How to Drop Two Stories without Breaking St*ff - A Sewer Story of Energy Dissipation

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• Project Background
• Alternatives Evaluation
• Project Execution
Project Background
June 7, 1938

- “major sewer project to extend the new trunk system and laterals into the east portion of Coeur d’Alene…”

- “The project would be easy to sponsor and could employ up to 300 WPA men next winter…”

- Also, “HOSS THIEF” IS CAPTURED (Texas cowboy admits to sheriff he stole horse in Spokane last night)
# 2013 Wastewater Collection System Master Plan Update

## Chapter 7 – Capital Improvement Plan

<table>
<thead>
<tr>
<th>ID</th>
<th>Project/MH ID</th>
<th>Recommend Action</th>
<th>Capital Cost ($)</th>
<th>Timeframe</th>
<th>As needed with growth</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Ongoing</td>
<td>0-5 Years</td>
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<tr>
<td>RR.1a</td>
<td>M1-09</td>
<td>Drop manhole replacement</td>
<td>$706,000</td>
<td>X</td>
<td></td>
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<tr>
<td>RR.1b</td>
<td>M1-09</td>
<td>Drop manhole replacement (alternate approach)</td>
<td>$646,000</td>
<td>X</td>
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Master Plan CIP RR.1

**CORE ISSUE**: Poor Condition

**BACKGROUND**
Manhole M1-09 is the confluence of two of the major interceptors in the system. The M Interceptor (30-inch) is approximately 30-feet deep at this manhole and the B Interceptor (24-inch) is about 13-feet deep. Flow from the B Interceptor and an 8-inch line from the north drops about 17-feet inside manhole M1-09. The condition of the manhole has deteriorated due to the harsh condition created by the large drop and resulting impact and turbulence.

Existing homes and utilities will require a small construction footprint for improvements. Two preliminary alternatives were developed for the CIP.

**RECOMMENDED SOLUTION**

**RR.1A**
- Replace M1-09 with new 96-inch manhole.
- Construct new 96-inch drop manhole east of M1-09.
- Opinion of Probable Cost (Jan 2013 Dollars) $706,000

**RR.1B**
Reduce excavation costs by routing the B-Interceptor to a shallower manhole.
- Re-route the B-Interceptor from B1-01 south down 9th Street and west on Pine Avenue to M1-11.
- Construct new 96-inch drop manhole east of M1-11.
- Rehabilitate MH M1-09.
- Opinion of Probable Cost (Jan 2013 Dollars) $646,000
# Energy Dissipation Alternatives

- “Controlled” Hydraulic Jump
- Vortex Flow Insert
- Vortex Drop Shaft
- Plunging Flow Drop Shaft
- Stacked Drop Manholes

<table>
<thead>
<tr>
<th>Other Options</th>
<th>Plunging drop (same as existing)</th>
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<tr>
<td>(not evaluated)</td>
<td>Conventional internal drop shaft</td>
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<tr>
<td></td>
<td>External drop (backdrop MH)</td>
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<td>Baffled drop shaft</td>
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<td>Drop shaft with turbine</td>
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Hydraulic Jump
Because of the free surface, gravity is the driving force in open channel flow. The ratio of inertial to gravity forces in open channel flow is the most important governing dimensionless parameter. It is called the Froude number, defined by

\[ F = \frac{V}{(gD)^{1/2}} \]

in which \( V \) is the mean velocity, \( D \) is a length scale related to depth, and \( g \) is gravitational acceleration. In some instances the Reynolds number also is important, as

**FIGURE 3.1**
Application of the momentum equation to a hydraulic jump in a nonrectangular channel.
Hydraulic Jump in Circular Conduit

Hydraulic jump occurs with an abrupt change in depth from supercritical to subcritical flow, creating significant energy loss. A “roller” rides continuously up the surface of the jump, entraining air and creating complex internal flow patterns. Turbulence is produced at the boundary.

Undular hydraulic jumps develop two-phase flow that significantly increases flow resistance due to the presence of air pockets, and reduces discharge capacity (Gargano, et al.)

Fig. 2. Undular hydraulic jump for $y_0 = 0.62$ and $F_r = 1.59$ involving choking flow

Fig. 3. Definition of undular hydraulic jump in circular conduit: (a) section and (b) plan
Hydraulic Jump in Circular Conduit

Subcritical Flow Section

Supercritical Flow Section

Variable/ uncontrolled range of hydraulic jump
Hydraulic Jump in Circular Conduit

Description
- Steep section of pipe with supercritical flow followed by shallow section (subcritical flow), forcing hydraulic jump to occur within the pipe or at a manhole (for free-surface)
- Vented manhole positioned upstream of supercritical pipe section to release air pockets that develop within the pipe and as a point for odor treatment

Advantages
- Energy dissipation occurs within closed conduit, eliminating the need for a drop shaft or other energy dissipating structure

Disadvantages
- Many factors influence location and type of hydraulic jump. If variables cannot be perfectly controlled, undular hydraulic jump may exist wherein the pressure at the top of pipe may drop below atmospheric, causing damage to the pipe, or produce air pockets that resist flow and reduce capacity of the pipe.
- Deep construction required to force supercritical/subcritical flow regimes, resulting in high construction costs. May require thick wall HDPE and pipe anchors.
- May require separate odor control facilities to address sulfide gasses released from turbulent flow caused by hydraulic jump. Limited site makes odor control facilities challenging.
Vortex Flow Insert
“The IPEX Vortex Flow Insert (VFI) is a revolutionary technology for eliminating odorous emissions and minimizing corrosion in vertical sewer drops. With no moving parts and requiring virtually no maintenance, VFIs have delivered significant cost savings in installations across North America.

The VFI’s patented spiral flow design eliminates odorous and corrosive gases in a unique way. It uses the wastewater’s own flow energy to suppress the turbulence which releases noxious gases. The spiral flow creates a downdraft which traps airborne gases and forces air into the sewage flow to oxidize odorous gases. By installing a Vortex drop structure, municipalities can save thousands of dollars in monthly chemical feed, air-phase treatment and maintenance costs.”
Vortex Flow Insert

Description
- Pipe constructed at typical slope and construction depth
- Prior to final discharge, flow enters a plastic device inserted into a manhole. Flow enters a vortex-inducing top section, followed by a drop shaft which draws airborne gases into a final energy dissipation pool which entrains air into the flow, reducing odorous sulfide gas emissions

Advantages
- No moving parts
- Low maintenance
- Design entrains dissolved oxygen, reducing odors and minimizing corrosion damage

Disadvantages
- Unconventional maintenance
- Lack of familiarity - no known installations in region
Vertical Drop Shaft
“The Hydro Vortex Drop™ Shaft, is a self-activating energy dissipation system with no moving parts, designed to safely drop water or sewage from virtually any height in order to prevent noise, vibration, and infrastructure damage.”
Vortex Drop Shaft

Description

- Pipe constructed at typical slope and construction depth
- Flow enters inlet structure (shallow manhole) for horizontal flow into a stainless steel vertical drop conduit
- Vertical drop shaft of narrowing diameter dissipates energy
- Vent pipe at top of drop shaft mitigates unstable flow condition by providing smooth transition between air-entrained vortex mode and pipe full mode
- Discharge structure at bottom of drop shaft withstands impact forces, removes entrained air, and directs flow to outlet

Advantages

- Accessible for maintenance
- Compact, simple structures for cost effective installation
- High discharge capacity means smaller drop shaft diameter compared to conventional drop shafts
- No need for vortex inducing top chamber
- Energy dissipation base results in reduced outlet chamber size

Disadvantages

- Requires weir wall to create pool... potential for grit and solids accumulation requiring regular maintenance
- May need secondary bypass drop pipe in order to provide maintenance access to primary drop shaft
- Cost (drop shaft approx. $55,000 for this project – excluding installation and other materials)
- Few installations in the US. Most installations are in UK and Canada.
Plunging Flow Drop Shaft
Internal Drop Structure
Plunging Flow Drop Shaft

Description

- Ductile Iron pipe vertical drop shaft with elbow base for energy dissipation in existing or new manhole. Tee and capped riser on top of drop shaft for maintenance access.

Advantages

- Conventional construction and materials
- High energy loss (up to 95%)

Disadvantages

- Potential for pipe vibration, reduced capacity, and excessive pool depth if not properly aerated as flow transitions from partial pipe (free surface) to full pipe (pressurized) flow. Requires careful hydraulic design including air vent at top and rounded inlet to reduce this potential.
- Long-term erosion of base elbow
- Unsteady flow could cause blowout and loss of manhole or drop shaft covers or even “geysers” spilling to above grade
- May need secondary bypass drop pipe in order to provide maintenance access to primary drop shaft, requiring valves or gates
Stacked Drop Manholes
Stacked Drop Manholes

- Previous case studies (Edmonton, Alberta) focused on stacked drop manholes (2 at a time) for 50 m of total drop throughout a stormwater system to reduce overall pipe depth and construction costs.
- Energy dissipation measured to range from 70 to 95%.
- Design recommendations: 3Dx3D vault; rectangular opening w/height = D; Drop height up to 8D.
  - For CdA CIP RR.1 (24” pipe), this means (2) 6’x6’ vaults with total drop height up to 16’.
Stacked Drop Manholes

Description

- Pipe constructed at typical slope and construction depth
- Prior to final discharge, two or more rectangular chambers stacked adjacently at staggered depths with rectangular openings

Advantages

- Shallow pipe depth provides economical construction
- Dissipates energy by 50% to 90%
- Straightforward maintenance access
- Conventional construction and materials... precast or cast-in-place manholes are low cost compared to a fabricated vortex device

Disadvantages

- Potential for long-term erosion of manhole walls... consider lining manholes for protection (adds $$$)
Key Design Elements
Because of the free surface, gravity is the driving force in open channel flow. The ratio of inertial to gravity forces in open channel flow is the most important governing dimensionless parameter. It is called the Froude number, defined by

\[ F = \frac{V}{(gD)^{1/2}} \]

If \( F > 1 \), supercrit.
If \( F < 1 \), subcrit. \hspace{1cm} (1.1)

in which \( V \) is the mean velocity, \( D \) is a length scale related to depth, and \( g \) is gravity.

In some instances the Reynolds number also is important, as

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**FIGURE 3.1**
Application of the momentum equation to a hydraulic jump in a nonrectangular channel.
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Hydraulic Analysis

Graphical Results

Figures in below shows predicted sewage level at both flow rates:

0.35MGD

3.89MGD
Hydraulic Analysis

Conclusion

- Mean flow velocity at the entrance of vortex is approximately 6 ft/s at 0.35 MGD and 7.5 ft/s at 3.9 MGD.
- Once entered the vortex ramp drop, the flow starts to accelerate to a velocity of approximately 11 ft/s at the outskirt at 0.35 MGD and over 10 ft/s at 3.9 MGD.
- The depth of flow in the influent pipe is approximately 2 in at 0.35 MGD and about 8.5 in at 3.9 MGD.
- At 0.35 MGD Froude number = \( \frac{V}{\sqrt{gy}} \) = 5 ft/s / (32.2 ft/s\(^2\) x 0.17 ft)\(^{1/2}\) = 2.56
- At 3.9 MGD Froude number = \( \frac{V}{\sqrt{gy}} \) = 7.5 ft/s / (32.2 ft/s\(^2\) x 0.71 ft)\(^{1/2}\) = 1.57
- The flow is supercritical across the entire flow range since Froude number > 1 at both top and bottom ends of the flow range.
Bypass Structure
Manhole Rehabilitation
COATING THICKNESS SCHEDULE

<table>
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<tr>
<th>DEPTH FROM RIM</th>
<th>COATING THICKNESS (MDFT)</th>
<th>EXPECTED CONDITION TIER</th>
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</thead>
<tbody>
<tr>
<td>5</td>
<td>500</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>550</td>
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<td>9</td>
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<td>11</td>
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<td>2</td>
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<tr>
<td>13</td>
<td>700</td>
<td>2</td>
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</table>

GENERAL NOTES:

- Pipe with TEB
- Cored and Risen, Salvage Existing Frame and Hangers and Salvaged Frame and Cover with
- 8" Exterior Drop, Filled with Sand and Capped, Abandoned in Place

RECORD DRAWN

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Model Number: S900B

31'