DOWNTOWN KODIAK SEWER MAIN & LIFT STATION 2 FORCE MAIN PIPE EVALUATION

EXISTING GRAVITY MAIN CAPACITY LOWER MILL BAY TO MARINE WAY EAST

						Depth Full = 0.4 (< 50% Full)		Depth Full = 0.8 (≥ 50% Full)	
Pipe Segment Description	Diameter (Inches)	Pipe Class / SDR	Slope (Rise/Run)	Pipe Inside Dia. (Inches)	Manning n-Value	Depth of Flow (inches)	Flow at 0.4 Full (GPM)	Depth of Flow (inches)	Flow at 0.8 Full (GPM)
MH on Lower Mill Bay Road to MH at L109	12	AC 150	0.0039	12.00	0.012	4.8	288	9.6	964
MH at L109 to MH NW of Carolyn	12	AC 150	0.0039	12.00	0.012	4.8	288	9.6	964
MH NW of Carolyn St to MH at Carolyn St	12	AC 150	0.0023	12.00	0.012	4.8	221	9.6	740
MH at Carolyn Street to MH at E. Rezanof	12	AC 150	0.0039	12.00	0.012	4.8	288	9.6	964
MH at E. Rezanof to MH in Easement	12	AC 150	0.0017	12.00	0.012	4.8	190	9.6	636
MH in Easement to MH at Kashevarof Cir	12	AC 150	0.0065	12.00	0.012	4.8	372	9.6	1,244
MH at Kashevarof Cir to MH at 2nd Easement	12	AC 150	0.1072	12.00	0.012	4.8	1,509	9.6	5,053
MH at 2nd Easement to MH at Center St	12	AC 150	0.0189	12.00	0.012	4.8	634	9.6	2,123
MH at Center St to MH at Mill Bay	12	AC 150	0.0087	12.00	0.012	4.8	430	9.6	1,439
MH at Mill Bay to MH at Mission Rd	12	AC 150	0.0055	12.00	0.012	4.8	343	9.6	1,148
MH at Mission Rd to MH NW of Marine Way	12	AC 150	0.0125	12.00	0.012	4.8	514	9.6	1,723
MH NW of Marine Way to MH at Marine Way East	12	AC 150	0.0898	12.00	0.012	4.8	1,381	9.6	4,625

POSSIBLE UPSIZING OF THE MAIN FROM LOWER MILL BAY TO MARINE WAY EAST

						Depth Full = 0.4 (< 50% Full)		Depth Full = 0.8 (≥ 50% Full)		Compared to 12"
Pipe Segment Description	Diameter (Inches)	Pipe Class / SDR	Slope (Rise/Run)	Pipe Inside Dia.(Inches)	Manning n-Value	Depth of Flow (inches)	Flow at 0.4 Full (GPM)	Depth of Flow (inches)	Flow at 0.8 Full (GPM)	Increase of Flow (Flow at 0.8 Full)
MH on Lower Mill Bay Road to MH at L109	16	CL50 DIP	0.0039	16.70	0.012	6.68	695	13.36	2,327	1,363
MH at L109 to MH NW of Carolyn	16	CL50 DIP	0.0039	16.70	0.012	6.68	695	13.36	2,327	1,363
MH NW of Carolyn St to MH at Carolyn St	16	CL50 DIP	0.0023	16.70	0.012	6.68	534	13.36	1,787	1,047
MH at Carolyn Street to MH at E. Rezanof	16	CL50 DIP	0.0039	16.70	0.012	6.68	695	13.36	2,327	1,363
MH at E. Rezanof to MH in Easement	16	CL50 DIP	0.0017	16.70	0.012	6.68	459	13.36	1,536	900
MH in Easement to MH at Kashevarof Cir	16	CL50 DIP	0.0065	16.70	0.012	6.68	897	13.36	3,004	1,760
MH at Kashevarof Cir to MH at 2nd Easement	16	CL50 DIP	0.1072	16.70	0.012	6.68	3,643	13.36	12,200	7,146
MH at 2nd Easement to MH at Center St	16	CL50 DIP	0.0189	16.70	0.012	6.68	1,530	13.36	5,124	3,002
MH at Center St to MH at Mill Bay	16	CL50 DIP	0.0087	16.70	0.012	6.68	1,037	13.36	3,473	2,034
MH at Mill Bay to MH at Mission Rd	16	CL50 DIP	0.0055	16.70	0.012	6.68	827	13.36	2,771	1,623
MH at Mission Rd to MH NW of Marine Way	16	CL50 DIP	0.0125	16.70	0.012	6.68	1,242	13.36	4,159	2,436
MH NW of Marine Way to MH at Marine Way East	16	CL50 DIP	0.0898	16.70	0.012	6.68	3,334	13.36	11,165	6,540

EXISTING GRAVITY MAIN CAPACITY FROM OVERFLOW TO MARINE WAY WEST

						Depth Full = 0.4 (< 50% Full)		Depth Full = 0.8 (≥ 50% Full)	
Pipe Segment Description	Diameter (Inches)	Pipe Class / SDR	Slope (Rise/Run)	Pipe Inside Diameter (Inches)	Manning n-Value	Depth of Flow (inches)	Flow at 0.4 Full (GPM)	Depth of Flow (inches)	Flow at 0.8 Full (GPM)
MH at Overflow to 1st MH SW of Overflow	8	CL50 DIP	0.0606	8.5	0.012	3.4	452	6.8	1,515
1st MH SW of Overflow to MH NE of Thorsheim	8	CL50 DIP	0.0121	8.5	0.012	3.4	202	6.8	676
MH NE of Thorsheim to MH at Thorsheim	8	CL50 DIP	0.0299	8.5	0.012	3.4	318	6.8	1,063
MH at Thorsheim to MH at Yukon Street	8	CL50 DIP	0.0253	8.5	0.012	3.4	292	6.8	979
MH at Yukon Street to MH at Y Intersection	10	CL50 DIP	0.0053	10.5	0.012	4.2	236	8.4	790
MH at Y Intersection to 1st MH Past Center	10	CL50 DIP	0.0030	10.5	0.012	4.2	176	8.4	589
1st MH Past Center to 2nd MH Past Center	10	CL50 DIP	0.0038	10.5	0.012	4.2	200	8.4	668
2nd MH Past Center fo MH at Marine Way	10	CL50 DIP	0.0038	10.5	0.012	4.2	199	8.4	668

DOWNTOWN KODIAK SEWER MAIN & LIFT STATION 2 FORCE MAIN PIPE EVALUATION

EXISTING GRAVITY MAIN CAPACITY FROM REZANOF TO LIFT STATION 2 - MARINE WAY WEST

Pipe Segment Description	Diameter (Inches)	Pipe Class / SDR	Slope (Rise/Run)	Pipe Inside Diameter (Inches)	Manning n-Value	Depth Full = 0.4 (< 50% Full)		Depth Full = 0.8 (≥ 50% Full)	
						Depth of Flow (inches)	Flow at 0.4 Full (GPM)	Depth of Flow (inches)	Flow at 0.8 Full (GPM)
Rezanof MH to MH SE of Rezanof	12	DIP CL50	0.018	12.00	0.011	4.8	671	9.6	2,249
MH SE of Rezanof to Shelikof	12	AC 150	0.018	12.00	0.012	4.8	616	9.6	2,061
MH at Shelikof to MH at Liquor Store	12	AC 150	0.008	12.00	0.012	4.8	407	9.6	1,364
MH at Liquor Store to MH at Mecca Store	12	AC 150	0.005	12.00	0.012	4.8	336	9.6	1,124
MH at Mecca Store to MH at Wells Fargo	12	AC 150	0.005	12.00	0.012	4.8	335	9.6	1,123
MH at Wells Fargo to MH by LS2	12	AC 150	0.008	12.00	0.012	4.8	411	9.6	1,376

PROPOSED LIFT STATION 2 FORCE MAIN - MARINE WAY EAST (WITH 4-INCH OVERFLOW)

Static Head = 19.32

Diameter (Inches)	Pipe Type Class / SDR	Discharge (GPM)	Pipe Inside Diameter (Inches)	Flow Velocity (FPS)	Pipe Length (Feet)	Hazen Williams C-Factor	Frictional Head Loss (Feet)	Total Dynamic Head (Feet)
8 (Existing)	DIP CL52	800	8.390	4.64	550	130	5.37	24.69
8	HDPE SDR21	800	7.754	5.44	550	140	6.87	26.19
8	HDPE SDR17	800	7.550	5.73	550	140	7.82	27.14
8	HDPE SDR11	800	6.963	6.74	550	140	11.60	30.92
10	HDPE SDR21	800	9.665	3.50	550	140	2.35	21.67
10	HDPE SDR17	800	9.410	3.69	550	140	2.68	22.00
10	HDPE SDR11	800	8.679	4.34	550	140	3.97	23.29

PROPOSED LIFT STATION 2 FORCE MAIN - MARINE WAY EAST (WITH 6-INCH OVERFLOW)

Static Head = 19.32

Diameter (Inches)	Pipe Type Class / SDR	Discharge (GPM)	Pipe Inside Diameter (Inches)	Flow Velocity (FPS)	Pipe Length (Feet)	Hazen Williams C-Factor	Frictional Head Loss (Feet)	Total Dynamic Head (Feet)
8	DIP CL52	1,300	8.390	7.54	550	130	13.20	32.52
12	DIP CL52	1,300	12.450	3.43	550	140	1.69	21.01
12	HDPE SDR21	1,300	11.463	4.04	550	140	2.52	21.84
12	HDPE SDR17	1,300	11.160	4.26	550	140	2.87	22.19
12	HDPE SDR11	1,300	10.293	5.01	550	140	4.26	23.58
14	HDPE SDR21	1,300	11.301	4.16	550	140	2.70	22.02
14	HDPE SDR17	1,300	12.253	3.54	550	140	1.82	21.14
14	HDPE SDR11	1,300	12.586	3.35	550	140	1.60	20.92

AC Pipe Inside Diameters			
Nominal	Class 100	Class 150	Class 200
4	4.00	4.00	4.00
6	6.00	5.85	5.70
8	8.00	7.85	7.60
10	10.00	10.00	9.63
12	12.00	12.00	11.56
14	13.59	14.00	13.59
16	15.50	16.00	15.50

MANNING'S FORMULA

$$Q = A * 1.486/n * R^{2/3} * S^{1/3}$$

Where;

Q = Discharge (cu. ft./sec.)
A = Cross-sectional Area of Flow (sq. ft.)
n = Coefficient of Roughness
R = Hydraulic Radius (ft.)
S = Slope of Pipe (ft./ft.)

Hydraulic Radius

$$R = A / P$$

Where;

R = Hydraulic Radius (ft.)
A = Cross-sectional Area of Flow (sq. ft.)
P = Wetted perimeter (ft.)

Partially Full Pipe Flow Calculations - U.S. Units

I. Calculation of Discharge, Q, and average velocity, V

for pipes less than half full

Instructions: *Enter values in blue boxes. Spreadsheet calculates values in yellow boxes*

Inputs

Pipe Diameter, **D** =	12	in
Depth of flow, **y** = (must have y ≤ D/2)	4.8	in
Manning roughness, $\mathbf{n_{full}}$ =	0.012	
Channel bottom slope, **S** =	0.0039	ft/ft
y/D =	0.400	
$\mathbf{n/n_{full}}$ =	1.27	
n =	0.015	

Calculations

Pipe Diameter, **D** =	1	ft
Pipe Radius, **r** =	0.5	ft
Circ. Segment Height, **h** =	0.4	ft
Central Angle, **θ** =	2.74	radians
Cross-Sect. Area, **A** =	0.29	ft^2
Wetted Perimeter, **P** =	1.4	ft
Hydraulic Radius, **R** =	0.21	ft
Discharge, **Q** =	0.641	cfs
Ave. Velocity, **V** =	2.19	ft/sec
pipe % full $[(A/A_{full})*100\%]$ =	37.35%	

Equations used for calculations:

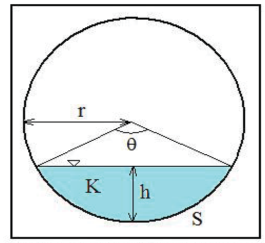
r = D/2

h = y

$$\theta = 2\arccos\left(\frac{r-h}{r}\right)$$

$$A = \frac{r^2(\theta - \sin\theta)}{2}$$

$$P = r * \theta$$



Partially Full Pipe Flow Parameters
(Less Than Half Full)

R = A/P (hydraulic radius)

$Q = (1.49/n)(A)(R^{2/3})(S^{1/2})$ (Manning Equation)

V = Q/A

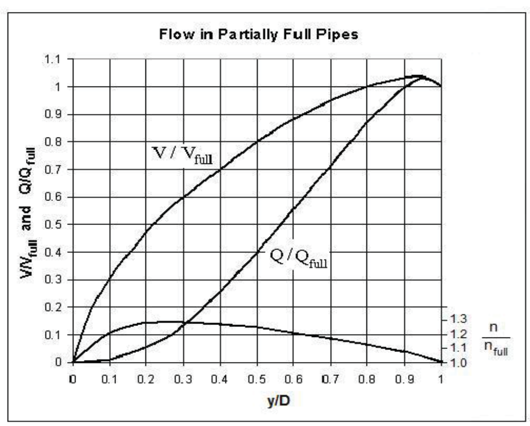
287.30

Calculations

If 0 < y/D ≤ 0.03, then n/n_{full} =	2.33
If 0.03 < y/D ≤ 0.1, then n/n_{full} =	1.73
If 0.1 < y/D ≤ 0.2, then n/n_{full} =	1.40
If 0.2 < y/D ≤ 0.3, then n/n_{full} =	1.29
If 0.3 < y/D ≤ 0.5, then n/n_{full} =	1.27

Equations used to calculate $\mathbf{n/n_{full}}$:

0 < y/D ≤ 0.03	n/n_{full} =	1 + (y/D)(1/0.3)
0.03 < y/D ≤ 0.1	n/n_{full} =	1.1 + (y/D - 0.03)(12/7)
0.1 < y/D ≤ 0.2	n/n_{full} =	1.22 + (y/D - 0.1)(0.6)
0.2 < y/D ≤ 0.3	n/n_{full} =	1.29
0.3 < y/D ≤ 0.5	n/n_{full} =	1.29 - (y/D - 0.3)(0.2)



Partially Full Pipe Flow Calculations - U.S. Units

II. Calculation of Discharge, Q, and average velocity, V

for pipes more than half full

Instructions: *Enter values in blue boxes. Spreadsheet calculates values in yellow boxes*

Inputs

Pipe Diameter, **D** =	12	in
Depth of flow, **y** =	9.6	in
(must have $y \geq D/2$)		
Full Pipe Manning roughness, $\mathbf{n_{full}}$ =	0.012	
Channel bottom slope, **S** =	0.0039	ft/ft

Calculations

$\mathbf{n/n_{full}}$ =	1.1	
Partially Full Manning roughness, **n** =	0.013	

Calculations

Pipe Diameter, **D** =	1	ft
Pipe Radius, **r** =	0.5	ft
Circ. Segment Height, **h** =	0.200	ft
Central Angle, **θ** =	1.85	radians
Cross-Sect. Area, **A** =	0.67	ft^2
Wetted Perimeter, **P** =	2.2	ft
Hydraulic Radius, **R** =	0.30	ft
Discharge, **Q** =	2.15	cfs
Ave. Velocity, **V** =	3.19	ft/sec
pipe % full $[(A/A_{full})*100\%]$ =	85.8%	

Equations used for calculations:

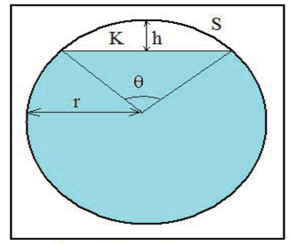
$r = D/2$

$h = 2r - y$

$$\theta = 2\arccos\left(\frac{r-h}{r}\right)$$

$$A = \pi r^2 - \frac{r^2(\theta - \sin\theta)}{2}$$

$$P = 2\pi r - r*\theta$$



Partially Full Pipe Flow Parameters
(More Than Half Full)

$R = A/P$ (hydraulic radius)

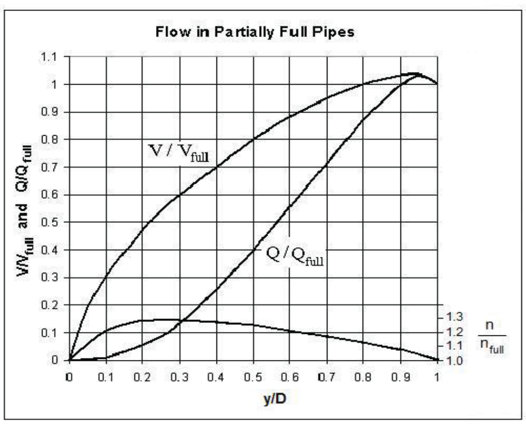
$Q = (1.49/n)(A)(R^{2/3})(S^{1/2})$ (Manning Equation)

$V = Q/A$

P

962.1466248

Equation used for n/n_{full}: $\mathbf{n/n_{full} = 1.25 - (y/D - 0.5)*0.5}$ (for $0.5 \leq y/D \leq 1$)



Partially Full Pipe Flow Calculations - U.S. Units

III. Calculation of Normal Depth for Pipes Less Than Half Full

Instructions: *Enter values in blue boxes. Spreadsheet calculates values in yellow boxes*

Inputs			**Calculations**		
Pipe Diameter, **D** =	8.5	in	Pipe Diameter, **D** =	0.708333	ft
Manning roughness, n_{full} =	0.013		Pipe radius, **r** =	0.4	ft
Channel bottom slope, **S** =	0.0072	ft/ft	The Manning equation can be rearranged to:		
Volumetric Flow Rate, **Q** =	1	cfs	$Q/(1.49*S^{1/2}) = (A*R^{2/3})/n$		

$Q/(1.49*S^{1/2})$ = 7.909 = target value for $(A*R^{2/3})/n$

Iterative (trial & error) Solution:

(Select values of y_o, to find the value of y_o that makes $(A*R^{2/3})/n$ as close to the target value as possible)

y_o ,ft	y_o/D	θ, radians	A, ft^2	n	P, ft	$(A*R^{2/3})/n$	difference from target value
0.5	0.706	3.990	0.30	0.0157	1.41	6.693	-1.217
0.4	0.565	3.401	0.23	0.0161	1.20	4.722	-3.188
0.3	0.424	2.835	0.16	0.0164	1.00	2.824	-5.085
0.35	0.494	3.118	0.19	0.0163	1.10	**3.744**	**-4.166**
0.34	0.480	3.062	0.19	0.0163	1.08	3.554	-4.355
0.36	0.508	3.175	0.20	0.0162	1.12	3.936	-3.974

NOTE: For Q = 1 cfs, this set of calculations shows that y_o = 0.35 ft (accurate to 2 signif. Figures) because the "difference from target value" is less for y_o = 0.35 than for y_o = 0.34 or 0.36.

Equations used for calculations:

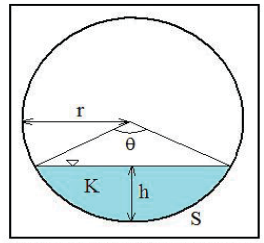
r = D/2

h = y

$$\theta = 2 \arccos\left(\frac{r-h}{r}\right)$$

$$A = \frac{r^2(\theta - \sin\theta)}{2}$$

$$P = r*\theta$$



Partially Full Pipe Flow Parameters
(Less Than Half Full)

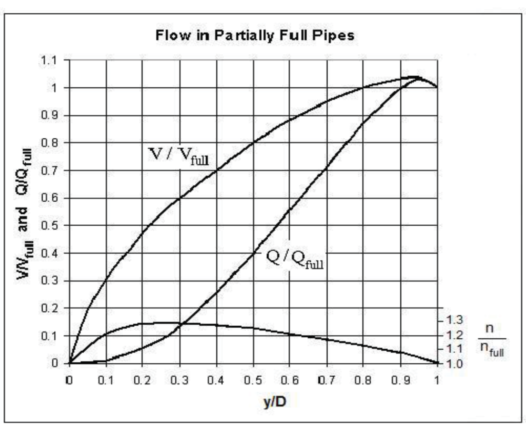
R = A/P (hydraulic radius)

$Q = (1.49/n)(A)(R^{2/3})(S^{1/2})$ (Manning Equation)

V = Q/A

Equations used to calculate n/n_{full}:

$0 < y/D \leq 0.03$	n/n_{full} =	1 + (y/D)(1/0.3)
$0.03 < y/D \leq 0.1$	n/n_{full} =	1.1 + (y/D - 0.03)(12/7)
$0.1 < y/D \leq 0.2$	n/n_{full} =	1.22 + (y/D - 0.1)(0.6)
$0.2 < y/D \leq 0.3$	n/n_{full} =	1.29
$0.3 < y/D \leq 0.5$	n/n_{full} =	1.29 - (y/D - 0.3)(0.2)



Partially Full Pipe Flow Calculations - U.S. Units

IV. Calculation of Normal Depth for Pipes More Than Half Full

Instructions: *Enter values in blue boxes. Spreadsheet calculates values in yellow boxes*

Inputs

Pipe Diameter, **D** = 48 in

Manning roughness, n_{full} = 0.011

Channel bottom slope, **S** = 0.0003 ft/ft

Volumetric Flow Rate, **Q** = 18 cfs

Calculations

Pipe Diameter, **D** = 4 ft

Pipe radius, **r** = 2.0 ft

The Manning equation can be rearranged to:

$Q/(1.49*S^{1/2})$ = $(A*R^{2/3})/n$

$Q/(1.49*S^{1/2})$ = 697.5 = target value for $(A*R^{2/3})/n$

Iterative (trial & error) Solution:

(Select values of y_o, to find the value of y_o that makes $(A*R^{2/3})/n$ as close to the target value as possible)

y_o ,ft	h, ft	θ, radians	A, ft^2	n	P, ft	**$(A*R^{2/3})/n$**	difference from target value
3	1.00	2.094	10.11	0.0124	8.38	926.0	228.5
2	2.00	3.142	6.28	0.0138	6.28	457.0	-240.5
2.5	1.50	2.636	8.26	0.0131	7.29	687.3	-10.2
2.51	1.49	2.626	8.30	0.0130	7.31	692.1	-5.4
2.52	1.48	2.616	8.34	0.0130	7.34	**696.9**	**-0.6**
2.53	1.47	2.605	8.38	0.0130	7.36	701.7	4.2

NOTE: For Q = 18 cfs, this set of calculations shows that y_o = 2.52 ft

(accurate to 3 significant figures)

Equations used for calculations:

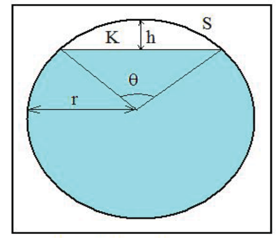
r = D/2

h = 2r - y

$$\theta = 2\arccos\left(\frac{r-h}{r}\right)$$

$$A = \pi r^2 - \frac{r^2(\theta - \sin\theta)}{2}$$

$$P = 2\pi r - r*\theta$$



Partially Full Pipe Flow Parameters
(More Than Half Full)

R = A/P (hydraulic radius)

Q = $(1.49/n)(A)(R^{2/3})(S^{1/2})$ (Manning Equation)

V = Q/A

NOTE: For $0.5 \leq y/D \leq 1$: n/n_{full} = 1.25 - (y/D - 0.5)*0.5 (see graph below)