November 2012 **DRAFT**

KETTLE MORAINE CORRECTIONAL INSTITUTION

WATER SYSTEM EVALUATION

Prepared for

WISCONSIN DEPARTMENT OF ADMINISTRATION
PROJECT NO. 11L1I

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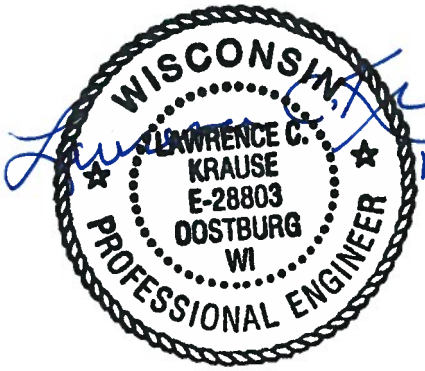

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EXECUTIVE SUMMARY

The Kettle Moraine Correctional Institute (KMCI) operates and maintains its own water distribution system. The system consists of two wells, a ground storage reservoir, and an elevated tower. The distribution system consists of a network of mostly ductile iron piping. The distribution system was constructed in the early 1960's, and most of the piping is still original.

Due to the increased frequency of line breaks and problems associated with interior plumbing systems, KMCI would like to investigate these issues and develop and implement a plan to make improvements to the overall water system. This project is to evaluate the wells and existing underground piping system, the facility's water chemistry, and the interior piping systems and associated equipment.

Well No. 3, constructed in 1994, appears to be in good condition. Well No. 4, which was brought online in 2006, appears to be having problems with sand/silt accumulating in the ground storage reservoir and getting into the distribution system.

KMCI has experienced an increase in the number of water main breaks over the last year or so. During the summer of 2011, five breaks in one area were repaired. Two additional breaks occurred during November 2011, and one in December 2011 (a break occurred in the line from the elevated storage tank). Most of the breaks appeared to be blowholes, but there are some which have been circumferential (snapped). Samples of line breaks show that the interior of the pipe is in good condition, and the exterior of the pipe is experiencing corrosion.

As part of this evaluation, a corrosion indication survey was performed on the majority of the distribution system piping. This was a "non-invasive" survey where no excavation of distribution system piping was required. The report showed that approximately 8 percent of the distribution system is highly likely to experience an increasing rate of near-term pipe failure. 16 percent is likely to begin to experience failures in the near future. The corrosion and reduced service life for the piping is likely attributed to soil conditions which are not favorable to ductile iron pipe.

Recommendations from the report include:

- Piping that was found to be highly likely to experience near-term failure (Immediate Concern) should be replaced.
- Piping that was found likely to begin to experience failure (Major Concern) should be replaced as funding and schedule allow.
- The soil environment at KMCI is not favorable for ductile iron pipe. Non-metallic water main or cathodic protection for new metallic mains should be considered.

The water treatment and water heating equipment at each of the buildings was inspected and documented as part of this study.

As part of this evaluation, Process Research Solutions, LLC, was retained to investigate the possibility that microbial activity is responsible for the pinhole leaks in the copper piping and loss of sacrificial anodes in the water heaters and water storage tanks.

Major conclusions from the study:

- Based on the analysis of a failed pipe sample and testing for microbiological activity at various buildings on the campus, microbiologically influenced corrosion appears to be occurring in the KMCI water system.
- Source water, specifically from Well No. 4, appears to be inoculating the water system with microorganisms.
- The introduction of Well No. 4 water to the system appears to have exaggerated the microbiological component to corrosion in the water system.
- The new Health Services Unit appears to be greatly affected by microbiologically influenced corrosion.
- Some of the corrosion in the hot water piping may be due to excessive water velocities.

Recommendations based on the Process Research Solutions report and our site visits were developed and include:

- Retain a well specialist to determine the microbiological impact on the wells, especially Well No. 4. Determine whether routine maintenance could be performed on the wells to keep microbiological activity low.
- Consider dosing the water supply with a biofilm removal chemical. Removing the biofilm would enable the chlorine residual to react with the microorganisms. This alternative will involve installing chemical storage and feed facilities at each well house. There appears to be adequate room available for the additional equipment.
- Clean water treatment equipment and water heaters/storage tanks with the biofilm removal chemical.
- The HSU building should be treated with a high dosage of biofilm removal chemical, and use a maintenance dosage to keep the system clean. Continue to monitor microbiological activity after the initial cleaning.
- Review water velocities in hot water recirculation piping as part of a pipe replacement evaluation/design.
- Consider adding sodium hypochlorite feed systems to the water softeners so that softener resins may be dosed with higher concentrations of chlorine during regeneration.
- Increase routine monitoring to track trending of lead, copper, iron, manganese, and microbiological activity in the water system.
- Determine whether the fire sprinkler systems are experiencing microbiologically influenced corrosion, and treat those systems if needed.
- The failure of anode rods in less than a year is unusual, especially since other building systems are not experiencing this issue. KMCI should confirm that the anode material in the newer water heaters/storage tanks is the same as the older units. Anodes are normally made of aluminum, magnesium, zinc, or alloys of these metals. Each material will be affected in different ways depending on the water chemistry.

- Additional investigation of the School's water system should be performed to attempt to locate and remove additional cross connections between the hot and cold water systems.
- The scaling issue in Unit 6 – Wolf may be due to softener operation, or, like the School, cross connections between the hot and cold water systems. Additional investigation to identify the cause of scaling is recommended.
- KMCI should consider replacing/upgrading plumbing components and piping in the buildings that are experiencing significant leaks/failures. This is a long term recommendation that would be done in a prioritized manner starting with the buildings that have the most severe problems.
- Rehabilitation or replacement of Well No. 4 should be considered based on the evaluation recommended by Process Research Solutions.

This evaluation developed several recommendations for addressing distribution system main failures, building corrosion issues, and plumbing system operations. The recommendations were prioritized for future planning, and estimated construction costs were prepared.

INTRODUCTION

The Kettle Moraine Correctional Institute (KMCI) operates and maintains its own water distribution system. The system consists of two wells, a ground storage reservoir, and an elevated tower. The distribution system consists of a network of mostly ductile iron piping. The distribution system was constructed in the early 1960's, and most of the piping is still original.

KMCI has experienced an increase in the number of water main breaks over the last year or so. During the summer of 2011, five breaks in one area were repaired. Two additional breaks occurred during November 2011, and one in December 2011 (a break occurred in the line from the elevated storage tank). Most of the breaks appeared to be blowholes, but there are some which have been circumferential (snapped). KMCI staff has observed that most of the ductile iron piping was installed without proper bedding materials. Samples of line breaks show that the interior of the pipe is in good condition, and the exterior of the pipe is experiencing corrosion.

Water treatment at KMCI includes chlorination at the well sites and ion-exchange softening for the facility's boiler and hot water systems. Interior plumbing systems are showing signs of corrosion. Fixtures are becoming corroded, hot water copper piping is developing pinhole leaks, and mixing valves are scaling. Inspection of failed copper piping shows significant interior pitting. Water heaters are experiencing significant scale buildup and rapid loss of sacrificial anodes, resulting in shortened equipment life.

Due to the increased frequency of line breaks and problems associated with interior plumbing systems, KMCI would like to investigate these issues and develop and implement a plan to make improvements to the overall water system. The first phase of the project is to evaluate the wells and existing underground piping system, the facility's water chemistry, and the interior piping systems and associated equipment.

WELLS

Well No. 3 and its associated well house were constructed in 1994. The well is approximately 339 feet deep, and has a pumping capacity of approximately 400 gpm. The well pumps directly into the distribution system. Sodium hypochlorite is added just upstream of a flow meter for disinfection. There are sample taps upstream and downstream of the chemical feed point.

The system appears to be in good condition. The startup and shutdown of the well pump was observed to determine whether the check valve was operating properly. A check valve that opens or closes too quickly can cause water hammer in the distribution system. The well pump started and stopped smoothly, and the check valve opened and closed smoothly. There was no indication of water hammer.

KMCI staff indicated that testing for chlorine residual for this well is difficult due to the short length of pipe between the application point and the sample tap.

The water quality from Well No. 3 is very good and is typical of groundwater in this region of the state:

- Total Hardness 340 mg/L as CaCO3
- Calcium Hardness 165 mg/L as CaCO3
- Magnesium Hardness 175 mg/L as CaCO3
- Alkalinity 290 mg/L as CaCO3
- Total Dissolved Solids 330 mg/L as CaCO3
- Iron less than 0.02 mg/L
- Manganese less than 0.001 mg/L

Well No. 4, its associated well house, and the ground storage reservoir were constructed in 2005-2006. The well is approximately 315 feet deep and has a pumping capacity of approximately 350 gpm. The well pump discharges to a 200,000 gallon ground storage reservoir. Water from the ground storage reservoir is pumped into the distribution system with two high service pumps, each rated at 350 gpm.

The well discharge piping includes a sample tap, check valve, flow meter, sodium hypochlorite feed point, and isolation valves. There is no sample tap downstream of the sodium hypochlorite feed point. There is also a sample tap on the common discharge header of the high service pumps.

Well No. 4 was originally drilled to a depth of 343 feet. During the initial pump testing, excessive turbidity in the water was noted. After the pump test was completed, the well was televised. The video showed a fractured seam of limestone/dolomite scale that had a significant amount of fine material.

Additional pumping at rates of 1,100-1,300 gpm did improve water clarity, but not to acceptable levels. The well was partially abandoned to isolate the fractured layer that was contributing the fine material. An additional pump test was performed at a rate of 320 gpm, and the water showed no turbidity and had good clarity.

A review of the construction records showed that Well No. 2, which was abandoned when Well No. 4 was brought online, had similar problems when it was brought online. Well No. 2 was located adjacent to the Well No. 4 well house.

The well has been online for approximately 6 years. KMCI staff has taken the ground storage reservoir out of service for maintenance and inspection. KMCI staff noted that there was a significant accumulation of fine material and sand on the floor of the reservoir at the well pump discharge. This indicates that there may still be a turbidity issue with the well; however, the detention time in the reservoir allows the fine material to settle out.

The mechanical systems appear to be in good condition. The startup and shutdown of the well pump and high service pumps was observed to determine whether the check valves were operating properly. The well pump started and stopped smoothly, and the check valve opened and closed smoothly. There was no indication of water hammer. The high service pumps and their associated check valves also operated properly.

Well No. 4 water quality is similar to Well No. 3, but does have higher levels of iron and manganese. USEPA established secondary maximum contaminant levels (MCL's) for iron (0.3 mg/L) and manganese (0.05 mg/L), and Well No. 4's water quality meets these standards.

- Total Hardness 318 mg/L as CaCO3
- Calcium Hardness 168 mg/L as CaCO3
- Magnesium Hardness 150 mg/L as CaCO3
- Alkalinity 280 mg/L as CaCO3
- Total Dissolved Solids 270 mg/L as CaCO3
- Iron 0.17 mg/L
- Manganese 0.026 mg/L

The similarity in water quality between the wells is a good indication that there are no unusual chemical reactions occurring in the distribution system due to mixing of the wells' water.

DISTRIBUTION SYSTEM

The distribution system consists of a network of mostly ductile iron piping. The distribution system was constructed in the early 1960's, and most of the piping is still original. Most of the piping is 6-inch diameter. KMCI staff has observed that most of the ductile iron piping was installed without proper bedding materials.

KMCI has experienced an increase in the number of water main breaks over the last year or so. During the summer of 2011, five breaks in one area were repaired. Two additional breaks occurred during November 2011, and one in December 2011 (a break occurred in the line from the elevated storage tank). Most of the breaks appeared to be blowholes, but there are some which have been circumferential (snapped). Samples of line breaks show that the interior of the pipe is in good condition, and the exterior of the pipe is experiencing corrosion.

The elevated storage tank was taken offline during the summer 2011 for maintenance. The elevated storage tank acts as a pressure spike dampener when pumps start and stop. When the tank is offline, significant spikes in system pressure and water hammer can occur as pumps start and stop. This likely contributed to the frequent breaks during the summer. This is supported by the fact that most of these breaks occurred on the north side of the facility on the mains between Well Nos. 3 and 4.

As part of this evaluation, a corrosion indication survey was performed on the majority of the distribution system piping. This was a "non-invasive" survey where no excavation of distribution system piping was required. The complete survey report is included in Appendix A.

The report showed that approximately 8 percent of the distribution system is highly likely to experience an increasing rate of near-term pipe failure. 16 percent is likely to begin to experience failures in the near future. The corrosion and reduced service life for the piping is likely attributed to soil conditions which are not favorable to ductile iron pipe.

Figure 1 is a summary of the corrosion indication survey. The survey identified the following piping classifications:

- Immediate Concern
- Major Concern
- Moderate Concern
- Minor Concern

Recommendations from the report include:

- Piping that was found to be highly likely to experience near-term failure (Immediate Concern) should be replaced.
- Piping that was found likely to begin to experience failure (Major Concern) should be replaced as funding and schedule allow.
- The soil environment at KMCI is not favorable for ductile iron pipe. Non-metallic water main or cathodic protection for new metallic mains should be considered.

The Immediate Concern piping identified as Segment 1 is the line that runs across the site between Well Nos. 3 and 4. This is the same line that experienced numerous failures in 2011.

The line running to the elevated storage tower was rated as a Major Concern. This line experienced a break in December 2011.

Prioritization of piping replacement was discussed with KMCI staff during a project meeting. Two alternatives were discussed:

1. Replace Immediate and Major Concern piping site wide as a first project, then replace Moderate Concern piping in subsequent projects.
2. Delineate site into three zones, and replace Immediate, Major, and Moderate Concern piping in three projects.

It was decided by KMCI that the second alternative would be the better alternative for facility security because it focuses construction in specific areas instead of scattered sites throughout the facility.

Three zones were identified and are shown in Figure 2. The first project would focus on the north side of the facility where most of the line breaks have been occurring. The second project

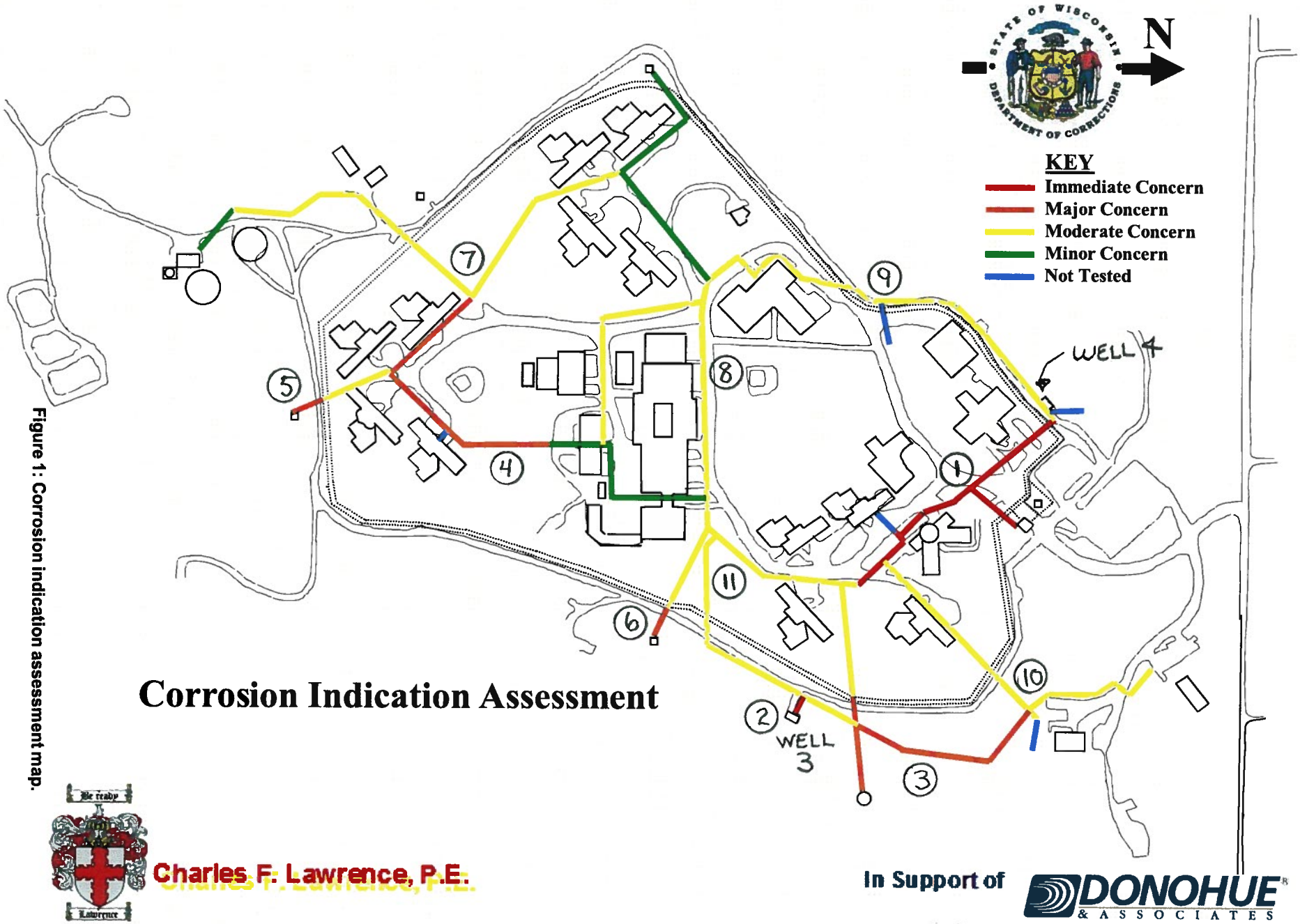

Figure 1: Corrosion indication assessment map.

Figure 1: Summary of Corrosion Indication Assessment

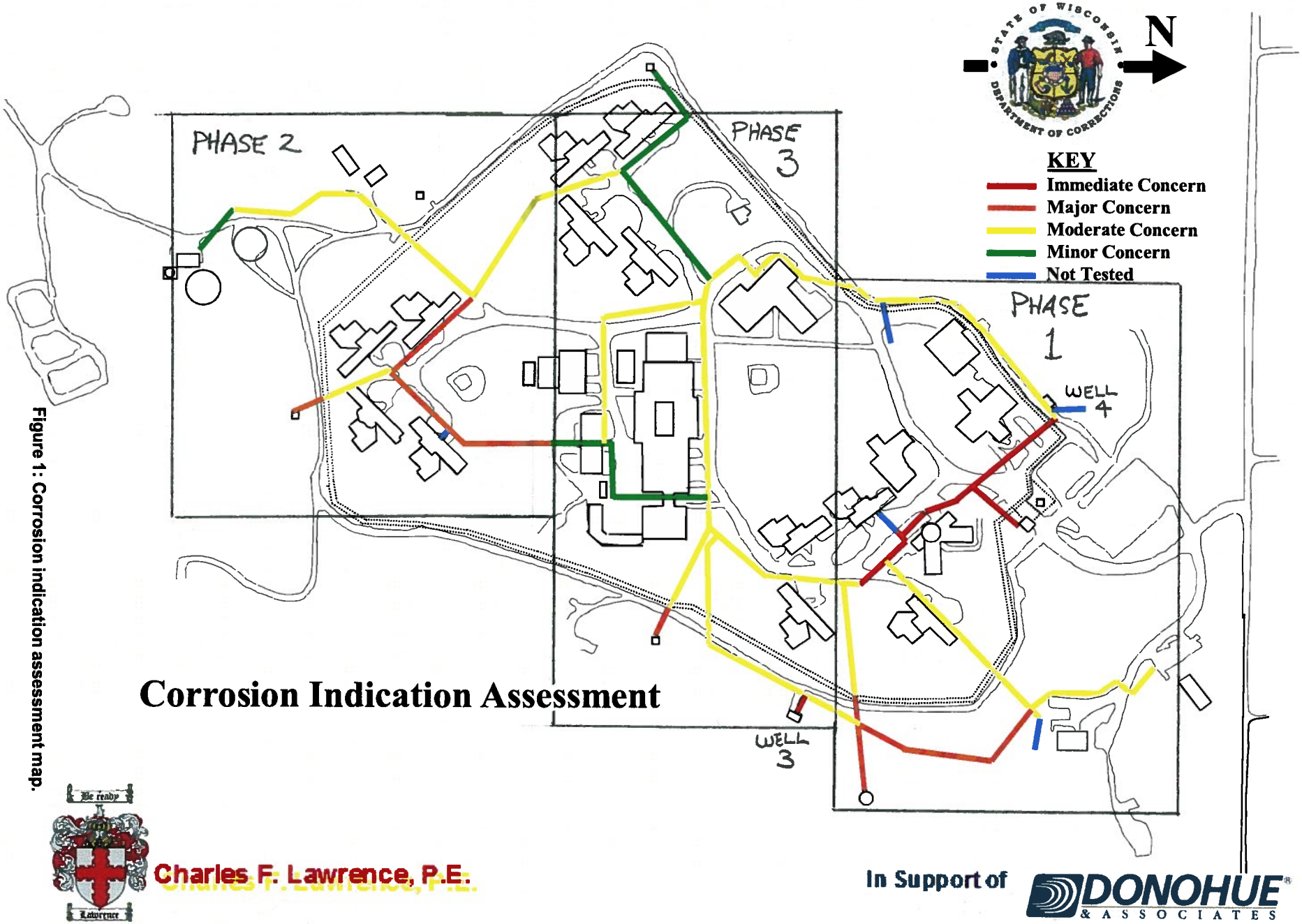

Figure 1: Corrosion indication assessment map.

Figure 2: Recommended Distribution System Replacement Phasing

would focus on the south side of the facility where there is some Major Concern piping. The third project would focus on the center of the facility where most of the piping is of Moderate and Minor Concern.

Construction cost opinions were prepared for each zone, and are summarized in Tables 1-3. The following assumptions were made:

- Non-metallic C900 piping, 8-inch diameter (upsized from the existing 6-inch diameter)
- Replacement of fire hydrants (included in contingency)
- Replacement of existing valves, and additional valves to better isolate buildings and distribution piping segments for maintenance/repairs

Construction Costs

Phase 1: North Site	$ 805,600
Phase 2: South Site	$ 475,600
Phase 3: Central Site	$ 522,100

BUILDING PLUMBING SYSTEMS

KMCI does not utilize a central facility for treatment or heating its water supply. The hot water equipment in Building Nos. 2, 6, and 11 serve groups of buildings. Building Nos. 13, 14, 15, 16, School, Food Service, and the wastewater treatment plant have their own hot water system equipment. The new Health Services Building (HSU) which recently completed construction and will soon be occupied also has its own hot water system.

Water is softened utilizing ion exchange softening prior to heating. Due to chloride effluent limits for the wastewater treatment plant, the softening systems in each building have been optimized to minimize salt usage. Some of the softening systems utilize brine recycling, and all of the softeners have been upgraded to regenerate based on water usage and not elapsed time.

KMCI regularly tests the hardness of the softener effluent for all of the buildings.

The water treatment and water heating equipment at each of the buildings was inspected and documented as part of this study. The following summarizes this information:

Wastewater Treatment Plant Laboratory

- Laboratory has experienced breaks in the incoming service water ahead of the water softener. Most were pinhole leaks, and mostly near the water softener inlet.
- Hellenbrand water softener system
    - Model No. 155-24E
    - 24,000 gr capacity
    - 8.0 gpm @14.5 psig
    - Recharges based on volume

Table 1
KMCI

Water System Study

Buried Piping Replacement - North Site

CONSTRUCTION COST OPINION

General Description

ITEM	Units	Quantity	Unit Cost ($)	Initial Cost ($)
Piping Segment - Immediate Concern				
Piping Segment 1: 900 Feet 8"	LF	900	96	86,400
Valves	Each	6	3,500	21,000
Piping Segment - Major Concern				
Piping Segment 3: 900 ft 8"	LF	900	96	86,400
Valves	Each	4	3,500	14,000
Piping Segment 9: 975 ft 8"	LF	1,125	96	108,000
Valves	Each	5	3,500	17,500
Piping Segment 10: 825 ft 8"	LF	825	96	79,200
Valves	Each	5	3,500	17,500
Subtotal				430,000
Contingency			30%	129,000
Subtotal				559,000
Contractor Overhead & Profit			25%	139,750
Total Construction Cost				**698,750**
Engineering			15%	104,813
Total Initial Cost				**803,563**

Table 2
KMCI

Water System Study

Buried Piping Replacement - South Site

CONSTRUCTION COST OPINION

General Description

ITEM	Units	Quantity	Unit Cost ($)	Initial Cost ($)
Piping Segment 4: 975 ft 8"	LF	975	96	93,600
Valves	Each	6	3,500	21,000
Piping Segment 5: 75 ft 8"	LF	75	96	7,200
Valves	Each	1	3,500	3,500
Piping Segment - Moderate Concern				
Piping Segment 7: 1200 ft 8"	LF	1,200	96	115,200
Valves	Each	4	3,500	14,000
Subtotal				254,500
Contingency			30%	76,350
Subtotal				330,850
Contractor Overhead & Profit			25%	82,713
Total Construction Cost				**413,563**
Engineering			15%	62,034
Total Initial Cost				**475,597**

Table 3
KMCI

Water System Study

Buried Piping Replacement - Central Site

CONSTRUCTION COST OPINION

General Description

ITEM	Units	Quantity	Unit Cost ($)	Initial Cost ($)
Piping Segment - Immediate Concern				
Piping Segment 2: 75 ft 8"	lf	75	96	7,200
Valves	Each	1	3,500	3,500
Piping Segment - Major Concern				
Piping Segment 6: 75 ft 8"	LF	75	96	7,200
Valves	Each	1	3,500	3,500
Piping Segment - Moderate Concern				
Piping Segment 8: 975 ft 8"	LF	975	96	93,600
Valves	Each	6	3,500	21,000
Piping Segment 11: 1275 ft 8"	LF	1,275	96	122,400
Valves	Each	6	3,500	21,000
	Each			
Subtotal				279,400
Contingency			30%	83,820
Subtotal				363,220
Contractor Overhead & Profit			25%	90,805
Total Construction Cost				**454,025**
Engineering			15%	68,104
Total Initial Cost				**522,129**

  - No brine recycle
  - Installation Date: Unknown
- AO Smith electric water heater
  - Model No. ELSF 10
  - 10 gallon capacity
  - Installation Date: Unknown

Unit 14 - Segregation

- Water Softener
  - Hellenbrand
  - H150 series, duplex unit Size 2162
  - Brine recycle
  - Installation Date: 2011
- Hot water storage tanks
  - RJS 120, Lochinvar Corporation, Lebanon, IN
  - Three units in parallel
  - 119 gallons capacity, each
  - 112F on outlet
  - Installation Date: 2007
- Boiler and heat exchanger
- Problems with piping in area around heat exchangers. There have been no issues since the water softeners were replaced.
- The old softeners had to be regenerated manually for the last two years or so. One unit would regenerate automatically, but the other would not. Sometimes a few days went by before manual regenerations were initiated.

Unit 11 - Menominee

- Hellenbrand water softener
  - H200M Series, Size 2472
  - Brine reclaim
  - Installation Date: Unknown
- Hot water storage tanks (hot water heat)
  - Bock 119ST
  - 4 units in parallel
  - 119 gallons capacity, each
  - Installation Date: 2011
- Gas-fired water heaters (for domestic HW use)
  - Bock

  - Two units
  - 91 gallons capacity, each
  - 435 gph @ 90F rise
  - Installation Date: 2011
- Boiler and heat exchanger
  - Provide HW for building heating
- Three segments of underground copper piping for the building heating system between Building Nos. 11 and 12 were replaced in 2009.

School

- Hellenbrand water softener
  - Size 2162, Model 72-A1004
  - Conductivity probes for control (do not work)
  - Brine recycle
  - Installation Date: 2003
- Hot water storage tanks
  - AO Smith TJV-120-A
  - Two units
  - Glass lined
  - 119 gallons capacity, each
  - Installation Date: 2012

- Since our site visit, KMCI staff replaced the two hot water storage tanks at the School. Additional pipe replacement around the storage tanks and heat exchanger were completed in 2011. During the tank replacement, KMCI staff noted a major buildup of material in a section of pipe between the water tank an heat exchanger. The material appeared to be a crystal/glass material near the center of the pipe. When it was broken off, silt/sand was found near the wall of the pipe.

  Donohue requested that KMCI staff try to dissolve the material in distilled water and in a 10-20 percent acid solution. The material did not dissolve in distilled water, but most of it readily dissolved in the acid solution, producing a significant amount of bubbling. This indicates that the majority of the material is calcium carbonate. Calcium carbonate will produce carbon dioxide gas when dissolved in acid. The material left over appeared to be silt/sand.

  Based on KMCI staff observations in the Well No. 4 ground storage reservoir, it is likely that the sand/silt is coming from Well No. 4. Earlier we noted that the sand/silt settles out in the reservoir, but there may be times when there is inadequate detention time available due to the high service pumps running at the same time as the well.

In addition, the elevated storage tank was out of service for 5 months in 2011. During these 5 months, KMCI staff feel a large amount of sand was pumped into the distribution system, as the booster pumps needed to run 24 hours a day to keep the system pressurized and provide water on demand. There was probably a great deal of short-circuiting occurring, and this allowed sand/silt to be pumped to the distribution system. KMCI staff noted that when they performed system flushing last spring, there was a lot of sandy/muddy water compared to previous years.

The presence of calcium carbonate in the material is puzzling assuming that the softeners are operating properly. KMCI staff may have solved this mystery in that they have found several cross connections between the softened hot water piping and the unsoftened cold water system in the past.

The hardness tests on the softener effluent are almost always between 0-1 grains/gallon, but the hot water system hardness is usually around 5 grains/gallon. This is a high enough concentration to cause scaling problems. If there is a cross feed of unsoftened cold water into the hot water system, it is likely the contributor to the majority of the scaling in the School's system.

Unit 16 - New Arrivals

- Marlow water softener
  - Model and capacity unknown
  - Installation Date: Unknown
  - No brine reclaim
- Water heater
  - Bock Model Midco RE4700BA
  - 627 gph @ 90F rise
  - 83 gallons capacity
  - Installation Date: 2007
- No hot water storage
- They experimented with magnets to control scaling in this building years ago, there did not appear to be any benefit.
- No problems with plumbing in this building.

Unit 13 - Canteen

- Water softener
  - Clack 0948
  - Capacity unknown
  - Installation Date: Unknown

  - Small unit (household size)
- Water heater
  - State
  - Two units, one is offline
  - 100 gallons capacity, each
  - Installation Date: 1995

Unit 6 - Wolf

- Setup and equipment very similar to Unit 11
- This building has lime scaling issues.
- Hellenbrand water softener
  - H200M Series, Size 2472
  - Brine reclaim
  - Installation Date: 2005
- Hot water storage tanks (hot water heat)
  - AO Smith
  - 4 units in parallel
  - 119 gallons capacity, each
  - Installation Date: Unknown
- Gas-fired water heaters (for domestic HW use)
  - Bock
  - Two units
  - 91 gallons capacity, each
  - 435 gph @ 90F rise
  - Installation Date: 2011
- Boiler and heat exchanger
  - Provide HW for building heating
- There appears to be salt or calcium carbonate buildup on top of Water Storage Tank No. 3. This may indicate a potential for failure in the near future.

Unit 2 - Chippewa

- Setup is the same as Units 6 and 11.
- Custom Care water softener
  - Brine reclaim
  - Installation Date: 2005
- Hot water storage tanks (hot water heat)
  - Bock 119ST
  - 4 units in parallel

  - 119 gallons capacity, each
  - Installation Date: 2011

- Gas-fired water heaters (for domestic HW use)
  - Bock
  - Two units
  - 91 gallons capacity, each
  - 435 gph @ 90F rise
  - Installation Date: 2010
- Boiler and heat exchanger
  - Provide HW for building heating

Unit 15 - Eagle

- Custom Care water softener
  - Capacity unknown
  - Brine reclaim
  - Installation Date: 2005
- Hot water storage tanks
  - Lochinvar
  - Three units in parallel
  - 119 gallons capacity, each
  - Installation Date: Unknown
- Boiler and heat exchanger

Food Service

- Water softener
  - BWC (Brauch Water Conditioning Company, Inc.)
  - Capacity unknown
  - Recharges based on flow
  - No brine reclaim
  - Installation Date: over 13 years ago
  - System has worked reliably
- Steam boilers
- Heat exchanger to hot water system

In general, the interior plumbing systems are showing signs of corrosion. Plumbing fixtures are becoming corroded/pitted and hot water copper piping is developing pinhole leaks. Inspection of

failed copper piping shows significant interior pitting. Some of the facility's water heaters are experiencing significant scale buildup and rapid loss of sacrificial anodes, resulting in shortened equipment life.

Some of the corrosion in the hot water recirculation piping appears to be due to high water velocity. This is typically seen at bends in hot water recirculation piping.

As part of this study, Process Research Solutions, LLC, was retained to investigate the possibility that microbial activity is responsible for the pinhole leaks in the copper piping and loss of sacrificial anodes in the water heaters and water storage tanks. The preliminary report from Process Research Solutions is included in Appendix B.

The report reviewed the water chemistry characteristics of the well supplies and documented that there was adequate chlorine residual in the distribution system. The major focus of the investigation was to determine whether there was microbiological activity occurring in the water system. Failed copper piping samples were analyzed and it was determined that biofilms may be responsible for pinhole leaks. Extensive testing of water systems in campus buildings determined that there is microbiological activity occurring.

Major conclusions from the study:

- Based on the analysis of a failed pipe sample and testing for microbiological activity at various buildings on the campus, microbiologically influenced corrosion appears to be occurring in the KMCI water system.
- Source water, specifically from Well No. 4, appears to be inoculating the water system with microorganisms.
- The introduction of Well No. 4 water to the system appears to have exaggerated the microbiological component to corrosion in the water system.
- The new Health Services Unit appears to be greatly affected by microbiologically influenced corrosion.
- Some of the corrosion in the hot water piping may be due to excessive water velocities.

The recommendations from the Process Research Solutions report provide guidance for addressing the issues regarding microbiologically influenced corrosion at KMCI. These recommendations will be used to develop a plan for the next phase of the project. They include:

- Retain a well specialist to determine the microbiological impact on the wells, especially Well No. 4. Determine whether routine maintenance could be performed on the wells to keep microbiological activity low.
- Consider dosing the water supply with a biofilm removal chemical. Removing the biofilm would enable the chlorine residual to react with the microorganisms. This alternative will involve installing chemical storage and feed facilities at each well house. There appears to be adequate room available for the additional equipment.
- Clean water treatment equipment and water heaters/storage tanks with the biofilm removal chemical.

- The HSU building should be treated with a high dosage of biofilm removal chemical, and use a maintenance dosage to keep the system clean. Continue to monitor microbiological activity after the initial cleaning.
- Review water velocities in hot water recirculation piping as part of a pipe replacement evaluation/design.
- Consider adding sodium hypochlorite feed systems to the water softeners so that softener resins may be dosed with higher concentrations of chlorine during regeneration.
- Increase routine monitoring to track trending of lead, copper, iron, manganese, and microbiological activity in the water system.
- Determine whether the fire sprinkler systems are experiencing microbiologically influenced corrosion, and treat those systems if needed.

In addition to Process Research Solutions' recommendations, the following are additional recommendations based on the overall evaluation:

- The failure of anode rods in less than a year is unusual, especially since other building systems are not experiencing this issue. KMCI should confirm that the anode material in the newer water heaters/storage tanks is the same as the older units. Anodes are normally made of aluminum, magnesium, zinc, or alloys of these metals. Each material will be affected in different ways depending on the water chemistry.
- Additional investigation of the School's water system should be performed to attempt to locate and remove additional cross connections between the hot and cold water systems.
- The scaling issue in Unit 6 – Wolf may be due to softener operation, or, like the School, cross connections between the hot and cold water systems. Additional investigation to identify the cause of scaling is recommended.
- KMCI should consider replacing/upgrading plumbing components and piping in the buildings that are experiencing significant leaks/failures. This is a long term recommendation that would be done in a prioritized manner starting with the buildings that have the most severe problems.

  We are estimating that the building that house the water softening equipment, boilers, and water storage tanks will cost approximately $100,000 each to upgrade. Satellite buildings served by these systems will be approximately $50,000 each to upgrade.

- Rehabilitation or replacement of Well No. 4 should be considered based on the evaluation recommended by Process Research Solutions.

PRIORITIZATION OF RECOMMENDATIONS

This evaluation developed several recommendations for addressing distribution system main failures, building corrosion issues, and plumbing system operations. Table 4 summarizes the recommendations, prioritizes them, and includes estimated construction costs. The estimated construction costs should be used for planning purposes.

Table 4
KMCI
Water System Study
Prioritization of Recommendations

	Item	2012-2014	2014-2016	2016-2018
1	HSU Building Cleaning	$ 20,000		
2	Distribution System Piping Replacement	$ 805,600	$ 475,600	$ 522,100
3	Well Evaluation	$ 30,000		
4	Chemical Feed Facilities for Biofilm Removal Chemical	$ 30,000		
5	Sodium Hypochlorite Feed Facilities for Ion Exchange Softeners	$ 40,000		
6	Increase Routine Monitoring of Water Chemistry	$ 10,000	$ 11,000	$ 12,000
7	Newer Water Heater/Storage Tank Anode Evaluation			
8	School Water System Investigation	$ 10,000	$ 20,000	
9	Unit 6 - Wolf Scaling Investigation	$ 5,000		
10	Upgrade/Replacement of Building Plumbing Systems		$ 250,000	$ 250,000
11	Replacement or Rehabilitation of Well No. 4		$ 750,000	
	Total	$ 950,600	$ 1,506,600	$ 784,100

HSU Building

Work at the HSU building has already begun in order to meet a deadline for building occupancy. Donohue and Process Research Solutions developed a plan for adding the biofilm removal chemical and designed a chemical feed system for dosing the chemical. Chemical feed equipment was procured by DSF and installed by a plumbing contractor. The water system was charged with the biofilm removal chemical and allowed to react for about 48 hours. The system was then flushed. KMCI staff have been running water in the HSU to keep the system fresh. The biofilm removal chemical dosage was reduced to a maintenance dosage of 0.5 mg/L.

A monitoring plan was prepared by Process Research Solutions and the first round of samples will be collected on November 26, 2012. Samples will be tested for biological activity to determine whether the cleaning procedure was successful and that the maintenance dosage of chemical is working.

APPENDIX A

CORROSION INDICATION ASSESSMENT

CHARLES F. LAWRENCE, P.E.

APPENDIX B

KETTLE MORAINE CORRECTIONAL INSTITUTION

WATER QUALITY INVESTIGATION

PROCESS RESEARCH SOLUTIONS