Energy Considerations for Wastewater Pumping Systems and Lift Stations

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Today’s Topics

- A few “essentials” of hydraulics and energy
- Impacts of:
  - design flows
  - forcemain systems
  - pump operating scenarios
- Energy results for a hypothetical station
- A homework challenge
Essential Hydraulic Ingredients

1. Flowrates
2. Differential Heads
3. Equipment Efficiencies

energy $ \quad \text{power}$
Useful Power and Energy Formulas for Wastewater Pumping Applications

Power Input (KW) = \frac{0.000189 Q_{gpm} H_{ft}}{e_p e_m e_{vfd}}

Energy Usage per Vol. Pumped (KWH / MG) = \frac{3.14 H_{ft}}{e_p e_m e_{vfd}}
A Hypothetical Pumping Scenario

WHAT SPECIFIC PUMPING EQUIPMENT SHALL WE SELECT?

El. 920 existing sewer invert

Grade El. 940

PUMPING STATION

WHAT DESIGN FLOWS ARE APPROPRIATE?

El. 950

AVG. DRYWEATHER FLOW YEAR 1 = 400 GPM AVG.
DRYWEATHER FLOW YEAR 20 = 600 GPM

WHAT FORCEMAIN DIAMETER(S) ARE OPTIMUM FOR THIS SYSTEM?

12”? TWIN 10”? 14”? TWIN 12”? 16”?

8,000 FT. FORCEMAIN LENGTH

El. 920 existing sewer invert

30 FT. STATIC LIFT

El. 950

GRAVITY OUTFALL
Facilities Handle a Wide Range of Flows

Selecting peak design is not an obvious decision. Part engineering, part policy-driven. But very influential on the remaining design.

For example:

- **normal dry weather**
- **wet event C**
- **wet event B**
- **wet event A**

Normal flow range: ± 200-600 gpm
## Which Peak Design Flow(s) Should We Choose for this Facility?

<table>
<thead>
<tr>
<th>Time</th>
<th>Normal dry weather flow range (gpm)</th>
<th>Average flow (gpm)</th>
<th>Possible Peak Design Flows (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tighter system, lighter rains, and/or less conservative</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2.5 x avg.</td>
</tr>
<tr>
<td>Present conditions</td>
<td>200 - 600</td>
<td>400</td>
<td>1,000</td>
</tr>
<tr>
<td>20-year future</td>
<td>300 - 900</td>
<td>600</td>
<td>1,500</td>
</tr>
<tr>
<td>Ultimate buildout?</td>
<td>400 - 1,200</td>
<td>800</td>
<td>2,000</td>
</tr>
</tbody>
</table>

For this design project?

For a future expansion?
Differential Head: What Affects It?

\[ \Delta H_p = \text{Static Head} + \sum \text{Minor Losses (valves, fittings, exit)} + \text{Pipe Friction Losses} \]
Forcemain Sizing: A Balancing Act

- A wide range of flows to be handled
- We’d like a “large” diameter to keep friction losses & horsepower reasonable at peak flows
- But we’d like a “smaller” diameter so that normal, everyday flows have velocities above 2 feet/sec.
- Larger forcemains have higher construction costs but allow smaller motors and lower energy costs.
System Head Curves with Various Force mains

- 12-inch forcemain
- Twin 10-inch force mains
- 14-inch forcemain
- Twin 12-inch force mains
- 16-inch forcemain

Total Pumping Head in feet vs. Discharge in gpm

- 136.3' for 12-inch forcemain at 2,500 gpm
- 106.6' for Twin 10-inch force mains at 2,000 gpm
- 91.2' for 14-inch forcemain at 1,500 gpm
- 73.2' for Twin 12-inch force mains at 1,000 gpm
- 71.3' for 16-inch forcemain at 500 gpm

30' static lift
Project Cost and Energy Components with Various Forcemain Systems

Putting our energy costs in perspective

Shown for 2-pump constant speed system

Nominal forcemain size (inches)
Pump Selection and Operating Scenarios

- **Overlapping Considerations**
  - How many total pumps?  Variable-speed or constant?
  - How to handle the peak?  Parallel pumping?  Future expansions?

- **A Two-pump Constant-speed Station?**
  - Common approach for smaller stations
  - Each unit is sized for peak.  Expect high energy use.

- **A Three-pump (or more) Constant-speed Station?**
  - Various combinations of sizes and/or parallel pumping
  - Small pump(s) for typical normal flow can save energy

- **A Variable-Speed Station?**
  - Can provide desired flow flexibility with fewer total pumps
  - But must account for variable pump efficiencies and VFD losses
Which operating point is most efficient?
Searching for the Best Individual Pumps

Which operating point is most efficient?

\[
\frac{(3.14)(91')}{(.81)(.95)} = 371 \text{ KWH/MG}
\]

\[
\frac{(3.14)(48')}{(.69)(.95)} = 230 \text{ KWH/MG}
\]
Impacts on Normal Daily Pump Operations

Example: two equal pumps, constant-speed

Example: multi pump (3 or more) graduated-capacity, constant speed system. Small unit sized for 2 ft./sec.
Variable-speed Pumping

How low should we go?
Energy Results for a Range of Designs

Present Worth of 20 Years' Energy

- **SINGLE 12” FM**
- **TWIN 10” FM’S**
- **SINGLE 14” FM**
- **TWIN 12” FM’S**
- **SINGLE 16” FM**

**Legend:**
- Blue: Two pumps, constant speed. Each pump sized for peak design flow.
- Green: Three or more pumps, constant speed. Small pump sized at 2 ft./sec.
- Orange: Two pumps with variable speed drives. Each pump can range from 2 ft./sec to peak design flow.

$400,000$
$350,000$
$300,000$
$250,000$
$200,000$
$150,000$
$100,000$
$50,000$
$0$
Summary Observations for Energy Usage in Wastewater Pumping

- Energy usage can be affected at several levels:
  - Selection of design flow(s)
  - System design, including forcemain and valving selections
  - Pump selection and operating strategies (e.g. size and # of pumps, variable-speed vs. constant, well levels, efficiencies)

- In studying multiple design alternatives for a hypothetical mid-sized station, present worth energy costs ranged from 100% to 300% of the lowest cost option.

- Multi-pump, graduated-capacity constant speed pumping scenarios will tend to provide the lowest energy costs.

- Choose pumping options carefully, and don’t pump at higher heads than necessary.
Comments, Questions? Thank You!

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