure specific testing is generally performed for the protective coating and pipe lining. Evaluation tests include liquid penetrant, magnetic particle testing, ultrasonic testing, and wave guide many other technologies, each with a specific function, advantage, and limitation. Hydrostatic testing can also be performed as a form of NDE and measures the pressure decay of a closed system. In any case, all tests are performed by experienced professionals and thorough documentation is required. As ASME code already calls for pipe inspection, most NPPs will have the resources to implement this step.

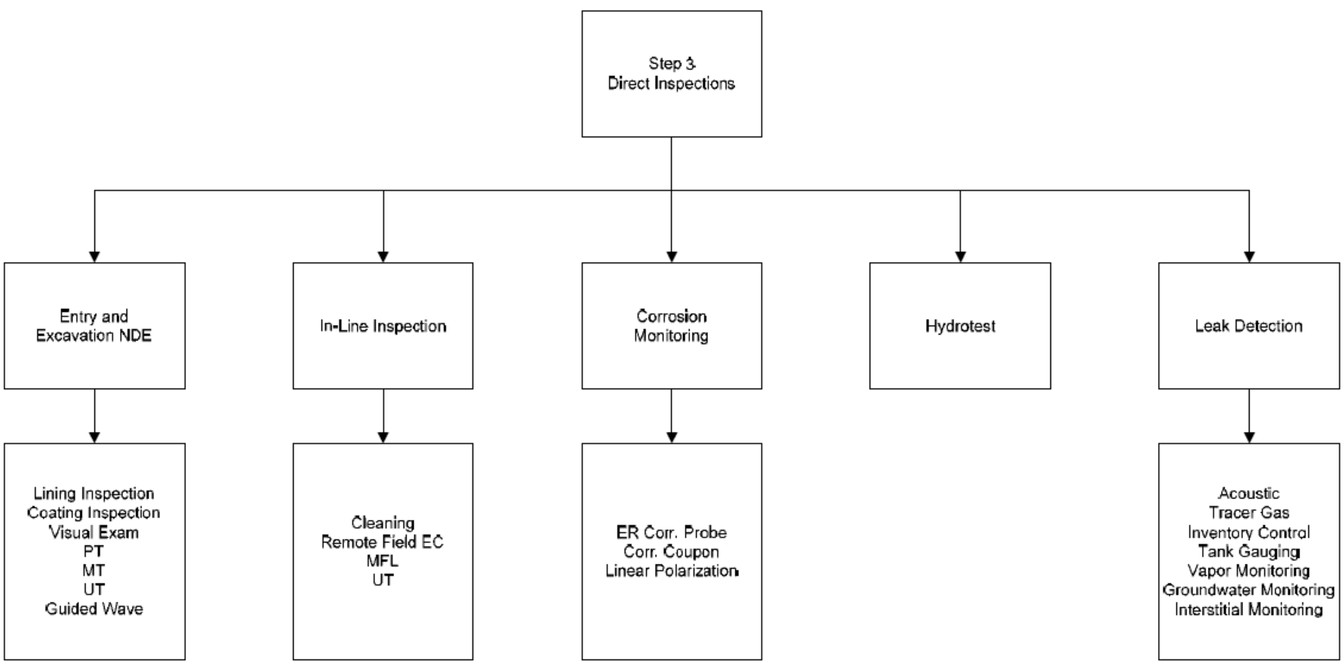

Figure 7: Inspection Techniques (EPRI 2010)

Step 4) Fitness for Service Evaluation

The process for determining if a piping system is fit for service varies for each type of piping material and is based on the design analysis of the pipe. Specific codes have been put in place to determine fit and not-fit conditions. Additionally, some piping systems which have been determined as non-safety related and have low consequence of failure are described as run-to-failure. When making the fit-for-service decision, the condition assessment, code requirement, and pre-determined run/repair status of the pipe must be considered. It is also recommended that a database be maintained of inspection data so that decision aiding models can be created for piping sections. This modeling can help to determine fitness for service and aid in the run/repair/replace decision making process.

Step 5) Repairs

If the decision is made to repair a section of pipe, several factors must be considered, primarily based on piping material and repair location. Repairs for metal piping segments can be grouped as welded or non-welded, and repair requirements differ based on the safety or non-safety categorization of the pipe for each category. Techniques for repair are provided by the American Society of Mechanical Engineers (ASME) code requirements, the EPRI, and the NRC. The technique selected for repair must also be in compliance with NPP specific regulations and requirements. The next step to repair, after selection of the repair technique, is preparation of a repair plan. A repair plan must be completed prior to executing any action and must address the following concerns:

- Effect on system operation and flow conditions
- The effect of repair and repair material on operation and service condition. Also the design life of the repair must be specified and a plan for re-inspection or replacement created.
- The design strength of the repair in comparison to operational loads and potential accidents. This is completed in accordance with specified design code and relevant standards.
- Define fabrication and field installation requirements, as well as repair personnel qualifications, and NDE and pressure/leak testing post repair.
- Post repair operating conditions to ensure they are within repair design limitations.

When the repair or maintenance activity is completed, Risk Ranking should be updated accordingly.

Step 6) Prevention, Mitigation, and Long Term Strategy

Based on the risk of failure assessment, it may be determined that systems experiencing especially high risk of failure undergo mitigation procedures to counteract the conditions causing failure. Measures are specified for the prevention of both ID deterioration and OD deterioration, including water treatment, lining, cathodic protection, and special trench fill, among others.

Evaluation

From the framework standpoint, this program recommendation contained many of the desired elements of an effective asset management program. Inspection and Data collection techniques were extensively discussed, as well as condition assessment via risk ranking and fitness for service determination. Decision making support was present via the fitness for service evaluation, but it was not thorough from a framework perspective. No other decision support techniques were discussed other than risk ranking and fitness for service. Items such as life cycle cost analysis and budgetary considerations come into play when making decisions for maintenance and management decisions. Deterioration modeling for use in decision making support was, as with NEI 09-14 [Rev 1], not thoroughly accounted for. It was mentioned as part of the fitness for service evaluation, but no methods were presented of discussed. Finally, use of GIS for an asset management system was not discussed. Overall, the literature contained elements of an asset management program, but was missing others presented within framework for effective asset management. See Figure 2.2 for framework analysis.

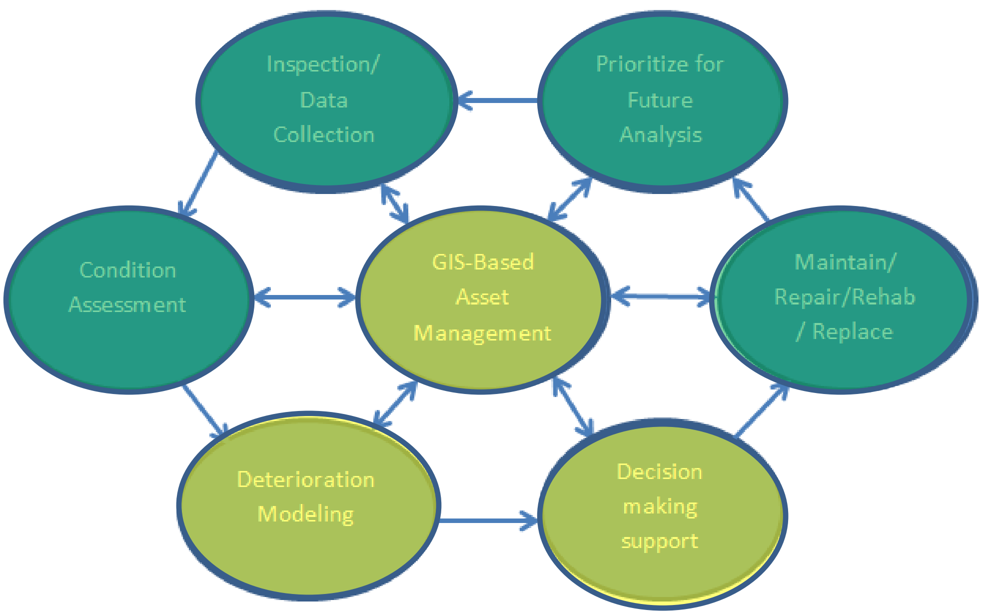

Figure 2.2: Asset Management Program evaluation for EPRI – Recommendations for an Effective Program to Control the Degradation of Buried and Underground Piping and Tanks.

3. EPRI Life Cycle Management Planning Sourcebooks – Volume 2: Buried Large-Diameter Piping

<u>Review</u>

Though established before the advent of the NRCs mandate for buried piping program reform, the life cycle management sourcebooks are a thorough and holistic management guide for buried piping. This sourcebook was established for efficient long range planning of piping 20” or greater, though it is specifically mentions that it can also be utilized for smaller piping systems. The systems it focuses on include condenser circulating water system (CCW), the essential service water system (ESW), and the non-essential service water system (NESW).

The life cycle management (LCM) process described in this reference is divided into four sections:

- System, Structure, or Component (SSC) Categorization/Selection
- Technical Evaluation
- Economic Evaluation
- Implementation

SSC Categorization and Selection is simply the establishment of what type of system is being evaluated, being buried piping in this case. This series of sourcebooks covers a myriad of systems each with their own set of boundaries, environments and functions.

The Technical and Economic evaluations are the first steps to completing the LCM. See Figure 8 for the flowchart followed for LCM for buried piping.

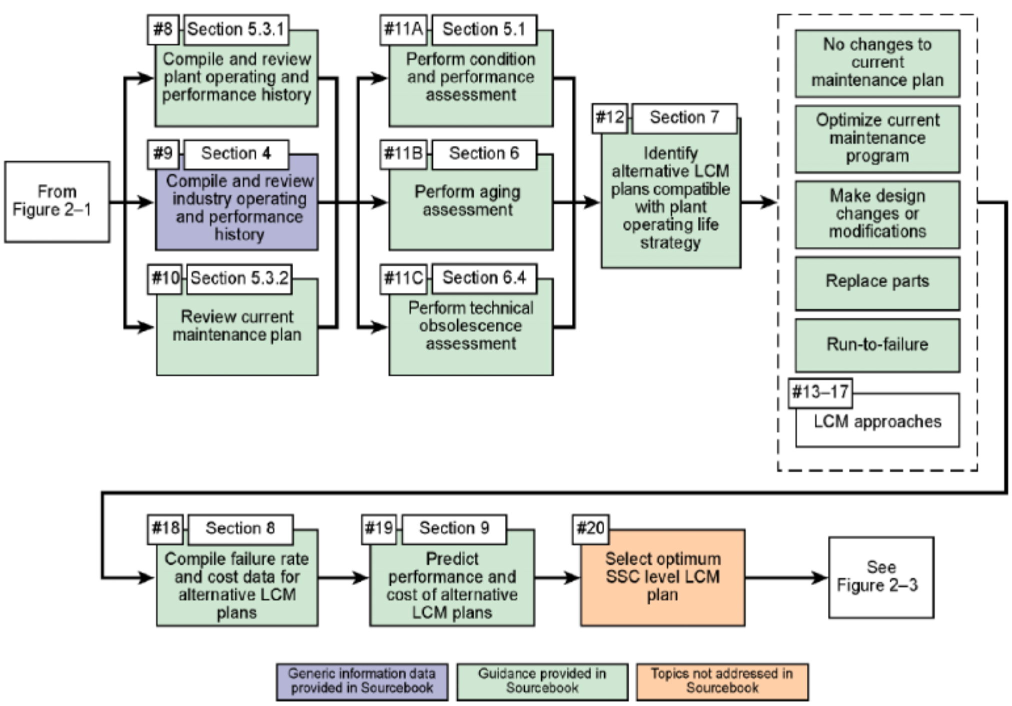

Figure 8 EPRI LCM Planning Flowchart - Technical and Economic Evaluation (EPRI 2002)

As seen in the flowchart, when establishing an LCM for buried piping, the first thing to consider is operating and performance history. Within this reference is a large compilation of qualitative information compiled in order to display past issues and concerns with these specific buried piping systems. Additionally, common active and passive maintenance practices are established. With this establishment comes the condition review of all assets.

In this review, the ID, OD, cathodic protection, yard surface above the piping systems, building conditions near piping systems and coating systems are evaluated. The reference provides all information on what to look for and how to document all conditions found. The purpose for this evaluation is to establish if the current condition of the asset can meet requirements for the extended period of remaining life. History of all maintenance activities and documentation regarding the systems is compiled for the condition review The most recent maintenance activities and inspection records are used to establish condition. If the results of the condition review are dated or inconclusive, additional inspection and testing is necessary to document condition. It is noted that condition monitoring prior to implementation of this plan can assist in establishing current condition. Effective monitoring can lend previous data and analyze trends to determine what current condition may be. Numerous resources are listed for advanced monitoring technologies to implement, including NRC, EPRI and NACE references for NDE and inspection.

When maintenance history and condition have been established, the next procedure is to conduct a generic aging assessment for all buried piping. This reference specifically sights usage of the NRC's Generic Aging Lessons Learned document for an aging assessment of buried piping systems.

The Generic Aging Lessons Learned (GALL) Report is a collaborative document compiled for the purpose of reviewing and summarizing effective industry practices for all manner of asset within NPPs. This document is currently in its 2nd revision and is written based on actual management practices that have been deemed effective. Its purpose is to aid NPP Staff with evaluation of their management practices and develop suitable Aging Management Programs for continued operation and re-licensing. Additionally, this report outlines a plan for licensing and renewal for NPPs ensuring they demonstrate adequate management programs and procedures.

While the GALL report covers effective aging management practices for every major component of NPPs, EPRI's report addresses only sections XI-M20, 28, and 34. The addition of XI-M41 specific to buried piping and tanks was implemented in the most recent addition of the GALL report, after publication of this EPRI reference, though it is now the most applicable Aging Management Program (AMP) for this review. Its structure follows the same format as those outlined in XI-M20, 28 and 34:

1) Scope - This GALL report AMP covers all applicable buried and underground piping systems typically found in NPPs, including Service Water, Condensate, Fuel and Lubricant Oil, Fire Protection, and Storage Tanks. The scope also covers all typical materials used for these systems and provides guidance for all typical effects aging.

2) Preventative Actions - The preventative actions outlined in this section are required based on material type and environmental conditions, and are actions taken to ensure all operability requirements are met. It outlines required coatings, cathodic protection systems, and required backfill quality for each available piping material. It additionally outlines coatings required for underground piping and tanks of each material.

3) Parameters Monitored/Inspected - The aging effects addressed in the AMP are due primarily to chemical decomposition, loss of material due to general corrosion, and cracking due to stress corrosion. The general methods of detection for these mechanisms include visual inspection, non-destructive evaluation such as ultrasonic testing to determine wall thickness, and pipe-to-soil potential for metallic pipes using cathodic protection.

4) Detection of Aging Effects - As with preventative actions, the methods used for detection of aging are specific to material and environmental conditions. The two primary means of detection are though the Opportunistic Methods, which involve conducting inspections when the opportunity presents itself, and Directed Methods, in which the risk ranking dictates the time of inspection. The time period for direct inspections is on a revolving timeframe, which resets if an opportunistic inspection presents itself. The location of inspection is based on the risk ranking determined by a set of AMP specific parameters.

5) Monitoring and Trending - The overarching goal of monitoring and trending is to record a history of buried and underground piping systems based on two criteria. This history can then be used to evaluate the condition and susceptibility of the system. For piping systems with cathodic protection, the soil-to-pipe potential is monitored to evaluate the effectiveness of the protection..

6) Acceptance Criteria - The acceptance criteria used to evaluate the condition of buried and underground utilities is a standardized set of regulations. Each failure mode is allocated a minimum criteria for failure, and if the asset is well within the limits specified, it is considered acceptable. While some evaluation criteria are somewhat

subjective, others are delineated via standardized codes from NACE, Code of Federal Regulations (CFR) requirements, and ASTM specifications.

7) Corrective Actions - While other APM specifications are laid out specifically within the GALL report, the corrective actions program, quality assurance (QA) procedures, site review and approval process, and administrative controls are only reference in 10 CFR Part 50, Appendix B.

8) Confirmation Process - The Confirmation process is the means by which the preventative and corrective action programs are evaluated and deemed adequate. As with corrective actions, this process is also established in the CFR.

9) Administrative Controls - Administrative controls provide a formal review and approval of all corrective actions. As with corrective actions and confirmation processes, these controls are established via the CFR.

10) Operating Experience - While the aging management criteria are set forth in the previous sections, the GALL report also provides a section for the use of operating experience. For nuclear facilities, tracking and recording valuable lessons learned and expert knowledge can mitigate future aggravations and problems. It is important to track piping segments, failure modes, causes of failure, and actions taken. In this section 6 significant examples of operator experience are listed for reference.

At the completion of the aging analysis, the useful life of the asset can be determined. While some segments of piping can display no signs of aging for the entire life of the power plant, others will encounter common aging effects, including:

- Coating degradation due to chemical change, water osmosis, or embrittlement
- Steady corrosion penetration in carbon steel piping
- Biological corrosion
- Gradual buildup of deposits and corrosion, leading to clogging

The physical and environmental conditions at each plant will determine the extent to which buried piping system will display these, and other signs of aging. This section of the reference also outlines the useful life of numerous piping materials given typical degradation mechanisms and influence for common piping systems.

When useful life of the asset has been established, alternative LCM plans can be generated and analyzed for optimization. Within this section, several common conditions are noted, including No Known problems, OD corrosion, ID corrosion, and Significant Breakdown of ID. Various approaches of LCM are presented for each. In addition to establishing these alternatives, consideration must be given to long term performance potential of the buried piping segment. When choosing an LCM it is important to first determine how the piping segment may behave in the future in order to make a decision that will be optimal for the system. LCM approaches include, but are not limited to:

- Continue current practice
- Install or upgrade cathodic protection
- Replace piping
- Install structural liner and in situ repairs
- Chemical treatment
- Coat pipe ID

Each of the alternatives presents cost and consequences which are discussed. Also considered is economic evaluation. The remaining life of the plant must be considered to ensure that the alternative selected will be suitable for the remaining life, but will also be economically practical. If the failure rate of the pipe can be determined and compared to the remaining life, this will enhance economic decision making. Some concerns to consider when preforming economic decision making include:

- Direct and indirect maintenance costs
- Cost resulting from voluntary plant shutdown for implementation
- Costs from regulatory actions such as additional NRC inspection or justification for actions
- Costs from clean-up of spills, contamination, or damage
- Capital and training cost resulting from replacement
- Cost of the effect on power generation due to expected failure rates

With the consideration of failure rates, pipe history, and economic analysis, it is possible to make an informed decision as to the LCM for a given segment of pipe.

Evaluation

The EPRI Life Cycle Management Planning Sourcebooks – Volume 2: Buried Large-Diameter Piping addressed numerous asset management elements from the framework for an asset management program. It addressed the need for continued inspection and data collection in order to establish pipe history and condition; it discussed the need to determine pipe condition, both for current ailments concerning the pipe as well as potential for future degradation; it considers inspection results, economic data, and future condition prediction analysis for decision making support; and it displays the need to consider numerous repair/replace/rehab/maintain options for potential life cycle management actions. While it doesn’t specifically address advanced deterioration modeling techniques, it did emphasize the need to determine remaining useful life through simple deterioration analysis. One area that was not discussed was prioritizing the piping segment for future analysis, though this may be assumed depending on which LCM is chosen. Finally, as an overall GIS-Based asset management plan, this source of recommendation contained numerous elements of a complete asset management plan, but did not discuss the use GIS for the tracking and monitoring of assets and overall did not fully fulfil the framework presented for this report. See Figure 2.3 for framework analysis.

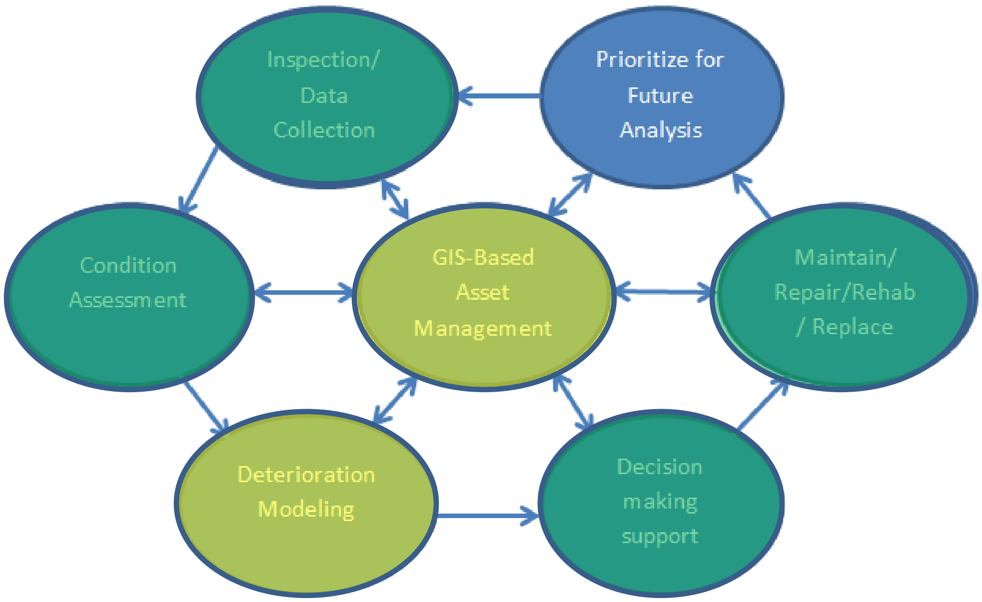

Figure 2.2: Asset Management Program evaluation for EPRI – Recommendations for an Effective Program to Control the Degradation of Buried and Underground Piping and Tanks.

b) Literature Recommended Practice Summary

Based on the literature reviewed, the following table of asset management practices discussed in literature was generated representing guidance for asset management in accordance with the presented framework for this report:

Table 1: Literature Recommendations for Asset Management Practices

Literature Recommendation For Asset Management Practices							
	Inspection/ Data Collection	Condition Assessment	Deterioration Modeling	Decision Making	Maintain/ Repair/Replace	Prioritize for Future	GIS-Based Asset Management Plan
NEI 09-14 [Rev 1]	X	X		X		X	X
EPRI 2010	X	X	X	X	X	X	X
EPRI 2002	X	X	X	X	X		X

Fulfilled	x
Partially fulfilled	x
Not Impleneted	

Overall it can be seen that throughout industry literature, there is consistent and thorough fulfillment of recommendation for Inspection and Data Collection. Literature recommends both established practices required for reporting purposes as well as the use of non-required new technologies for enhanced inspections and more thorough analysis. Additionally, the same can be said for Condition Assessment. Industry literature discusses extensive use of condition assessment techniques, both required and recommended. Between Risk Ranking procedures and establishment of current condition through inspection results, history, and possible causes and consequences of failure, the framework for condition assessment of buried piping is fulfilled. Finally, a common trend throughout literature guidance is the use of decision making technology and support. While EPRI's Recommendation for an Effective Program to Control Deterioration or Buried and Underground Piping and Tanks discusses the use of fitness for service evaluation, this was primarily a review of risk ranking to determine fitness for service. Conversely, NEI09-14 [Rev 1] contained risk ranking, as well as the use of an asset management plan for future implementation. While the specific guidance for this asset management plan was not presented, the preliminary establishment for the required use of a system is there. In EPRI's Sourcebook for Life Cycle Management, decision support tools included history of the asset, common causes for failure, future life expectancy or the plant and the asset, and cost analysis for decision making.

Throughout the industry, management actions (repair, replace, rehab, maintain) are commonly standardized. These standard practices are in accordance with federal regulation, ASME code, and NACE recommendations. These actions were discussed in EPRI documentation, but were not mentioned in NEI 09-14 [Rev 1].

Similarly, prioritization for future analysis was fulfilled in NEI 09-14 [Rev 1] as well as EPRI 2010, but was not discussed in the EPRI LCM Sourcebook.

Throughout all literature, one aspect of the framework for asset management that was not fulfilled was the use of deterioration modeling for enhance decision making. Simple deterioration calculations were recommended in the EPRI LCM Sourcebook, and it was addressed briefly in EPRI 2010, but not the use of technology, such as finite element analysis for determination of failure potential.

c. Verification of Recommended Practice

For verification of the recommendations for asset management practices an industry expert was contacted on 26 APR 2013. He is an EPRI specialist in the area of NDE. The following is a summary of discussion with the industry expert:

1) Industry Guidance

Over the past 2-3 years, aging management plans have been widely implemented and improved due to the Buried Piping Integrity Imitative and subsequently the publication of NEI 09-14 [Rev 1] and EPRI 2010 Recommendations. Over 2600 excavations and non-destructive evaluations have been performed in compliance with new standards and initiatives. Currently, the program is in its third stage of inspection and documentation, having completed publication of procedures and oversight, and risk ranking of all assets. Due to the wide success of the program and the recent events occurring in Fukushima, Japan on 11 March 2011, the dates for program completion have been adjusted. The accident at Fukushima triggered an industry investigation in order to learn from the events and correct any known discrepancies with U.S. programs. In addition to this, the NDE test finding and evaluations had been so widely successful that it was determined the aggressive schedule for the Buried Piping Integrity Program could be relaxed. A great deal of time and consideration was given to this decision.

Over the past 2-3 years, data sharing has also seen great improvement in the field of buried piping evaluation and management. Databases have been compiled based on the results of NDE mandated by the buried pipe initiatives and are available for both industry use and EPRI evaluation.

2) NDE Technologies

Major improvements have been made in the past several years in the area of non-destructive evaluation. Currently the most common forms of evaluation include excavation, visual inspection of coatings, and ultrasonic testing. While these are the industry standards, further research has been conducted in the fields of phased ray ultrasonics, electromagnetic testing, eddy current technology, and structured light scanning.

Further NDE research is still being conducted. Ground penetrating radar is a form of NDE that has not yet been implemented but is being investigated for industry use. This form of NDE would provide industry with the ability to conduct evaluation of the piping structures without the need for excavation. If proven useful for industry use it would be the most economical option of NDE available and would save time and money.

3) GALL Report Discussion

It was noted that the GALL report is not a comprehensive guide for development of an asset management program. This publication was compiled in order to allow NPPs to develop aging management programs that would provide a reasonable level or certainty that safety related incidents would be prevented for the purpose of license renewal. Many NPP are nearing the end of their projected life and in order to remain in operation they must apply to the NRC to renew their license to operate. As part of this license renewal process they must have AMPs in place that have been developed with guidance from the GALL report and other industry guidance. The purpose of this report was not the development of comprehensive asset management programs or the prevention of non-safety related equipment incidents.

This is not to say that asset management programs are not in place within NPPs. It was noted that, though he was not able to speak to specifics of any NPP's program, facility managers do implement asset management strategies and focus on the economic impact of managing both safety and non-safety related equipment. These programs are specific to each NPP and are not regulated by the NRC.

4) Summary

Based on the discussion with the industry representative, it was concluded that industry guidance is currently base upon both NEI 09-14 [Rev 1] and EPRI 2010, as well as the requirements from EPRI 2002 for GALL report AMP implementation. While the uses of these documents fulfil many aspects of the framework, as discussed, there are still some areas that were not addressed. See Table 2:

Table 2: Literature Recommendations with Industry Verification

Literature Recommendation For Asset Management Practices with Industry Verification							
	Inspection/ Data Collection	Condition Assessment	Deterioration Modeling	Decision Making	Maintain/ Repair/Replace	Prioritize for Future	GIS Based Management Plan
NEI 09-14 [Rev 1]	X	X		X		X	X
EPRI 2010	X	X	x	X	X	X	X
EPRI 2002	X	X	X	X	X		X
EPRI Representative	X	X	X	X	X	X	X

Fulfilled	x
Partially fulfilled	x
Not Impleneted	

III. Establishment of Industry POCs

With the literature practice established, it was possible to begin establishing actual practice, beginning with establishing industry POCs in order to obtain the most current actual industry practices regarding asset management strategies for buried piping. Industry contacts were established to discuss actual practices at nuclear stations. For this study to be effective, it was established that at least three industry experts should be contacted in order to provide feedback on asset management practices for buried piping at NPPs. In order to complete this in an efficient and organized manner, a list of 15 potential NPPs was compiled for this study with contact information at each. See Appendix C, for the preliminary list of potential NPPs. This information was gathered via publically listed telephone directories and the NRC.gov webpage.

Based on this list, preliminary phone calls were made to each of the 15 locations in order to attempt to contact individuals to administer solicitation for this study. In many cases, telephone directories were not able to connect to individuals within the NPP. These potential contacts were eliminated from the list. In other cases, various departments were contacted via the directory and messages were left if contact was not established. No return phone calls were received based on messages left. Finally, in three cases, personal contact was made via phone call or email and a solicitation to provide feedback for the study was presented. In two cases this solicitation was accepted. These contacts became Primary Points of Contact, or POCs. In a separate third case, a POC was established via personal relationship to an employee of a nuclear station, but regarded as an expert in his field. These contacts and their respective NPPs will remain anonymous for this study in order to prevent the release of private of any proprietary information, and will be referred to hereafter as NPPs “A” “B” and “C”.

IV. Collection of Industry Response

Once the list of POC participants was established, industry responses were collected. Before this could be accomplished, a questionnaire was developed to administer via teleconference. This questionnaire served as conversation guide during industry interviews, but if necessary could have been administered via email for written responses though this was not necessary in any case. Each POC was contacted and a conversation followed under direction of the developed questionnaire. Each POC contacted held a different position within their NPP so answers were varied and sometimes required clarification. The questionnaire can be found in Appendix D.

V. Qualitative Industry Analysis

When responses were received, the next step was to analyze each response in accordance with the framework for asset management and determine trends or common asset management practices within the industry, as well as identify areas of dissimilarity. Each trend was analyzed individually and then a summary of industry practice was established.

a. NPP "A" Review

The NPP "A" was the first POC contacted. The member contacted was the Supervisor of Engineering Programs and manager of the Buried Piping Program at that location. The questionnaire was administered and a summary of the results is as follows.

1) Inspection and Data Collection

The primary method of inspection and data collection implemented at NPP "A" is excavation, OD visual inspection, and ultrasonic thickness (UT) testing. On occasion, methods such as pipe pigging will be utilized for ID pipe camera inspection and UT measurement, but this can only take place in the event of an outage. These inspections are not regularly scheduled due to the necessity to shut down operations for a pigging inspection to take place. Additionally, pigging can only be performed in locations with easy pipe access, such as Plant Service Water.

Additional methods of NDE are not commonly utilized or researched for usage at NPP "A". The reason for this is due to the fact that they are not accepted measures of inspection for NRC requirements. The NRC has yet to implement them for official reporting so there is no incentive to pursue them.

2) Condition Assessment

Risk ranking and inspection results are the primary means of determining condition of buried assets. Inspection results are compared to ASME code requirements to determine if piping is failed or near failure. Risk ranking software is used to evaluate the risk of failure versus the consequence.

It is estimate that approximately 60% of the industry utilizes BPWorks as the risk ranking software of choice. Additionally, in-house or other outsources risk ranking software can be utilized since there is no requirement, but the majority use BPWorks as endorsed by EPRI. As more data is fed into the risk ranking software, the more accurate and decisive the results will be.

3) Deterioration Modeling

For additional pipe analysis, deterioration model is not commonly used, particularly not at individual NPPs. Simple formulas for corrosion rates are used for basic modeling, but no advanced software for finite element analysis or similar models. Some seismic considerations are modeled, but not for regular management practices. Additionally, minimum wall thickness is determined and used in simple models.

4) Decision Support Tools

For decision making support, the station's Life Cycle Management Plan is implemented. This plan dictates when inspections will occur and takes into consideration matters of condition, risk, and budget. Due to the fact that nuclear stations are preparing for license renewal, having a management plan to balance these competing factors is essential. Each decision that is made has to undergo political and economic challenges.

5) Maintain/Replace/Renewal/Rehabilitate Actions

The actions that are taken to manage deteriorated piping are dictated by ASME and NRC code. These codes can be restrictive of implementation of new technology. In order to utilize a new method of repair or replacement, all deviations from base code must undergo a strict, expensive and expansive approval process. This can hinder the implementation of utilizing new techniques. The industry pushes the use of new technologies. In most cases, only non-safety related systems will be approved for use of new pipe repair and replacement technologies by the ASME.

6) Future Prioritization

Each segment of piping that is inspection and/or undergoes maintenance activities is prioritized for future analysis. The results of each action are used to update the cumulative BPWorks database and update risk ranking. Annually, these risk rankings are reviewed and the most recent risk ranking results are used for prioritization. These results are used to justify actions and budget plans for future inspections and maintenance actions within the life cycle management plan.

7) Asset Management Summary

Based on the response from NPP “A”, it was determined that many asset management practices are in place. Though inspection and data collection methodologies are not as robust as potentially indicated in the literature, specifically EPRI 2010, they perform the required inspections based on analysis and planning. Condition assessment is conducted thoroughly through risk ranking and inspection comparison with code requirements. Decision making is very involved, utilizing the life cycle management plan for each system and also considering condition and risk ranking. Maintenance and repair activities are dictated by strict code, but the life cycle management plan, inspection, and risk ranking help to determine which activities should be implemented and when to implement them, while also considering condition, code requirements, and budgetary concerns. All activities are recorded and used to plan for future inspection and maintenance and all data is compiled to update risk ranking.

The only areas or the asset management framework not fulfilled are deterioration modeling and the use of a GIS interface for asset management. Though advanced deterioration modeling is not utilized for asset management, basic simple modeling is used to determine failure rate to aid in decision making. It was also noted that though all of these elements are in place, the use of a GIS interface is not utilized. These software programs are available specifically for buried piping at nuclear plants, but they are not practical or necessary. The data used to geographically populate the GIS system is not available because many piping system diagrams are incomplete and outdated. The amount of money and time that would need to be dedicated to determine geographic information for each piping system outweighs the benefit of having such a program. See Figure 2.4 for framework analysis.

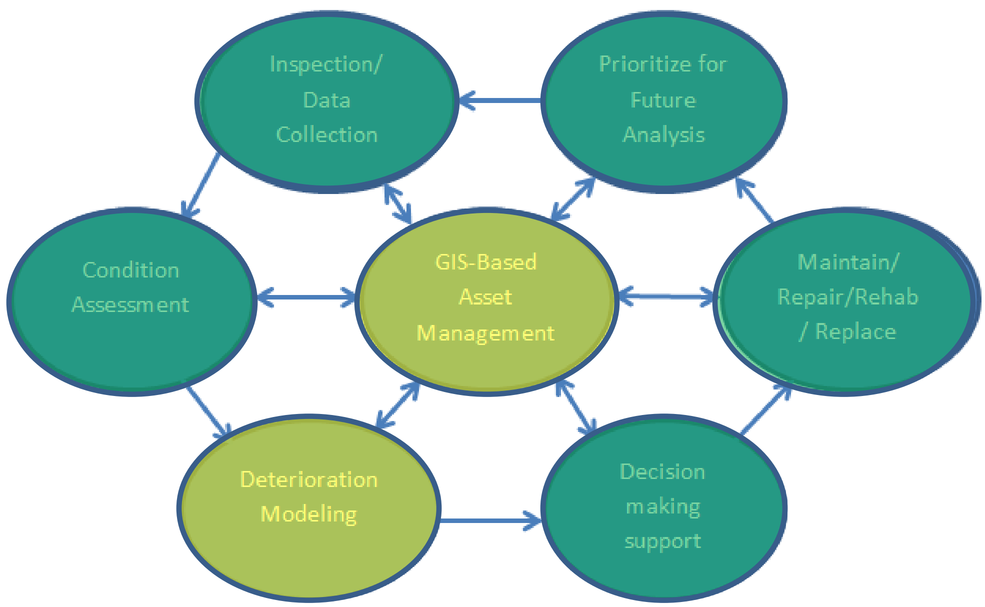

Figure 2.4: Asset Management Program evaluation for NPP "A".

b. NPP "B" Review

NPP "B" was the second NPP to be interview for this practice review. The member that was spoken to was owner of the plant's Buried Pipe and Tank Program. The questionnaire was administered and a summary of the results were as follows.

1) Inspection and Data Collection

Inspection techniques are conducted using standard, approved NDE technologies. These include excavation for visual inspection, UT measurements, and in some cases, pigging when practical. The need to shut down the power plant to schedule a pigging inspection prevents it from being a regular inspection practice, but when a shutdown occurs, this technique is used. Additionally, new tests have been implemented using Remote Field Electromagnetic Technique (RFET) with positive results. Guided wave is an additional technology that has been utilized, though continued use is not expected due to some false indications resulting in extensive, expensive excavations.

2) Condition Assessment

Condition is determined by use of the minimum wall thickness standards. A minimum wall thickness is determined for each piping segment and compared to the metal loss results determined from the visual inspection and UT testing. With each issue that is encountered, a report is placed on file. If leaks are detected in safety related piping, they must be repaired and the plant cannot operate until the issue is resolved.

Additionally, risk ranking is utilized for condition assessment and ranking. NPP "B" does not utilize BPWorks, but rather utilizes an in-house developed risk ranking software. This software utilizes similar inputs to BPWorks and functions in accordance with EPRI recommendations. This NPP is scheduled for decommissioning, but prior to the announcement, the use of MapPro, a software developed by the same organization as BPWorks, was scheduled for implementation. This software uses BPWorks as a database, but also has functions such as GIS interface for enhanced management.

3) Deterioration Modeling

Deterioration modeling is not utilized other than for corrosion rate calculations.

4) Decision Support Tools

Decision support tools that are utilized for management action decisions include application of ASME code and review of inspection results. It was also noted that engineering experience and judgment are relied upon for sound decision making. Budgetary consideration is also given to decision making strategies, but primarily only for determining how and when a piping segment will be repaired, replaced, or maintained. Budgetary concerns will never drive the NPP to not perform the necessary actions, but will dictate the schedule for repair. In all cases, a damaged or non-functioning piping segment will be restored to its original design condition or better.

5) Maintain/Replace/Renewal/Rehabilitate Actions

Actions that are taken for pipe repair are conducted in accordance with ASME code requirements. These requirements must be followed in all cases, but there are some exceptions. In cases such as microbial induced corrosion ASME code may allow for new technologies and non-standard techniques to be implemented, but must be approved by the ASME.

6) *Future Prioritization*

Any issue encountered when inspecting piping must be annotated in a condition report. These condition reports are what generate the need for maintenance and repair plans. The status of these piping systems is reviewed at least twice per year in a Problem Identification and Resolution (PR&I) Assessment. At these assessments it is determined if proper action is being taken and prioritizes those which require further review.

7) Asset Management Summary

Though no "asset management" program is used by name at NPP "B", the program for oversight and management of buried piping assets is dictated by the Underground Piping and Tanks Program. It encompasses all aspects discussed for management of buried assets. Additionally, NPP "B" was the only plant considering implementation of a GIS based management system, being MapPro. If

Based on the review of asset management practices in relation to the framework utilized in this report, it was determined that NPP "B" fulfils most aspects of the framework for an asset management program. Inspection and data collection techniques are utilized, as with NPP "A", based on NRC inspection requirements, with some additional ID inspection occurring when practical. Condition assessment is based on metal loss determined by testing and compared to code, as well as consideration of risk ranking. Decision support includes sound engineering judgment, ASME code requirements and license renewal requirements, including resolution of any safety related issues prior to continue plant operation. Additionally, budgetary considerations dictate how and when activities are performed. Maintenance activities are based on NRC and ASME code and requirements, though some exceptions can be implemented with approval in certain cases. Finally, the use of the PI&R assessments showed that some consideration was given to prioritization for future use, but additional information was unknown.

Areas that were unknown or not fulfilled included the use of deterioration modeling. See Figure 2.5 for framework analysis.

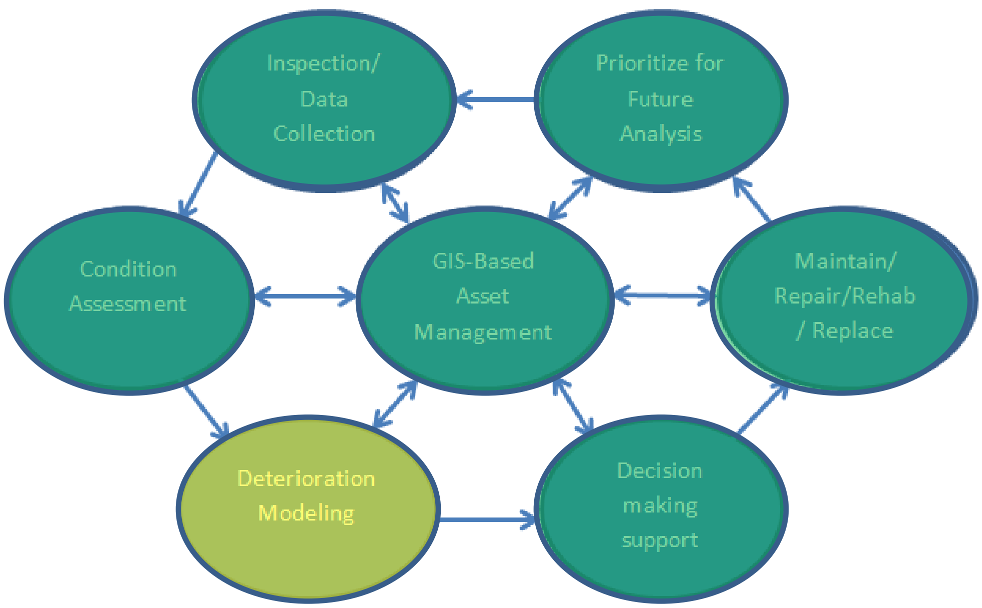

Figure 2.5: Asset Management Program evaluation for NPP "B".

C. NPP "C" Review

The final NPP contacted was the Program Engineer at NPP "C". This industry representative oversees the buried piping program at NPP "C" and was familiar with all asset management strategies implemented. The questionnaire was administered and a summary of the results is as follows.

1) Inspection and Data Collection

Inspection techniques are dictated by NRC requirements as well as the need to complete effective risk ranking. Inspection techniques include excavation with visual inspection, and UT measurements for metal loss. In addition, guided wave technology is utilized at nearly every inspection. Though guided wave technology is not considered a direct inspection, it is recommended by EPRI and is a good way to determine the quality of the piping segment.

Pigging is also utilized for ID visual inspection and UT measurements, though in many cases accessing a piping system is what prevents this method from being utilized.

2) Condition Assessment

Condition assessment of the piping systems is completed utilizing risk ranking and fitness for service testing. NPP "C" utilizes BPWorks as its risk ranking software and all inspection data and relevant pipe data is recorded. This data is additionally shared annually with EPRI for additional analyses and data sharing purposes. Fitness for service calculations are conducted utilizing past thickness measurements, corrosion rate, and minimum wall thickness to determine a rate of decay.

3) Deterioration Modeling

Deterioration modeling software is not utilized by NPP "C" for piping asset management, though simple corrosion rate calculations are conducted. Additionally, some metallurgical analysis is conducted for pipe analysis, but not for the purpose of management of the systems, or decision support.

4) Decision Support Tools

Decision support tools that are utilized for supporting management action decisions include the results of the risk ranking and fitness for service calculations. Additionally, these results are presented to a piping condition committee for review if replacement is required. This process takes into account budget, schedule, and future of the system management.

5) Maintain/Replace/Renewal/Rehabilitate Actions

Actions that are taken for pipe repair are conducted in accordance with ASME code requirements. These requirements must be followed in all cases, but there are some exceptions. In cases such as microbial induced corrosion ASME code may allow for new technologies and non-standard techniques to be implemented, but must be approved by the ASME.

6) *Future Prioritization*

In additional to code inspection requirements, the BPWorks systems is used and updated to help prioritize the schedule for piping inspection and maintenance. Inspection results, maintenance activities, and surrounding environmental conditions are used to populated the software and enhance future prioritization, inspection schedule, and decision making.

7) Asset Management Summary

Asset Management practices at NPP "C" are similar to those reviewed previously. Inspection and data collection are completed in accordance with industry standards, though additional use of pigging and guided wave technologies are utilized for enhanced data collection for accurate risk ranking. A schedule for inspection is dictated by code, risk ranking, and condition assessment. Condition assessment is determined using risk ranking and the calculations for fitness for service. This process implements minimum wall thickness and corrosion rates to evaluate fitness for service. Decision making support is provided by the risk ranking and fitness for service tools, as well as committee action for determination of piping replacement. All maintenance and repair or rehabilitation techniques are completed in accordance with code and specification. Future prioritization is determined by risk ranking, condition assessment, and fitness for service.

Once again, deterioration modeling and GIS management are not utilized, though the implementation of an asset management program is scheduled to be implemented in accordance with NEI 09-14 [Rev 1]. See Figure 2.5 for framework analysis.

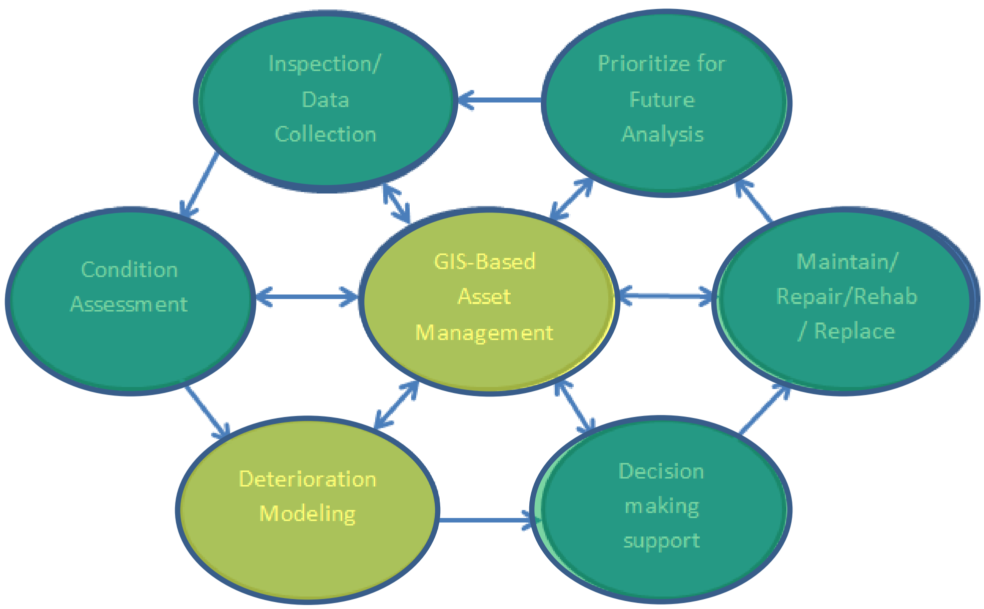

Figure 2.5: Asset Management Program evaluation for NPP "C".

d. Review of Industry Practice Results

After completing the industry review, the data was then used to populate a table displaying industry trends. See Table 3 for trending representation.

Table 3: Industry Practices for Asset Management

Asset Management: Industry Practice							
	Inspection/ Data Collection	Condition Assessment	Deterioration Modeling	Decision Making	Maintain/ Repair/Replace	Prioritize for Future	GIS Based Management Plan
NPP "A"	X	X	X	X	X	X	X
NPP "B"	X	X	X	X	X	X	X
NPP "C"	X	X	X	X	X	X	X

Fulfilled	x
Partially fulfilled	x
Not Impleneted	

Based on the results of the industry practice review, it is evident that there are trends within the industry for asset management practices. The first trend is the use of extensive inspection and data collection techniques. Though the extent of the use of new technologies was varied from plant to plant, each NPP completed inspections in accordance with industry standards, including the use of excavation, UT measurements, and visual inspection for all piping systems. Additionally, non-required methods of inspection such as guided wave technology and RFET are utilized, varying from plant to plant.

Second, the determination of condition assessment for all buried piping segments is a trend within the industry. The use of risk ranking as well as fitness for service calculations are utilized throughout the industry, though the means by which risk ranking is determined can vary. As with the literature, deterioration modeling is not part of asset management other than computations for corrosion rates. Decsion support tools can includelife cycle management plans, risk ranking, and condition assessmnet, but also consist of budgetary considerations and future planning. Management activities such as maintenance or replacement are dictated by ASME code, but may also utilize new technology if approved. Finally, the use of risk ranking and life cycle management plans are used for prioritization.

VI. Conclusions

With the practice review and literature guidance reivew complete, analysis could be made about current asset management practices and conclusions could be drawn about the extent of asset management within the nuclear community for buried piping. A complete table compiling both the literature analaysis and industry analysis can be seen in table 4.

Table 4: Complete Literature and Industry Asset Management Review

Literature Recommendation For Asset Management Practices with Industry Verification								
		Inspection/ Data Collection	Condition Assessment	Deterioration Modeling	Decision Making	Maintain/ Repair/Replace	Prioritize for Future	GIS Based Management Plan
Reccommendation	NEI 09-14 [Rev 1]	X	X		X		X	X
	EPRI 2010	X	X		X	X	X	X
	EPRI 2002	X	X	X	X	X		X
	EPRI Representative	X	X	X	X	X	X	X
Practice	North Anna	X	X	X	X	X	X	X
	Plant Hatch	X	X	X	X	X	X	X
	Vermont Yankee	X	X	X	X	X	X	X

Based on the two reviews conducted, it was evident that asset management practices are in place and reccommended in accordance with nearly every asepect of the asset managemnt framework presented in the report. The category that was lacking across all guidance and practice is the use of advanced deterioration modeling for analysis and decision making, and GIS software for asset monitoring and tracking. While these elements are missing from the industry, it has net been determined exactly what effects they have on asset management for buried piping at nuclear power plants, and how programs would be affected if these elemets were implemented.

Another concluction that can be drawn is the Non-Destructive Evauation and Risk Ranking are the primary means, though not the only means, by which asset are monitored and evaluated. The methods of NDE employed in the industry are in accordance with required guidance, but additional reccommended methods are not extensively utilized. This is due to the lack of incentive to participate in NDE programs if the results are not considered admissable by regulating organizations. They serve as indicators for the benefit of the owner, but cannot be used to comply with regulation.

For decision making support, it was cocluded that code requirements are the ultimate say in the decision to repair, replace, rehabilitate, or maitain an asset, but what actions can be taken also depends on risk ranking, cost and lifecycle analysis, and fitness for service. Additionally, the actions that are taken are also goverend primarily by code requirements. In some cases, non standard actions can be taken, but this requires extensive approval processes. In these cases, it was determined that code requirements greatly restrict the implementation and utilization of new technologies and

Additionally, it was determined that GIS is not rgularly utilized or recommended by industry literature and guidance, and is not utilized regularly within the industry itself. This is due to the lack of information available about the exact geographic location of the assets, and the expense that gathering such data would accrue. While it is true that GIS software is available, the industry may not feel that benefit of such a program would outwiegh the cost to procure and run it. Though it is hard to determine exactly what effect a GIS system would have on any one individual asset management program, there are technologies available within other industries such as transportation and water, where detection of such assets for the purpose of determining goegraphic location are availalable and researched. It may be beneficial for industry research to explore this as a means of determining location for the purpose of gathering geographical data for use in GIS.

The final conclusion that can be drawn from this analysis is that prioritization for future analysis is both recommeneded and conducted within the industry. Risk ranking serves as the primary means for future prioritization, but additionally, life cycle management planning can be used, taking risj ranking into account to determine future actions and inspection schedules.

For a complete display of asset management strategies discussed with refference to the established framework, see Appendix E.

F. Final Conclusions and Impact

The goal of this project was to determine industry trend for practices of asset management, both in guiding literature and in industry practice. Additionally, these trends were compared to a framework for infrastructure asset management to determine what categories of asset management the industry fulfills.

Based on this analysis, the following conclusions were determined:

- Industry fully complies with required industry regulation for inspection and data collection, but literature contains far more methodologies for inspection and data collection that are not used in practice.
- Risk Ranking is the primary tool for condition assessment both in literature and in practice, though other techniques are used within industry practice.
- Deterioration modeling software is not recommended, utilized, nor required for buried pipe asset management at NPPs.
- Decision making support for management practices is governed primarily by code requirements, though risk ranking and life cycle cost analysis are also used both in guiding literature and in practice.

- Maintenance, Repair, replacement, and rehabilitation methodologies are standardized by industry code and followed as such. Some approved exceptions are allowed.
- Risk Ranking is the primary tool for future prioritization of buried piping management practices.
- GIS software is available but not recommended, required, or utilized for buried piping asset management.

The immediate impact of this study is the determination of common asset management practices found in guiding and required industry literature and in industry practice. The results have been compiled into one document and compared to an accepted framework for infrastructure asset management.

This report also recognizes that in many cases, technology is not necessarily utilized to its full potential. Many forms of NDE are prescribed by the EPRI, but only few new technologies are utilized, and not at every power plant. This is due to practicality for varied applications, cost, varying inspection results, and the fact that these new technologies are not required by the NRC or ASME code.

The larger scale impact of this study is that it begins the process of improving asset management practices for buried piping at NPPs. The need was identified in this report for improved NPP practices within the nuclear power industry for buried piping. Current buried piping systems are beginning to age and, until recently, had little asset management. Now that the practice and requirements/recommendations have been identified, future research can being evaluation the methodologies themselves. Additionally, the potential for this study is the identification of asset management practices for other industries seeking to improve asset management. Industries with similar issues and infrastructure may be able to use this report to improve their own practices.

As asset management for buried piping at NPPs begins to improve, the impact will be the decrease potentially hazardous leaks, decrease in maintenance and repair costs for piping systems at nuclear power plants, and improved health and safety for surrounding communities. In order for this to occur, this research must continue, starting with evaluation of the practices identified in this report and identification of deficiencies.

Potential for Future Research

Based on the conclusions identified in this study, it is now possible to outline areas for future researchers to pursue with regards to asset management for buried piping at NPPs. Some areas identified are as follows:

G. Future Research

1) How effective are current asset management strategies for buried piping at NPPs?

The purpose of this study was to determine what asset management strategies are recognized in guiding literature and in current practice for buried piping at NPPs. The effectiveness of these strategies was not evaluated. By evaluating effectiveness, it may be possible to then pinpoint gaps in the strategies that are recommended and implemented. This can lead to improved asset management strategies, eventually resulting in more reliable piping systems, fewer leaks, and preserved public health and safety.

2) What piping and pipeline asset management strategies are available in other industries and not being utilized at NPPs?

The focus of this project was exclusively on the methods and strategies for asset management recommended by guiding literature and in industry practice. Identification of additional asset management plans and strategies in other industries could potential reveal solution for improving the strategies implemented for asset management of buried piping at NPPs. Improved asset management can lead to improved plant health and public safety.

3) Could deterioration modeling benefit a NPP buried piping asset management plan?

It was identified in this project that the use of deterioration modeling for asset management of buried piping is not present in either recommendations and requirements, or within industry practice itself. This element was identified as one of the six components of an effective infrastructure asset management plan in this report. Future research could determine if the use of deterioration modeling could benefit asset management practices for buried piping and determine how it could be implemented. This could lead to improved practices and increase plant health, decreased maintenance costs, and increased safety, or it could identify that the framework for asset management utilized in the study is not effective for buried piping at nuclear power plants.

4) Could GIS software benefit a NPP buried piping asset management plan?

It was identified in this project that the use of GIS Software for asset management of buried piping is not present in either recommendations and requirements, or within industry practice itself. This element was identified as one of the components of an effective infrastructure asset management plan in this report. Future research could determine if the use of GIS software could benefit asset management practices for buried piping and determine how it could be implemented. This could lead to improved practices and increase plant health, decreased maintenance costs, and increased safety, or it could identify that the framework for asset management utilized in the study is not effective for buried piping at nuclear power plants.

Nuclear power plants are complex systems requiring great amounts of care and consideration to promote safe, reliable, and sustainable operations. Buried piping at these power plants is one aspect of their infrastructure that has been denied this care and consideration for a long period of time. In order ensure continue safe operations of nuclear power facilities, implementation of effective asset management techniques is essential. This study outlined the recommended, required, and practiced asset management techniques within the nuclear industry today. Though this study was not all encompassing, it did establish a baseline for future research to work from. With continued research it may be possible to identify issues and better asset management procedures to implement at nuclear power plants and ensure they continue to operate effectively, efficiently, and safely.

Appendix A: Research Objectives and Schedule

Table 1. Research Objectives and Sub-tasks	
Research Objectives	Tasks
R1 – Establish Recommended Practice: Identify the recommended asset management plan published by the NRC and EPRI guidelines.	T1.1 – Research Literature on recommended practice. T1.2 - Complete literature review T1.3 – Research EPRI representatives, and NRC representatives willing to participate T1.4 – Verify recommended practice with EPRI and NRC representatives
R2 - Establish Industry POCs: Identify industry experts willing to provide input into current industry practice of asset management for buried piping.	T2.1 – Research U.S. NPPs (both local and remote), T2.2 – Compile a potential contact list T2.3 – Contact members on preliminary list T2.4 – Compile a list of applicable point of contact (POCs) who are willing to participate
R3 – Collect Industry Responses: Identify current industry strategies actively being used.	T3.1 – Establish a questionnaire (verbal list of questions) to ask each POC. T3.2 – Contact each affirmed POC and administer questionnaire via conversation. T3.3 – Record results
R4 – Qualitative Industry Analysis: Establish trends and similarities between actual asset management strategies for buried piping.	T4.1 – Review questionnaire results T4.2 – Group and record questionnaire results with similar responses T4.3 – Establish common practices and trends for industry strategies
R5 - Comparative Analysis and Conclusions: Establish similarities and differences between recommended practice and actual practice. Draw conclusions and make recommendations.	T5.1 – Compare industry practice with recommended practice T5.2 – Make conclusions on similarities and differences of industry vs. recommended practice T5.3 – Determine validity of conclusions T5.4 – Make recommendations to industry leaders T5.5 – Outline areas for future research T5.6 – Present Findings

Project Schedule

Objectives and Tasks	May		June		Jul		Aug		Sep		Oct		Nov		Dec	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
R1 - Establish Recommended Practice																
T1.1 - Research Literature on recommended pratice																
T1.2 - Complete Literature review																
T1.3 - Research EPRI and NRC Representatives																
T1.4 - Verify recommended practice with EPRI/NRC																
R2 - Establish Industry POCs																
T2.1 - Research U.S. NPPs																
T2.2 - Compile potential contact list																
T2.3 - Contacts members for participation																
T2.4 - Compile new POCs who will participate																
R3 - Collect Indutrsy Responses																
T3.1 - Establish Questionnaire																
T3.2 - Contact POCs to administer questionnaire																
T3.3 - record results																
R4 - Qualitative POC Analysis																
T4.1 - Review Questionnaire results																
T4.2 - Group similar responses																
T4.3 - Establish common practices and trends																
R5 - Comparative Analysis and Conclusions																
T5.1 - Compare Industry vs. recommended pratice																
T5.2 - Make conclusions on similarities and differences																
T5.3 - Determine validity																
T5.4 - Make recommendations																
T5.5 - Outline areas of future research																
T5.6 - Present Findings																

Appendix B. Bibliography

(2011). "Facts Sheet on Underground Pipes At Nuclear Reactors." *U. S. NRC,* http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/buried-pipes-fs.html (Sep. 1, 2013).

(2013). "Buried Piping Activities." *U. S. NRC,* http://www.nrc.gov/reactors/operating/ops-experience/buried-piping-activities.html (Sep. 1, 2013).

NUREG/CR-6679, Assessment of Age-Related Degradation of Structures and Passive Components for U.S. Nuclear Power Plants, Nuclear Regulatory Commission, August 2000.

Recommendations for an Effective Program to Control the Degradation of Buried Pipe, EPRI, Palo Alto, CA, 2008. 1016456.

Guideline for the Management of Buried Piping Integrity, Nuclear Energy Institute, NEI-09-14, December 2009.

Lish, K. C. (1972). *Nuclear Power Plant Systems And Equipment*, Industrial Press Inc., New York.

"Liquid Radioactive Release Lessons Learned Task Force Final Report" U.S. NRC, Sept. 2006 http://pbadupws.nrc.gov/docs/ML0626/ML062650312.pdf

Memo from G. Jaczko, U. S. Nuclear Regulatory Commission, to R. W. Borchardt, "Evaluation of Buried Piping at Nuclear Reactor Facilities", dated September 3, 2009.

Ground Water Protection Initiative, Nuclear Energy Institute, NEI 07-07 August 2007.

NUREG-1801, Generic Aging Lessons Learned (GALL) Report, Nuclear Regulatory Commission, July 2001.

"Groundwater Contamination Due Undetected Leakage of Radioactive Water," US NRC, Information Notice 2006-13, July 10, 2006. http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/2006/in200613.pdf

NUREG/CR-6876, Risk-Informed Assessment of Degraded Buried Piping Systems in Nuclear Power Plants, Nuclear Regulatory Commission, June 2005.

Inspection Procedure 62002, Inspection of Structures, Passive Components, and Civil Engineering Features at Nuclear Power Plants, Nuclear Regulatory Commission, December 21, 1996.

NRC Staff's Revised Proposed Finding of Fact and Conclusions of Law, Part 2: Contention NYS-5 (Buried Piping and Tanks). Atomic Safety and Licensing Board. 22 Apr. 2013.

Nalluri, V. (2011) "Asset Management Practices for Buried & Underground Piping at Nuclear Power Plants" Final Report, Virginia Tech.

Plant Support Engineering: Buried Pipe End-of-Expected-Life Considerations and the Need for Planning. EPRI, Palo Alto, CA: 2008. 1016687.

Recommendations for an Effective Program to Control the Degradation of Buried and Underground Piping and Tanks (1016456, Revision 1). EPRI, Palo Alto, CA, 2010. 1021175.

S. Sinha, "Infrastructure Asset Management" Course CEE 5080, Virginia Polytechnic Institute and State University, Blacksburg, Spring 2013, Graduate Course.

Wood, J. (2007). *Nuclear Power*, 1st Ed, The Institute of Engineering and Technology, London.

Appendix C. Contact List

Table C List of Potential Contacts

List of Potential Contacts			
Station	City	State	Publicly Listed Directory
Joseph M. Farley Nuclear Plan	Columbia	AL	(334) 899-5156
Arkansas Nuclear One	Russellville	AR	(479) 858-5000
Waterford Steam Electric Station	Killona	LA	(504) 363-8737
Pilgrim Nuclear Station	Plymouth	MA	(508) 830-7000
Brunswick Steam Electric Plant	Southport	NC	(910) 457-2900
James A. Fitzpatrick Nuclear Power Plant	Oswego	NY	(315) 342-3840
Perry Nuclear Generating Station	Perry	OH	(440) 259-3737
Peach Bottom Atomic Power Station	Delta	PA	(717) 456-7014
Limerick Generating Station	Pottstown	PA	(800) 483-3220
Catawba Nuclear Station	York	SC	(803) 831-3000
Sequoyah Nuclear Plant	Soddy-Daisy	TN	(865) 632-2101
Surry Power Station	Surry	VA	(757) 357-5410
North Anna Power Station	Mineral	VA	N/A
Edwin I. Hatch Nuclear Plant	Baxley	VA	(912) 537-5900
Vermont Yankee Nuclear Power Station	Vernon	VT	(802) 257-7711

Appendix D: Sample Questionnaire to Outline Asset Management Discussion with Industry POC

1) Do you have a designated asset management plan for buried piping at your power station?

2) How do you determine what inspection methods to used when inspecting your piping?

3) Are new technologies used or explored for inspection and data collection?

4) How do you determine a schedule for inspection of buried piping?

5) How do you collect and store the data from inspections?

6) Is inspection data shared within the nuclear community?

7) How do you determine condition of your buried piping systems?

8) Do you utilize Risk Ranking?

9) Do you utilize BPWorks?

10) What information goes into your Risk Ranking procedure?

11) Do you utilize deterioration modeling for pipe analysis?

12) What other information is considered when deciding what actions to take (repair, replace, maintain) with buried piping segments?

13) Do you consider life cycle cost, or budgetary concerns?

14) What dictates the procedures for completing repair/replace/maintain activities?

15) Are new technologies explored for maintenance procedures?

16) Is your risk ranking updated after maintenance, repair actions, or inspection?

17) How do you prioritize your piping inspections and maintenance?

18) Do you utilize GIS software for management practices?

19) How do you feel about the use of GIS software for management practices?

Appendix E.

Overview of Practices and Literature for Asset Management of Buried Piping at Nuclear Power Plants