Ohio

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Low Velocities in Force Mains: Impacts and Solutions

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Low Velocities in Force Mains (FMs): Presentation Outline

- Overview
- Complications and consequences
- Contributing factors
- Standards and engineering practice
- Design and O&M solutions
- Case studies
- Conclusion
- Questions

Overview: Low Velocity in Force Mains

Primary Concerns:

1. Solids deposition
2. Gas pocket accumulation (incl. air binding)
3. Grease / Biofilm accumulation

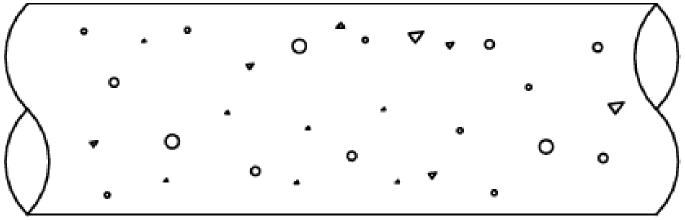
Which can lead to:

- Pipe deterioration
- Reduced asset life
- Increased life-cycle cost

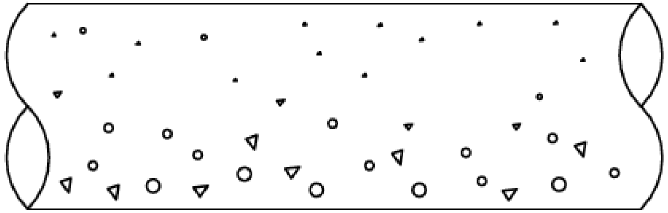
Overview:
Solid-liquid Horizontal Flow Behavior

Behavior is dependent on fluid properties, velocity, particle sizes, density, etc.

- **Homogeneous suspension:** Particles are uniformly suspended and move at the same velocity as the fluid.



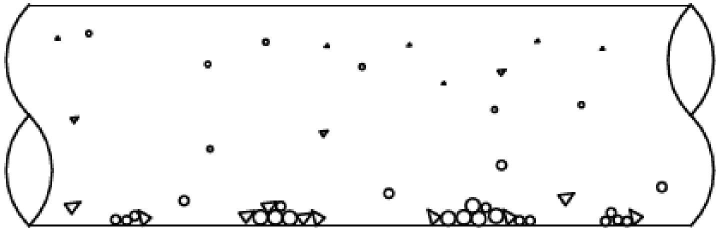
- **Heterogeneous suspension:** A concentration gradient exists within the pipe as coarse particles move slower and begin to settle.



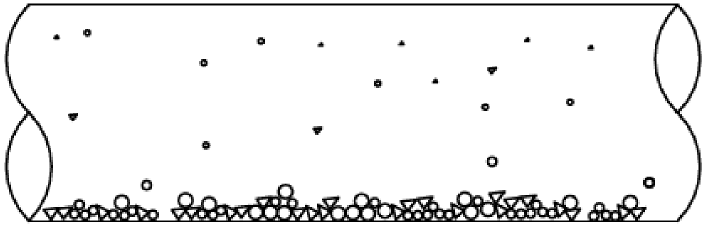
Overview:
Solid-liquid Horizontal Flow Behavior

Heterogeneous flow can lead to solids deposition (“saltation regime”)

Particles travel in discontinuous movements or by sliding/rolling along the bottom, if at all.



Sliding bed



Stationary bed

Overview:
Solid-liquid Horizontal Flow Behavior

A sliding bed can cause abrasion of the pipe invert.

Stationary beds reduce available pipe cross-sectional area.

Goal: Operate at adequate velocity to achieve heterogeneous suspension without solids deposition

Overview:
Gas pocket accumulation (air binding)

Sewer gas can come out of solution within a FM and accumulate causing:

1. Reduction in pipe cross-sectional area (increases pumping head)

2. Pipe corrosion from H_2S attack

Additional Complications from Low Velocity in Force Mains

In addition to solids deposition and accumulation of gas pockets, other complications may include:

- Grease / biofilm accumulation
- Microbial activity, H_2S, odorous and corrosive conditions

Common Consequences Associated with Low Velocity in FMs

Potential consequences:

- Increased system head losses due to reduced cross-sectional area (smaller ID) and higher roughness factor
- Increased operating pressure (pump seals, piping, valves, and other appurtenances)
- Reduced pumping capacity

Common Consequences Associated with Low Velocity in FMs

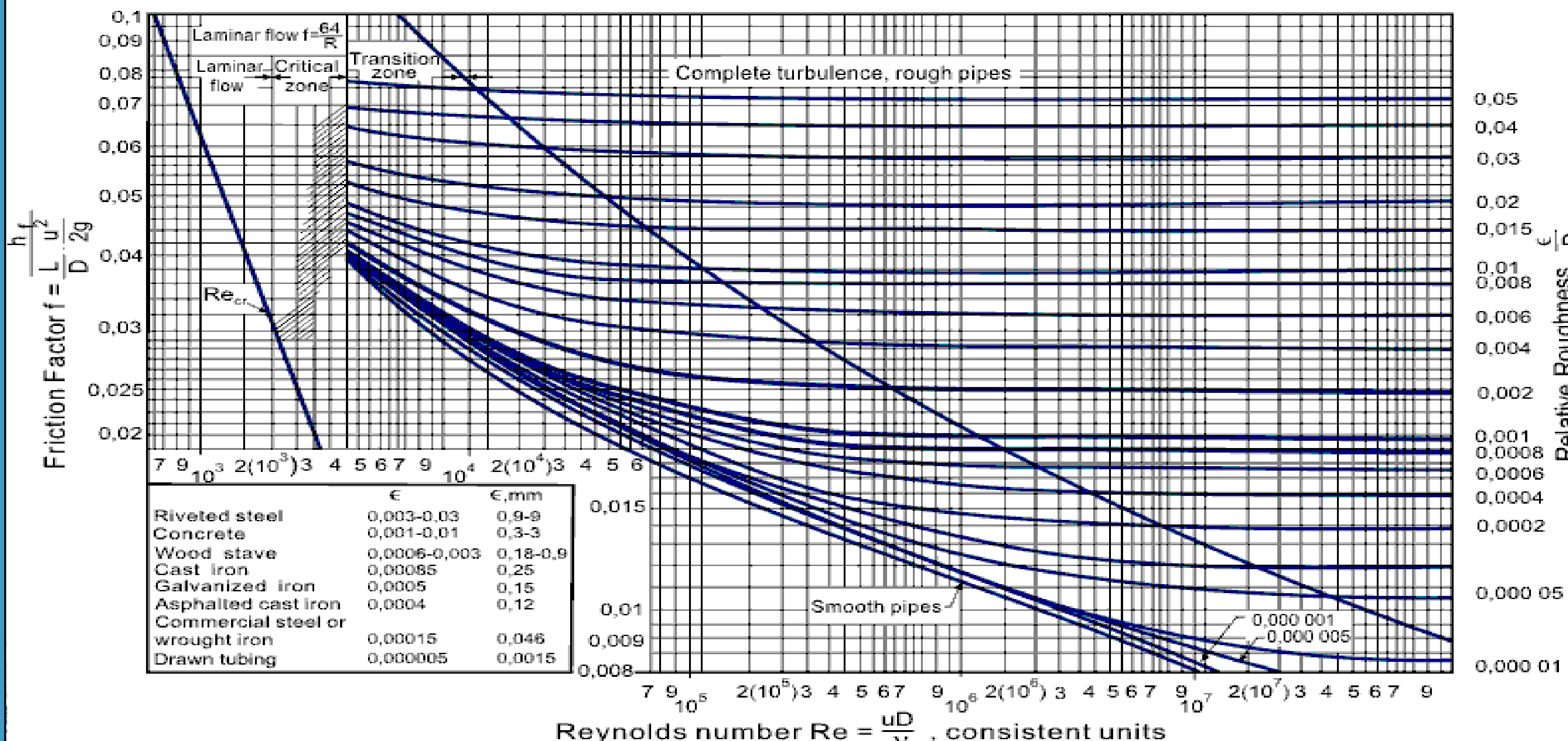
Potential consequences (cont.):

- Increased odor and corrosion within the FM and downstream sewers and MHs
- Pipe abrasion (sliding bed or H_2S attack)
- Increased O&M costs (e.g. electrical use, chemical use, cleaning costs, etc.)
- Reduced asset life

Additional Considerations (designers)

Hazen-William’s equation is only valid in “transition zone”—not at velocity or diameter extremes

(Moody chart)



Contributing Factors

Circumstances that may lead to low velocity:

- Small PSs with 4” FMs (80 gpm = ~2 fps)
- Existing FMs reused for smaller PSs
- Manifolded FMs serving multiple pump stations)
- Systems with no / low initial contributing flow (incl. phased developments)
- High wet-weather / average flow ratio
- High TDH (long FM or static head)

Contributing Factors

Circumstances that may lead to low velocity:

- PS down-sizing or other system changes
- Wear of pump components (impellers, volutes, etc.)
- Accumulation of gas pockets (air binding) in FM
- Increased system headlosses:
  - Grease accumulation
  - Biofilm growth resulting from use of ammonium calcium nitrate or certain other chemicals for odor and corrosion control in a long FM
  - FM relocations (e.g. add length and fittings)

Standards and Engineering Practice for Force Main Velocity

What Velocity is not "Low Velocity"?

Standards and Engineering Practice for Force Main Velocity

***Ten States Standards* (2004 ed.)[1]:**

"At design pumping rates, a cleansing velocity of at least 2.0 ft/s should be maintained."

***Pumping Station Design*, (3rd ed.)[3]:**

"The lowest design velocity … for raw wastewater is 2 ft/s to keep grit moving, and a peak daily velocity of 3.5 ft/s is desirable to resuspend settled solids."

"Velocities as low as 1.6 ft/s are tolerable with two daily flushes."

"If velocities are <2.5 ft/s, a daily flush at 4.0 ft/s long enough to sweep out the entire volume … is desirable."

Standards and Engineering Practice for Force Main Velocity

Piping Handbook **(7th ed.)[2]:**

"It is common practice to design sanitary sewers … to provide for velocities of 2 ft/s .... Storm sewers are commonly designed for a minimum full-flow velocity of 3 ft/s in order to resuspend sediment …."

USEPA, "Wastewater Technology Fact Sheet: Sewers, Force Main" (2000)[4]:

"Force mains … are typically designed for velocities between 2 to 8 ft/s."

Standards and Engineering Practice for Force Main Velocity

***Sanitary and Industrial Wastewater Collection—Pumping Stations and Force Mains*, Department of the Army and Air Force (1985)[5]:**

"Velocity criteria for force mains are based on the fact that suspended organic solids do not settle out at a velocity >=2.0 fps. Solids will settle at velocities <1.0 fps …. However, a velocity of 2.5 to 3.5 fps is generally adequate to resuspend and flush the solids from the line."

"[For large pumping stations] it will generally be sufficient to design for velocities of 0.5 up to 7.0 or 8.0 fps."

Standards and Engineering Practice for Force Main Velocity

Although general consensus is >~2.0 ft/s to prevent deposition and ~3.5 ft/s to resuspend solids, application varies between designers and projects

- *Adjustable-speed pumps*
- *Multiple-pump systems*
- *Shared / manifolded force mains*
- *Frequency of cleansing / scouring*

Standards and Engineering Practice for Force Main Velocity

Table B-9, *Pumping Station Design*, 3rd ed.[3]:

Velocities Required to Scour Air Pockets from Pipelines.

Velocities, ft/s					Pipe diameter, in.
Slope					
0%	5%	25%	45°	90°	
1.4	1.4	1.6	1.7	1.8	1
1.9	2.0	2.2	2.4	2.5	2
2.3	2.5	2.7	2.9	3.1	3
2.7	2.9	3.1	3.4	3.5	4
3.3	3.5	3.8	4.2	4.3	6
3.8	4.1	4.4	4.8	5.0	8
4.3	4.6	4.9	5.4	5.6	10
4.7	5.0	5.4	5.9	6.1	12
5.1	5.4	5.8	6.3	6.6	14
5.2	5.6	6.0	6.6	6.8	15
5.4	5.8	6.2	6.8	7.0	16
5.7	6.1	6.6	7.2	7.5	18

Design Engineering Solutions:

- Proper hydraulic evaluation, incl. maintaining minimum velocity >=2 ft/s whenever possible
- Evaluation of alternate alignments and profiles
- Consideration of parallel pipes (if wide flow range)
- Proper air valve selection—incl. avoiding air valves wherever feasible by avoiding intermediate high points and/or achieving air-scouring velocity
- Proper odor / corrosion control measures

Design Engineering Solutions:

- Proper pump and impeller selection
- Evaluation of constant- vs. adjustable-speed pumps
- Appropriate pump controls—e.g. auto-flushing
- Consideration of screening and grit removal
  - Reducing amount of solids—esp. grit and other large particles—can reduce the required cleansing velocity
- Consideration of flushing and/or pig-launching and retrieval connections

Operation and Maintenance (O&M) Solutions

- Regular flushing at higher velocity (auto or manual)
- Maintain pumps to preserve original pumping capacity—debris-free, proper clearances, no blowby
- Refurbish or replace impellers as needed to maintain design (or higher) pumping capacity
- Change pump controls

Operation and Maintenance (O&M) Solutions

- Chemical "shocking" to kill biofilm growth
- Mechanical Pipe Cleaning (e.g. pigging)
- Odor / corrosion control chemical

Operation and Maintenance (O&M) Solutions

ICE PIGGING by Utility Service Group – Atlanta
(currently up to 24-inch diameter)

http://www.utilityservice.com/icepigging.html

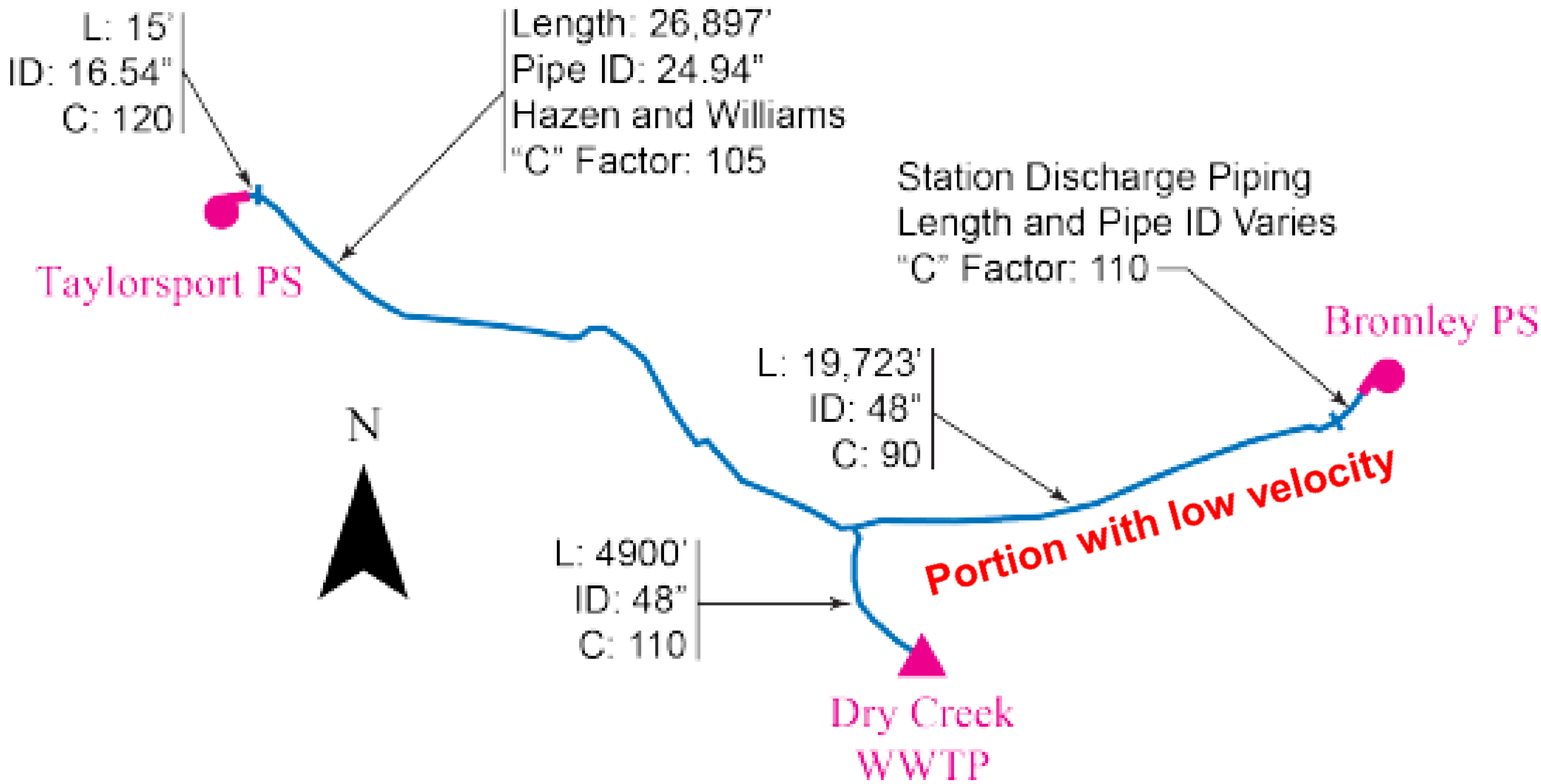
Ice slurry with semi-solid properties

Before ICE PIGGING

After ICE PIGGING

ICE PIGGING process samples from start to finish

Case Study 1 – Bromley & Taylorsport (Manifolded Force Mains)



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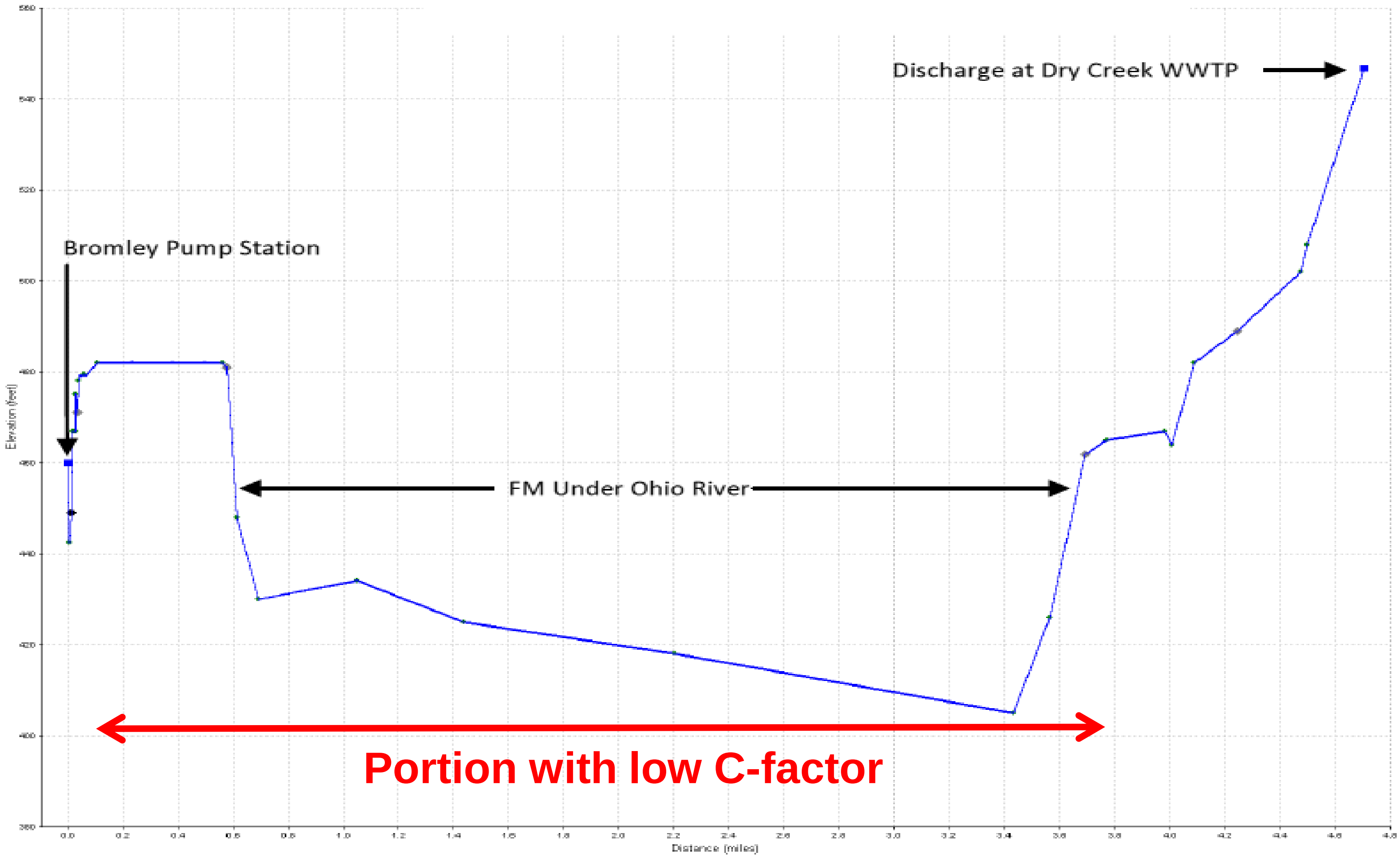
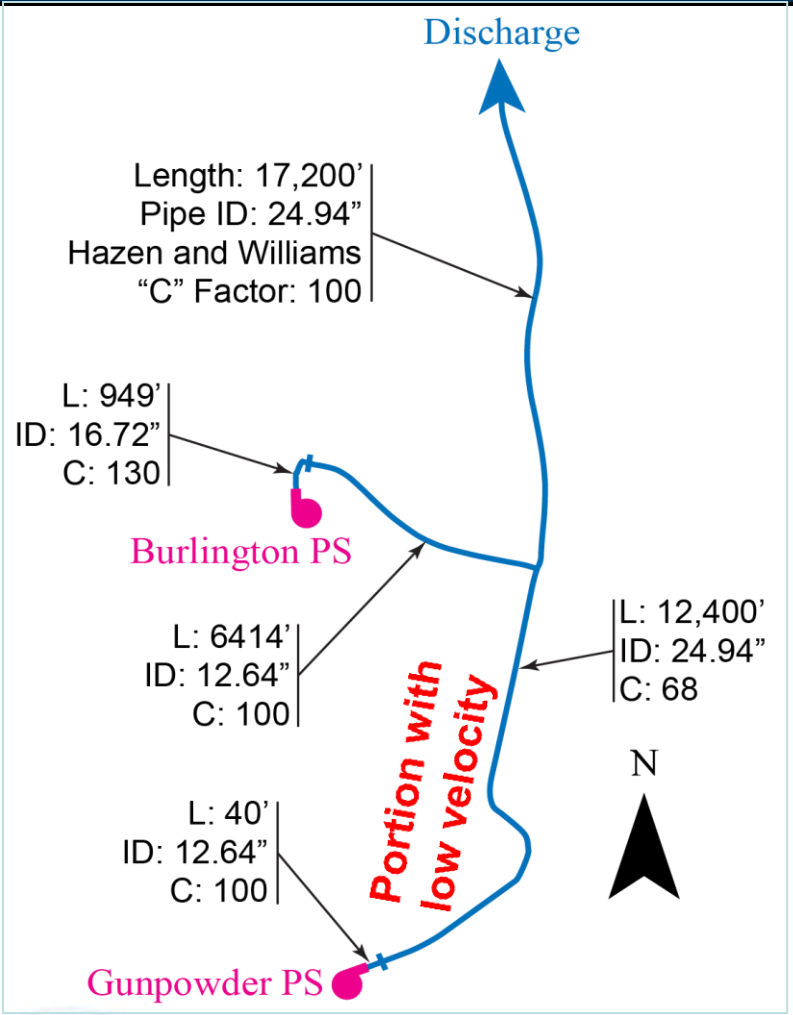
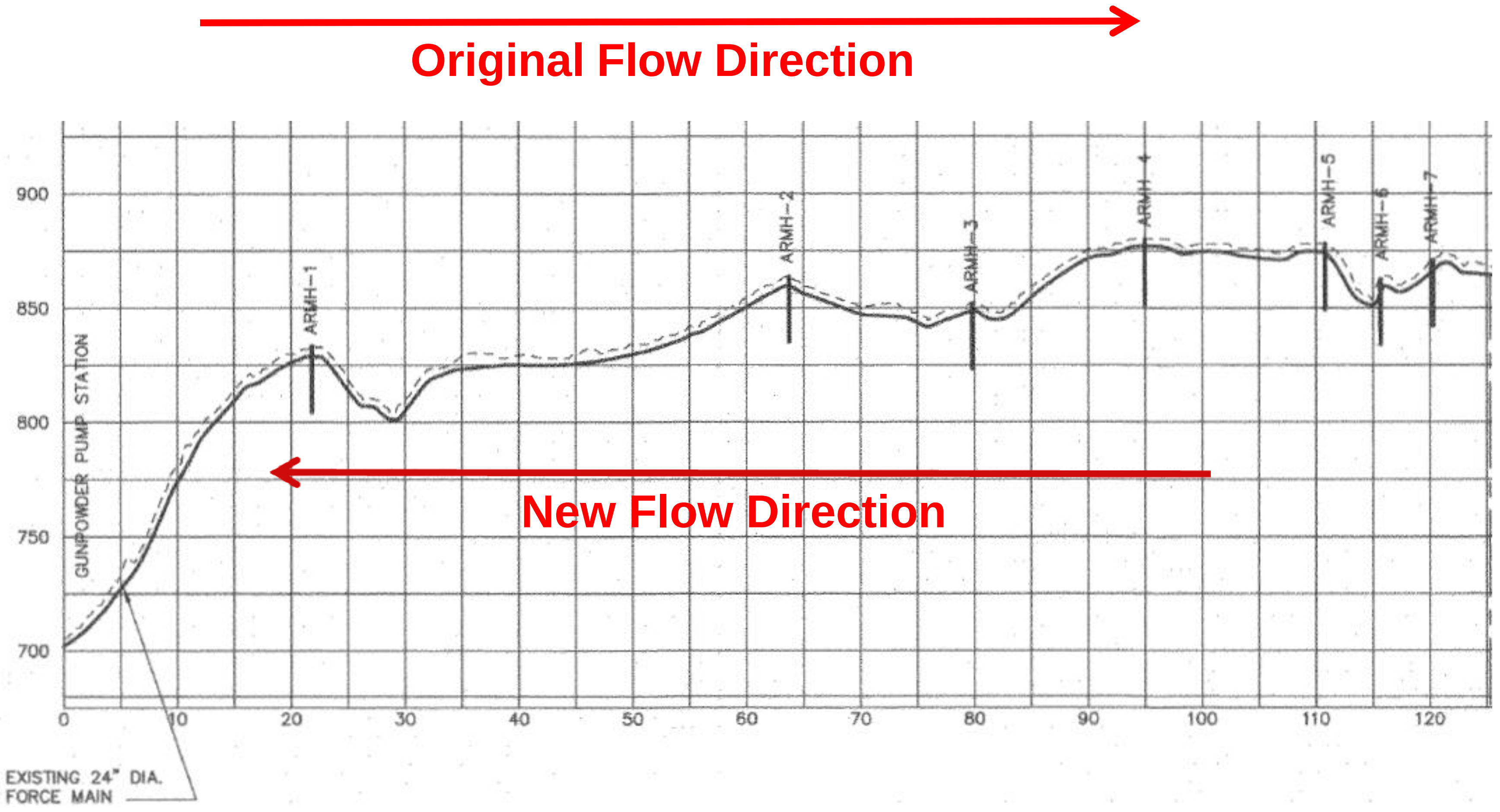


Case Study 2 – Gunpowder & Burlington (Manifolded Force Main)



Case Study 2 – Gunpowder & Burlington Force Main



Case Study 2 – Gunpowder & Burlington Force Main

Darker flow due to flow reversal in FM resuspending sedimentation

Conclusion / Review

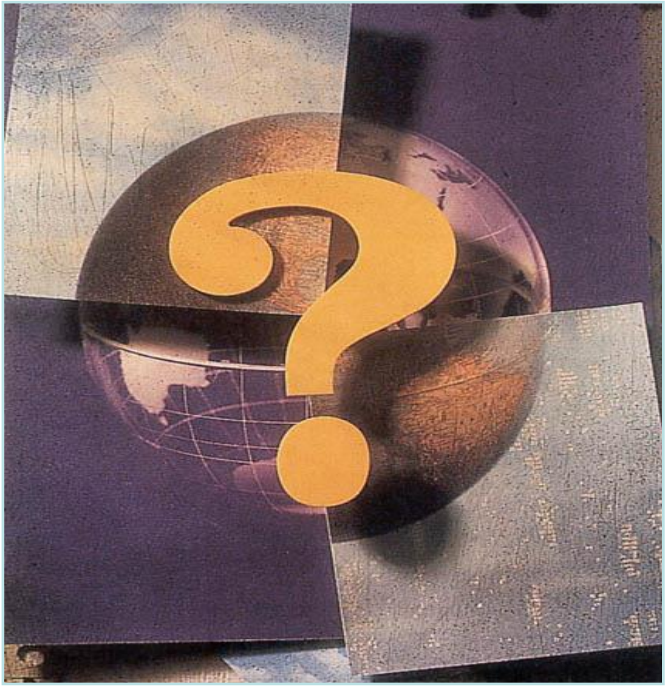
Remember:

- Appropriate FM velocities (~2 – 8 ft/s)
- Reasons why low velocities are undesirable
- Potential complications and consequences
- Contributing factors to low velocities
- Design and O&M solutions

Proper understanding allows:

- Engineers to make better design decisions
- Utility operators to better understand FM O&M issues
- Maximizing FM piping life and reducing life-cycle costs

Questions?



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4. USEPA (2000) "Wastewater Technology Fact Sheet: Sewers, Force Main": EPA 832-F-00-071.
5. Departments of the Army and the Air Force (1985) "Sanitary and Industrial Wastewater Collection—Pumping Stations and Force Mains": Army TM 5-814-2, Air Force AFM 88-11, Vol. 2.
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