Today's presentations will cover:

**Perspectives on Wastewater Pump Station Renewal/Rehabilitation/Replacement Management**

(Based upon MOP FD-6)

**Perspectives on Wastewater Pump Station Renewal/Rehabilitation/Replacement Management**

**WEF CSC Committee**

- **Tina Wolff**
  - Principal Environmental Engineer
  - Malcolm Pirnie, Inc.
  - Ft. Wayne, IN

- **James J. Paluch**
  - Assistant Superintendent / Collection System Ops
  - Joint Meeting of Essex & Union Counties, Elizabeth, NJ

- **Thomas Curl**
  - Engineer V
  - San Jacinto River Authority
  - The Woodlands, TX
## Perspectives on Wastewater Pump Station Renewal/Rehabilitation/Replacement Management

**Webcast Sub-Committee Members**

- Abraham Araya – Seattle, Washington
- Samantha Bartow – Taylor, South Carolina
- Thomas Curl – The Woodlands, Texas
- Mattie A. Engels – Dallas, Texas
- Wes Frye – Nashville, Tennessee
- Chris Johnston – Burnaby, British Columbia
- Stephen A. Lipinski – Duluth, Minnesota
- John Nelson, Pewaukee, Wisconsin
- James J. Paluch – Elizabeth, New Jersey
- Tina Wolff – Fort Wayne, Indiana

## Existing Sewer Evaluation and Rehabilitation

- WEF Manual of Practice FD-6
- ASCE Manuals and Reports on Engineering Practice No. 62
- 2009, Third Edition
Chapter 6 – Selection of Sewer Rehabilitation Methods and Materials

• OVERALL CONTENTS
  • Introduction & Overview
  • Rehabilitation Types, Materials, Methods
  • Pipeline Repair, Renewal, Replacement (RRR)
  • Appurtenance RRR (Manholes, Service Laterals, Pump Stations)
  • The Selection Process
  • Quality Assurance / Quality Control

The A, B, C’s Series Continues

• November 2010: Perspectives on Pipeline Replacement
• February 2011: Manhole Repair, Renew, Replace
• June 2011: Service Connection/Sewer Lateral Repair, Renew, Replace
• November 2011: Perspectives on Wastewater Pump Station Renewal/Rehabilitation/Replacement Management – Series Webcast (4 of 4)
Collection System Challenges

- Rehabilitation – repair, renewal, replacement – is a constant part of sewer management
- Financial limitations are forcing us to “do more with less”
- The refining of traditional procedures and the development of new concepts are required

Key Ideas

- Proper and efficient identification of lift station issues is key
- A systematic approach to lift station diagnosis increases likelihood for successes
- An asset maintenance program is needed to maximize lifespan and control cost
- There is a need to understand the reliability of an asset
- Replacement can be an opportunity to increase functionality
Speakers and Agenda

- Joe Jacobs, PE
  - Troubleshooting
  - Systematic Approach
  - The Next Step

- Dave Jurgens, C.M.R.P.
  - Importance of Maintenance
  - Understanding ‘Reliability’
  - RTF – Run to Failure
# Speakers and Agenda

- **Howard Smith, P.E.**
  - Alternative Rehab Concept
  - Benefits & Considerations
  - Lakeside Storage Facility

---

## Troubleshooting for Wastewater Pumping Systems

It’s broke, now what do I do?

Troubleshooting for Wastewater Pumping Systems

November 16, 2011

Joe Jacobs, PE
Malcolm Pirnie, The Water Division of ARCADIS
There are many possible causes for pumping system problems and identifying the cause can be time consuming and often very frustrating!

A systematic approach with field pumping tests is necessary to eliminate potential causes and to identify the most likely cause.

Understanding the original basis of design can be an important tool to aid with the identification of anomalies in the pumping system.

Most problems are not problems with the pump, but with the pumping system itself.

Helpful Troubleshooting Tools Include:

- Senses including: Eyes, ears, touch, and smell
- Tools including:
  - Flashlight or mirror for wet well inspections
  - Tape measure to verify wet well water surface elevations
  - Stop watch to time pump fill and draw tests
- Instruments including:
  - Pressure Gauges
  - Flow Meter
  - Tachometer
  - Infrared Temperature Monitor
  - Volt & Amp Meter
Helpful Troubleshooting Documents Include:

- Pump Performance Curves or Manufactures Certified Pump Curves
- Maintenance Records
- Computer Logs/Data Trends
- Design Phase System Curves
- Design Drawings and Specifications
- Vendor operations and maintenance manuals

Troubleshooting Procedures

1. Review existing data and maintenance logs to identify when operational changes may have occurred.
2. Perform visual inspection of pumping facilities for indications of trouble.
3. Perform field pumping tests to observe facilities in operation and to collect performance data.
4. Analyze data collected and compare field data to design data.
5. If trouble is still not found, disassemble pumps and piping systems and perform more extensive inspections.
1. Review Existing Data and Maintenance Logs

- Review maintenance logs to identify:
  - When impellers were last inspected
  - When pump tests were last performed
  - When bearings, wear rings, and impellers were last replaced and the frequency of replacement
- Review SCADA system alarm history to identify reoccurring alarms and the frequency of alarms

1. Review Existing Data and Maintenance Logs

- Review existing flow data over an extended period of time to establish when a change in performance may have occurred
- Compare sudden changes in performance with maintenance logs and alarm history to correlate the performance change with a specific maintenance task or alarm condition
1. Review Design/Record Drawings to Verify the Following

- Review design drawings and specifications to identify original basis of design data including wet well level setpoints, flows, pipe sizes and critical dimensions
- Review force main profile drawings and verify that air and vacuum valves were provided at all high points along the alignment

2. Perform Visual Inspections to Verify the Following:

- Pump wet well down and check for grit, solids, and debris at the pump intake
  - Grit, solids and debris that restrict the pump intake can increase suction pressures resulting in pump cavitation and can reduce pumping capacity
- Verify that level control devices are functioning properly and are calibrated to the required setpoints
  - Constant speed pumps with improper level setpoints can cycle on and off more frequently resulting in possible motor overloads or reduced motor life
  - Level setpoints that are set too low can result in improper inlet submergence or NPSH conditions and can result in pump cavitation and reduced flow capacity
2. Perform Visual Inspections to Verify the Following:

- Verify that the suction and discharge isolation valves are fully open
  A partially closed valve will increase head resulting in reduced pumping capacity

- Verify that the discharge check valve is functioning properly
  Rags and debris can pack on the disc when pump is not in use restricting the check valve operation resulting in additional headloss in the system

- For wet pit submersible pump stations, verify that pump is properly seated on discharge elbow
  Rags and debris that prevent proper seating of the submersible pump on the discharge elbow can result in leakage or blow-by, which reduces conveyance capacity of the system
  This is a common reason for reduced flow capacity in submersible pump stations

- Verify that flow meters and pressure gauges are operating properly and have been calibrated recently
  Field pumping tests with inaccurate flow measurement or pressure readings will result in the wrong conclusions
2. Perform Visual Inspections to Verify the Following:

- Along force main alignment, check each air and vacuum valve for proper operation
  
  Air release valves that are plugged or not functioning can result in air binding in the force main, which reduces pumping capacity.

  In cold climates, air and vacuum valves can freeze preventing proper operation.

- High points higher than the hydraulic grade line are locations where column separation occurs. These locations are also potential areas for pipe corrosion and odors as air is pulled into the force main when pumps stop and expelled when pumps start.

3. Perform Field Pumping Tests to Monitor and Record the Following:

- Prepare a sketch of the pumping system to record elevations, pressure, and flow rates collected during test.
- Monitor and record pumped flow rate.
- Monitor and record suction and discharge pressures (Correct pressures recorded to centerline of pump volute)
- Measure/record wet well levels.
- Measure/record force main discharge elevation.
- Monitor and record pump volts and amps.
- Record the time that all measurements were taken.
3. Perform Field Pumping Tests to Monitor and Record the Following:

- When feasible, measure pump bearing temperatures with an infrared temperature monitor
  
  *High bearing temperatures can be a sign of the following:
  - Unbalanced loads on the pump impeller from sub-surface vortices
  - Unbalance pump impeller
  - Poor shaft alignment between pump and motor

- When feasible, monitor pump shaft speed with a tachometer
  
  *The pump can not deliver the design flow rate unless the impeller is turning at the specified speed.
  - With variable speed operation, verify the maximum speed at the drive is set to 60 Hz.
  - Verify SCADA controls are set to allow pump to operate at 100% of speed.

3. During Field Pumping Tests Observe the Following

- Unusual noises such as cavitation sounds in pump housing
  
  *Cavitation sounds are an indication of poor inlet or suction piping conditions, which can be the result of:
  - Free or sub-surface vortices in the Wet Well
  - Strong inlet currents to pump intake
  - Net Positive Suction Head (NPSH) Required greater than NPSH Available
    - Improper intake submergence
    - Pump operating too far to the right on pump curve
  - Air entrainment in wet well
  - Air or grit deposition in suction piping
3. During Field Pumping Tests Observe the Following

- Observe the discharge pressure gauge
  - Fluctuating pressures over a 5-10 p.s.i. range at a high rate of speed indicating uneven discharge flow and is another sign of pump cavitation
3. During Field Pumping Tests Observe the Following

- Check for free surface vortices in wet well
  - Free surface vortices can result in pump cavitation
  - Free surface vortices can impose unbalance loads on the pump impeller resulting in high bearing temperatures or pump vibration

![Free Surface Vortices Diagram](image)


- Verify the check valve is open and the lever arm moves freely
  
  A check valve lever arm that does not move freely can be an indication of a ragging or plugging issue or a broken disc or disc pin

- Listen for check valve slam when pump starts or stops
  
  Check valve slam is an indication of hydraulic transients in the force main system
  - Air and vacuum valves not functioning properly
  - Check valve selection not appropriate for system

- Look for pump or motor vibrations
  
  Pump and motor vibrations can be an indication of a pump mechanical problem:
  - Bad bearing
  - Imbalanced or clogged impeller

![Check Valve Lever Arm Diagram](image)
Pump Station Troubleshooting

I can’t find anything wrong! Now what do I do?

4. Analyze Data Collected to Verify the Following

- Based on recorded flow rates and force main size, calculate operating force main velocities
  - Velocities should be greater than 2.0 ft/s to minimize solids and grit deposition
  - Velocities should exceed 3.0 to 4.0 ft/s daily to resuspend settled solids and grit
  - Velocities greater than 7.0 ft/s result in excessive head/power requirements and can result in high surge pressures that cause check valve slam and hydraulic transients in the system
- Compare amp draw readings to nameplate data
  - High amp readings can be an indication of ragging or other obstructions within the pump
4. Analyze Data Collected to Verify the Following

- Calculate motor horsepower based on measured volts and amps and compare to expected horsepower from the manufacturers pump curve
  - Motor horsepower is true indication of work performed by pump
  - Low motor horsepower indicates that pump is not doing work expected and could be due to several reasons including:
    - Submersible pump blow-by at discharge connection
    - Worn pump impeller or wear rings
    - Suction inlet problems and or cavitation
- Calculate the percent voltage imbalance between each motor lead or phase
  - A voltage imbalance (unequal voltages on a 3 phase power service) will cause the motor to run hotter and could result in motor overloading and decreased motor life.

4. Compare Field Data to Design Data

- Data point is on the pump curve, but left of the design point.
- Indicates higher head conditions than design.
- Possible Causes:
  - Grit or solids in force main.
  - Air accumulation at high points
  - Change in friction factor due to scale buildup or corrosion
4. Compare Field Data to Design Data

- Data point is on the pump curve, but right of the design point.
- Indicates lower head conditions than design.
- Possible Causes:
  - New force main with friction less than anticipated during design

---

4. Compare Field Data to Design Data

- Data point is below the manufacturers rated pump curve
- Possible Causes
  - Pump cavitation due to poor inlet conditions
  - For submersible pumps, blow-by at pump discharge elbow
  - Pump speed slower than rated speed
  - Worn impeller or wear rings
  - Ragging or material trapped in pump

---

If motor is not sized to operate at all points on the head capacity curve, possible motor overload

High NPSH required could result in cavitation under low wet well conditions

Use amps and volts recorded during test to calculate working horsepower. This can provide a check on the accuracy of the flow and pressure measurements

Verify measured pump speed equals pump rated speed

Field Test Data Point

Design Point

Field Test Data Point
Troubleshooting Procedures Revisited

1. Review existing data and maintenance logs to identify when operational changes may have occurred.
2. Perform visual inspection of pumping facilities for indications of trouble.
3. Perform field pumping tests to observe facilities in operation and to collect performance data.
4. Analyze data collected and compare field data to design data.
5. If trouble is still not found, disassemble pumps and piping systems and perform more extensive inspections.

Good Luck!!!

Pump Station Troubleshooting

Questions?

Joe Jacobs, PE
Malcolm Pirnie, The Water Division of ARCADIS
(614) 430-2717
joe.jacobs@arcadi-us.com
Maintenance: The Key to Asset Life

Dave Jurgens, King County WTD Reliability

Topics:

• A bit about King County WTD.
• Journey to Reliability and Enterprise Asset management (EAM).
• Reactive versus Proactive; should we let it just fail?!?!
• Reliability Basics
• Summary / Wrap up
King County WTD

• 3 Large plants / 2 Small Plants serving 1.5 million residents over 420 Square Miles
• Serves Greater Seattle and outlying areas.
• Treatment Capacity: about 800 MGD
• 42 Pump Stations in 353 miles of line
• Resource Recovery incl: Reclaimed Water, Biosolids, Methane Gas sales and 1.9MW Cogeneration Plant.

...WTD’s journey towards EAM: a three year tour...

Then:

• 1/12 CMMS modules being used (open/close WO’s) with about 7000 assets loaded.
• Only the biggest jobs planned / scheduled.
• Little / No standardization of assets / Work Types / Failure Codes
• Repetitive failures of “like” assets.

Now:

• 11/12 modules being used. 52,000 assets loaded, interfaces with Operations Systems / emp. time Cards / KPI - Metrics software
• 4 planner schedulers; coordinate all maintenance one week in advance.
• Steering Committee’s (3) formed to address definition, direction, and spec guidance.
• Root Cause Analysis (RCA), Failure Modes & Effects (FMEA), and Reliability Pass used to address “bad actors”.
Reliability Basics

- 60-70% Reliability determined at the design level.
- 10% determined through as-built adherence.
- 10-20% determined through Install
- 10% determined through commissioning.

Generally, after commissioning Reliability cannot be changed w/o redesign.
LIFE-CYCLE COST COMMITMENT

Early decisions largely determine life-cycle cost.

LIFE-CYCLE COST EXPENDITURE

The cost of early effort is relatively low.

O&M cost is estimated 60 – 80% of total LCC.
**Average Lifecycle Costs Total**

- Design and Development 10 – 20%
- Build - Fabrication / Installation 15 – 25%
- **Operations and Maintenance (O&M) 60 – 80%**
- Disposal < 5 %

Need to **build Reliability / Maintainability / safety** in design/development phase to reduce O&M (LCC) cost

*Assurance Technologies Principles and Practices by Raheja & Alocco*

---

**RCM Maintenance Strategy Types – Critical Assets**

- **Predictive Technologies heavily employed.**
  - IR / Vibration / LOA / Ultrasonic
  - Less time required to evaluate condition w/ minimized risk.
- **FMEA (Failure Modes Effects Analysis) performed on most critical assets.**
  - System experts review all failure types and develop mitigation strategy.
  - Time consuming yet thorough.
- **PM Optimization (PMO) performed on all major PM’s to address over / under PM’ing based on criticality.**
- **Root Cause Failure Analysis (RCA)**
  - “Forensic Examination” of failure event.
  - Established trigger threshold.
  - Traceable and Accountable corrective actions derived.
RCM Maintenance Philosophy – A Paradigm Shift

- An understanding that the vast majority of failures are not necessarily linked to the age of the asset.
- Changing from efforts to predict life expectancies to trying to manage the process of failure.
- An understanding of the difference between the requirements of an asset from a user perspective, and the design reliability of the asset.
- An understanding of the importance of managing assets on condition (often referred to as condition monitoring, condition based maintenance, and predictive maintenance).
- Linking levels of tolerable risk to maintenance strategy development. Spectrum: High PM/PdM -> “Run to Fail” (RTF)

Run to Failure

(RTF):

Conscientious classification of an asset’s level of care in which it may be allowed to fail without prevention.

- Requires understanding time impact on the process if the asset fails (MTBF).
- Requires understanding effect on plant downtime when an unexpected
- Asset very low risk type (Low consequence of failure & low probability of failure):
- Does not defeat function of higher level assets.
- Unfortunately very few assets qualify.

“Think Airplane Engines as opposed to passenger overhead reading lights”
### Run to Failure (RTF): Analogy

<table>
<thead>
<tr>
<th></th>
<th>My Lawnmower</th>
<th>My Neighbor’s Lawnmower</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procurement:</strong></td>
<td>$120</td>
<td>$120</td>
</tr>
<tr>
<td><strong>Maintenance per Annum:</strong></td>
<td>$0 (0hrs)</td>
<td>$3,440 (40hrs: $86/hr-hr)</td>
</tr>
<tr>
<td><strong>Avg Lifespan (MTBF)</strong></td>
<td>3yrs</td>
<td>10yrs</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td>$360</td>
<td>$35,600</td>
</tr>
</tbody>
</table>

### Reality Check:

- **#1 Sump Pump – Bellevue PS**
Reality Check: #1 Sump Pump – Bellevue PS

Mfr’s Recommended Maintenance

- Daily: Current / Ammeter Flux Check – .10 Hr
- Monthly: Insulation Resistance Check – 2 Hrs
- Semi-Annual: Mechanical Seal Check – 4 Hrs
- Annual – Overhaul Pump – 12 Hrs

Total: 80.5 Hrs / Yr
Labor Cost ($86/Hr LR) $6923 / Yr

(Does not include Materials / Travel Time etc…)
Reality Check:

### #1 Sump Pump – Bellevue PS

- Run to Failure (RTF): Risks
  - Without proper analysis (Known Criticality and Consequence of Failure) RTF will almost ALWAYS exceeds PM / PdM Costs
  - Often a ‘hybrid’ RTF type approach used to identify “over-PM / PdM” conditions.

**Bottom Line:** RTF must be:

- Analyzed
- Consciously Decided
- Tracked / Re-analyzed based on failures.
Reliability Engineering plays a part in the 7 Elements of EAM ensuring a detailed approach is taken to assess and improve our Current State.
Our Background is with the City of Duluth, Minnesota.

Where the EPA has mandated control and elimination of wastewater overflows by 2013.

Duluth SSO Facilities

Five Lift Stations with integrated storage between 0.3 and 8.3 million gallons.
Duluth Lift Station No. 1 Profile

- Storage facilities operated like an oversized wet well
- Wet wells designed for ADF
- Storage area floors slope at 1% minimum to wet well

Maintenance

What Maintenance Comes with a Storage Facility?

- Periodic Structural Inspection
- Maintenance of Level Sensors
- Possibly Odor Control
- Cleaning
The first storage basin is designed as a primary clarifier.

- Required basin area = $\frac{ADF \text{ (gal)}}{2000 \text{ gal/day/ft}^2}$
- Only the first basin received cleaning after each use
- Secondary basins remain clean because of transfer pipes

Maintenance

Storage Facility Cleaning Philosophy

Very Labo
Intensive:

Manually

6 workers for several hours
Duluth's cleaning systems utilize either process or potable water and can be automatically controlled.

Tipping Trough Sediment Flushers wash grit and sludge into wet well channel.

Flush water can be supplied by several different methods:

- Manual Fill With Dry Hydrant
- Automated Potable Water
- Process Water
**Maintenance Time Savers**

**Valve Extensions**

- Exercising valves
- Eliminates confined space to operate handwheels

**Access And Fall Protection**

**Portable Guard Rails**

- Light, all aluminum and easy to haul in a truck
- Installation and removal requires no tools
- Meets the OSHA requirements for guard rail
**Provisional Railing Sockets**
- Stainless steel schedule 40-2.5” sleeve
- Cast in-place or core drilled and with annular space filled with epoxy.

**Access And Fall Protection**
- Desire to cover the railing sleeves to:
  - Keep odors in
  - Keep surface water out
  - Discourage children from filling up with rocks and debris
- Covers were fabricated much like an expandable pipe plug
Protective Fall Grating

- Can be retrofitted or ordered with the original equipment
- Allows operators to observe without additional fall protection
- Allows ladders, cords, and hoses to pass through annular spaces
- Gates can be installed in single or double doors hatches, are lockable, and typically have a 300 PSF rating.

Access And Fall Protection

Additional Monitoring

- Monitor Storage Facility Level / Volume
- Send Alarms
- Record Trends
- Reporting
- Control the Discharge of the Stored Sewage
What Did Storage Cost?

Average cost per gallon: $1.78

Data samples from Northern Minnesota construction between 2004 and 2010 of below grade cast in place concrete tanks

---

Storage On A Smaller Scale

- At this pump station average daily flows were 470 GPM with peaks at 5500 GPM.
- This storage provides approximately 90 minutes of pump station shut down
- Clearly not effective at buffering high flows, but sufficient time for wet well cleaning
Storage On A Smaller Scale

- Modified an existing Wet Well into compartments for maintenance purposes.
- Concrete surfaces received an epoxy coating to inhibit corrosion.
- New split wet well with 40,000 gallons of storage.
- Alternative was to fill the unnecessary wet well space with concrete and have no storage.
- Very little additional cost.

Optimizing Storage for Maintenance

- During bi-annual cleaning, wet well is isolated from flows and enabled to be completely drained while flows go into basin 2.
- Previously cleaning was performed with live flows in the lift station which was not as effective or labor efficient.
- Unexpected Force Main Breaks from the Lift Station 1 facility utilized storage many times until a permanent fix for the forcemain could be devised, no wastewater hauling or bypass pumping was ever mobilized.
- Ultimately the force main was replaced in segments, the storage was utilized once again to control flows during pipe connections.

**Storage During Pipe Repairs**

**Storage During Pipe Replacement**

- 2012 Project to Replace 3500 feet of force main leaving this facility
- Storage Facility will be used for 4 days while a Contractor replaces pipe
- Then temporary connections to existing pipe allow discharge or storage for 2 days
- One day of float in the schedule
- Estimate this will save 4 weeks of bypass pumping with an estimated cost of $50,000
The Endion Storage Facility is below grade in the center of the photo with the Endion Pump Station on the right.

Endion Storage Facility Lift Station No. 50

The major challenges we experienced during construction is incorporating a plan that provides a restoration useful to the public.

Lakeside Storage Facility Lift Station No. 51

The Lakeside Storage Facility Lift Station is under construction.

Site
Lakeside Storage Facility  Lift Station No. 51
Restored

Thank You For Your Attention

At This Time Questions Are Welcome

Question and Answer Session
Perspectives on Wastewater Pump Station
Renewal/Rehabilitation/Replacement
Management

(Based upon MOP FD-6)
Key Ideas

• Proper and efficient identification of lift station issues is key
• A systematic approach to lift station diagnosis increases likelihood for successes
• An asset maintenance program is needed to maximize lifespan and control cost
• There is a need to understand the reliability of an asset
• Replacement can be an opportunity to increase functionality

2012-13 Collection System Infrastructure Management Series

• February 2012: Planning and Implementing CMMS
• June 2012: Condition Assessment: Building out your CMMS
• November 2012: Asset Management: Translating your data to information
• February 2013: Business Case for Action
• June 2013: Optimized System Operations
• November 2013: Designing for Asset Management
Thank you for joining today’s presentation:

**Perspectives on Wastewater Pump Station Renewal/Rehabilitation/Replacement Management**

(Based upon MOP FD-6)