Evaluating Treatment Process Equipment the GIS Way

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Abstract

Meeting increasing stringent compliance standards with aging equipment, controls, and structures is among the most challenging aspects of wastewater treatment operations facing cities and towns today. Proactive assessment of the physical condition of the plant's components permits managers and operators to prepare the facility for near and longer term performance demands. The City of Elkhart and HNTB Corporation collaborated to develop an assessment procedure for all major equipment components of the Elkhart's Wastewater Treatment Plant. The project involved detailed evaluations of equipment conditions with respect to regulatory compliance, operational efficiency, and safety. Using a unique scoring procedure, recommendations and costs for corrective maintenance, replacements, and upgrades were established along with corresponding priorities for implementation. The project then linked this informational database into the City of Elkhart's GIS as an interactive facility management application. Managers and operators at Elkhart now have the roadmap needed to prepare for the plant's immediate operational future.

Keywords: ass*et management, database, fixed assets, GIS*

Introduction

Effective management of wastewater treatment facilities is an increasingly complicated task. More stringent regulations, tighter fiscal budgets and dwindling loan and grant funding opportunities are forcing utility managers to push the operational and performance envelopes of systems and equipment. Too often, critical preventive maintenance tasks are compromised, pushing systems and equipment beyond normal service life limits. Not only do such compromises end up often costing the utility more, but permit compliance can be seriously jeopardized.

What managers need more now than ever are interactive data management tools that provide concise directives on proactive and corrective maintenance activities without the cumbersome details of data record updates. These tools must be designed such that the utility systems and equipment become a portfolio of assets holding value to be managed, rather than merely hardware to be oiled once in a while. With utility assets, priority is given first to the degree of its importance to the overall portfolio. It can not be presumed that financial value alone defines its standing in the portfolio.

The Wastewater Treatment Plant staff at the City of Elkhart has addressed the challenge of managing its utility systems and equipment using the asset management paradigm. The goal of this program was to form a portfolio of the wastewater treatment systems and associated equipment assets that results in a logical "roadmap" for expenditures over the next several years and develop a format for managing all fixed assets. The objectives were to 1) establish the baseline physical conditions of all critical mechanical and electrical systems, 2) evaluate effectiveness of proactive maintenance

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practices already in place, 3) establish criteria for prioritizing needs for corrective maintenance, 4) establish criteria for prioritizing capital improvements, and 5) establish a methodology for ranking the degree of importance of systems and components to arrive at pragmatic recommendations for changes and improvements. The outcome is an improved confidence in NPDES permit compliance, a set of prioritized improvements necessary to sustain compliance into the future, and a more "user-friendly" system for managing fixed assets.

Methodology[3]

Preparation of the Database

Accomplishing the goal required use of several key tools. First, a "facilities management" module within the City Geographic Information System (GIS v. 8.1) was developed to serve as the database management engine. Second, linked to this module was the systems and equipment database developed in ACCESS. A data form was developed for each treatment unit process and its associated critical mechanical and electrical equipment. Along with data inputs describing physical condition and maintenance record, each form requires an installation date, expected remaining service life, and general cost data for each component. These latter pieces of information are integral to the component's value as an asset.

To populate the database, engineers from HNTB Corporation along with Elkhart plant operators and maintenance personnel, conducted detailed on-site surveys of each process component. Assessments were conducted on equipment in each of the following unit processes: headworks, primary treatment, secondary treatment, tertiary treatment, sludge thickening, sludge digestion, sludge dewatering, and electrical gear. To aid in these surveys, preventive maintenance records, installation records, operational records, corrective maintenance records, and work-order records were reviewed. The project team used a simple tiered ranking scheme to assess the condition of each component.

In this scheme, a numerical value of 1 through 4 was assigned to each component. The numerical values corresponded to the following:

Level 1: In "*like-new*" condition. At this category, equipment is operable and/or running, efficiently serving its intended function. The component shows little sign of wear or use, and ongoing preventive maintenance should retain a high level of operability for the foreseeable future.

Level 2: In "*adequate*" condition. Within this category, equipment is operable and/or running, efficiently service its intended function. However, the component shows signs of wear and ;use, but ongoing preventive maintenance should retain an adequate level of operability in the foreseeable future.

Level 3: In "*semi-operable*" condition. Equipment in this category may or may not be operable and/or running. These may be in need of minor repair to regain operability, or may be running in a marginal condition. The attention needed by this component may be due to age, wear, lack of efficiency, improper application, or otherwise does not efficiently service its intended function. Minor work (i.e., that can be

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[3] Much of the text for this section comes from the "*Wastewater Treatment Plant Equipment Evaluation*", prepared for Public Works and Utilities, City of Elkhart, May 2002, by HNTB Corporation

accomplished by plant personnel using stock equipment and parts) is needed to bring the equipment item to a Level 2 or Level 1 condition.

Level 4: In "*inoperable*" condition. Equipment in this category is not operable or is clearly operating in a marginal condition. Major work (i.e., requiring contract services, rental of tools, or a significant equipment replacement purchase) is needed to bring the item to a Level 2 or Level 1 condition.

Because a component is merely a part of the sum total of all parts of the system, there will be cases in which a specific component is more critical to the functionality of the system than others. Similarly, there are those whose criticality is less. Therefore, it as recommendations were evaluated, it was important to first determine this level of criticality. For those items that received a Level 3 or Level 4 assessment, additional criteria were applied to clarify how a recommendation would be structured. The three additional criteria used were:

- Safety
- Compliance
- Efficiency

The safety category is intended to describe the priority of the recommendation in terms of its affect on the safety of plant staff and the general public. Issues that need to be considered included hazardous environments (explosive, toxic, confined spaces, electrical hazards, etc.), potential to release harmful chemicals into the immediate work environment or into the atmosphere, and the potential to cause basement backups or surface flooding problems in the collection systems.

For compliance, the category is intended to describe the priority in terms of its affect on the ability of the plant to meet permit effluent limits and otherwise stay in compliance with the NPDES permit held by the City of Elkhart. Issues such as impacts on plant capacity, redundancy, alternative operating modes available, difficulty of accommodating unit outage, impact on operation of other equipment, affect on need to bypassing, and the overall degree of separation from the compliance-critical treatment process train.

The efficiency category is intended to describe the priority of the recommendation in terms of its affect on the cost to operate and maintain the facility. Issues such as the degree of operator attention required, difficulty and cost to obtain replacement parts, energy costs, chemical costs, maintenance costs, and any other cost issues that will be improved by the recommended work task.

These additional criteria require an assignment of severity. For each of the Safety, Compliance, and Efficiency assessments, a category of HIGH, MEDIUM, or LOW priority is assigned. For example, a HIGH priority for a safety element would represent a recommendation that calls for elimination of an *existing* or *imminent* safety hazard. Similarly, a HIGH priority should be given to recommendations needed to eliminate *imminent* compliance problems, such as places where redundancy is inadequate, or an existing equipment condition appears to threaten the reliable treatment of plant design capacity flows, such as unplanned outages in critical process areas. For the efficiency category, the three degrees also involve time of payback for the recommended improvement. For example, a HIGH priority is given to recommendations with an immediate payback, i.e., less than one year return on investment, while a LOW priority is given to recommendations with nominal payback.

With the scoring completed for all the Level 3 and Level 4 condition components, a set of improvement recommendations was drafted. The prioritization of the recommendations was numerically represented by applying a weighting factor to the assessment categories of safety, compliance, and efficiency in the following manner:

$$\text{Rank Score} = (2 \times \textit{Safety}) + (3 \times \textit{Compliance}) + (1 \times \textit{Efficiency})$$

To complete the assessment process, costs for improvement recommendations for the Level 3 and Level 4 components along with a brief narrative description of the type of improvement required were added to the database. The following is an example of how the above assessment procedure was applied to a screw pump drive mechanism in the preliminary treatment process. The drive in question is shown in **Figure 1**.

Figure 1

Condition Assessment = **4** (conditions at 3 or higher require additional evaluation)

Safety =	**3**	scores assigned based on team's judgment
Permit =	**3**	
Efficiency =	**1**	

$$
\begin{aligned}
\text{Summary Score} &= (\textit{Safety} \times 2) + (\textit{Permit} \times 3) + (\textit{Efficiency} \times 1) \\
&= 6 + 9 + 1 \\
&= \mathbf{16}
\end{aligned}
$$

The summary score of 16 places this equipment component at the top of the priority list for improvements. Recommendation for improvements include repair to pinion gear unit. The cost for the repair is estimated at $15,000. Because of its high summary score, the timetable for the repair is immediate, or the first available budget cycle. For the City of Elkhart this would translate to repair in 2003.

Preparation of the GIS Link

The final step in the asset management module development for Elkhart was linking the ACCESS database to the GIS platform. This element of the program was designed to allow a "user-friendly" platform that allows more operators, maintenance personnel, supervisors and managers to use the system.

To accomplish the GIS link to the ACCESS database, the software requirements for the management system were first defined. The GIS package applied was ArcGIS[4], Version 8.1. The application was developed using ArcObjects™,[5] and customized using Visual Basic for Application (which is embedded within ArcCatalog and ArcMap). The use of this tool allows for the development and use of multiple map templates for developing map layouts. This aspect of the project included an extensive development of graphical user interfaces to provide the bridge between the database and the GIS.

The primary GUI for data management, called the ***WWTP Assets Inventory***, includes forms for equipment, parts, maintenance, operations, recommended upgrades, photo images and CADD files. A series of reports and query options are also included. With the GIS platform in place, all future inputs regarding equipment assessments will be done directly through the GIS. **Figure 2** is an example of the ***WWTP Assets Inventory*** GUI within the GIS platform that serves as the key data input tool. As indicated, the form has the seven tabs described earlier.

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[4] Licensing agreement through Environmental Systems Research Institute, Inc. (ESRI)

[5] ArcObjects is a framework that allows for the creation of domain-specific components from other components. The ArcObjects components collaborate to serve every data management and map presentation function common to most GIS applications. The ArcObjects framework is built using Microsoft's Component Object Model (COM) technology.

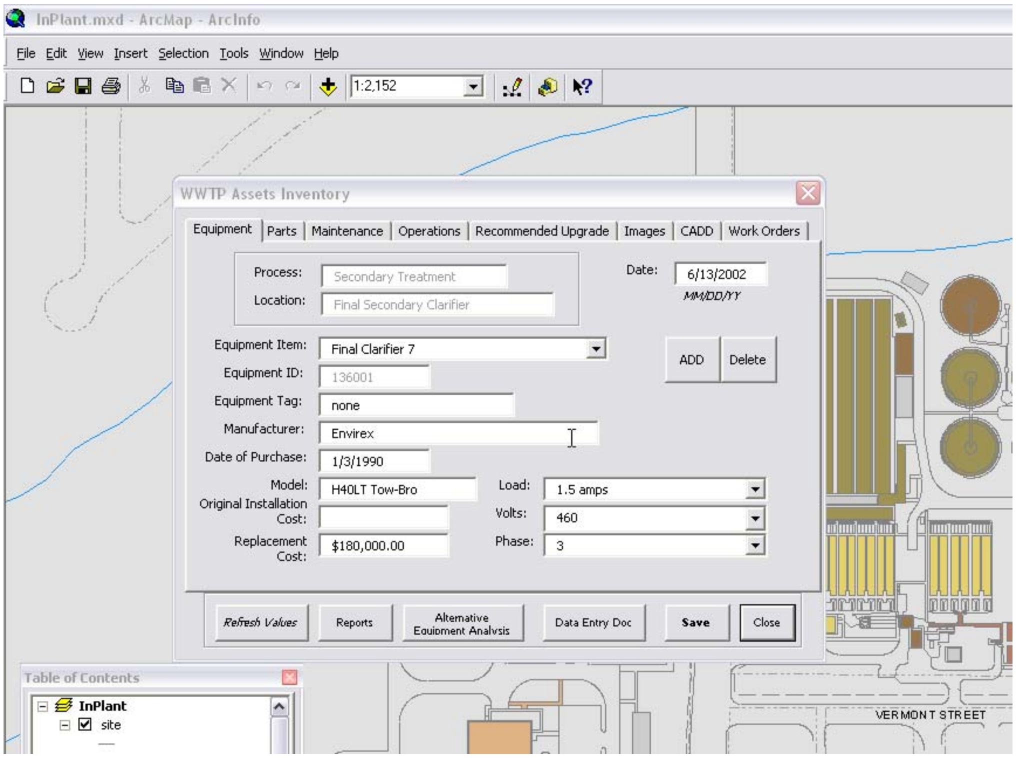


Figure 2

Table 1 illustrates a typical form generated by the ACCESS database that details an equipment recommendation. Such a table was generated for each of the 51 components requiring a recommendation.

Table 1: ACCESS Data Form

Facility Name / Equipment	Manufacturer / Model	General Comment	Energy Use, Hp	Performance Comment	Condition	Summary Score / Cost Estimate	Improvement Description
Headworks	WEMCO	System inoperable. Pump & piping clogs in wet weather when grit volume increases. Pump: 1760 RPM, 37/18.5 Amps; 200 gpm @ 40' TDH; 11" impeller, 4"	15	During wet weather, operators spend several hours on each shift trying to keep system operable	4	11	Evaluate system, design and construct a grit removal system that works. Units appear undersized; benefit could be achieved through reconfiguration of piping alignments

		discharge; 4” pipe	
Grit Pump 1	CE		$15,000

Asset Management

A benefit of the GIS-based platform is formulating a facilities plan to manage the fixed equipment assets. Within each equipment record is information regarding the date of purchase, the age of the equipment/component, its installation cost (if known), its replacement cost, and it expected remaining service life. Using these data, queries can be made within the GIS, for example, to highlight those processes or equipment whose remaining service life is less than 5 years. Once isolated, these can be compared against the condition assessments to determine if shifts in priorities for recommended improvements need to be made.

Results

In the assessment process, a total of 149 separate pieces of equipment were evaluated. Of these, 51 received condition assessment scores of either Level 3 or Level 4, thereby requiring a recommendation for improvement to their condition. These 51 components were grouped into five general treatment process areas: grit facility improvements, final clarifier rehabilitation, blower replacement, return/waste activated sludge pump PLC programming, and digesters. Schedules for the improvements were also tied to the recommendations along with a “ball-park” cost estimate. The proposed schedule considers a two-tiered time table. For the higher priority items, the schedule for implementation of upgrades, rehabilitations and replacements was set for completion by year-end 2005. Less priority items are slated for implementation beyond that time.

The recommendations all received a ranking score between 6 and 16 points, within the possible range of a low of 6 and a high of 18. The priority for implementation is that the highest scored items are to be completed first. This resulted in a total estimate for the initial assessment program resulted in $2.1 million worth of recommended improvements. **Table 2** details the recommendations, grouped by their priority score.

Table 2: Recommendations by Priority Score

FY 2003	Ranked Score	Estimate
Screw Pump pinion gear replacement	16	
Digester Rehab: Cover, mixing, safety improvements	14	
HVAC improvements to meet electrical safety needs	9	
Electrical gear maintenance	14	
RAS Line rehab; acquisition of emergency gear	14	
Subtotal 2003		**$553,000**
FY 2004		
MCC replacements throughout plant	14	
Flow meter replacement at NI Lift Station	12	
$FeCl_2$ feed pump replacements	12	
Subtotal 2004		**$747,000**
FY 2005		
Final Clarifier Rehabs	12	
Grit removal equipment replacement	11	
Primary Clarifier drive replacement	10	
Primary sludge pump replacement	10	
RAS/WAS pumping PLC programming	10	
Blower replacement	8	
Scum grinder pump replacement	6	
Subtotal 2005		**$814,000**
Total through 2005		**$2,114,000**

Managing the plant's equipment assets requires a knowledge of the expected and actual remaining service life of the components. A query of the GIS database for those items that have 5 years, or less, and 10 years, or less, of service life remaining results in a table such as shown in Table 3. This report tabulates each specific item in order of ascending service life through ten years is displayed. This query is illustrated in **Table 3**.

Table 3: Expected Remaining Service Life Query

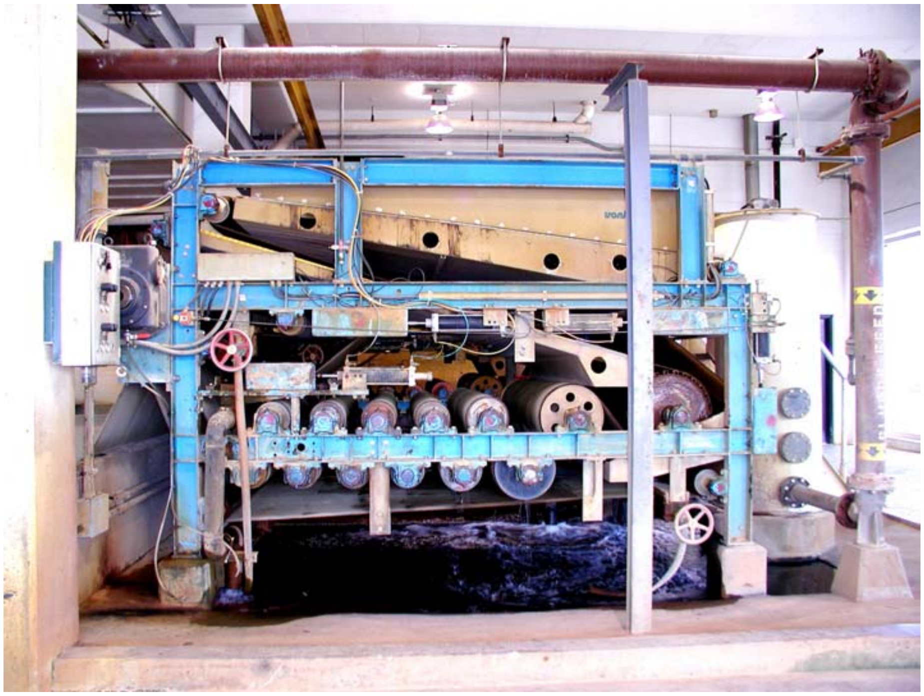
Equip ID	≤5 years Remaining
106001	Digester 1 – cover, mixing
107001	Digester 2 – cover, mixing
108001	Digester 3 – cover, mixing
126004	Grit Washer 1
126005	Grit Washer 2
126009	Grit Pump 1
126010	Grit Pump 2
126011	Grit Pump 3
127003	Raw Screw Pump 3
128005	NI LS Flow Meter
148007	MCC – W5
149008	MCC – W6
158003	MCC – W4

Equip ID	≤10 years Remaining
102014	Belt Filter Press 4
102015	Belt Filter Press 5
120001	Primary Sludge Pump 1
120002	Primary Sludge Pump 2
140001	Primary Clarifier Dr. 1
141001	Primary Clarifier Dr. 2
143001	Primary Clarifier Dr. 3
144001	Primary Clarifier Dr. 4
145001	Primary Clarifier Dr. 5
130001	Final Clarifier 1
132001	Final Clarifier 3
148001	Aeration Blower 1
148002	Aeration Blower 2

A correlation of the information in **Table 2** can be made with that of **Table 3**. The items highlighted in **Table 2** represent components that not only have marginal service life time remaining, but also are in relatively poor operating condition. Those highlighted in orange represent items that are in the less-than-five year service life category, while those in yellow represent less than ten. A second query in GIS is run to reflect this correlation and is shown in Figure 12. Information in this format is especially useful to a utility manager when developing a longer-term replacement and capital plan.

The facilities assessment for the Elkhart Wastewater Treatment Plant provides the baseline for the asset management process. Asset management implies placing a timed value for fixed equipment and structures and having that value depreciated over its expected service life.[6] Several advantages are noted. First, all equipment and structures, not just those in disrepair are evaluated giving the manager opportunity to prepare and update a more comprehensive capital planning. Secondly, it provides opportunity for maintenance personnel to see value in preventive maintenance activities. By being proactive, equipment components can at times be extended, thereby reducing the overall long-term cost burdens to the utility. For the manager, costing out the maintenance activities helps determine whether or not it is prudent to continuing maintaining the system beyond its service life or to replace with either similar or alternative technology. Thirdly, by having estimates on service life and associated cost estimates for replacement/upgrade, the manager has opportunity to better balance financial impacts by staggering replacements based on depreciation schedules instead of being directed by corrective maintenance needs. Finally, managing the systems as assets allows one to make cost effective upgrades by taking advantage of technological advances to modify existing systems rather than waiting for full system replacement when the service life has run its course. The following is an example of how a belt filter press is being treated as an asset for the Elkhart Treatment Plant.

[6] The City of Elkhart uses a simplified straight-line depreciation method for equipment and facilities.



The data and respective management information on this piece of dewatering equipment is given in the table below.

Table 4: Asset Management– Dewatering Process: Belt Filter Press No. 2

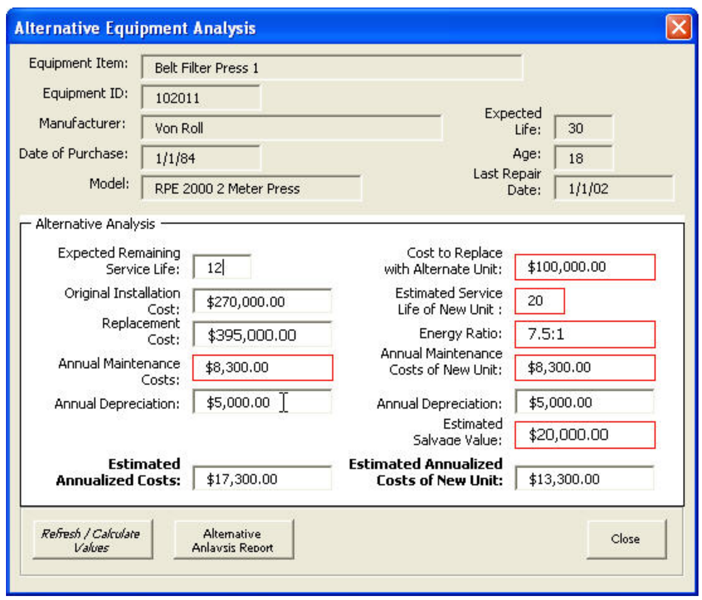
Equipment ID	102011
Facility Name	Dewatering
Equipment Name	Belt Filter Press No. 2
Manufacturer	Von Roll
Model	RPE 2000 2-meter Press
Energy Usage	5.2 kW-hr/day
Operational Usage	Daily / 6-hr continuous
Assessment of Existing Condition	2
Date of Purchase	1/1/84
Current Length of Service	18 years
Date of Last Repair	3/1/02
Nature of Last Repair	Complete Rehabilitation
Expected Remaining Service Life	10 years
Initial Purchase and Installation Costs	$270,000
Current Estimated Value	$60,000
Cost to Replace with Equivalent Unit	$395,000
Annual Maintenance Costs	$8,300
Annual Depreciation	$6,000
Estimated Annualized Cost	$13,300
Estimated Present Worth Value based on Remaining Service Life†	$102,703

(Table 4 Cont.)

Cost to Replace with Alternate Unit[7]	$420,000
Estimated Service Life of New Unit	25 years
Energy Usage Ratio to Existing Unit	7.5 : 1
Annual Maintenance Cost of New Unit	$3,500
Annual Depreciation of New Unit	$16,800
Estimated Salvage Value	$25,000
Estimated Annualized Cost*	$19,300
Estimated Present Worth Value based on Service Life of New Unit†	$272,014

*Assumes that new unit is purchased outright with existing funds.
†Assumes an annual interest rate of 5%.

An essential element of this example is establishing a present worth value to the existing equipment based on its remaining service life and the major annual O&M costs. As shown, an alternatives analysis exercise is easily amended to the table as a simplified means for determining if continued use of the existing equipment is still cost effective, or if replacement with alterative technology is the preferred approach.



Using this type of management model applied to each of the fixed assets, the manager now has a realistic present value of all the treatment plant systems, and a set of timetables for system replacements and upgrades. This example illustrates the asset tool as applied to the engineering component of managing the physical plant and operations. Though not part of this project, the GIS data link can also be expanded to include the financial accounting aspects of GASB 34 protocol compliance as well.

Conclusions

In order to develop a long term asset management plan for the wastewater treatment plant facility, the City of Elkhart adopted a two-phased approach. The first phase involved an

[7] In this example, the assumption is that the alternative unit would be a type of centrifuge technology. With centrifuge technology, the through-put of the system is higher. This allows for fewer units to operate at the current feed rates. Therefore, the unit cost comparison requires a factor applied to account for higher through-put rates. In this example, that factor would be in the range of 0.7. It should also be noted that values used in this example are not intended to be representative of a particular centrifuge unit or model.

in-plant assessment of the fixed equipment assets. The assessment was to determine the existing conditions of the components. Four tiers of condition were established ranging from completely inoperable and in need of immediate replacement, to essentially new with little signs of wear or use. Where appropriate, estimates of remaining service life were made. The information gathered populated a database that became the baseline for the second phase of the project, a GIS-based facilities plan for longer term managing of the plants fixed assets.

Phase 1 of the work resulted in 51 items in need of corrective attention. For these items, a prioritization scheme was applied to rank the degree of importance to the Elkhart operations based on criteria of safety, compliance, and efficiency. The scoring resulted in thirty items recommended for repair, replacement or upgrade within the next 3 years, at an approximate cost of $2.1 million.

The GIS platform provides an excellent tool for managing the fixed assets. With the database linked to the GIS platform, simple, visual queries communicate valuable information for decision-making for the longer term planning horizons. Because of the GIS being interactive, it results in more persons (operators, supervisors, and managers) using the module. Increased use directly correlates to increased familiarity with treatment plant systems and results in more logical capital and replacement programs that can be endorsed by the rate-paying public.

References

"*Wastewater Treatment Plant Equipment Evaluation*", Prepared for: Public Works and Utilities, City of Elkhart, May 2002, HNTB Corporation