THE LURE OF LEVEL-ONLY MONITORING FOR I/I MEASUREMENT

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In 1889, Robert Manning presented his velocity formula (Manning's Equation) to the Institute of Civil Engineers and it quickly became the standard for velocity calculation of open channel flows.

Flow volume is expressed as Q = VA where "Q" is flow, "V" is velocity, and "A" is wetted cross-sectional area. " A" is derived from depth measurement. In the mid-1970s, technology enabled direct measurement of "V". Thus, area/velocity (A/V) meters produced quick and reliable flow (Q) measurement in gravity wastewater and stormwater systems.

A/V meters are today's flow measurement standard, well-established for their reliability and accuracy and software advancements like machine learning enabling advanced analytics.

WET WEATHER CHALLENGES

Wet weather, producing rainfall derived infiltration and inflow (RDII or I/I), challenges collection system capacity leading to overflows, discharges, and increased WRF flows impacting operating costs.

In response, utilities spend many millions annually to locate and quantify I/I collection system sources.

Depth-only monitors (DOMs) are today being promoted as A/V meter alternatives for measuring I/I. DOM costs can be 25% to 70% less than A/V meters, motivating budget-challenged utilities to consider them. Since DOMs only measure depth, they use empirical equations such as Manning's or other proprietary algorithms to derive velocity.

Manning's Equation is expressed as:
$v = (1.486)/n \, R^{(2/3)} \, S^{(1/2)}$

Where,
- v is velocity,
- n is the Manning co-efficient of roughness (boundary resistance),
- R is hydraulic radius,
- S is slope (of the water surface; often interpreted as pipe slope).

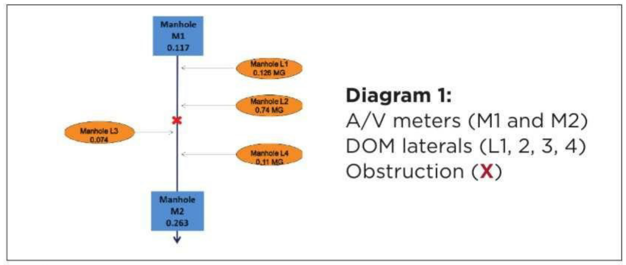
When variables are known and conditions are ideal, Manning's may reasonably determine velocity. Yet, few sewers exhibit ideal conditions. For example, the roughness coefficient can be determined through pipe material and condition engineering tables. However, "condition" allows for subjectivity. Assumptions about hydraulic radius (pipe roundness), slope consistency, or that flow is uniform steady-state create more opportunities for error. Manning's-based velocity (flow) error is ±20% under ideal conditions. When adding the potential for error, DOM data quality becomes suspect.

A/V METERS VERSUS DOMS: COMPARATIVE TESTS

Tests were conducted assessing DOM data quality for determining their flow measurement suitability.

Test 1:

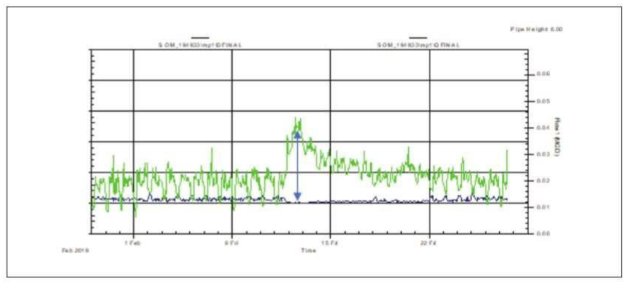
A/V meters were installed at either end of a main (M1 and M2, Diagram 1) and DOMs installed at four laterals. The flow difference between the upstream A/V meter (M1) and the downstream A/V meter (M2) was 0.146 MG. Yet, the sum of all the four depth-only devices was 1.023 MG. The DOM values were 601% higher than the directly measured A/V value. The discrepancy was due to a blockage (**X**) that created a back-water condition, causing upstream water levels to increase at L1 and L2, thus overstating the DOM calculated flow.



Test 1

Test 2

Hydrograph 2 illustrates issues of slope variance. DOM depth (blue) shows a decrease in flow. Yet, the A/V meter (green) reveals that flow doubled. The DOM didn't detect slope change and the corresponding shallower, *higher velocity* flow. The DOM measuring a level decrease and not measuring the velocity change, calculates a flow reduction when, in fact, *flow increased.* Problematically, the DOM data concludes that there is "no issue" while the A/V data reveals a significant flow increase.



Test 2. *Hydrograph 1: DOM (blue), A/V (green).*

Test 3

Ten sites with ten-plus years of A/V meter data were assessed. Chart 1 shows ***A/V Avg Flow.*** Using this data set, Manning's was substituted for actual measured velocity to yield flow as ***Level Avg Flow.*** The average flow ***Net Difference*** and ***Net Difference %*** between A/V and DOM with Manning's demonstrate a -27% variance (JH3, best case) and a -77% (A2B, worst case).

Location Code	A/V Avg Flow	Level Avg Flow	Net Difference	Net Difference %
FG7	1.41	2.39	0.98	69.5%
CC1	1.65	2.15	0.5	30.3%
B35	3.54	4.59	1.05	29.7%
JH3	3.52	2.57	-0.95	-27.0%
B45	3.28	2.35	-0.93	-28.4%
RT1	4.63	3.18	-1.45	-31.3%
JJ2	1.28	0.79	-0.49	-38.3%
A3B	5.62	3.01	-2.61	-46.4%
BG1	1.86	0.71	-1.15	-61.8%
A2B	3.01	0.68	-2.33	-77.4%

Test 3. *Chart 1: Comparison of average A/V meter flow data versus calculated average depth-based flow data.*

CONCLUSION

Capital Improvement Project (CIP) decisions must be substantiated by methods that produce sound data and insights. These tests raise concerns about DOM effectiveness for determining flow.

Even when a "ballpark value" is thought to be sufficient, the question arises: can DOMs even get us near the ballpark?

Using DOMs for I/I assessment will result in lower initial cost. Yet, the cost of poor or errant data can be many times greater. By contrast, acquiring accurate data, while more expensive initially, will result in defensible decisions, yielding the returns that a utility seeks.