Sacramento County Regional Sewer District

Interceptor Sequencing Study

Technical Memorandum 4
Facility Criteria

August 2009

Sacramento Regional Sewer District

Interceptor Sequencing Study

TECHNICAL MEMORANDUM
NO. 4
Facility Criteria

TABLE OF CONTENTS

Page No.

LIST OF TABLES

1.0 INTRODUCTION

This Technical Memorandum (TM) presents the research that was conducted to supports the use of facility criteria for wastewater gravity flow velocity and pipeline invert slope; pump station firm capacity; and emergency storage. The proposed criterion will be used to evaluate the interceptor wastewater conveyance system using the hydraulic model.

The purpose of this Technical Memorandum is to recommend facility criteria to be used in conjunction with hydraulic criteria to develop and evaluate future project alternatives for the Interceptor Sequencing Study.

Facility criteria have been separated into two separate categories based on its application in the ISS:

- Design Criteria – Criteria used to design new facilities. Design criteria are generally a conservative value that is typically used in design standards to allow for various unknown factors that can impact a facility's real world performance. These range from construction defects to varying flow conditions.

- Performance Criteria – Criteria used when evaluating the performance of the existing system. Lower performance criteria values generally tend to carry more risk.

2.0 OBJECTIVE

The objective of this TM is to evaluate the current criteria that will be used to plan, to model hydraulically, and design interceptor sewer facilities and if appropriate, recommend new facility criteria. The facility criteria and flow generation criteria developed in Technical Memorandum 3 represent the parameters that will be used to evaluate existing facilities and plan future interceptor facilities.

As presented in the July 20009 ISS Leadership meeting, Appendix A provides a summary of the Facility Criteria to be used for hydraulic model evaluation of the interceptor system for the purposes of the Interceptor Sequencing Study.

3.0 MANNING'S "N" AND D/D RATIO

3.1 Background

Manning's value "n" for the coefficient of roughness of pipes has been thoroughly investigated and extensive data are readily available. The appropriate "n" values are those that will better predict the flow capacity of the installed pipes during their service life. The “n” value varies from 0.009 to 0.015 for different pipe materials. SRCSD has been using the “n” value of 0.013 for all pipe materials. The 0.013 is also widely accepted by other waste water agencies. This section will also discuss the accepted values for the depth of sewer flows (d/D ratio) and the roughness coefficient (Hazen-Williams coefficient, C) that is recommended for sewer pressure systems (forcemains).

3.2 Research and Industry Standards

3.2.1 SRCSD-CSD-1 Sacramento Sewerage Expansion Study 1993

3.2.1.1 Manning’s “n” Factor

“*Manning’s “n” factor is the friction factor utilized in the Manning’s equation for gravity flow to describe the roughness of a particular pipe material or condition. There has been much debate over the changing of the “n” value over time and the benefit of the smoother wall of T-Lock lined pipe. A Manning’s “n” value of 0.013, the most widely accepted value in the industry, provides some of the conservatism if, in fact, there is a significant benefit to the smoother T-Lock pipe walls.*

The study recommended the “n” factor of 0.013 be used for all pipe materials citing that:

“*Some of the sewerage agencies believe that after a period of time, the deterioration of the pipe surface and joints increase friction and recommend that higher “n” value should be used in design. The cities of Los Angeles, san Jose, and Sacramento recommend an “n” value of 0.014 in their new design standards for combined or storm drains.”*

3.2.1.2 Depth of Flow

“Depending on the pipe size, three different criteria concerning the depth of flow are being used by major sewer agencies in California.

1) For *smaller pipes, usually up to 12” or 15” in diameter, the depth of flow to pipe diameter (d/D) ratio of 0.7 or 0.75 is used for the design at peak flow. This lower (d/D) ratio is used to avoid flow blockages in smaller pipes due to debris.*

2) Larger pipes (18” to 120”) are generally designed to flow full at design flow conditions. A pipe designed for full or 100 percent capacity has a d/D ratio of 1.0.

3) In order to save cost, some agencies allow surcharging of large diameter gravity flow interceptors (greater than 60”) under peak flows associated with infrequent (long return period) storm events. The main disadvantage of this approach is that once surcharging is allowed, its extent is hard to control and may result in flooding basements and other low lying areas. Also, gravity sewers are not designed for pressure flows, and flows under surcharged conditions may result in some ex-filtration of sewage.”

The study recommended that sewer lines 12-inch and larger be designed for full pipe under peak design flow conditions citing that the criteria is widely accepted and complies with the County standards.

3.2.1.3 Hazen-Williams "C" Factor

This is not discussed in any detail in the 1993 Expansion Study but, in Appendix B, on Page 9, it does say:

"For the design of force mains…A "C" value of 120 to 140 should be used in the Hazen-Williams formula for pressure pipes".

In Table 4-1 in Section 4 of the main body of the study a Hazen-Williams "C" value of 120 is recommended for the model hydraulic criteria.

3.2.2 SRCSD – Interceptor Master Plan 2000

3.2.2.1 Manning's "n" Factor

The Interceptor Master Plan 2000 indicated that: *"An "n" value of 0.013 shall be used as an average coefficient for all sizes and types of pipe material. Although pipe manufacturers claim lower values for some pipe materials and linings, this slightly conservative value is intended to compensate for offset joints, poor alignment, grade settlement, sediment deposition, and the effect of slime and grease build-up in interceptors."*

3.2.2.2 Depth of Flow

The Interceptor Master Plan 2000 did not address the depth of flows in interceptors; however, it did mention that for design purposes, pipe is assumed to be completely full.

3.2.2.3 Hazen-Williams "C" Factor

Section 5.5.2 of the MP2000 deals with pressure systems and quotes the Hazen-Williams formula:

$$Q = 1.318 \; x \; C \; x \; R^{0.63} \; x \; S^{0.54} \; x \; A$$

"C" is the roughness coefficient for which the document states:

"The roughness coefficient varies with pipe material, velocity, size, and age. The value to be used for design for all types of pipe material shall be ***C = 110****. This value is generally equivalent to a Manning's n value of 0.013, which is used in the HydroWorks model."*

3.2.3 SRCSD Interceptor Design Manual (IDM)

3.2.3.1 Manning's "n" Factor

"Manning's roughness coefficient, "n", is assumed to be constant in pipes flowing partly full or completely full for the purposes of SRCSD interceptor design." And Field research by the Los Angeles County Sanitation Districts concluded that the "n" value of long term installed sanitary sewers was about 0.014 for all pipe materials due to the slime buildup and wall and joint wear. An "n" value of 0.013 is also the most widely accepted value in the industry. An "n" value of 0.013 shall be used for sizing gravity sewers regardless of the type of pipe selected. Although pipe manufacturers claim lower values for some pipe materials and linings, this slightly conservative value is intended to compensate for offset joints, poor alignment, grade settlement, sediment deposition, and the effect of slime and grease build-up in interceptors."

3.2.3.2 Depth of Flow

The Interceptor Design Manual also did not recommend a design depth of flows in Interceptors; however, it did mention that for design purposes, pipe should be designed to flow full.

Table 4.1 Manning's "n" and d/D Ratio for SRCSD and Other Agencies

Sources	Design Criteria	Pipe Type
SRCSD-SASD Sewerage Expansion Study 1993/1994	0.013	All
SRCSD Master Plan 2000	0.013	All
SRCSD Interceptor Design Manual	0.013	All
City of Los Angeles	0.014	All
Union Sanitary District	0.013	All
Delta Diablo Sanitation district	0.013	All
City of San Jose	0.015	RCP
Los Angeles County Sanitation District	0.013	All

Sources	Design Criteria
SRCSD-SASD Sewerage Expansion Study 1993/1994	0.7 for pipe 12" or smaller 1.0 for pipe larger than 12"
SRCSD Master Plan 2000	1.0 Implied
SRCSD Interceptor Design Manual	1.0 Implied
Los Angeles County Sanitation District	1.0 for pipe large than 60" 0.75 for pipe from 24"-60" 0.50 for pipe smaller than 24"

3.2.3.3 Hazen-Williams "C" Factor

The IDM repeats the MP2000 saying that C = 110 (Section 8, Page 9).

3.2.4 The American Concrete Pipe Association

The ACPA - Concrete Pipe Insights Publication discussed the difference between the laboratory test values of Manning's "n" and accepted design values. The publication indicated that laboratory results are usually obtained by using clean water and ideal conditions which are not field represented for the life service of the pipes. The publication also indicated a 20 to 30% "design factor" is good engineering practice and is widely accepted.

Table 4.2 Flow Rate for Different "n" Values

36" diam. pipe	S=0.0001	n=0.013 n=0.012 n=0.011 n=0.010	Q=21.5 cfs Q=23.5 cfs Q=25.5 cfs Q=28.2 cfs	09 % more 18 % more 27 % more
48" diam. pipe	S=0.0001	n=0.013 n=0.012 n=0.011 n=0.010	Q=46.5 cfs Q=50.5 cfs Q=55.5 cfs Q=60.5 cfs	09 % more 18 % more 27 % more
60" diam. pipe	S=0.0001	n=0.013 n=0.012 n=0.011 n=0.010	Q=85.0 cfs Q=93.0 cfs Q=100.0 cfs Q=110.0 cfs	09 % more 18 % more 27 % more
72" diam. pipe	S=0.0001	n=0.013 n=0.012 n=0.011 n=0.010	Q=138.0 cfs Q=150.0 cfs Q=162.0 cfs Q=180.0 cfs	09 % more 18 % more 27 % more

3.2.5 Sanitation Districts Agency Capacity Management Section Reports

Capacity Management performed an analysis to explore the hydraulic model's sensitivity to Manning's "n" (see Appendix B for full report). The report used available flow meter data and GIS pipe size and slope information to calculate Manning's "n." The table below summarizes the pipe information and flow meter types considered and the modeling results.

Table 4.3 Manning's "n" Value Analysis of Existing System

Flow-Monitoring Points	Pipe Size/Type	Flow Meter Type	Calculated "n"
Dry Creek Interceptor -- Site 50418	24" VCP	Area-Velocity	0.011
Dry Creek Interceptor -- Site 398	18" VCP	Area-Velocity	0.014
Dry Creek Interceptor -- Site 355	66" RCP	Flodar	0.011
McClellan Interceptor -- Site 418	46" RCP	Flodar	0.013
Northeast Interceptor -- Site 71130	102" RCP	Area-Velocity	0.012
Jackson Interceptor -- Site 71131	84" RCP	Area-Velocity	0.011
Bradshaw Interceptor -- Site 71132	102" RCP	Area-Velocity	0.010

Key conclusions from this analysis:

- Manning's "n" factor varies throughout the existing system with years in service (condition) being the primary influencing factor.
- Currently, there is not sufficient flow monitoring data collected for the model to predict the Manning's "n" factor. More data is needed to confirm meter data is not biased (to measured velocity, depth, or both) and to check consistency along a trunk or interceptor.
- Additional flow monitoring data and scrutiny of GIS data (inputted into the model) is recommended to further evaluate Manning's "n" factor...

3.2.6 Hazen-Williams "C" – Internal Technical Memorandums

3.2.6.1 LNWI Pump Station Design Guidelines

In the "System Head Curve Guidelines" (Section 2.3.2.2) The Hazen-Williams friction factor is given a range of 110 – 140.

3.2.6.2 New Natomas and South River Pump Stations Basis of Design Report (BODR).

This references the 110 – 140 range above and states:

"Using a range of C-Values for design is reasonable since it is anticipated that the forcemain's C-Value will change with time. Pipelines in service for many years can have C-Values lower than when they were first installed. C-Values can be affected by corrosion, grease, grit accumulations, and air accumulation at high points. The C-value of a forcemain will decrease from its value when new, but after a period of time the C-value will likely reach a point of equilibrium where suspended solids, grease, and/or air accumulation have reduced the forcemain area to a point where velocities are high enough to maintain solids in suspension."

3.3 Discussion

3.3.1 d/D Ratio

Pipes 12" in diameter and smaller are frequently designed with a d/D factor of less than 1.0 to avoid pipe blockages. The smallest interceptor is generally around 36" in diameter. At this pipe size, blockages to debris or grease build-up are not a concern and therefore designing with a d/D equal to 1.0 is appropriate. For performance evaluations, d/D values higher than 1.0 may be acceptable. It is recommended that allowable surcharge be used as the performance criteria.

3.3.2 Manning's "n" Value

SRCSD past practice and industry standards suggest that 0.013 continues to remain an appropriate design value. Efforts to back-calculate Manning "n" values by the hydraulic model utilizing area-velocity data from flow meters in the system resulted in inconsistent and inconclusive results.

3.3.3 "C" Value

SRCSD experience and industry standards suggest that 110 continue to remain an appropriate design value. When evaluating relatively new facilities for performance, it may be prudent to perform an analysis of the force main to back-calculate an actual C factor for use during a limited time period.

3.4 Recommendations

3.4.1 d/D Ratio

Design Criteria - 1.0

Performance Criteria – Based on allowable surcharge

3.4.2 Pipe Friction Factors

Design Criteria (Gravity Pipe) - n=0.013

Design Criteria (Force Main) - C=110

Performance Criteria (Gravity Pipe) – n=0.013 unless model calibration studies indicate lower values is appropriate.

Performance Criteria (Force Main) – C=110 unless studies indicate higher value is appropriate.

4.0 WASTEWATER GRAVITY FLOW VELOCITY & PIPELINE INVERT SLOPE

4.1 Background

Wastewater flow velocity and the invert slope of a pipeline are closely related to each other and setting each of these as criteria is important in designing an efficient gravity sewer system. A minimum velocity of flow is required to ensure that the system is "self-cleansing". This will minimize the amount of particulate matter that builds up on the bottom of the pipe resulting in maximizing flow and reducing sulfide generation. The correct invert slope is necessary to achieve this minimum velocity as well as make effective use of the available grade so as to carry flows the furthest distance by gravity within the system. Although not as critical, the maximum velocity and slope are important to protect the sewer facilities from corrosion, erosion and separation of solid matter.

Since the beginning of the existence of SRCSD, there have been a number of official documents that have been prepared to plan and design interceptor sewer systems within its jurisdiction. The following narrative references these documents and how they address the issues of gravity flow velocity and pipeline slope:

4.1.1 MASTER PLANS

4.1.1.1 SRCSD & CSD-1 Sacramento Sewage Expansion Study (April 1993) (prepared by James M. Montgomery):

In Appendix B, “Recommended Design Criteria”, “Minimum Velocities”, the document explains that:

… [self cleansing] velocities are a function of re-suspension of particles deposited during lower velocities in the sewers. It is assumed that the largest particles in the wastewater collection system will be deposited along the invert of the sewer during periods of low flow. In order to move these solids down the sewer, the boundary shear stress created by the water needs to be sufficient to initiate motion of the particles.

The shear stress, T_0, is defined by: $T_0 = WRS$

Where:

W = Specific weight of water.

R = Hydraulic Radius.

S = Slope.

Further, it says:

Researchers have found that solids contained in domestic wastewater vary between 1 and 5 mm in size. Recommended values of the shear stress (T_0) are 0.03 lb/sq ft for particle size less than 1mm and 0.07 lbs/sq ft for particles greater than 1 mm.

This document does not provide more detail on which “researchers” it refers to and what studies these “researchers” were basing their conclusions on. The document recommends that, for pipes larger than 24-inches in diameter, the minimum velocity at peak dry weather flow (PDWF) should be from 3 to 4 ft/sec (fps). For a comparison of standards used by other agencies, Table 3.1 is provided:

Table 4.4 Sewer Design Criteria

Agency	Design Criteria
City of Los Angeles	Manning’s “n” = 0.014 for all pipes
	3 fps min in pipes at ADWF
	4 fps min in inverted siphons

Union Sanitary District	Manning's "n" = 0.013
	2 fps min in pipes at 1 hour PDDWF
Delta Diablo Sanitation District	Manning's "n" = 0.013
	2 fps min in pipes at 1 hour PDDWF
	Min slope of 0.08% in pipes >= 24" diameter
San Jose	Manning's "n" = 0.015 for RCP
Los Angeles County Sanitation Districts	Manning's "n" = 0.013
	2 fps min at ADWF
	Flow Depth d/D = 1.0 for > 60"
	d/D = 0.75 for D = 24" to 60"
	d/D = 0.5 for D <= 24"
	Pipe Material D <= 36" VCP
	D>= 36" RCP with T-Lock.

4.1.1.2 SRCSD Interceptor System Master Plan 2000 (MP2000) (Prepared by Black & Veatch)

In Volume 1, Section 5.5.1.1, "Velocity and Slope", the following is stated:

Sanitary sewers conveying municipal wastewater with its associated grit and solids content are commonly designed such that a minimum cleansing velocity of 2 feet per second is achieved at peak wet weather flow. This criterion has proved adequate in many municipal wastewater systems throughout the United States for small diameter pipes. If deposition does accumulate in these size sewers, it may be easily removed using standard sewer maintenance equipment and procedures. In larger diameter sewers, however, removal of deposited solids becomes more difficult. Therefore, for large diameter sewers the concept of minimum cleansing velocities is a function of re-suspension of particles deposited during periods of low flow resulting in low velocities. It is reasonable to assume that the largest particles in the wastewater conveyance system will be deposited along the invert of the sewer during periods of low flow. In order to move these solids down the sewer, the boundary shear stress created by the wastewater needs to be sufficient to initiate motion of these particles.

The shear stress, T_0, is defined as

$$T_0 = \gamma \times R \times S$$

Where:

γ = specific weight of water
***R** = hydraulic radius*
***S** = invert slope*

Assuming that solids contained in domestic wastewater vary between 1 and 5 mm in size, the recommended values of the shear stress (To) are 0.03 lb/sq ft for particle size less than 1 mm and 0.07 lb/sq ft for particles greater than 1mm. Another consideration is the *minimum slope desirable from the construction standpoint. Previous standards have allowed this value to be as low as 0.0003 feet per foot. However, using this value if a contractor is only off grade by 0.1 of a foot per 1000 feet, the design slope is in error by 33%. For the purposes of this master plan, interceptors have been designed with a minimum slope of 0.0006. In special circumstances the SRCSD may consider lowering this value if warranted.*

The document does not discuss where it came up with the value of 0.0006 ft/ft for its minimum slope. It also does not provide a specific minimum velocity for large diameter pipes.

4.1.2 DESIGN MANUAL

4.1.2.1 SRCSD Interceptor Design Manual (IDM)

In Chapter 8, *Pipeline Design*, under "Velocity and Slope" (Page 8-5), the IDM goes into more detail about minimum velocity by citing a particular methodology (using Camp's Equation):

Large diameter sewer [36"or larger].

In larger diameter sewers (i.e. interceptor sewers), removal of deposited solids becomes more difficult. Therefore, for large diameter sewers the concept of minimum cleansing velocities is a function of re-suspension of particles deposited during periods of low flow with corresponding low velocities. It is reasonable to assume that the largest particles in the wastewater conveyance system will be deposited along the invert of the sewer during periods of low flow; periods of low flow are of primary concern, i.e., start-up flows. In order to move these solids, the boundary shear stress created by the wastewater needs to be sufficient to initiate motion of these particles. There are several methods that can be used to estimate this minimum velocity and the application of this process may not apply to all interceptor projects. SRCSD will make a determination on the applicability of this or any other minimum velocity methodology during design. The following explains one method using Camp's Equation:

$$V = [\frac{8B}{f} g(s-1)D_g]^{1/2}$$

Where:

V = velocity, ft/s
n = roughness coefficient
R = hydraulic radius, ft
s = specific gravity of the particle
Dg = diameter of the particle, ft
f = friction factor
g = gravitational acceleration (32.174 ft/s^2)
B = a dimensionless constant

Values for B range from about 0.04 to start motion of clean, granular particles to about 0.8 for adequate self-cleansing of cohesive material. Values for Dg, s, and B will be determined by SRCSD. Given the pipe diameter and slope, the minimum velocity required to achieve cleansing under full conditions can be calculated with Camp's Equation. Rearranging Manning's equation, find the slope for which this velocity occurs at full pipe conditions:

$$S_f = \left[\frac{V \times n}{1.486 \times R^{2/3}}\right]^2 \qquad (1)$$

Using this slope, the minimum flow able to provide self-cleansing can be determined for the design conditions. Substituting the result from equation (1) into equation (2) for various values of d/D, the slope for which cleansing will occur at various depth conditions can be determined. Choose values of d/D less than 0.5 to simulate conditions at less than half full (conditions where self-cleansing is less likely).

$$S = S_f \times 0.5576 \left(\frac{d}{D}\right)^{-0.8559} \qquad (2)$$

The flow, Q, for this slope, S, can then be determined using Manning's equation taking into account that the pipe is not flowing full:

$$Q = \frac{1.486}{n} \times a \times r^{2/3} \times S^{1/2} \qquad (3)$$

Where:

a = area of the partially full condition
r = hydraulic radius of the partially full condition

Using the values of S and Q determined using various values of d/D, a chart of S versus Q can be prepared. On the chart of Q versus S, find the slope being considered for design. Draw a line upward until the curve is intersected. The flow at this point represents the minimum flow necessary to achieve self cleansing for that diameter and slope.

Another consideration is the minimum slope desirable from the construction standpoint. ***Interceptors shall be designed with a minimum slope of 0.0005.*** *In special circumstances the SRCSD will consider lowering this value if warranted.*

For gravity lines, there is no specific maximum velocity limitation; therefore, greater slopes can be used whenever feasible. It should be noted that flow at critical and supercritical velocity may create undesirable turbulence, solids separation from liquids, hydraulic jumps, etc. and will require special design considerations to dissipate and provide additional corrosion protection from sulfide releases.

4.1.3 INTERNAL TECHNICAL MEMORANDUMS

4.1.3.1 Technical Memorandum No. 3 Velocity and Slope LNWI – Southport Gravity Sewer*

*Lower Northwest Interceptor.

This TM prefers not to use the Camp's Equation methodology as described in the IDM (above). It demonstrates that the variability of the constant B within this equation produces a wide range of velocities, whereas:

"The calculation of shear stress has been determined to be a more consistent and conservative estimate of the required minimum velocity for particle re-suspension".

This TM uses the recommendations of "*Sulfide in Wastewater collection and Treatment Systems, ASCE – Manuals and Reports on Engineering Practice – No. 69*" by using shear stress to find minimum velocity.

As with the MP2000, it states the equation:

$$T_0 = \gamma \times R \times S$$

Where:

γ = specific weight of water
***R** = hydraulic radius*
***S** = invert slope*

It states: "The *result is the average shearing stress required to re-suspend deposited grit near the invert of the pipe when the pipe is one-third full."*

"Recommended shear stress for particles less than 1-mm and greater than 1-mm are conservatively estimated to be 0.04-psf and 0.08-psf, respectively (from the ASCE reference above)*. Historically, the District has used a shearing stress equal to 0.07 for larger interceptor pipelines, such as Upper Northwest Interceptor 5/6, based on the premise that interceptors should be self-cleaning".*

The TM assumes minimum velocity criteria of 3 ft/sec, a d/D of 1/3, a Manning's "n" value of 0.013, and a minimum shear stress value of 0.05 psf. It states that these criteria…

"…are based on the consideration of re-suspending deposited solids and limiting the generation of odors."

But it does not state where it obtained these criteria. The TM's "References" include the SRCSD's MP2000 document but the MP2000 does not give a minimum velocity value for large diameter pipe.

The TM continues by using the flow generation expected in the LNWI system over the years and plotting these against shear stress using a range of slopes from 0.0005 to 0.00075 ft/ft. Then, where each curve related to a particular slope intersects the required shear stress (0.06 or 0.07) the flow is noted and the d/D is calculated, along with the velocity to see that it meets the minimum criteria. (the d/D, as stated earlier, is required to be around 1/3 for accurate shear stress results).

4.2 Research and Industry Standards

Within the wastewater industry there are published criteria for velocity and slope for sewer flows. The *Recommended Standards for Wastewater Facilities (RSWF)*, also known as the *Ten States Standards (TSS)*, published by *Health Research Inc., Health Education Services Division*, is one of those documents. In Section 33.41, "Recommended Minimum Slopes", of its 2004 Edition, it provides the following table for small diameter sewers, stating that:

All sewers shall be designed and constructed to give mean velocities, when flowing full, of not less than 2.0 feet per second (0.6 m/s), based on Manning's formula using an "n" value of 0.013. The following are the recommended minimum slopes which should be provided for sewers 42 inches (1050 mm) or less; however, slopes greater than these may be desirable for construction, to control sewer gases or to maintain self-cleansing velocities at all rates of flow within the design limits.

Table 4.5 Size to Minimum Slope

Nominal Sewer Size	Minimum Slope in Feet Per 100 Feet (m/100 m)
8 inch (200 mm)	0.40
10 inch (250 mm)	0.28
12 inch (300 mm)	0.22
14 inch (350 mm)	0.17
15 inch (375 mm)	0.15
16 inch (400 mm)	0.14
18 inch (450 mm)	0.12
21 inch (525 mm)	0.10
24 inch (600 mm)	0.08
27 inch (675 mm)	0.067
30 inch (750 mm)	0.058
33 inch (825 mm)	0.052
36 inch (900 mm)	0.046
39 inch (975 mm)	0.041
42 inch (1050 mm)	0.037

For larger diameter sewers it states:

Sewers 48 inches (1200 mm) or larger should be designed and constructed to give mean velocities, when flowing full, of not less than 3.0 feet per second (0.9 m/s), based on Manning's formula using an "n" value of 0.013.

It does not provide slopes for these larger diameter pipes.

In terms of maximum velocities, this document states, under Section 33.45, "High Velocity Protection":

Where velocities greater than 15 feet per second (4.6 m/s) are attained, special provision shall be made to protect against displacement by erosion and impact.

4.2.1 REFERENCE MANUAL

The "Civil Engineering Reference Manual – Ninth Edition" by Michael R. Lindeburg, PE, references the above table in Section 28.8 (Page 28-4) "Sewer Velocities" and also states that minimum design velocities actually depend upon the particulate matter size. He says that slopes slightly less than those listed may be permitted (with justification) in lines where design average flow provides a depth of flow greater than 30% of the pipe diameter.

4.2.2 OTHER AGENCIES

4.2.2.1 Los Angeles County Sanitation Districts

On 6/8/09 Interceptor Staff contacted Mr. Stan Pegadiotes, P.E, a project engineer from the sewer design section for the Sanitation Districts of LA County. He provided their "Sewer Design Guidelines" which, in section 5.4, "Pipe Slopes", states:

Pipe slopes shall be selected to provide adequate flow capacity while maintaining reasonable depth, avoiding substructure conflicts and is restricted by the available drop between the upstream and downstream tie-in points. The minimum pipe velocity should exceed 2 feet per second for self cleaning and preventing deposition of solids. The minimum velocity should be stringently adhered to and should be checked for initial flows as well. The maximum pipe velocity should generally be less than 10 feet per second to prevent possible erosion and excessive turbulence.

Again, there are no studies referenced to verify these requirements but Mr. Pegadiotes said that these came from empirical information.

4.2.2.2 Union Sanitary District

This district has a Union Sanitary District (USD) Standard Specifications. On page 67 it specifies slopes for pipe diameters up to 18-inches. For any diameter larger than 18-inches the design engineer is required to specify the slope and have USD approve the calculations.

4.2.3 OTHER STUDIES

Sensitivity of Cleansing Velocity Equations: In October 2007, Interceptor Engineering staff conducted an analysis to determine how sensitive equations (1), (2) and (3) were (from the IDM above) for determining the flow (Q) when the constants of the specific gravity (*s*), the diameter of the particle (D_g) or the dimensionless particle cohesiveness coefficient (*B*) were made variable.

Summarized in an email from Mr. Kyle Frazier (Senior Civil Engineer) to Mr. David Ocenosak (Principle Engineer) on 10/26/07, it was found that (in order of most to least sensitive):

1. When specific gravity (s) was increased 10% above the Interceptor Design Manual (IDM) value (2.5), this increased the minimum flow by 45%.
2. When particle diameter (Dg) is increased by 10% above the IDM value (0.005"), the flow (Q) increases by 27%.
3. When the cohesiveness (B) was raised 10% above the IDM value (0.8), the Q increases by just 10%.

4.2.4 PRACTICAL CONSIDERATIONS

The constructability of large diameter pipelines must be considered during design when it comes to laying a pipe to a certain slope, not to mention the limits to which survey crews can check the slope of a pipeline that has been laid. This will influence how flat the slope can be. The Interceptor Engineering ISS staff interviewed the Principal Land Surveyor for the County of Sacramento, Mr. William Carmack, and he had the following to say:

"In an open cut trench, we can achieve an accuracy* of about +/-0.02' given adequate access and about half an hour to make the measurements."

*Accuracy is relative to project control from which the measurements are made.

An accuracy of +/-0.02 feet (0.24 inches) means that, for a slope of 0.0003 over 1000 feet, the survey would only be about 7% in error. For an individual 15-foot stick of pipe however, that error would be about 440%. So survey accuracy is best over longer distances.

As an example of the "Grade Tolerances" required by project construction specifications, the Laguna Interceptor Extension (LIE) project expected the pipe invert to be installed <u>within 0.5 inches (0.04 ft)</u> of the design grade (Tech Spec Section 02617, 3.1,B,2). Another example: Upper Northwest Interceptor System 3 & 4, Variations from tunnel design grade: <u>One (1) inch maximum</u>. Using the more stringent tolerance of **<u>0.04 ft</u>**, if a slope of 0.0003 ft/ft was expected then, for every 1000 feet of pipe, the contractor is permitted to be about 13% in error. If a slope of 0.0005 ft/ft is required then the contractor is permitted to be about

8% in error. If a slope of 0.0006 ft/ft is required, then the contract is permitted to be about 7% in error (for every 1000 ft of pipe).

4.3 Discussion

4.3.1 Minimum Velocity

From the documents discussed above it is clear that this is defined as the self-cleansing velocity necessary to provide the shear stress (T_0) to move the largest expected particles down the pipe. Assumptions, especially those on specific gravity (*s)* and particle size (D_g), are most important in calculating these shear stresses. More research may be necessary to calibrate these equations for SRCSD's particular sewer systems. Notwithstanding this calibration, empirical formulas and numbers can be used to approximate this velocity. It is apparent that SRCSD and other municipalities have always used such empirical ways to get this velocity. There are different empirical methods for doing this (for example, using Camp's Equation in the IDM, or using the shear stress formula, as in the LNWI Southport Gravity TM). As a conservative estimate, it is reasonable to assume the IDM values for *s*, D_g and *B*. Then, using the above IDM method (or others equivalent), a theoretical minimum slope (*S*) can be deduced from prepared charts which lead to calculations of the minimum velocity. From empirical research stated in the RSWF, the SRCSD 1993 Expansion Sewer Study and other neighboring agencies, the consensus is that the minimum velocity for large pipe sizes ranges from **<u>2 to 4 ft/sec</u>**. Amongst other factors, these depend upon whether flows are Average Dry Weather Flows (ADWF) or Peak Dry Weather Flows (PDWF), a distinction which must be made. When using PDWF, SRCSD has usually accepted that the minimum velocity should be **3 ft/sec**. It is important that the design engineer looks carefully at the criteria for the particular system and allow for custom characteristics to determine that the flows meet an acceptable minimum velocity (such as in the *LNWI Southport TM* where they noted that particle sizes will probably be smaller downstream of the LNWI South Pump Station). The definition of "large pipe sizes" varies. In the *SRCSD 1993 Expansion Sewer Study* large pipes are defined as "…larger than 24-inches". The RSWF says 48-inches or larger, and the IDM says 36-inches or larger. As a general guide, Interceptor Engineering staff (in line with the IDM) have used 36-inch pipe as the lower end of interceptor size.

It is important to look at the expected future flows and work out when these flows will reach self-cleansing velocity. Until that time, Operations & Maintenance (O&M) will have to flush such a system to maintain its efficiency.

4.3.2 Minimum Slope

From research it appears that the minimum slope is determined more by the constructability in the field than it is with the minimum velocity of the flow in the pipe. A slope of 0.0003 ft/ft seems to be impractical to achieve in the field whereas an assumption of 0.0006 ft/ft or steeper allows for less error. The IDM uses 0.0005 ft/ft and, since this does appear to be achievable in the field (without a large amount of error), it seems to be an acceptable minimum when designing a sewer system.

4.3.3 Maximum Velocity

Although supercritical flow does not fatally flaw a system, it does require that additional design efforts must be expended to guard against pipe erosion, corrosion and excessive turbulence. Hydraulic jumps are acceptable but they must be located in the system and special design is necessary for the section of the pipe that they occur. From all the reference materials cited, a maximum velocity of between about 10 to 15 ft/sec was mentioned, and documents such as the IDM stated that there were no specific maximum velocities.

4.3.4 *Maximum Slope*

Similar to maximum velocities, there does not appear to be a documented maximum slope. It is left up to the design engineer to ensure that grade is not burned unnecessarily and that pipes with any excessively turbulent flows are designed to withstand long-term erosion and impact.

4.4 Recommendations

The Interceptor Engineering ISS staff recommends the following gravity pipe design criteria:

1. Minimum Velocity = 3 ft/sec (pending further calibration of SRCSD system). Important for design engineer to customize a particular sewer system, especially at start-up flows.

2. Minimum Slope = 0.0005 ft/ft.

3. Maximum Velocity = None. Design engineer to determine with SRCSD approval.

4. Maximum Slope = None. Design engineer to determine with SRCSD approval.

5.0 PUMP STATION FIRM PUMPING CAPACITY

5.1 Background

Firm Pump Station Capacity is defined as the flow capacity of a pump station facility with one pump out of service or on standby1. Pump flows must be able to meet peak wet weather demand when one pump is out of service or in standby.

5.2 Research and Industry Standards

5.2.1 PUMP STATION DESIGN MANUAL (PSDM) Prepared by Nolte Engineering

The Sacramento Regional County Sanitation District, Pump Station Design Manual states the following:

Classification: Design criteria for pumping stations vary depending on size. In addition, considering the critical nature of certain stations and the potential consequences of failure, additional features may be warranted. A discussion of pump station classifications as a function of capacity (size) and criticality (risk) follows below. For reference, classifications should consider the ultimate configuration of the station. Phasing of specific improvements may be possible depending on District input.

Size: Pumping station capacity can be defined in terms of hydraulic capacity, along with pump drive horsepower. This distinction is illustrated in the following table. ***Pumping capacity refers to firm pumping station capacity or capacity that is available under all operating conditions (e.g., one pump out of service).***

Table 4.6 Pump Station Classification by Size

Classification	Pumping Capacity	Pump Driver Horsepower
Small	< 4 mgd	< 30 hp
Medium	4 – 50 mgd	30 - 200 hp
Large	> 50 mgd	> 200 hp

Capacity Requirements: Several factors affect pumping station capacity requirements. The extent of the service area and equivalent dwelling unit factors are used to estimate average wastewater flows. Peaking factors, along with allowances for infiltration and inflow, determines the pump station capacity.

5.2.2 <u>OTHER AGENCIES</u>

5.2.2.1 State of Oregon Department of Environmental Quality

Firm pumping capacity is defined as the ability to deliver the rated station capacity with the largest pump out of service. The rated station capacity is defined as the five-year, peak hourly wet-weather flow or the 10-year peak hourly dry-weather flow, whichever is higher.

5.2.2.2 City of London, Canada

…multiple pumps shall be provided and sized to provide firm capacity. When two pumps are used, firm capacity shall be maintained by one pump and shall be of the same size. When multiple pumps are used, firm capacity shall be maintained by the remaining pumps when the largest pump is out of service. The capacity of the largest pump will be equal to the required firm capacity.

5.3 Discussion

The firm capacity of any pumping facility should be determined with one pump out of service to ensure that adequate capacity is available to meet all expected demand conditions. For comparison, the total capacity is the sum of the capacities of the all the associated pumps and is larger than firm capacity.

5.4 Recommendation

It is recommended that stations with variable speed pumps must be able to accommodate any flows (from minimum to maximum) and operate in a normal manner when any one of the pumps or drives is out of service. Stations with constant speed pumps must be able to accommodate design flows with one pump out of service or in standby.

6.0 EMERGENCY STORAGE

6.1 Background

Emergency storage is the utilization of in-line or off-line storage facilities to store sewage flows tributary to a pump station during an uncontrolled shutdown event. Emergency storage reduces the risk of Sanitary Sewer Overflows (SSO) caused by a pump station failure by providing for the storage of flows for a time period sufficient for Operations & Maintenance personnel (O&M) to respond to the emergency and place the pump station back into service. When incorporated into designs, the current standard is to provide approximately 6-8 hours of storage.

In-line storage is typically a low cost storage option that results in additional storage volume where limited space is available. In-line storage provides storage volume by taking advantage of trunk and interceptor lines that are not flowing at full capacity and therefore can handle additional flow. This is done by raising the hydraulic grade line (HGL) in the collection system.[1] In-line storage is a passive system that does not require activation during an emergency event. Care must be taken to prevent surcharging the collection system such that an SSO occurs (usually a specified minimum amount of freeboard between the maximum HGL and the lowest rim elevation on the collection system upstream of the pump station is provided). There is currently only one existing pump station, New Natomas Pump Station, designed with inline storage facilities.

Off-line storage is created by construction of facilities specifically designed to provide storage of sewage flow without utilizing any capacity in the pipeline system. This typically requires significant space for tanks (either located above or below ground) or detention basins, and usually requires pumping the sewage either into or out of the storage facilities. This system typically requires active control to be utilized during an emergency event. There are currently no offline storage facilities within the existing SRCSD system.

Pump station failures may occur due to an outage and/or breakdown in one or more of the following equipment2 systems:

- Supervisory Control And Data Acquisition (SCADA)
- Power
- Instrumentation
- Mechanical

SRCSD operates and maintains eight pump stations throughout the interceptor collection system. O&M generally does not provide full time staff to these facilities. O&M personnel are present at various pump station sites during normal working hours to perform routine maintenance, and all the sites are monitored via SCADA operations after normal working hours. However, O&M personnel may be stationed at critical pump station facilities for the duration of anticipated large storm events (24/7 if necessary) to reduce the response time to uncontrolled pump station shutdowns.

6.2 Research and Industry Standards

Below is selected documentation about how emergency storage is currently addressed.

6.2.1 <u>PUMP STATION DESIGN MANUAL (PSDM) Prepared by Nolte Engineering</u>

Emergency storage can be provided either on-line or off-line. On-line storage consists of additional capacity in the upstream gravity sewers that feed the pump station, oversizing of collection systems, surcharging of manholes, and supplemental storage in the wet well. Off-line storage is available in detention basins. Preference should be given to on-line storage, particularly in the collection systems, to minimize subsequent site requirements and to mitigate wet well operational issues.

Due to the District size, call-out of technicians during off-hours may lead to a two hour delay before M&O staff can reach a problem location. Once on-site, another two hours may be required to troubleshoot and resolve problems, particularly involving electrical and instrumentation issues. For these reasons, emergency storage and/or automatically-activated redundant equipment are critical concerns for the M&O group.

6.2.2 <u>EMERGENCY STORAGE BUSINESS CASE STUDY Prepared by MWH and HDR</u>

Based on the predicted frequency of an uncontrolled shutdown to occur once every three years… it is recommended the District consider implementing a means to provide storage to allow staff sufficient time to respond to an uncontrolled shutdown of a pumping station .

Additionally:

Taking into consideration the response time of the on-call staff and the time to diagnose the problem and restart the system, District staff has set criteria for the minimum storage time required to respond to an after-hours uncontrolled shutdown. For complex pumping stations, such as the Lower Northwest Interceptor (LNWI) pumping stations, the criteria is 6 to 8 hours of storage during an after-hours, non-storm event (i.e., dry weather flow), based on the following timeline (hrs:min):

0:00	*Problem occurs*
0:30	*Alarm acknowledged at SRWTP*
0:35	*Operator contacted*
0:50	*Operator responding*
1:50	*Operator on site*
2:10	*Diagnosis facility and attempt to restart*
3:10	*Restart/failure; call in additional staff*
5:10	*Additional staff arrive on site*
6:00 to 8:00	*Restart successful*

HDR evaluated how often an uncontrolled shutdown could occur.

An uncontrolled shutdown of a pumping station is defined as the loss of the ability to pump flow caused by a failure of equipment, including backup equipment. HDR has determined this type of failure could occur once every three years.

6.2.3 INTERNAL TECHNICAL MEMORANDUM Prepared by MWH

In-line storage is typically a low cost storage option that could result in additional storage volume where limited space is available. In-line storage increases storage volume by taking advantage of trunk and interceptor lines that are not flowing at capacity and therefore can handle additional flow. This is done by increasing the hydraulic grade line (HGL) in the collection system. Therefore, before applying in-line storage to mitigate an emergency situation, the maximum HGL elevation must be evaluated in order to determine the effect on the system. A serious potential for surcharging flow into the streets or basements exists without proper hydraulic evaluation of proposed in-line storage measures.

6.2.4 OTHER AGENCIES:

The following summarizes some of the key findings:

- To reduce the response time, agencies provide full-time staff at critical pumping stations or on-call staff in close proximity.
- Preventive measures to control SSOs are common among agencies. This is accomplished by bypass systems to divert flow away from a facility that is non-operational.
- Many agencies use off-line or in-line storage to prevent SSOs.

City of San Diego

Provides inline storage, but there are no standards, they vary for each pumping station.

Los Angeles County

Provides inline storage, dictated by response time, indicated by the time O&M can respond to each pump station.

Union Sanitary District

Provides at least 35 minutes of inline storage.

East Bay Municipal District

Flows are diverted to wet weather facilities during storm events.

Seattle Metro[3]

Gates are used to provide varying storage times for in inline interceptors and trunks.

6.2.5 <u>OTHER STUDIES:</u>

Summarized in an email from Erin Harper:

…it is [a] lack of time that creates the risk – regardless of the consequence of the overflow (flooding of a large commercial area or a large spill to a drinking water source has a much larger consequence to the County than a few homes flooded or a minor, but reportable quantity of sewage spilled that was contained to storm drains). We have very little ability to control the order of magnitude of the consequence, there will always be sewage pump stations downstream from commercial facilities, near drinking water sources, etc – but we can control the factor that increases the likelihood that we will have to pay the consequences - get provisions in place to get the time to put other operating options online.

Risk can only be mitigated by providing M&O with time to respond, evaluate and take action. No matter how many levels of redundancy we try to maintain and keep staff trained and competent, there will be failures that require a response and the only thing that is really helpful is good simple remote monitoring and enough time to get staff there before the "piper has to be paid". Never has M&O agreed to the concept that "through the incorporation of multiple redundancy features, a pump station would be classified as a high risk because of location could then be considered a medium risk facility" – the only thing I have heard discussed is that the increase in available time could allow a station to be reclassified. This failure to keep time as a key component in the determination of risk has made much of this discussion of risk meaningless to M&O.

On preventive measures that allow for continued pump station operation even when a SCADA communication failure occurs – please note – this is currently how the system is designed, the station PLC does not require that SCADA system be communicating to it to continue with its operation – however, M&O cannot tell if the station has continued to operate properly or not – and must then respond to determine that by physically going to the station. The more time available from when communication fails to when there is sewage on the ground allows M&O to determine if the communication failure is short duration (less than 20 minutes) – then maybe a response is not required until normal hours, provided communication continues. If however there is insufficient time allowance, then M&O must respond immediately. With radio communications, many times communication *failures are short and intermittent – so if there is sufficient time available, M&O may not be required to immediately send a response crew to the station.*

…the increase of available response time to more than 4 hours is the preferred method prior to attempting to provide enough redundant components to be able to have multiple levels of operating modes. There is also the aspect that currently M&O does not staff 24/7 with capability to control equipment from a centralized location – and in order to make the station PLC logic reasonable, this would need to be put in place.

6.3 Discussion

In-line storage is typically a low cost storage option that results in additional storage volume where limited space is available.

6.4 Recommendation

It is recommended that a thorough site-specific evaluation be made including the cost effectiveness of inline storage. More discussions between Engineering, O&M, and management are suggested to form a conclusion for inline emergency storage time requirements.

SASD DRY WEATHER FLOW DATA ANALYSIS

Summary of ISS Facility Criteria

Criteria	Design Future project sizing and design		Performance Timing of new projects and relief of existing system	
Pipe Friction Factors	Gravity Pipe n=0.013	Force Main C=110	Gravity Pipe n=0.013 unless model calibration studies indicate lower value is appropriate	Force Main C=110 unless studies indicate higher value is appropriate
Slope, min	Gravity Pipe Based on minimum velocity criteria with minimum of 0.0005 (constructability)	Force Main none	Gravity Pipe Based on minimum velocity criteria with minimum of 0.0005 (constructability)	Force Main none
Slope, max	Gravity Pipe None	Force Main None	Gravity Pipe None	Force Main None
Velocity, min	Gravity Pipe 3 fps PDWF at realistic flow scenario	Force Main 3 fps PDWF at realistic flow scenario	Gravity Pipe Interim Criteria: Consider cleaning costs until minimum is reached	Force Main Consider cleaning/flushing costs until minimum is reached
Velocity, max	Gravity Pipe 10fps or greater considered on case by case basis, risk and cost	Force Main 8 fps	Gravity Pipe None	Force Main Evaluate feasibility(surge), risk and cost
Pumping Station Firm Capacity	Largest pump out of service (Suitable for long range planning, apply Reliability Centered Design to final design)		Evaluate risk and cost of utilizing out of service pump to increase interim capacity	
Emergency Storage	As needed/feasible based on O&M response time (no change)		None	
Allowable Freeboard	N/A		Based on allowable surcharge	
Allowable Surcharge	None		Evaluate risk and cost of surcharge impacts to system, including contributing agencies.	
d/D Ratio	1.0		Based on allowable surcharge	

Appendix B

CAPACITY MANAGEMENT MEMO ANALYSIS OF MANNING'S N

Objective

The following objectives were considered for this evaluation:

- To calculate the Manning's n factors that should be considered in the Interceptor Sequencing Study's interceptor system's hydraulic modeling evaluations.
- To look for the recommended range of Manning's n factors that should be used under different pipe conditions.
- To determine the recommend Manning's n factor for the Bradshaw Interceptor hydraulic evaluations.

This study uses flow meter data collected by Capacity Management's Flow Monitoring group.

Approach

The following approach was taken to calculate the Manning's n factor:

- Create scattergraphs for select flow monitoring points in the Interceptor system:
  - Using flow meter data collected, plot the pipe's depths vs. velocities on a scattergraph. ***Table 2*** summarizes period that flow meter data was collected at the select points.
  - Using the hydraulic models, estimate the levels (depths) and velocities of the flows in these pipes/systems for various Manning's n factors. Plot the depths vs. velocities for each Manning's n factor on the same scattergraph as the flow meter data graph.
  - The modeling data plots should line up with the flow meter data plots.
  - Many factors could affect the fit (good fit or lack of a fit) between the modeling data and flow meter data. The following are some factors: inaccurate pipe data used in the hydraulic model, bias in the flow-monitoring data, and downstream flow obstructions). See ***Figures 2 - 13*** for the scattergraphs.
- Used all interceptor system flow-monitoring data available to calculate the interceptor's Manning's n factors. See ***Figure 1*** for the selected flow-monitoring points.
- Used the hydraulic model of the existing interceptor system to generate modeling data.

Results

Figures 2-13 shows the scattergraphs used to determine the recommended interceptor system's Manning's n factors. A best-fit curve was generated from the flow meter data's scattergraph and compared to the modeling data's scattergraphs for various factors. The recommended Manning's n factor is associated with the modeling data that lined up best with the flow meter data's best fit curve. ***Table 1*** below summarizes the recommended Manning's n factors for the selected flow monitoring points in the interceptor system.

Table 1. Recommended Manning's n Factor for Select Points in the SRCSD Interceptor System.

Flow-Monitoring Points	Recommended Manning's n Factor
Site 50418, D/S N17-MH0090A.1	0.011
Site 61121, D/S N17-MH0060K.1	0.013??? Hard to determine since the flow-monitoring data was affected by silt at and downstream of the site.
Site 398, D/S N17-MH0053J.1	0.014
Site 355, D/S N17-MH0029A.1	0.011
Site 15, D/S N17-MH0006A.1	Could not be determined. The flow-monitoring data was greatly affected by downstream pump operation.
Site 71022, D/S N33-MH0030A.1	Could not be determined. The flow-monitoring is very off from modeling data.
Site 418, D/S N33-MH0006A.1	0.013
Site 350, D/S N37-MH0035A.1	Could not be determined. It appears to be a differing pipe slope issue.
Site 71130, D/S N24-MH0011A.1	0.012
Site 71131, D/S N38-MH0081C.1	0.011
Site 71132, D/S N38-MH0079A.1	0.010
Site 67, D/S N25-MH0016A.1	Could not be determined. The flow-monitoring is very off from modeling data.

Observations

- Capacity Management does not have adequate flow-monitoring data to determine interceptors' recommended Manning's n factors. From this study, we learned that the n factors of some sites could not be determined because of inaccurate model pipe data, discrepancies between model and actual conditions, downstream pump operation, and so on. Even for some sites whose flow-monitoring data seemed to fit well with the modeling data, there could be bias in the flow-monitoring data and/or inaccurate model pipe slopes.
- To use flow-monitoring data to determine the Manning's n factor, it is important to obtain enough field confirmation data to be confident that the meter data is indeed not biased one way or the other (velocity or depth or both). Also, we should check for consistency at several points along the trunk or interceptor. For example, show that each of 3 meters placed in series (along say 2000 ft of the pipe) demonstrates lower n-factor "fits" better. This could require very extensive flow-monitoring.
- The flow-monitoring data shows that the interceptors' factors range from 0.010 to 0.014. Based on Site 71131 and Site 71132 data, the n factor of the new Bradshaw Interceptor is approximately 0.011. Yet, 0.011 should be further confirmed with more flow-monitoring points along the new Bradshaw Interceptor.
- We should look into why Site 71022 data is very different from modeling data.

Figure 1: Flow Monitoring Data Points Used In This Study

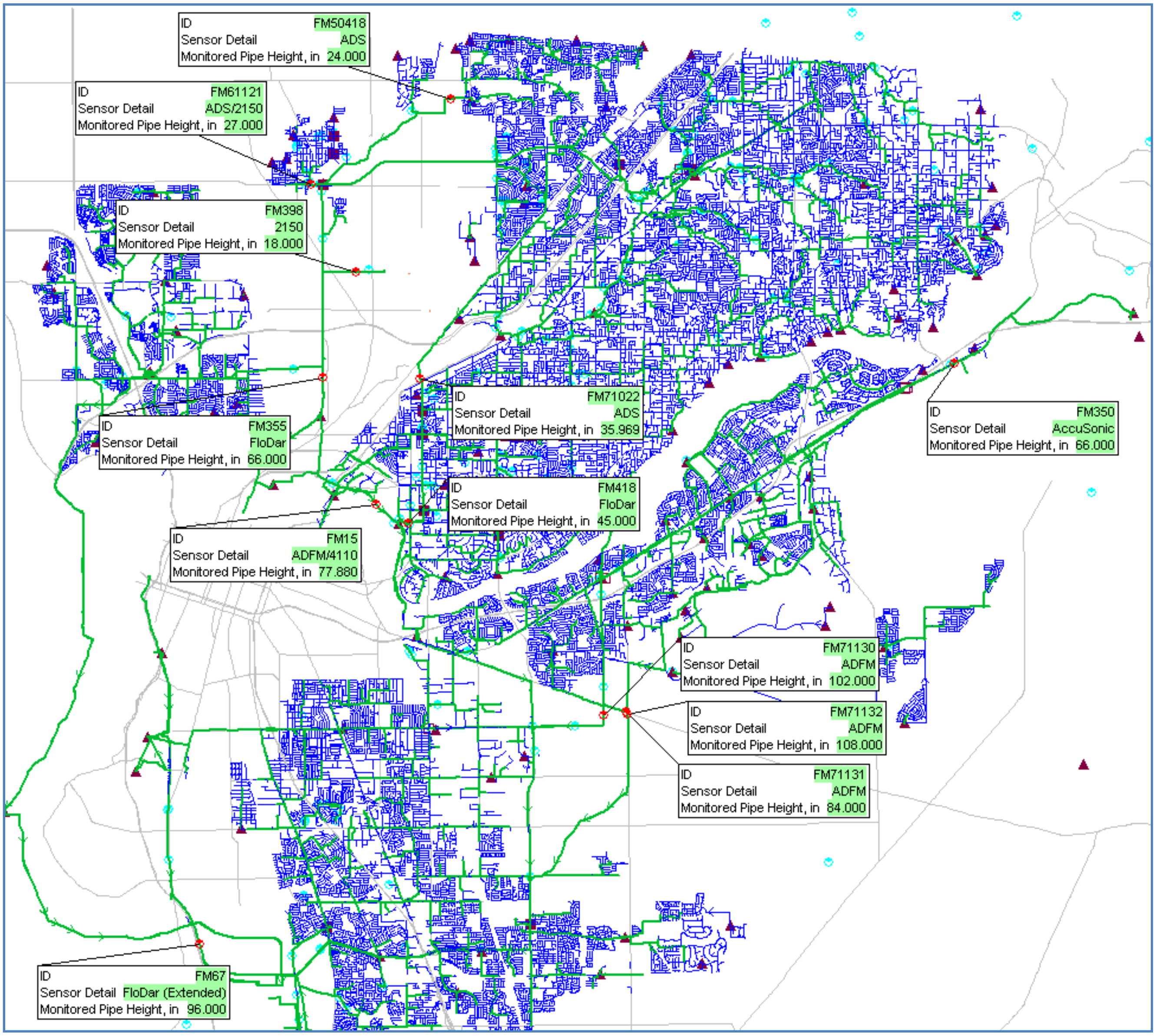


Figure 2: Site 50418, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

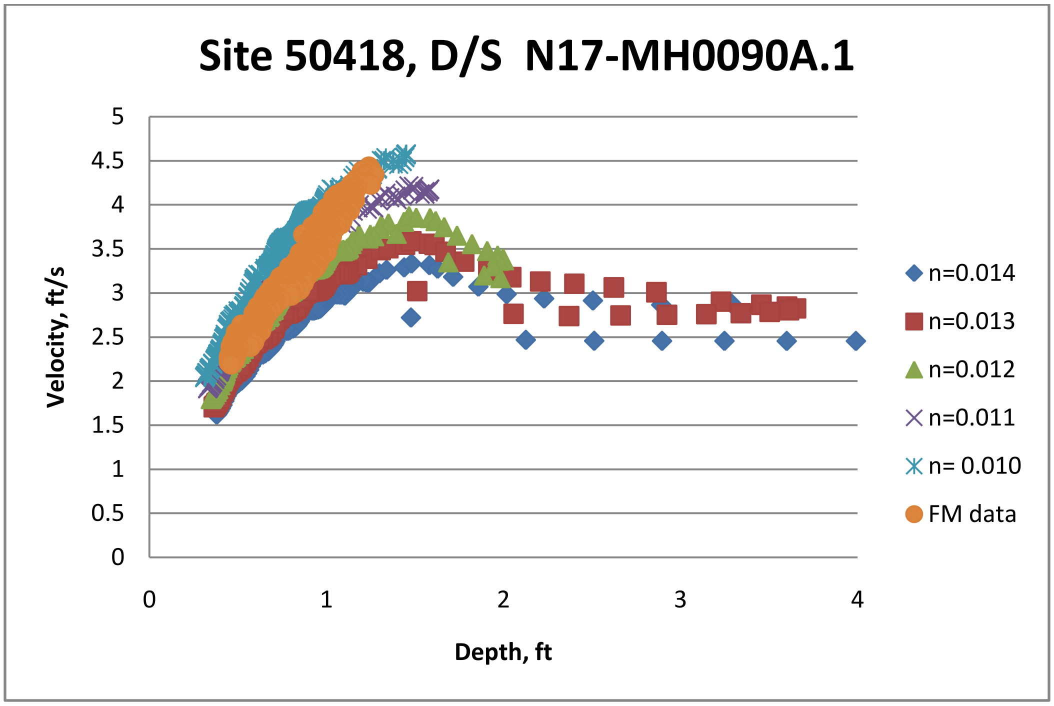


Figure 3: Site 61121, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

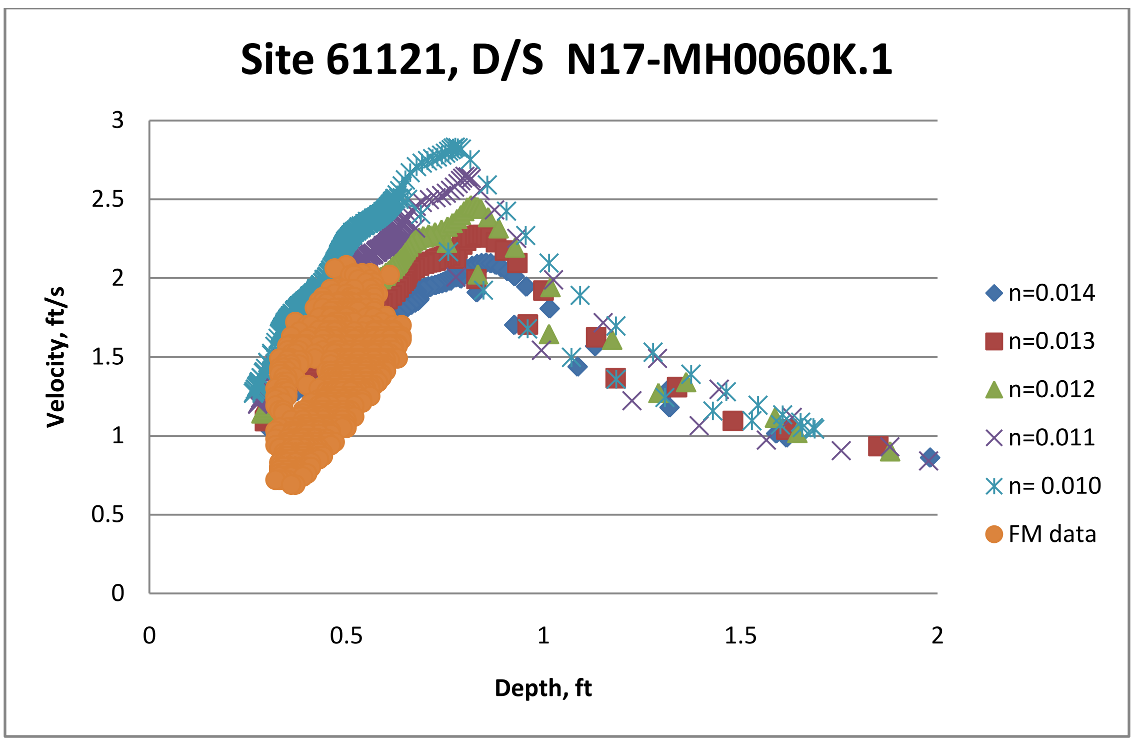


Figure 4: Site 398, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

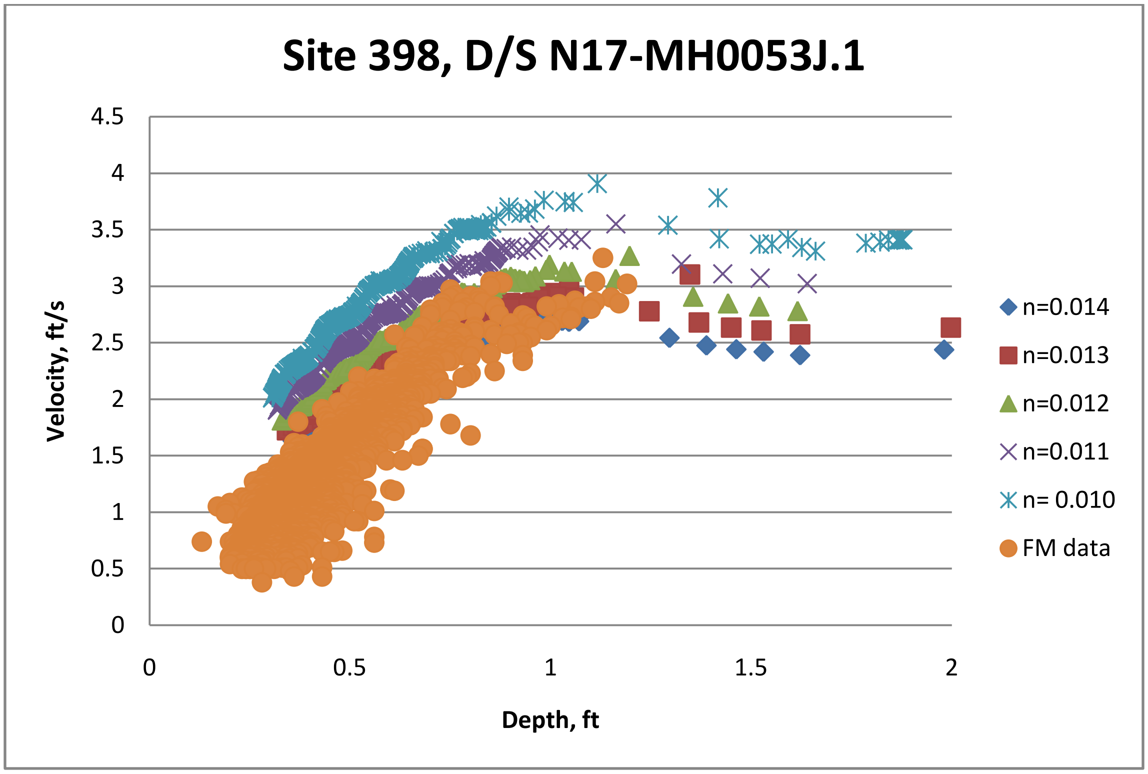


Figure 5: Site 355, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

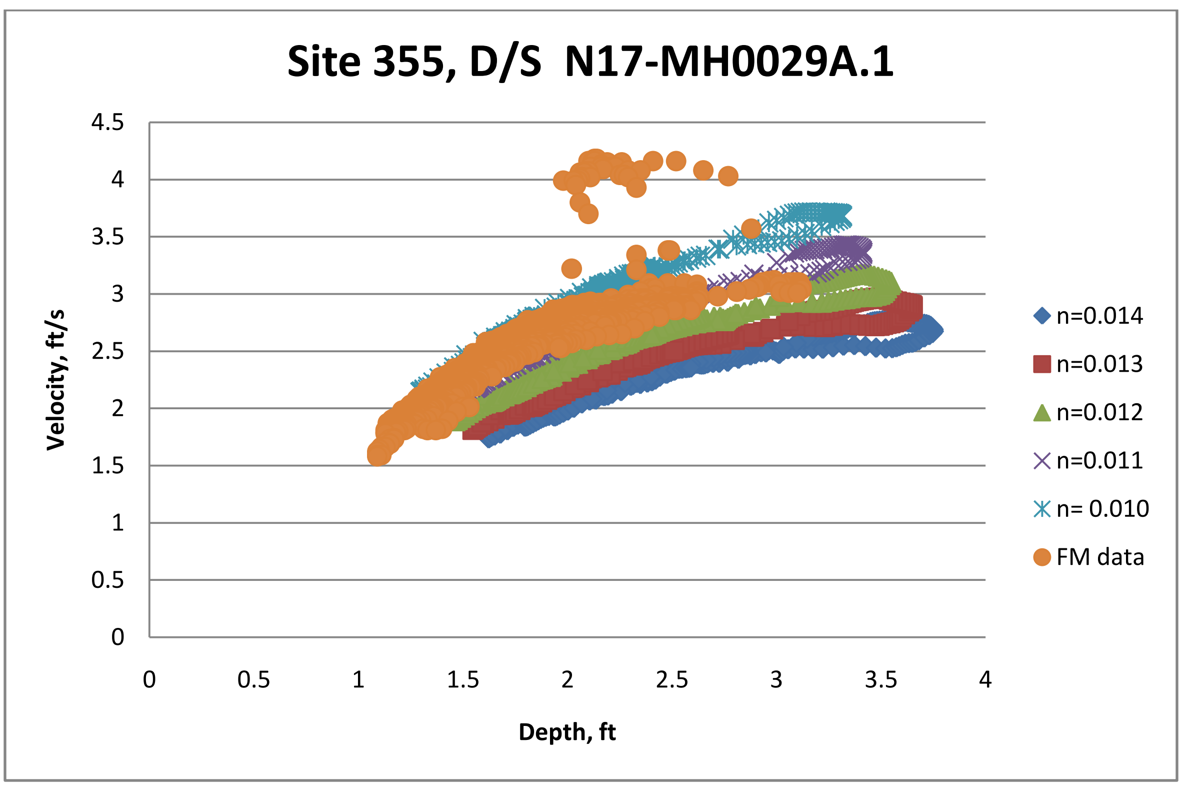


Figure 6: Site 15, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

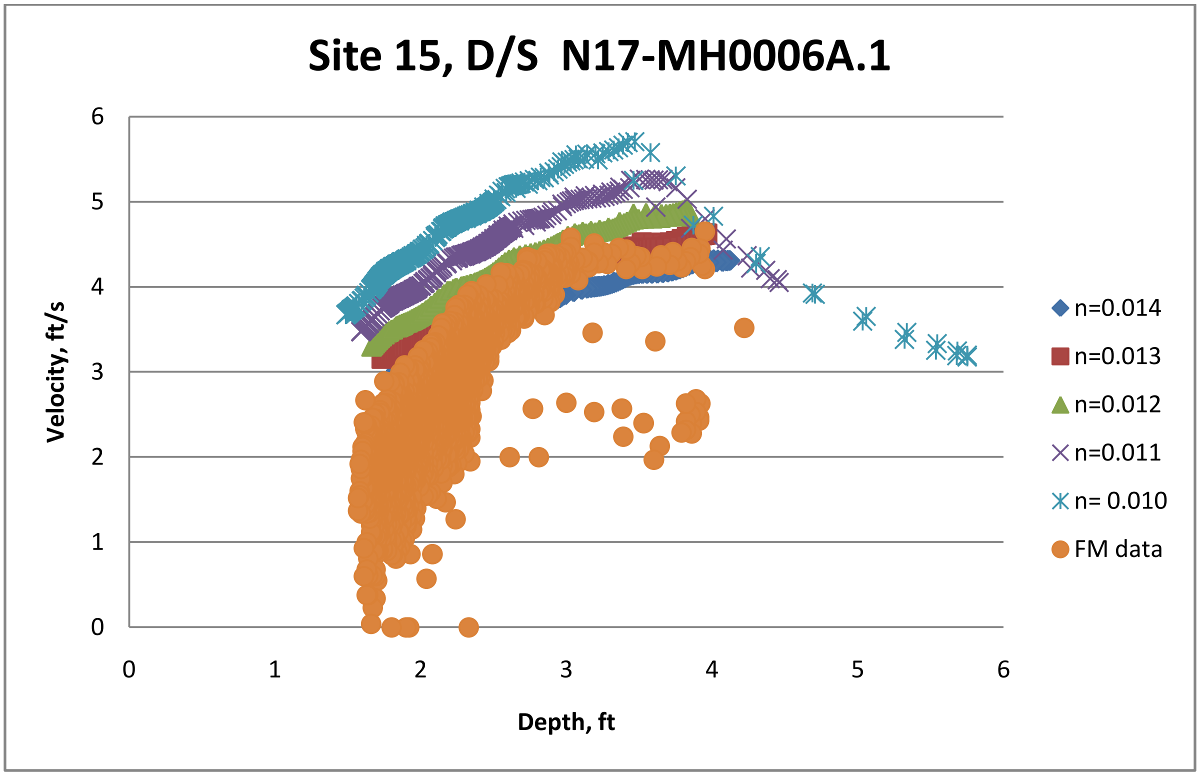


Figure 7: Site71022, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

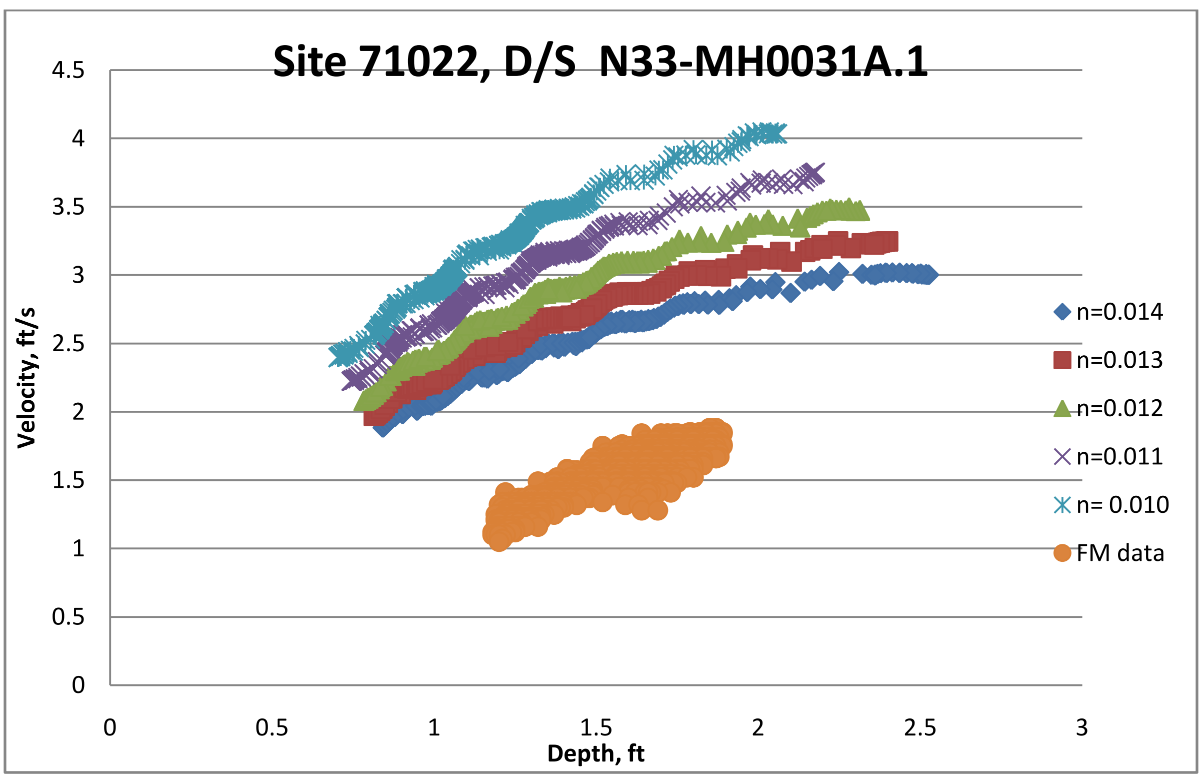


Figure 8: Site 418, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

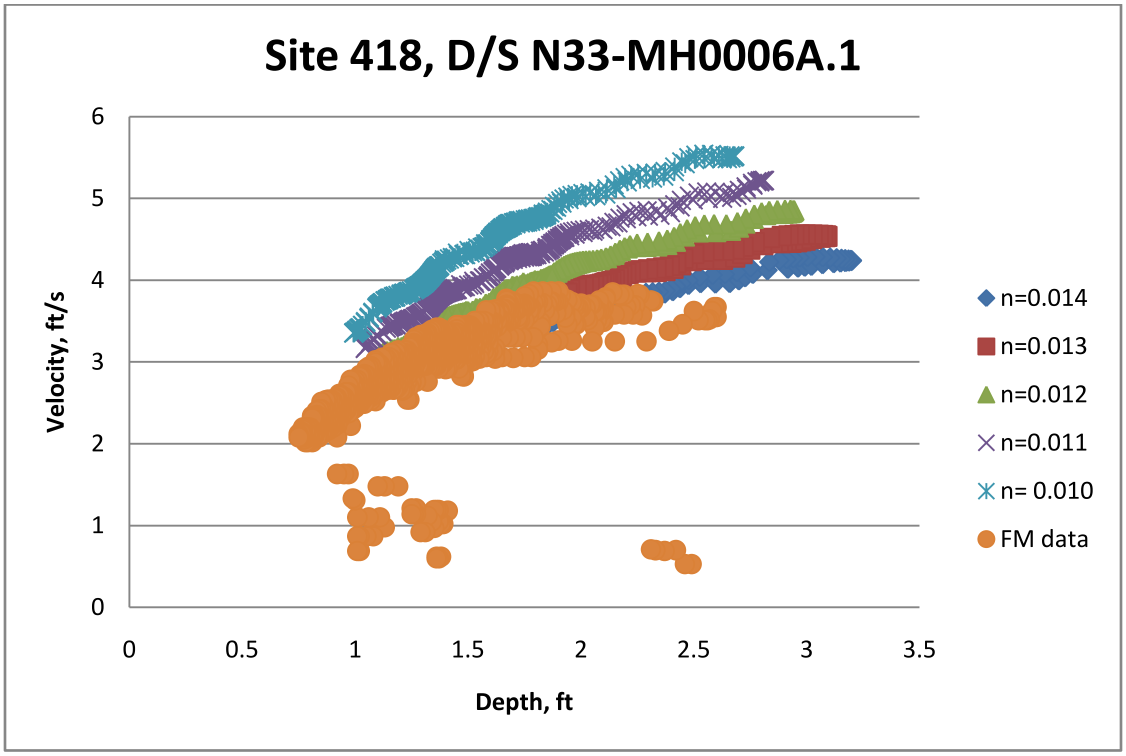


Figure 9: Site 350, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

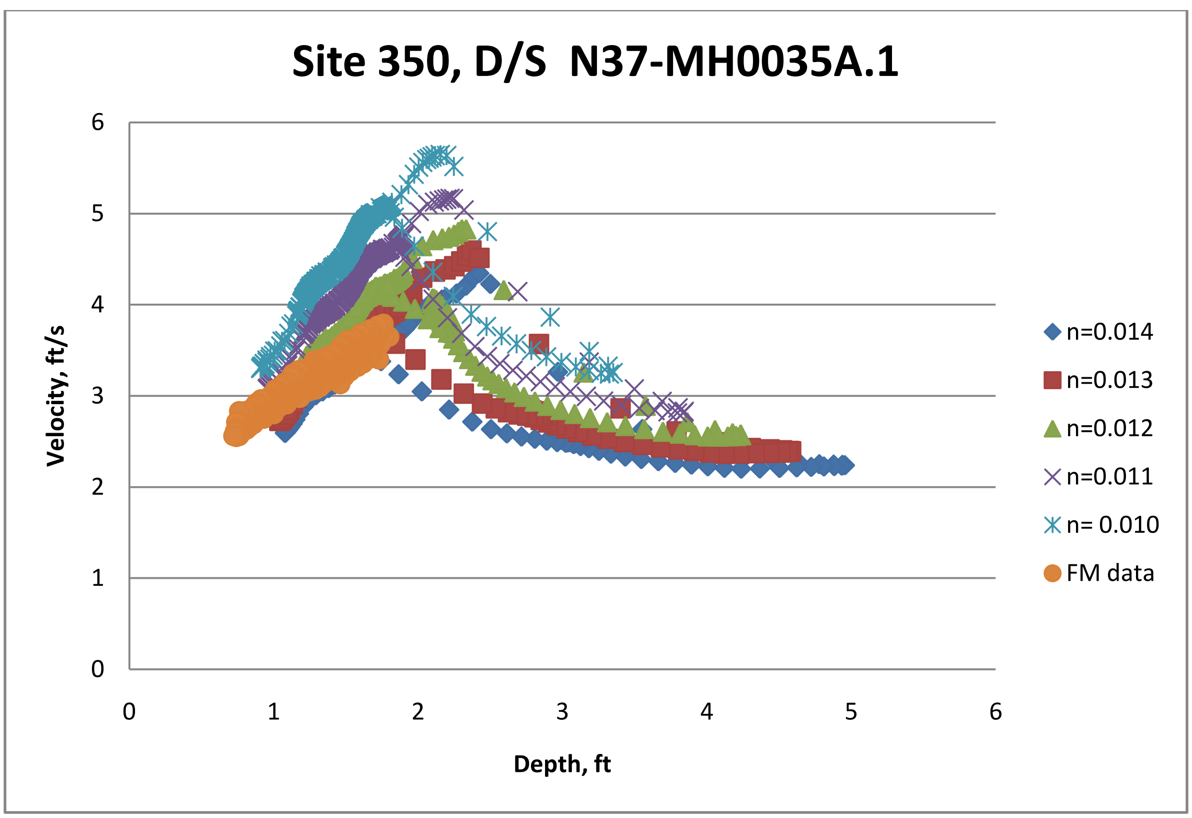


Figure 10: Site 71130, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

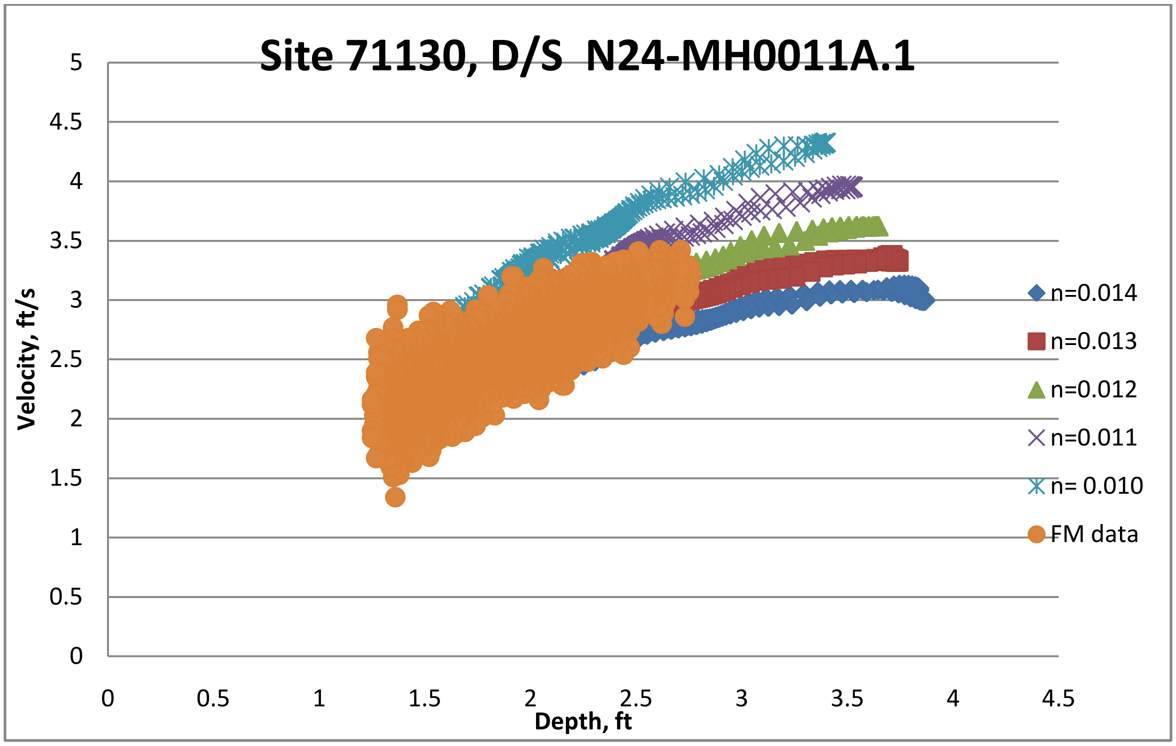


Figure 11: Site 71131, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

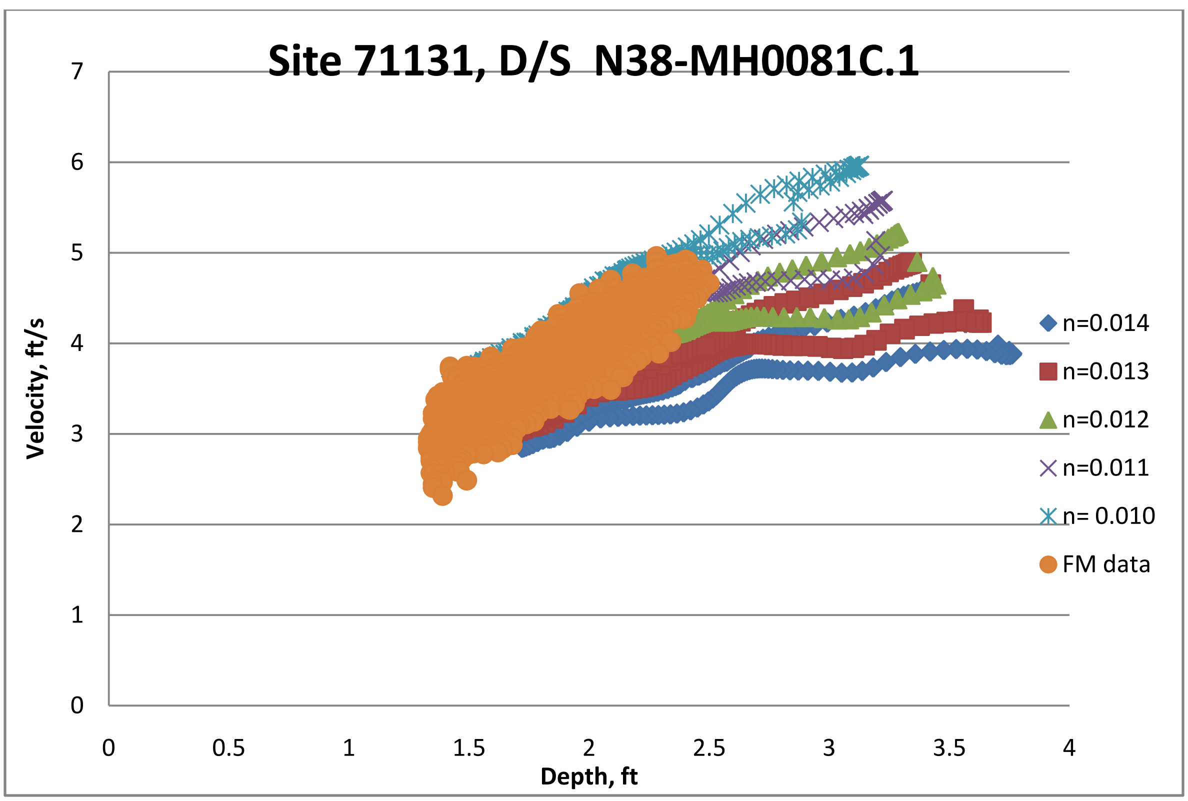


Figure 12: Site 71132, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

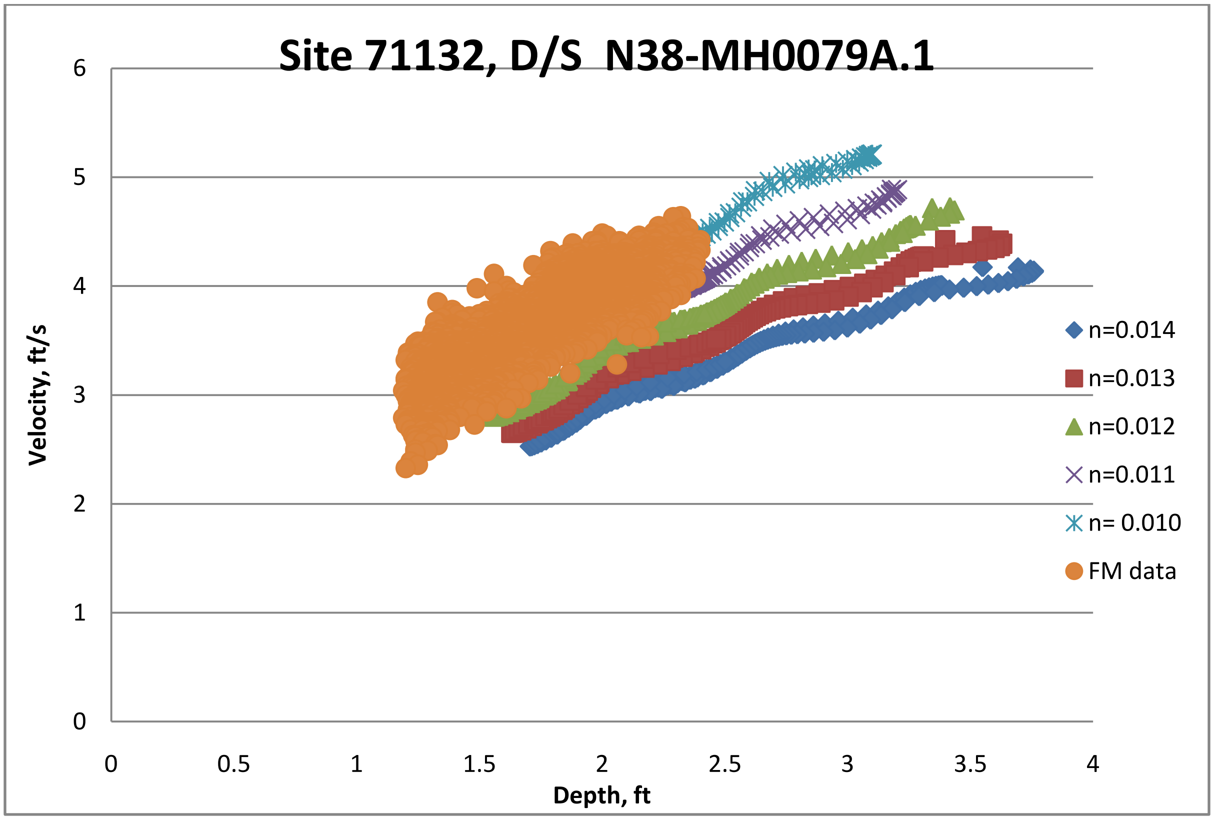


Figure 13: Site 67, Velocity And Level Scattergraphs For Modeling And Flow-Monitoring Data

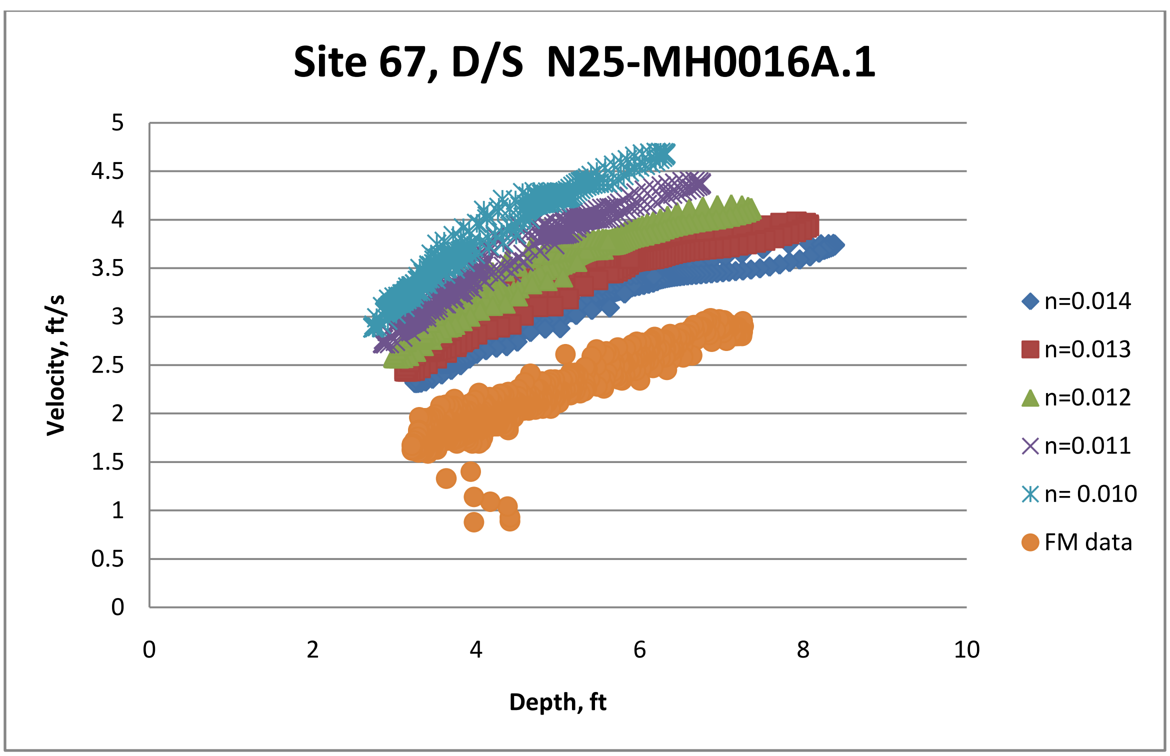


Table 2. Period Of Flow-Monitoring Data Used In This Study.

Flow meter	Period of data used
50418_ADS	2/1/2009 - 4/1/2009
61121_ADS	4/1/2008 - 6/1/2008
398_2150	2/1/2009 – 4/1/2009
355_FloDar	2/1/2009 – 4/1/2009
15_ADFM	2/1/2009-4/1/2009
71022_ADS	10/1/2008 – 11/1/2008
418_FloDar	2/1/2009 – 4/1/2009
350_Accusonic	3/1/2009 – 3/15/2009
71130_ADFM	2/1/2009 – 4/1/2009
71131_ADFM	2/1/2009 – 4/1/2009
71132_ADFM	2/1/2009 – 4/1/2009
67_FloDar	4/1/2009 – 5/10/2009

Appendix C

SASD LNWI MINIMUM FLOW CRITERIA – SENSITIVITY OF VARIABLES IN CAMPS EQUATIONS

Frazier. Kyle (MSA)

From: Frazier. Kyle (MSA)
Sent: Friday, October 26, 2007 11:10 AM
To: Ocenosak. David (MSA)
Cc: Page. Andrew (MSA); Hernandez. Catherine (MSA)
Subject: RE: Minimum flow criteria for LNWI - Sensitivity of variables in Camps Equation

Minimum Flow for Self-Cleansin...

Dave,

Catherine performed some calculations to determine the sensitivity of the variables. See attached results.

-Particle Specific Gravity - Has the largest impact on the minimum self cleansing flow. A 10% increase above the IDM specific gravity (2.5) increases the min flow by 45%.

-Particle Diameter - Has the next largest impact on minimum self cleansing flow. A 10% increase above the IDM particle diameter (.005) increases the min flow by 27%.

-Particle Cohesiveness - Has the smallest impact on the minimum self cleansing low. A 10% increase above the IDM particle cohesiveness (0.8) increases the min flow by 10%.

The relationship is exponential so relatively small changes in the variable values results in large changes in the minimum flow requirement.

I think this tells us that we need to calibrate this equation before we start putting any confidence in it. We need to collect grit out of the system and analyze the physical properties. Will Nishina did some work years ago but I don't remember that anything came out if it. Another idea that has been tossed around before is fund a study at Sac State to explore the issue in a lab environment.

Kyle

From: Ocenosak. David (MSA)
Sent: Tuesday, October 16, 2007 8:12 AM
To: Frazier. Kyle (MSA); Brady. Mike (MSA)
Cc: Norris. Stephen (MSA); Kido. Wendell (MSA); Del Sarto. Glen (MSA); Maidrand. Mitchell (MSA)
Subject: RE: Minimum flow criteria for LNWI

Thanks Kyle. Please continue with a sensitivity check.

Others - This is in the ballpark of past evaluations where we were looking for the minimum peak dry weather flow for solids transport.

Dave

From: Frazier. Kyle (MSA)
Sent: Monday, October 15, 2007 10:24 PM
To: Ocenosak. David (MSA); Brady. Mike (MSA)
Cc: Norris. Stephen (MSA); Kido. Wendell (MSA); Del Sarto. Glen (MSA); Maidrand. Mitchell (MSA)
Subject: RE: Minimum flow criteria for LNWI

Using Camp's equation, the Southport Gravity Sewer requires 13MGD minimum flow to move particles with the following properties:
B=0.8
Specific Gravity=2.5
Diameter=.005ft

The velocity at 13MGD is 3fps.

I have Catherine Hernandez looking at the sensitivity of the equation to the particle properties.

From: Ocenosak. David (MSA)
Sent: Wednesday, October 10, 2007 5:17 PM
To: Brady. Mike (MSA); Frazier. Kyle (MSA)
Cc: Norris. Stephen (MSA); Kido. Wendell (MSA); Del Sarto. Glen (MSA); Maidrand. Mitchell (MSA)
Subject: RE: Minimum flow criteria for LNWI

I think the 5 fps will be OK. Some time ago, we checked the Central Interceptor, which if I recall correctly, it is on a .0005 slope. The flow monitoring group stabbed the bottom of the pipe with essentially a paddle on the end of an aluminum rod. There was no sign of any built up debris (solid contact with the concrete invert). 5 FPS is a fairly high velocity for a gravity system.

Anyway, we'll look at the calculation to see what it suggests. The calculation is very conservative.

From: Brady. Mike (MSA)
Sent: Wednesday, October 10, 2007 4:02 PM
To: Frazier. Kyle (MSA); Ocenosak. David (MSA)
Cc: Norris. Stephen (MSA); Kido. Wendell (MSA); Del Sarto. Glen (MSA); Maidrand. Mitchell (MSA)
Subject: RE: Minimum flow criteria for LNWI

I spoke with Neal Mann, this afternoon and Neal states that the SRPS F/M has a velocity of 6 FPS at 66 MGD, and that with current flows out of NNPS, not flushing, the flows in the SPGS are 2.5 FPS. If flushing from NNPS at 60 MGD then flows are 5 FPS in the SPGS. I think we are in trouble, any comments? Also thanks Kyle and everyone for looking at this with such short notice.

Mike

From: Frazier. Kyle (MSA)
Sent: Wednesday, October 10, 2007 12:13 PM
To: Ocenosak. David (MSA)
Cc: Norris. Stephen (MSA); Brady. Mike (MSA)
Subject: RE: Minimum flow criteria for LNWI

As far as I can tell, LNWI design guidelines did not use Camp's equation. Designers were given an acceptable range of flow velocities.

I reviewed the SRPS and NNPS BDR and found the following:

-SRPS was designed for a startup flow of 11MGD.
-At 11MGD, using one force main, the velocity is 0.7fps
-The design made provisions for flushing using water from RD1000 at NNPS. This operation is supposed to raise the flow rate to 60MGD and create velocities in the forcemain of 4fps.

There is a flushing TM that we are currently looking for, but I doubt it will relate scour velocities to particle size, weight, or cohesiveness.

I can either have our staff try to apply Camp's equation and see if we can determine a required flow velocity, or I can ask MWH staff to make a recommendation (they would probably defer to the original PS designer).

Kyle

From: Ocenosak. David (MSA)
Sent: Tuesday, October 09, 2007 4:48 PM
To: Frazier. Kyle (MSA)
Cc: Norris. Stephen (MSA); Brady. Mike (MSA)
Subject: Minimum flow criteria for LNWI

Kyle - Mike Brady attended a meeting today with West Sac. Apparently, we will be receiving waste discharge to our interceptor from their water treatment facility with solids upwards of 15%. The solids are silts and polymers that may be highly cohesive.

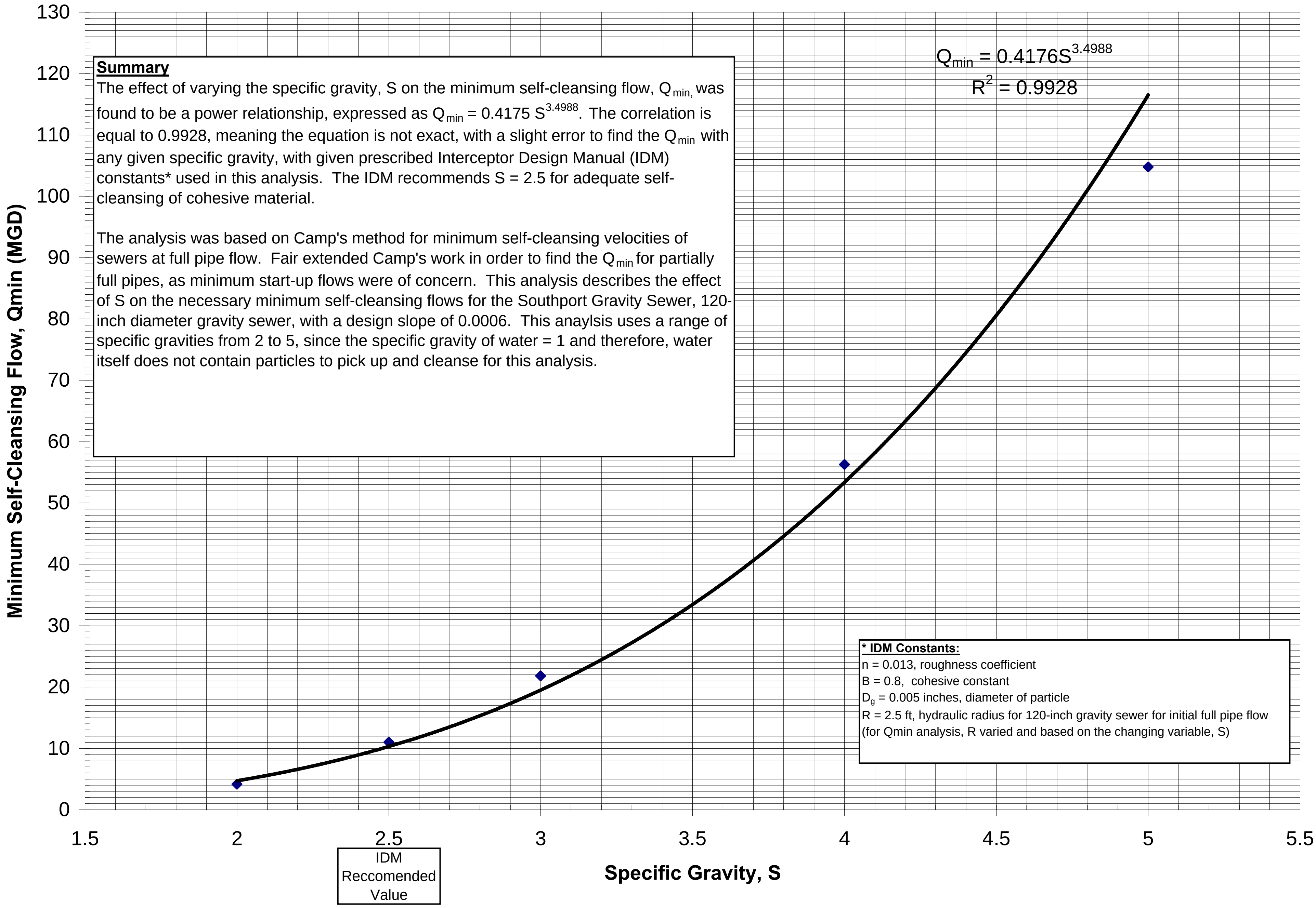
Please have someone review the design parameters for LNWI for minimum flow rate. Assuming we have some evaluation in the BDR's for the LNWI (probably need to consider both the gravity and force main lines), we need a flow velocity to deal with a shear value of 0.8. In Camp's equation, 0.8 is the value for self-cleaning of cohesive materials (see interceptor design manual). I'm assuming the other variables in Camp's equation would remain the same from the LNWI evaluation.

My understanding is that we need this information this week. This will likely drive the cost for the connection permit.

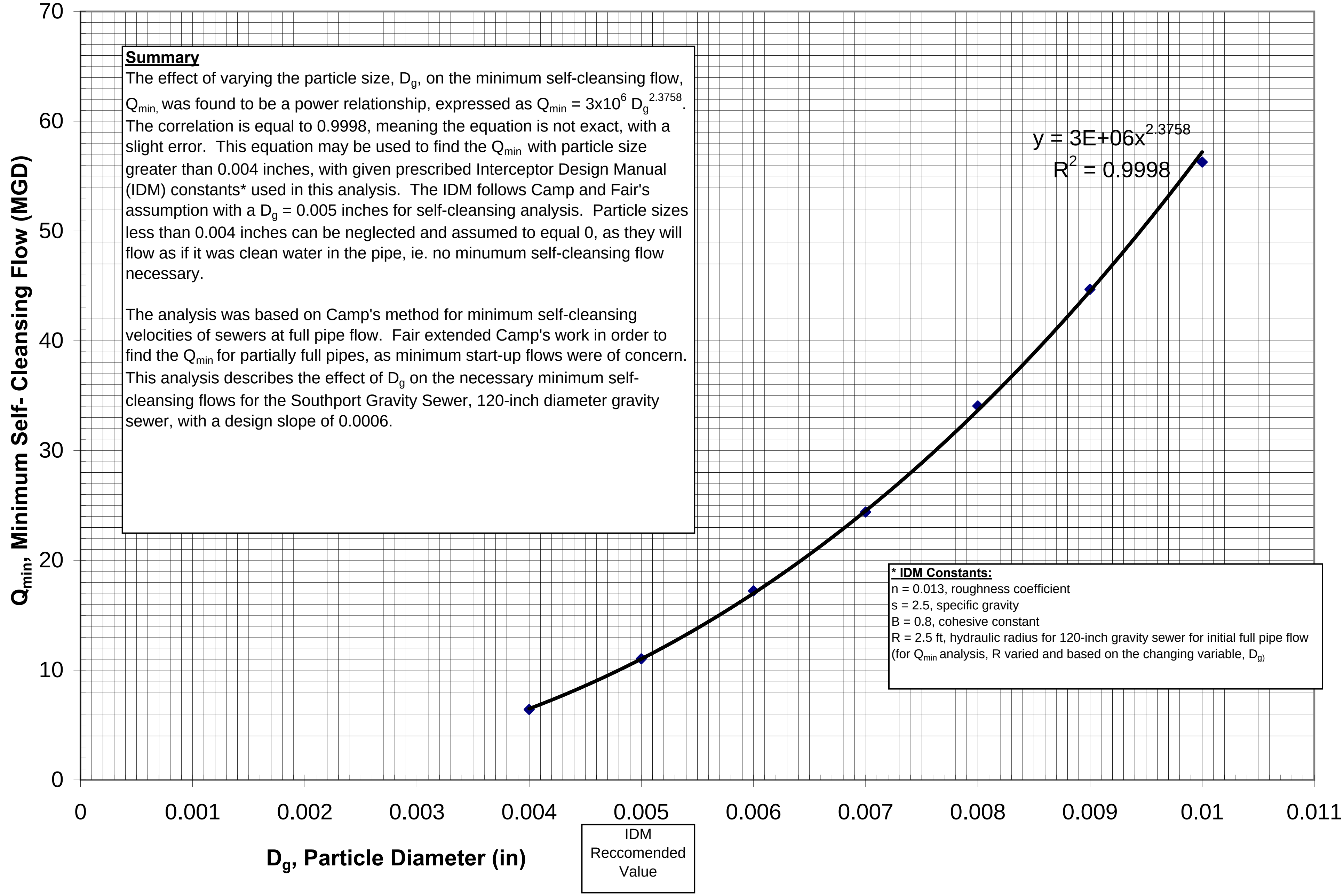
Thanks.

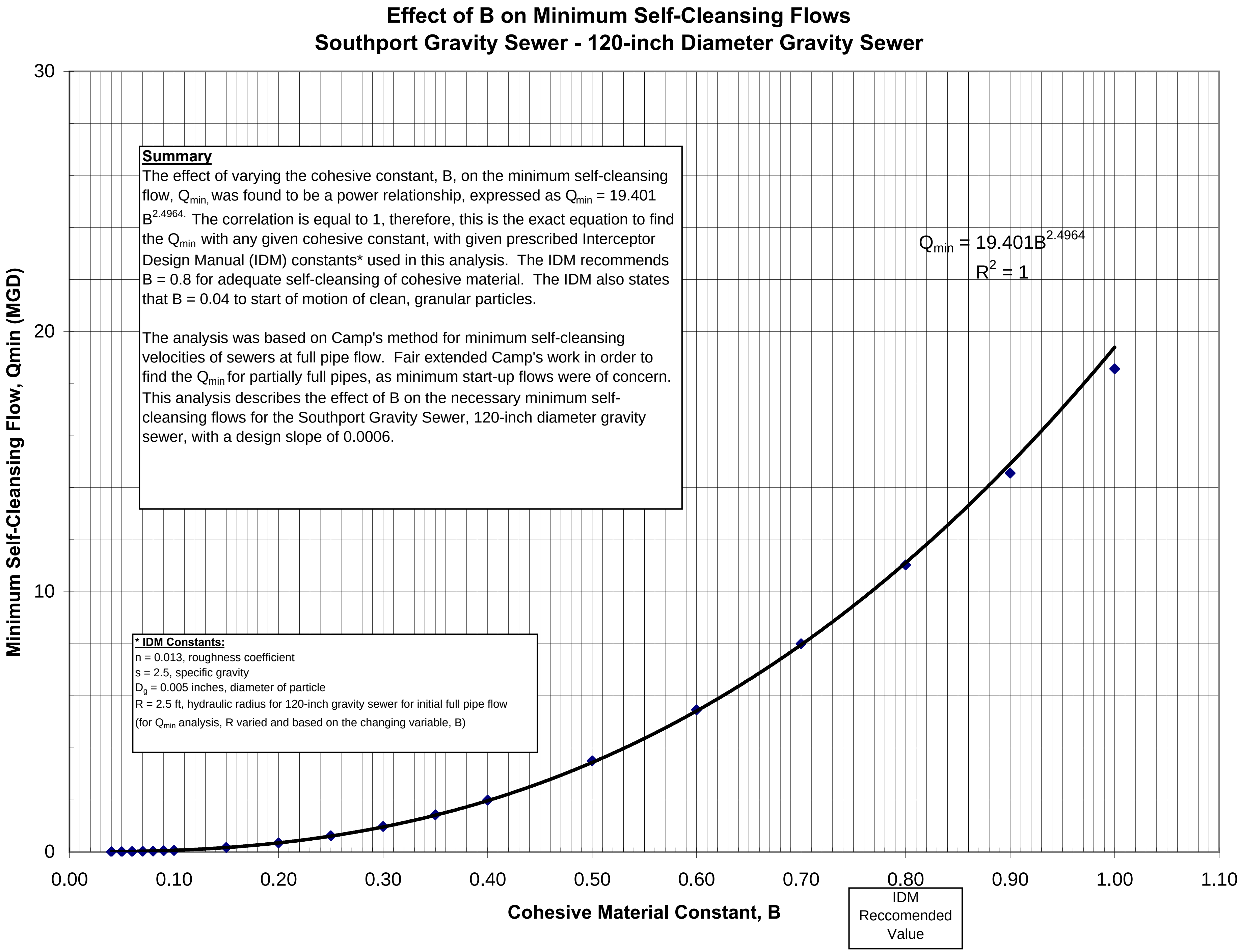
Dave Ocenosak
Principal Engineer
Sacramento Regional County Sanitation District
Interceptor Engineering
876-6054

Effect of Specific Gravity on Minimum Self-Cleansing Flows
Southport Gravity Sewer - 120-inch Diameter Gravity Sewer



Effect of Particle Diameter on Minimum Self-Cleansing Flows
Southport Gravity Sewer - 120-inch Diameter Gravity Sewer





Effect of B on Minimum Self-Cleansing Flows
Southport Gravity Sewer - 120-inch Diameter Gravity Sewer
Summary
The effect of varying the cohesive constant, B, on the minimum self-cleansing flow, Qmin, was found to be a power relationship, expressed as Qmin = 19.401 B2.4964. The correlation is equal to 1, therefore, this is the exact equation to find the Qmin with any given cohesive constant, with given prescribed Interceptor Design Manual (IDM) constants* used in this analysis. The IDM recommends B = 0.8 for adequate self-cleansing of cohesive material. The IDM also states that B = 0.04 to start of motion of clean, granular particles.
The analysis was based on Camp's method for minimum self-cleansing velocities of sewers at full pipe flow. Fair extended Camp's work in order to find the Qmin for partially full pipes, as minimum start-up flows were of concern. This analysis describes the effect of B on the necessary minimum self-cleansing flows for the Southport Gravity Sewer, 120-inch diameter gravity sewer, with a design slope of 0.0006.
Qmin = 19.401B2.4964
R2 = 1
* IDM Constants:
n = 0.013, roughness coefficient
s = 2.5, specific gravity
Dg = 0.005 inches, diameter of particle
R = 2.5 ft, hydraulic radius for 120-inch gravity sewer for initial full pipe flow
(for Qmin analysis, R varied and based on the changing variable, B)
Minimum Self-Cleansing Flow, Qmin (MGD)
30
20
10
0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
Cohesive Material Constant, B
IDM Reccomended Value