ABSTRACT
The most efficient method to assess the condition of pump stations is a challenge most utilities face. Many utilities take different approaches and these various approaches will be highlighted. Condition assessment can often be a first step in a more formal asset management program. Steps in development of a condition assessment include the review of current maintenance and condition assessment practices, a detailed condition assessment of key pump station and recommendations with a template for moving forward. The process is intended to result in knowledge transfer from CH2M HILL to utility staff to allow for the establishment of a formal pump station condition assessment program.

The benefit of an ongoing condition monitoring program is improved efficiency and costs of operation. An ongoing condition monitoring program leads to a utility being able to plan for procurement, repair, maintenance, and replacement of assets instead of being forced to respond in an emergency manner when an asset fails. A condition assessment program allows utilities to detect potential failures before an occurrence which saves utilities money in allowing for programming equipment replacement. Through an on-going condition monitoring program, the evaluation of the condition of existing infrastructure and needs for repair, rehabilitation, and/or replacement to maintain target service levels, reliability, etc. can be determined. This leads to proactive assessment of predictive funding demands on a utility to cover full costs of asset repair rehabilitation, or replacement.

The benefits of this process allow for utilities to establish formal business processes related to condition assessment through the use of Computerized Maintenance Management System (CMMS); documentation of roles and responsibilities along with workflows for condition assessment; and procedures to identify changes that could improve efficiency and costs of operation. This includes a process for maintenance analysis.

The pre-field condition assessment process, the tools and processes used in the field condition process, the manner in which the data was evaluated and interpreted, and recommendation for on-going condition monitoring programs will be addressed.

KEYWORDS: Condition Assessment; CMMS; Pump Stations; Asset Management

INTRODUCTION
Using a risk-based approach, a cross-section of staff participated in a series of workshops resulted in the development of consequence and likelihood of failure matrices that could be used for scoring systems, sub-subsystems and assets.

The purpose of developing the matrices is to develop priority rankings based on risk, consequences of failure, and likelihood of failure. The calculation of risk for the purposes of this process is the product of consequence and likelihood.

\[
\text{Risk} = \text{Consequence} \times \text{Likelihood}
\]

In the risk framework developed by each specific utility, weighting is applied to each of the consequence and likelihood factors so that relative importance of each criterion is captured. Therefore, the consequence and likelihood scores used in the risk equation are the sum of the weights and scores for individual criteria.
Consequence or Likelihood = \sum \text{Criterion Weight} \times \text{Criteria Score}

A desk-top evaluation of the physical condition of pump stations was conducted to develop an initial condition rating to be used in assessing the risk of station failure. This includes developing information for this evaluation from multiple sources including route crews. The results of the evaluation were then discussed in a validation workshop comprised of a composite team of reviewers, including key pump station crew members and operators. The goal of the composite team was to examine the preliminary assessment results to ensure that the potential for biases in the opinions of the route crews were minimized.

From the results of the risk evaluation, detailed field assessment was performed at various pump stations. For some utilities only the highest risk stations were evaluated at others all were analyzed for condition for training and knowledge transfer purposes. Detailed condition assessments provide significant benefits ranging from the identification of specific deficiencies in equipment assessed to the identification of specific maintenance steps that may be taken to increase asset life and reduce likelihood of failure.

The condition assessment process often leads to maintenance analysis. One method used for maintenance analysis is Reliability Centered Maintenance (RCM). RCM is generally used to achieve improvements in the establishment of safe minimum levels of maintenance, changes to operating procedures and the establishment of maintenance plans. Successful implementation of RCM will lead to increased cost-effectiveness and a greater understanding of the level of risk that the organization is presently managing.

RCM starts with the 7 questions below, worked through in the order that they are listed:

1. What is the item supposed to do and its associated performance standards?
2. In what ways can it fail to provide the required functions?
3. What are the events that cause each failure?
4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequences of the failure?
7. What must be done if a suitable preventive task cannot be found?

RCM creates a cost-effective maintenance strategy to address dominant causes of equipment failure. It is a systematic approach to defining a routine maintenance program composed of tasks that preserve important equipment functions. The result is a maintenance program that focuses scarce economic resources on those items that would cause the most disruption if they fail. RCM emphasizes the use of Predictive maintenance (PdM) techniques in addition to traditional preventive measures.

CH2MHILL teamed with staff to establish a risk base line for pump stations. A workshop occurred with key stakeholders to capture service level requirements and develop a consequence of failure matrix describing how service levels will be affected if a failure occurs. CH2MHILL performed a form of RCM or Maintenance Task Analysis (MTA) and condition assessment on the high risk assets (both processes and equipment). The RCM and Maintenance Task Analysis (MTA) identified failure modes for each asset and maintenance tasks to mitigate the failure modes were developed. The new maintenance tasks and their associated performance frequencies were provided to allow staff with a blueprint for implementing a proactive, best-in-class maintenance program. This process allows for a clear picture of the risk associated with systems and subsystems of plant process and assets failing.

**METHODOLOGY**

In the case studies, CH2M HILL facilitated a workshop where condition was part of the criteria in determining risk. Figure 1 presents a typical distribution of risk scores, with the pump station ranked from high risk to low risk.
CH2M HILL has developed a propriety tool, the Asset Condition Evaluation Systems (ACES), to assess the condition of clients’ assets, develop a “risk score” for each asset, and generate an optimal multi-year maintenance and capital improvement plan. CH2M HILL has applied the ACES tool at hundreds of facilities. Use of the tool has developed data and analytics to create fact-based maintenance and capital improvement strategies. Exposure to ACES also provides valuable training for maintenance and operations staff, teaching them to think strategically, using data, about where they spend their time and resources. The condition assessment approach techniques varied from visual to the use of predictive tools.

Based on risk, condition approaches could vary from institutional knowledge to use of predictive technology. RCM or maintenance task analysis for a variety of the high risk pump stations was performed. When conducting the RCM analysis the elements to execute include

- System Operating context
- System Definition
- System and sub-system functions
- Functional Failures
- Failure Modes and Effects
- Failure Management recommendations and audit trail
- Hidden failure management policies (functional checks)
- Anticipated cost of task

**DISCUSSION**

Condition assessment techniques vary widely and determining the best fit for your utility is critical. Steps in development of a condition assessment include the review of current maintenance and condition assessment practices, a detailed condition assessment of key pump station and recommendations with a template for moving forward. The process is intended to result in knowledge transfer from CH2M HILL to utility staff to allow for the establishment of a formal pump station condition assessment program.

The benefit of an ongoing condition monitoring program is improved efficiency and costs of operation. An ongoing condition monitoring program leads to a utility being able to plan for procurement, repair, maintenance, and replacement of assets instead of being forced to respond in an emergency manner when an asset fails. A condition assessment program allows utilities to detect potential failures before an occurrence which saves utilities money in allowing for programming equipment.
replacement. Through an on-going condition monitoring program, the evaluation of the condition of existing infrastructure and needs for repair, rehabilitation, and/or replacement to maintain target service levels, reliability, etc. can be determined. This leads to proactive assessment of predictive funding demands on a utility to cover full costs of asset repair rehabilitation, or replacement.

The benefits of this process allow for utilities to establish formal business processes related to condition assessment through the use of Computerized Maintenance Management System (CMMS); documentation of roles and responsibilities along with workflows for condition assessment; and procedures to identify changes that could improve efficiency and costs of operation. This includes a process for maintenance analysis.

In the changing maintenance paradigm, it is expected to have greater cost-effectiveness, greater safety, no damage to the environment, etc. compared to the 19050s when the job was to fix something when it broke. RCM starts with the 7 questions below, worked through in the order that they are listed:

1) What is the item supposed to do and its associated performance standards?
2) In what ways can it fail to provide the required functions?
3) What are the events that cause each failure?
4) What happens when each failure occurs?
5) In what way does each failure matter?
6) What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequences of the failure?
7) What must be done if a suitable preventive task cannot be found?

While working through these 7 questions you are ultimately determining what you can do, if you can do anything to prevent failure. P represents the potential for failure and F represents failure. The standard rule is the frequency of inspections should be 1/2 the P-F interval (3 months in this case). This would provide a minimum of 3 months lead time. If more time is needed, you can increase inspection frequency (it’s a tradeoff). Also, it may be justifiable to increase the frequency of inspection due to extreme failure effects (that’s the basis for installing fixed vibration monitoring).

FIGURE 2 – Determining the P to F interval
After an analysis is completed you shift the maintenance task performed both in type and frequency. Figure 3 is a visual example of how the shifting would occur.

**FIGURE 3 – Shift in Maintenance Tasks due to RCM**

<table>
<thead>
<tr>
<th>Pre-RCM</th>
<th>Existing pre-RCM routines</th>
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<tbody>
<tr>
<td>Post-RCM</td>
<td>Remaining pre-RCM routines</td>
</tr>
<tr>
<td></td>
<td>Redundancy</td>
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<td>New</td>
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</tbody>
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**CONCLUSION**

Detailed condition assessments provide five significant benefits:

1. Identification of specific deficiencies in equipment assessed
2. Identification of specific maintenance steps that may be taken to increase asset life and reduce likelihood of failure
3. Data for prioritizing the allocation of resources to maintenance and capital investments
4. Establishment of repeatable processes that can be applied broadly
5. Over time, through repeated assessments, the accumulation of data to build asset decay curves

Condition assessments provide valuable information for estimating the risk that an asset will fail and the consequences if it does. Because conducting a condition assessment can be expensive, and in some cases may damage the asset, care should be taken regarding when and how these assessments are conducted. Newer assets, with low risk and consequence of failure, generally do not require anything more than collection and analysis of data on corrective maintenance performed (to identify trends and emerging problems), and (if possible) monitoring of asset performance via a SCADA system. Critical assets—those where failure may cause extended and/or widespread customer service disruption, damage to property or the environment, etc.—generally require more proactive on-site condition assessment, including application of more advanced condition assessment techniques, such as vibration analysis (for plant equipment), ultrasonic thickness measurement and pressure testing (for pipes), etc.

The analysis of assessment data will result in a change of frequency and duration of maintenance tasks. The PM tasks did not include any “performance standards” and in most cases were left to the maintenance staff to determine the thresholds. Defined performance standards allow for better asset performance tracking and control of work quality (standardization across facilities and work crews).
Often task can be performed too frequent and not add additional value (based on the failure characteristics). Over a period of time extending the frequency of generator testing under load would provide the biggest single benefit to utilities in terms of savings (Fuel cost, Equipment wear, Deterioration, Man power, Operational costs, etc).