MASTER PLANNING NEW PHOSPHORUS LIMITS & ASSET MANAGEMENT NEEDS
Dayton, Ohio
Water Reclamation Facility

Presenters:
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Sharon Vaughn, City of Dayton
Peter Kube P.E., Arcadis

Prepared for the 2019 Ohio WEA Technical Conference & Expo
# Associate firms

<table>
<thead>
<tr>
<th>Firm Name</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD Concepts Inc. (CCI)</td>
<td>Electrical Assessment</td>
</tr>
<tr>
<td>Kabil Associates</td>
<td>Structural Assessment</td>
</tr>
<tr>
<td>PCS Technologies</td>
<td>I&amp;C Assessment</td>
</tr>
<tr>
<td>Gerkin Swafford Engineering Solutions</td>
<td>Civil/Mechanical Assessment, Project Management Assistance</td>
</tr>
<tr>
<td>Jones-Warner Consultants</td>
<td>Surveying, Utility Locating, Forcemain cost planning</td>
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<td>Automated Systems Engineering (ASE)</td>
<td>Electrical Engineering</td>
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<tr>
<td>Burgess &amp; Niple</td>
<td>Asset Management Assistance</td>
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<tr>
<td>Andromeda Systems Inc. (ASI)</td>
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<td>EmNet</td>
<td>Collection System Modeling</td>
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<td>Webster Environmental Associates</td>
<td>Odor Control</td>
</tr>
<tr>
<td>Bowker &amp; Associates</td>
<td>Odor Control QA/QC</td>
</tr>
</tbody>
</table>
Dayton Wastewater Final Infrastructure
Population anticipated to drop

Dayton population anticipated to drop 7% over next 23 years
Why Master Plan?

- Phosphorous Limits
- Asset Management Program
- Odor Control
- Biosolids Needs
- Efficiency and Cost Savings

Prudent Time To Plan
**Approach**

1. **Strategy**
   - Break Plant into Parts & Establish Treatment Necessities (aka “Level of Service”)

2. **Research & Asset Data Acquisition**
   - Historic Data And New Data

3. **Brainstorm and Test Alternatives**
   - For Individual Process Areas & “Entire Facility”

4. **Assemble projects into a sequence**
   - Determine financial forecast
Approach

1. Required to → Control Phosphorous, Improve odors
2. Need to → Maintenance/Replacement Projects
3. Should do → Status Quo or Replacement Alternatives or Sweeping change
4. Complete → Ongoing Projects

Advance all 4 simultaneously and then evaluate best path forward
Determine the metrics: Establish Levels of Service

Criteria for each process, what it HAS to do

1. Provides firm metrics/“rules” by which alternatives must abide, which
2. enables a fair comparison between alternatives

Examples Level of Service Statements:
1. Flows: plant flows, component flows
2. Digesters:
   • Maintain temperature of 98-degrees Fahrenheit in all digesters.
   • All recirculated digester feed to be at 98-degrees Fahrenheit (+/- 1 F).
   • For disposal solutions involving land application, achieve a Class B stabilized biosolid. (15 days SRT at Max Month Flow)
   • Process max month solids production with two digesters out of service (one east and one west out of service)….."
### Phosphorus Limit Received

OEPA set the limit based on 1 mg/L

<table>
<thead>
<tr>
<th>Effluent Characteristic</th>
<th>Concentration Specified Units</th>
<th>Discharge Limitations</th>
<th>Loading* kg/day</th>
<th>Monitoring Requirements</th>
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</thead>
<tbody>
<tr>
<td>01220 - Chromium, Dissolved Hexavalent - ug/l</td>
<td>-</td>
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<tr>
<td>31648 - E. coli - #/100 ml</td>
<td>-</td>
<td>-</td>
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<td>39100 - Bis(2-ethylhexyl) Phthalate - ug/l</td>
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<td>50050 - Flow Rate - MGD</td>
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<td>50092 - Mercury, Total (Low Level) - ng/l</td>
<td>1700</td>
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<td>12</td>
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<td>51173 - Cyanide, Free (Low-Level) - ug/l</td>
<td>92</td>
<td>-</td>
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<tr>
<td>51451 - Phosphorous, Total - Kg</td>
<td>131.64</td>
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<tr>
<td>61941 - pH, Maximum - S.U.</td>
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<td>61942 - pH, Minimum - S.U.</td>
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<td>6.5</td>
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</table>

* Phosphorus seasonal loading - Phosphorus, Total - Kg (Parameter Code 51451) is actually a calculated seasonal loading in "kilograms"

Although it is listed under a maximum concentration limit. Calculate the seasonal loading as follows: [median daily effluent flow (MGD) for period July 1 - October 31] x [median total phosphorus concentration (mg/l) for the period July 1 - October 31] x 3.7854. Round the result to two decimals and enter the calculated loading for this parameter in eDMRs once during the month of December. Also, see Part II, Item BB.
### Current Phosphorus concentrations

| Typical Phosphorus Concentrations July 1 - October 31 |
|---------------------------------|-----------------|-----------------|-----------------|
| Min                             | Usual Range Lower limit | Usual Range Upper limit | Max              |
| mg/L                            | mg/L             | mg/L             | mg/L            |
| 0.28                            | 1.0              | 3.0              | 4.0             |

- ~20% of samples below 1.0 mg/L
- ~70% in usual range 1.0 to 3.0 mg/L
- ~10% of sample above 3.0 mg/L
Process Modeling to evaluate proposed solutions
GPS-X Modeling Software by Hydromantis

The paramount tool for this Master Plan
## Additional Process Lab Testing

### Weekly Sampling and Analytical Requirements for Wastewater Characterization

<table>
<thead>
<tr>
<th>Location</th>
<th>Influent</th>
<th>North Primary Effluent</th>
<th>South Primary Effluent</th>
<th>Combined Effluent @ Low Lift PS</th>
<th>East Hummus Tanks Effluent</th>
<th>West Hummus Tanks Effluent</th>
<th>Final Settling Tank Combined Effluent</th>
<th>Plant Effluent</th>
<th>Centrifuge Centrate</th>
<th>GBT Filtrate</th>
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<tr>
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<td>6a</td>
<td>6</td>
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<td>Dissolved Sulfide</td>
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</tbody>
</table>

**Color Legend:**
- Green: currently collected parameter, no change in normal sampling frequency
- Blue: currently collected parameter, increased sampling frequency
- Yellow: new parameter

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Testing Data used to calibrate model
## Modeled Alternatives

### Existing Conditions

2.2.4 LS-EC-1 –  
2.2.5 LS-EC-1 –  

Primary Clarification Alternative  
2.4.1 Alternative LS-PC-1 –  
2.4.2 Alternative LS-PC-2 –  
2.4.3 Alternative LS-PC-3 –  

Baseline Alternative -  
2.5.1 Alternative LS-CA-1 – 

Phosphorus Removal Alternative  
2.6.1 Alternative LS-PR-1 –  
2.6.2 Alternative LS-PR-2 –  
2.6.3 Alternative LS-PR-3 – 

Combined Nitrogen and Phosphorus Removal Alternative  
2.7.1 Alternative LS-NR-1 – I  
2.7.2 Alternative LS-NR-2 –  
2.7.3 Alternative LS-NR-3 – C  
2.7.4 Alternative LS-NR-4 – Si  

Secondary Treatment Investigation  
2.8.1 Investigation LS-ST-1 –  
2.8.2 Investigation LS-ST-2 –  
2.8.3 Investigation LS-ST-3 –  
2.8.4 Investigation LS-ST-4 –  
2.8.5 Investigation LS-ST-5 –  

Pretreatment of Industrial Discharges Alternatives  
2.9.2 Alternative LS-PT-1 –  
2.9.3 Alternative LS-PT-2 –  
2.9.4 Alternative LS-PT-3 –  

Effluent Filters Alternatives  
2.10.1 Alternative LS-EF-1 –  
2.10.2 Alternative LS-EF-2 –  

Disinfection Alternatives  
2.11.1 Alternative LS-DI-1 –  
2.11.2 Alternative LS-DI-2 –
Phosphorus Control

Three practical methods:

1. Chemical Addition
2. Biological Nutrient Removal
3. Phosphorus Recovery
Chemical Addition Phosphorus Control

Addition of Phosphorus Sequestering Chemical into water:

Typical Locations:
1. After Aeration Basins
2. After Biosolids Dewatering
3. At Primary Clarifiers (Careful!)
Chemical Addition Jar Test

- Multiple chemicals
- Multiple plant locations
- Multiple doses
- Multiple tests
- Multiple people

4 Chemicals Tested
- Aluminum Chloride
- Polyaluminum Chloride (PACL)
- Ferric Chloride
- Rare Earth Metal
### Chemical Addition Costs

#### Chemical Unit Costs Quotes

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Cost per wet pound ($/lb)</th>
<th>Cost per gallon ($/gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride (a)</td>
<td>0.14</td>
<td>2.05</td>
</tr>
<tr>
<td>Ferric Chloride (b)</td>
<td>0.093</td>
<td>1.08</td>
</tr>
<tr>
<td>Alum (a)</td>
<td>0.1175</td>
<td>1.21</td>
</tr>
<tr>
<td>Alum (b)</td>
<td>0.08</td>
<td>0.90</td>
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<tr>
<td>PACI</td>
<td>0.165</td>
<td>1.80</td>
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<tr>
<td>Rare Earth Metal</td>
<td>0.68</td>
<td>8.80</td>
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</tbody>
</table>

#### Estimated Yearly Chemical Costs for Phosphorus Control to 1 mg/L

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Dose Ratio (lb chemical/lb ortho-P)</th>
<th>Ortho-P to be removed (lb/day)</th>
<th>Chemical Dose Required (lb/day)</th>
<th>Daily Chemical Cost ($/day)</th>
<th>Annual Chemical Cost ($/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>12.6</td>
<td>487</td>
<td>6,119</td>
<td>569</td>
<td>208,000</td>
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<tr>
<td>Alum</td>
<td>21.6</td>
<td>487</td>
<td>10,513</td>
<td>841</td>
<td>306,000</td>
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<tr>
<td>PACI</td>
<td>15.8</td>
<td>487</td>
<td>7,683</td>
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<td>Rare Earth Metal</td>
<td>13.8</td>
<td>487</td>
<td>6,707</td>
<td>4,651</td>
<td>1,665,000</td>
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#### Estimated Yearly Additional Sludge Hauling Costs for Phosphorus Control to 1 mg/L

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Sludge Generated (lb/day)</th>
<th>Daily Cost ($/day)</th>
<th>Annual Cost ($/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferric Chloride</td>
<td>4,836</td>
<td>79.34</td>
<td>28,960</td>
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<tr>
<td>Alum</td>
<td>3,034</td>
<td>49.78</td>
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<td>PACI</td>
<td>5,233</td>
<td>84.85</td>
<td>31,333</td>
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<tr>
<td>Rare Earth Metal</td>
<td>2,418</td>
<td>39.67</td>
<td>14,480</td>
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</tbody>
</table>

For Costs: Sludge Hauling wasn’t as influential as chemical
To drive Ortho-P removal closer to 0 requires exponentially more Ferric Chloride.
Control Phosphorus Using BNR

BNR
- Biological Phosphorus Removal (BioP), or
- Biological Nitrogen & Phosphorus Removal (TN)

- Control (starve or feast) Oxygen and Mixing to encourage Biology to Uptake Phosphorus …then remove/waste the Biomass quickly before it releases the phosphorus.

- Step feed to maximize aeration basin capacity during wet weather
Step Feed

- Additional gate for pass C influent (typ)
- Valve for pass B influent (typ)
- Proposed submerged orifice RAS influent into pass A (typ)
- Proposed pass B influent pipe (typ)
- Separate RAS lines from influent flumes and elevate above channel walls into new influent header
- Wall core from influent channel

Legend:
- IPS Flow Modifications
- RAS Flow Modifications
PROPOSED BAFFLE FOR ANAEROBIC ZONE SEPARATION (TYP)

REMOVE (OR SEPARATE) DIFFUSERS FROM ALL ANAEROBIC ZONES AND REPLACE WITH MIXING ONLY

EXTEND EFFLUENT CHANNEL FOR NEW AERATION BASINS

EXTEND INFLUENT CHANNEL FOR NEW AERATION BASINS

PROPOSED RELOCATED NORTH AERATION BUILDING
TN Removal

- Extend effluent channel for new aeration basins
- Extend influent channel for new aeration basins
- Proposed relocated north aeration building
- Proposed baffle for anoxic zone separation (TYP)
- Proposed IMLR piping
- Proposed IMLR (internal mixed liquor recycle) pump (TYP)
- Remove (or separate) diffusers from all anoxic zones and replace with mixing only
- Proposed baffle for anoxic zone separation (TYP)

Legend:
- Structural Modifications
- Process Modifications

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TN with Step Feed

- **Proposed Baffle for Anoxic Zone Separation (Typ)**
- **Remove (or separate)** diffusers from all anoxic zones and replace with mixing only.
- **Extend effluent channel for new aeration basins**
- **Proposed relocated north aeration building**
- **Extend influent channel for new aeration basins**
- **10th aeration basin potentially not required but may be constructed for future use and symmetry**
- **Extend effluent channel for new aeration basins**
- **Provision for Step Feed Piping**

Legend:
- **Black**: Structural Modifications
- **Orange**: Process and IPS Flow Modifications
- **Blue**: RAS Flow Modifications

*Descriptions see Alternative LS-PR-2*
Control Phosphorus with P extraction and Recovery

Excluded for two main reasons: Nutrient Recovery is most financially feasible behind BNR and Dayton adds ferric to sequester H2S for their air emissions permit which also binds phosphorus

Should BNR be implemented in the future, P recovery could be revisited
Results of Phosphorus Removal Alternatives Evaluation

Status Quo- No longer compliant
20-year Life Cycle

<table>
<thead>
<tr>
<th></th>
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<td>Construction Cost ($2018)</td>
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<td>Annual Chemical Costs</td>
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<td>$1,933,000</td>
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<td>-$4,485,000</td>
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<td>Total Costs over Present Worth Period</td>
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<td>$61,541,000</td>
<td>$64,567,000</td>
<td>$80,596,000</td>
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</table>
Odor Control
Asset Management is a body of management practices that...

- Targets the acceptable level of risk to the organization
- Delivers service levels customers desire and regulators require
- Applies to the entire portfolio of infrastructure assets at all levels of the organization
- Seeks to minimize total costs of acquiring, operating, maintaining, and renewing assets
- Works within an environment of limited resources
EPA / WERF/ WaterRF Framework

1. What is the current state of my assets?
   - System layout
   - Data hierarchy
   - Standards inventory
   - Develop asset registry

   - Condition assessment
   - Protocol
   - Rating methodologies
   - Assess Condition and failure modes
   - Determine residual life

2. What is the required LOS?
   - Valuation, life cycle costing
   - Determine life cycle and replacement costs
   - Demand analysis
   - Balanced scorecard
   - Performance metric
   - Set target Levels of Service (LoS)

3. Which assets are critical?

4. What are my best CIP and O&M strategies?
   - Failure mode and effects analysis
   - Business Risk
   - Desktop / Interviews
   - Optimize Capital Investment
   - Confidence level rating
   - Strategic validation
   - Optimized decision making
   - Optimize O&M Investment
   - Root cause analysis
   - Reliability centered and Predictive maintenance
   - Optimized decision-making

5. What is my best funding strategy?
   - Renewal annuity
   - Determine Funding Strategy
   - Build AM Plan
   - Asset management plan
   - Policies and strategies
   - Annual budget
Leading Practice Concepts of Asset Management for Capital Planning

- Levels of Service Based on Customer and Stakeholder Expectations
- Risk Management Based on Likelihood and Consequence of Failure
- CIP Using Life Cycle Cost, Business Cases and Prioritization

= Leading Practice Asset Management
Dayton’s Condition Assessment

📅 2 Weeks

📱 10 People (Tablets)

📍 3,989 Assets in 46 Categories

🏠 2 Facilities (WRF & PS)
Condition Assessment Tools

fulcrum Software

mobile location leverage

Condition Assessment Tools

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## Visual Condition Assessment - Overall Scoring Approach

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Excellent</td>
<td>Fully operable, well maintained, and consistent with current standards. Little wear shown and no further action required.</td>
</tr>
<tr>
<td>2 – Good</td>
<td>Sound and well maintained but may be showing slight signs of early wear. Delivering full efficiency with little or no performance deterioration. Only minor renewal or rehabilitation may be needed in the near term.</td>
</tr>
<tr>
<td>3 - Moderate</td>
<td>Functionally sound and acceptable and showing normal signs of wear. May have minor failures or diminished efficiency with some performance deterioration or increase in maintenance cost. Moderate renewal or rehabilitation needed in near term.</td>
</tr>
<tr>
<td>4 - Poor</td>
<td>Functions but requires a high level of maintenance to remain operational. Shows abnormal wear and is likely to cause significant performance deterioration in the near term. Replacement or major rehabilitation needed in the near term.</td>
</tr>
<tr>
<td>5 – Very Poor</td>
<td>Effective life exceeded and/or excessive maintenance cost incurred. A high risk of breakdown or imminent failure with serious impact on performance. No additional life expectancy with immediate replacement needed.</td>
</tr>
</tbody>
</table>
Performance Assessment

Stepped through each treatment area and discussed each components performance,
maintenance history,
opinion of remaining useful life

- Division Manager
- Plant Administrator
- Plant Engineer
- Treatment Supervisor
- Operation Supervisors
- Supervisor of Maintenance
- Supervisor of Electrical
Asset Management - Assembling a sequential List

**Condition Assessment Scores**
- Physical Condition (i.e. Corrosion, Leakage, Supports, Electrical, Structural Cracking)
- Performance Condition (Capacity, Regulatory, Reliability, O&M issues, Obsolescence)

**Consequence of Failure (CoF) Scores**
- Environmental
  - Regulatory Compliance
  - Impacts to Sensitive Areas
- Social
  - Level of Service delivery
  - Health and Safety
- Economic
  - Capital Costs
  - O&M Impact

**Redundancy Factor**
- Redundant units reduce the impact of failure

Risk = Max Condition Score \times Overall CoF Score \times Average of maximum in each category

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Asset Management - Assembling a sequential List

Risk Score

Estimated Useful Life

Remaining Useful Life based on:
- Years in Service
- Adjusted Estimated Useful Life (EUL)
  - General Asset EUL
  - Physical Condition
  - Asset Age/Expended Life

20-year CIP (Capital Improvement Plan) Recommendations for Repair and Replacement

Result is a Sequential List of Asset Maintenance Projects
Alternatives for Treatment Areas

1. Liquid Treatment Train
2. Solids Treatment Train
3. Odor Control
4. Preliminary Treatment
5. Pumping
6. Electrical & Standby Power
7. Instrumentation & Control
8. Gas & Energy Use
9. Non-Potable Water
Alternatives Brainstormed

Example of Alternatives for Thickening Process:

1. Status Quo: known deficiencies = DAF capacity and obsolescence

2. Additional DAF in new building → not cost-effective

3. Rotary Drum Thickeners (RDTs)

4. Centrifuges

5. Gravity Belt Thickeners (GBTs)

Potential Improvements:

6. Replace TWAS pumps with larger pumps
Alternatives Evaluated and Costed

1. Further investigated to conceptual engineering level
2. Triple bottom line scored: Environmental, Social, Financial
3. Best Scoring Alternative Selected
Tying it all together:
Project Priority List

Asset Management

<table>
<thead>
<tr>
<th>Risk Based Schedule &amp; Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>2.</td>
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<td>3.</td>
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<td>13.</td>
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<td>14.</td>
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<tr>
<td>15.</td>
</tr>
</tbody>
</table>

Process Area Alternatives Analyses

- Liquid Stream Alternatives
  - A
  - B
  - C
- Solids Stream Alternatives
  - D
  - E
- Odor Control Alternatives
  - F
- Preliminary Treatment
  - G
  - H
  - I
- Pumping
  - J
  - K
- Electrical & Standby Power
  - L
- Instrumentation and Control (SCADA)
  - Status Quo
- Non-Potable Water
  - Status Quo

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Tying it all together: Project Priority List

- **Priority Level 0**: Projects already Underway (IPS Pumps, Final Clarifier Mechanism Replacement, etc.)

- **Priority Level 1**: Projects required for an Immediate Regulatory Need (phosphorus limit driven).

- **Priority Level 2**: Critical Asset Management.

- **Priority Level 3**: Projects for Financial Gain (Selling of Biogas for profit)

- **Priority Level 4**: Projects supporting typical Regulatory Needs

- **Priority Level 5**: Projects Providing an Identified Benefit (aka. Potential Improvement projects).

- **Priority Level 6**: Projects for Asset Management and Existing Capacity/Future Capacity.

- **Priority Level 7**: Projects supporting Predicted Regulatory Need (expected in 10 years).
Conceptual Implementation Plan

Sequential Project List

B- Liquid Stream Highest Scoring Alternative
1. Asset
2. Asset

E- Solid Stream Highest Scoring Alternative
3. Asset
4. Asset
5. Asset
6. Asset

J- Pumping Highest Scoring Alternative
7. Asset
8. Asset
9. Asset
10. Asset
11. Asset
12. Asset

G – Preliminary Treatment Highest Scoring Alternative
13. Asset
14. Asset
15. Asset

Results in the following spend & schedule

Conceptual Implementation Costs
All Projects (updated 12/21/18)
Conceptual Implementation Plan

Conceptual Implementation Plan Sequential Project List

B- Liquid Stream Highest Scoring Alternative
1. Asset
2. Asset
E- Solid Stream Highest Scoring Alternative
3. Asset
4. Asset
5. Asset
6. Asset
   J- Pumping Highest Scoring Alternative
7. Asset
8. Asset
9. Asset
10. Asset
11. Asset
12. Asset
   G – Preliminary Treatment Highest Scoring Alternative
13. Asset
14. Asset
15. Asset

Financial Model

Loaded into Financial Model
Conclusion

• Regarding Odors:
  - Installing Biofilters for Odor Control at Trickling Filters
    - BOD has not dropped enough to omit the Trickling Filters or even half of them.
    - The cost for additional Aeration Basins that could replace the Trickling Filters is too high compared to Biofilters

• Regarding Phosphorus
  - Chemical addition using Ferric Chloride is being installed at the WRF because:
    - BNR is decisively more expensive than chemical addition and,
    - Phosphorus limits aren’t below the practical range for chemical addition.

Dayton is advancing their Implementation Plan
Thank you.

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Additional Items to Share
Energy Efficiency Recommendations

Top 5 Energy Use Systems

<table>
<thead>
<tr>
<th>Major Process/Top Energy Use Systems</th>
<th>Electric Energy Use (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 INTERNAL PLANT PUMPING</td>
<td>26.68%</td>
</tr>
<tr>
<td>#2 SECONDARY TREATMENT</td>
<td>22.73%</td>
</tr>
<tr>
<td>#3 INFLUENT PUMPING</td>
<td>16.84%</td>
</tr>
<tr>
<td>#4 SLUDGE HANDLING</td>
<td>6.78%</td>
</tr>
<tr>
<td>#5 ANAEROBIC DIGESTION</td>
<td>6.43%</td>
</tr>
<tr>
<td>Balance of Plant Identified</td>
<td>13.28%</td>
</tr>
<tr>
<td>Balance of Plant Unidentified</td>
<td>7.25%</td>
</tr>
<tr>
<td>Total</td>
<td>100.00%</td>
</tr>
</tbody>
</table>
GIS created
Hydraulic Profile

Using InfoWorks Integrated Catchment Model (ICM)
Thank you.

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