City of Aberdeen
INFILTRATION AND INFLOW STUDY
SUPPLEMENT – REHABILITATION ALTERNATIVES
21 January 1999

Summary Overview

Basin flow monitoring indicates that although infiltration is noticeable, it does not have a major effect on either conveyance or treatment capacity. Peak flows through the system mimic rainfall patterns, indicating that inflow is a major capacity problem for the treatment plant. However, large flows persist for a day or more after the rainfall ceases, which suggests that extraneous flow is induced into the collection system from defects near the ground surface (above the normal high groundwater levels that appear as infiltration). Tides above about elevation 10 also influence some areas near the river.

City efforts over the years have identified a number of defects within the sewer system that remain to be corrected and are carried in the Hanson files as Pending Work Orders. A number of these defects are sewer main pipe faults, which result in infiltration but have relatively little affect on the peak flow volumes. However, the total list does not appear to include sufficiently serious faults that would generate the bulk of the extraneous flows measured in the existing sewers.

The majority of extraneous flow seems to originate in numerous unidentified faulty sewer stubs, manhole risers/castings, side sewers, drainers, illicit storm inlets, or basement/foundation drains. Most such defects can only be identified through a lengthy further investigative process. Repair efforts are not likely to be very successful until the plumbing beneath the houses are addressed, and not just the side sewer from the sewer main up to the building foundation.

Repair and rehabilitation of sewer systems is an uncertain business. Even new sewers have leaks that admit extraneous flow. Repairs rarely even approach new standards. For Aberdeen, the uncertainties are particularly notable in that most of the faults have yet to be located. Certainly the pipe replacements resulting from the 1976 *Facilities Plan* did not reduce extraneous flow to the degree expected.

Existing trunk sewers generally have adequate capacity to convey the estimated 2-year storm event now and in the year 2020; though some increase in pumping capacity would be needed at several stations. Continued operation this mode would have the sewer system acting as a supplement to the storm drain system; with the peak flows receiving treatment and disinfection before discharge.

Rehabilitation can be formulated as a series of increasing levels of effort to reduce the extraneous flows. Work would proceed through these levels at increasing costs in relation to the avoided treatment cost until an appropriate degree of cost-effectiveness is achieved. The most cost-effective way to define work levels is by ranking the flow monitoring basins to identify where the best flow reductions can be anticipated.

Revised Categorization of Flow Monitoring Basins

The Composite Storm Summary tabulates peak day extraneous flow in each of the basins. Two comparisons are then computed: first, for the total extraneous flow by basin; and second as flow per inch-mile. These comparisons indicate that the basins can be grouped into five categories in descending severity of extraneous flow as shown below:

Category A – Highest extraneous flow per inch-mile: Basins 2 and 3b

Category B – High extraneous flow: Basins 4, 6, and 10a plus probably 19

Category C – Significant extraneous flow: Basins 8, 13, and 14

Category D – Modest extraneous flow: Basins 7, and 18

Category E – Insignificant extraneous flow: no further investigation justified

Rehabilitation Approach

The degree of effort devoted to sewer system repair and rehabilitation can be formulated into six levels starting with no rehabilitation and working through the majority of the system. Selection of the appropriate level to actually complete requires a subjective decision balancing several factors:

- estimated cost-effectiveness and affect on City budget
- risk that flow reduction will not be achieved or will exceed expectations
- community acceptance of the resulting program

The activity to be included in each of these levels is summarized below:

Level 1 – No I/I Rehabilitation: Provide conveyance and treatment capacity for forecasted flow

1. Add pumping capacity at Pump Stations 1, 2, 3, 4, 8, 9, and 13

2. Increase pipe capacity where needed, which appears to be only the force mainfor the Pump Station 2.

3. Provide treatment for the entire peak flow stream.

Level 2 – Repair the Known Defects: Exclude routine maintenance contributing only infiltration

1. Provide appropriate additional conveyance and treatment capacity as in Level 1.

2. Repair all pending work orders listed in Hansen that contribute significant extraneous flow using commercial contractors.

3. Repair the additional defects noted in the supplemental list by Earth Tech and City staff.

Level 3 – Known Defects + Investigate & Repair Highest Inch-Mile Basins (Category A):

1. Provide appropriate additional conveyance and treatment capacity as in Level 1.

2. Repair the known defects as described in Level 2

1. Perform further investigations in Flow Monitoring Basins 2 and 3b, which evidence the highest ratio of storm response versus dry weather flows:
   a. Inspect all manholes per Section 7.3 Stage 1 and repair defects.
   b. Trace the flow path upstream from manhole to manhole of high storm flows to identify abrupt changes that may locate defects.

c. Conduct hydrostatic tests per Section 7.3 Stage 2 of all sewer mains that predate 1976 and any newer mains that Step 2.b. indicated may have extraneous flow.
d. Conduct hydrostatic tests of all side sewers per Section 7.3 Stage 3 within sewer main reaches that Step 2.c. indicated as high leakage.
e. Repair all defects found.
f. Re-test the failed sewer mains and quantify the reduced leakage.
g. Compute the cost of investigation and repair in relation to reduced peak flow to define a per gallon cost.

Level 4 – Perform Investigation & Repair within the Next Highest Rated Basins (Category B):

1. Provide appropriate additional conveyance and treatment capacity as in Level 1.
2. Repair the known defects as described in Level 2.
3. Perform the investigation and repair described in Level 3.
4. Perform a similar investigation and repair in Basins 4, 6, 10a and 19.

Level 5 – Perform Investigation & Repair in Category C Basins

1. Provide appropriate additional conveyance and treatment capacity as in Level 1.
2. Repair the known defect as described in Level 2.
3. Perform the investigation and repair described in Levels 3 and 4.
4. Perform similar investigation & repair in Flow Monitoring Basins 8, 13, 14 & 19

Level 6 – Perform Investigation & Repair in Category D Basins

1. Provide appropriate additional conveyance and treatment capacity as in Level 1.
2. Repair the known defect as described in Level 2.
3. Perform the investigation and repair described in Levels 3, 4 and 5.
4. Perform a similar investigation and repair in Flow Monitoring Basins 7 & 18

Work Program

Accomplishment of the work elements described in each of the above Levels of Effort requires a series of specific projects as outlined below:

Project 1 – Increase Conveyance Capacity

Department of Ecology *Criteria for Sewage Works Design* requires pump stations to be designed to transmit the maximum day flow with one pump out of service. Maximum day flow is defined therein as 2.5 times the average day wet weather flow.

Facility	Existing Capacity	Needed Capacity	Est. Project Cost
Pump Station # 1	14.4 mgd	27.0 mgd	$ 3,700,000
# 2	8.6 mgd	12.4 mgd	1,200,000
# 2 Force Main	14-inch x 970 lf	Second 14-inch	400,000
Pump Station # 3	0.17 mgd	0.22 mgd	40,000
# 4	0.58 mgd	0.70 mgd	50,000
# 8	0.50 mgd	0.60 mgd	50,000
# 9	0.50 mgd	0.84 mgd	60,000
# 13	1.22 mgd	1.80 mgd	200,000
Estimated Total			$ 5,300,000

Project 2 – Repair Known Defects

Specific Repairs	Quantity	GPD/ Defect	Total MGD	Repair % Effective	MGD Removed	Estimated Project Cost
Hansen Files						
A - Stub Sewers	221	1,000	0.221	50	0.11	$ 180,000
B - Manholes	350	1,000	0.404	80	0.32	280,000
C - Side Sewers	135	5,000	0.675	50	0.34	68,000
D - Drainers	47	7,000	0.329	70	0.23	5,000
Added Repairs						
E - 3 Storm Inlet Connections			0.20	90	0.18	$ 50,000
F - MH 279INTIS18 Market & B – tideal			0.10	70	0.07	10,000
G - MH 279INTIS14 suspected drain			0.02	90	0.02	5,000
H - MH SSMINT24A overflow unsealed			0.01	70	0.01	5,000
I - MH GHCINT221 on Evans			0.05	70	0.03	20,000
J - MH 177INT3G5 from Mill Street			0.01	70	0.01	20,000
Estimated Totals					1.32	$ 640,000

Estimated Cost per gpd Removed = $ 640,000 / 1,320,000 gpd = $ 0.48

Project 3 – Category A Flow Monitoring Basins:

Work Element	Quantity	Number Tested	Number Repaired	Project Cost
Basin 2				
Manholes	18	15	12	$ 8,000
Sewer Mains	5,164 lf	18 reaches	40 stubs	24,000
Side Sewers	40	30	30	99,000
Basin 3b				
Manholes	50	40	35	$ 25,000
Sewer Mains	14,719 lf	50 reaches	80 stubs	50,000
Side Sewers	200	170	150	540,000
Totals				$736,000

Extraneous Flow for the Category A Basins = 0.534 + 2.034 = 2.568 mgd

Estimated Rehabilitation Effectiveness = 70 %

Estimated Extraneous Flow Removed = 1.80 mgd

Estimated Cost per gpd Removed = $ 0.41

Project 4 – Category B Flow Monitoring Basins:

Work Element	Quantity	Number Tested	Number Repaired	Project Cost
Basin 4				
Manholes	90	80	70	$ 43,000
Sewer Mains	22,448 lf	90 reaches	150 stubs	93,000
Side Sewers	560	420	380	1,266,000
Basin 6				
Manholes	75	65	55	34,000
Sewer Mains	16,838 lf	70 reaches	100 stubs	64,000
Side Sewers	300	160	140	468,000
Basin 10a				
Manholes	80	70	60	37,000
Sewer Mains	18,080 lf	70 reaches	100 stubs	64,000
Side Sewers	440	380	350	1,164,000
Totals				$3,233,000

Extraneous Flow for the Category B Basins = 1.309 + 0.888 + 0.788 = 2.985 mgd
Estimated Rehabilitation Effectiveness = 60 %
Estimated Extraneous Flow Removed = 1.79 mgd
Estimated Cost per gpd Removed = $ 1.81

Available data does not allow Basin 19 to be evaluated on the same basis as the three above. However, a similar program in Basin 19 is estimated to cost about $ 600,000 and may remove about 0.70 mgd in extraneous flow.

Project 5 – Category C Flow Monitoring Basins:

Work Element	Quantity	Number Tested	Number Repaired	Project Cost
Basin 8				
Manholes	150	140	120	$ 74,000
Sewer Mains	42,317 lf	140 reaches	150 stubs	103,000
Side Sewers	900	600	400	1,300,000
Basin 13				
Manholes	180	160	130	81,000
Sewer Mains	49,155 lf	170 reaches	200 stubs	134,000
Side Sewers	1,050	800	600	2,040,000
Basin 14				
Manholes	40	35	30	19,000
Sewer Mains	10,983 lf	35 reaches	50 stubs	32,000
Side Sewers	250	200	160	540,000
Totals				$4,323,000

Extraneous Flow for the Category C Basins = 0.735 + 1.904 + 0.680 = 3.319 mgd
Estimated Rehabilitation Effectiveness = 50 %
Estimated Extraneous Flow Removed = 1.66 mgd
Estimated Cost per gpd Removed = $ 2.60

Project 6 – Category D Flow Monitoring Basins:

Work Element	Quantity	Number Tested	Number Repaired	Project Cost
Basin 7				
Manholes	65	60	50	$ 31,000
Sewer Mains	19,101 lf	60 reaches	30 stubs	27,000
Side Sewers	140	110	90	303,000
Basin 18				
Manholes	70	60	50	31,000
Sewer Mains	19,228 lf	60 reaches	80 stubs	52,000
Side Sewers	320	190	160	537,000
Totals				$ 981,000

Extraneous Flow for the Category D Basins = 0.799 + 0.571 = 1.370
Estimated Rehabilitation Effectiveness = 35 %
Estimated Extraneous Flow Removed = 0.48 mgd
Estimated Cost per gpd Removed = $ 2.04

Determination of Cost Effective Work Level

Cost-effectiveness is the relationship between repair/rehabilitation cost and the avoided cost for conveyance plus treatment of the removed extraneous flow. This relationship may be clearest when only capital costs are considered, as fewer assumptions need to be worked into the equations. Attempting to forecast the time-value of money may only complicate matters without really adding more precision to the conclusion.

Capital costs for a treatment facility are estimated to range from $2.50 to $ 3.50 per gpd of average day flow during the maximum month, exclusive of any needed property acquisition costs.

Recognizing the uncertainties inherent in I/I rehabilitation and estimating the extraneous flow actually removed, it is prudent that cost-effectiveness considerations limit rehabilitation work to not more than about 2/3 of the avoided treatment cost. This would be about $ 2.00 per gallon removed during peak day conditions, and corresponds to implementing repair work only of Projects 1 through 4. The budget cost estimates for these sewer collection system projects are summarized below:

Project 1 – Increase Conveyance Capacity	$ 5,300,000
Project 2 – Repair Known Defects	640,000
Project 3 – Category A Basins	736,000
Project 4 – Category B Basins	3,833,000
Estimated Total Costs	$ 10,509,000

Projects 2, 3, and 4 are estimated to remove about 5.6 mgd under peak day conditions. If achieved, such reductions may allow some reduction in the Project 1 estimated costs. Cost estimates have not been prepared for the additional treatment capacity that is required, or for the storm drainage improvements that would be desirable.

NORTH

0 1000 2000

SCALE IN FEET

RAIN GAUGE R1

RAIN GAUGE R2

#3A FROM EAST

#3B FROM SOUTH

RIVER

CHEHALIS

COSMOPOLIS

LEGEND

#9 FLOW MONITORING STATION, FLOW METER NUMBER AND DIRECTION OF FLOWS BEING MEASURED.

9 FLOWMETER DRAINAGE BASIN BOUNDARY AND IDENTIFIER

Date	No.	Description	By
		REVISION	

ONE INCH 0 1" AT FULL SIZE
IF NOT ONE INCH SCALE ACCORDINGLY

Project No: 28143.01

Designed: CPL | Checked: CPL

Drawn: CAD TEAM | Scale: 1"=1000'

Date: DEC 1998 | Apprd:

EARTH TECH

10800 N.E. 8th St. 7th Floor, Bellevue, WA 98004 · 425 453-9404 · 425 453-9470 (FAX)

720 S. 333 St. Ste. 200, Federal Way, WA 98003 · 253 838-8202 · 253 874-0677 (FAX)

1200 Dupont St. Ste. 2-B, Bellingham, WA 98225 · 360 734-3202 · 360 734-0818 (FAX)

CITY OF ABERDEEN

SANITARY SEWER INFILTRATION & INFLOW STUDY

WASTEWATER COLLECTION SYSTEM

FIGURE 3.1
FLOW MONITORING DRAINAGE BASINS

FILE INFORMATION: 1/04/99 Abd3-DL.dwg Abd-sm1.dwg Abd-sm2.dwg Abd-sm7.dwg

E:\SAVE\

DRAWING NO.

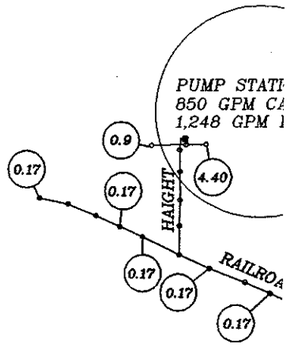
SHEET NO. OF

NOTES

MUM CAPACITY OF THE MODELED PIPING SYSTEM
ERMINED BY INCREASING THE INPUT FLOWS
RCHARGING OCCURRED IN THE PRIMARY TRUNKS.
MUM PIPE CAPACITY IS 27 MGD.

AINDER OF THE MODELED PIPES WERE EVALUATED
TOTAL SYSTEM FLOW OF 27 MGD.
ET WAS THE ONLY PIPE SYSTEM THAT
GED UNDER THESE CONDITIONS, AND THE HGL
BELOW GRADE.

ATION IMPROVEMENTS ARE BASED ON ONE PUMP
SERVICE AT EACH STATION. STATIONS REQUIRING
AL CAPACITY ARE CIRCLED.



LEGEND

1.36 FLOW INJECTION, IN CFS

PUMP STATION

N

0 800 1600 2400
SCALE IN FEET

RDEEN
VER
LOW STUDY

WASTEWATER COLLECTION SYSTEM

MODEL INPUTS AND PUMP STATION IMPROVEMENTS REQUIRED FOR YEAR 2020

DRAWING NO.

SHEET NO. OF

Date | No. | Description
REVISION

FIGURE 6.1
COMPOSITE STORM SUMMARY

CITY OF ABERDEEN
WASTEWATER COLLECTION SYSTEM
FLOW MONITORING SUBBASIN FLOW SUMMARY
Composite Storm Summary

date of storm used	11/13/98	12/1/98	11/13/98	11/24/98	11/20/98	11/24/98	11/24/98	11/13/98	12/12/98	11/20/98	12/12/98	11/24/98	12/1/98	11/28/98	11/20/98	11/13/98	12/1/98	11/24/98	11/24/98	11/24/98	
Subbasin No.	**1**	**2**	**3A**	**3B**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**10A**	**11**	**12***	**13**	**14**	**15**	**16**	**17**	**18**	sum
Estim. base sanitary flow @ 2.5 x 80 x #svcs.	88,600	5,800	124,600	65,600	95,200	36,000	52,000	41,000	36,200	109,600	43,000	38,800	21,400	36,200	179,400	101,800	62,000	37,200	44,800	51,400	1,270,600
Dry weather Avg. flow (gpd)	89,000	36,000	219,000	35,000	181,000	90,000	72,000	81,000	255,000	183,000	95,000	72,000	70,000	299,000	76,000	120,000	53,000	50,000	120,000	159,000	2,355,000
Min dry weather flow = dry weather infiltration (gpd)	11,800	20,000	140,000	58,000	75,000	43,000	29,000	(20,000)	86,000	72,000	45,800	24,000	37,000	178,000	(44,000)	69,000	19,000	8,000	50,000	36	901,636
Sanitary sewer base flow (gpd)	77,200	16,000	79,000	(23,000)	106,000	47,000	43,000	101,000	169,000	111,000	49,200	48,000	33,000	121,000	120,000	51,000	34,000	42,000	70,000	158,964	1,453,364
Total LF sewer pipe	34,320	5,164	39,382	14,719	22,448	13,469	16,838	19,101	42,317	26,729	19,319	18,080	9,820	18,747	49,155	10,938	14,137	13,428	9,178	19,228	
Total sewer pipe mi.	6.50	0.98	7.46	2.79	4.25	2.55	3.19	3.62	8.01	5.06	3.66	3.42	1.86	3.55	9.31	2.07	2.68	2.54	1.74	3.64	
Total sewer pipe in-mi.	52.00	8.35	71.97	30.17	37.36	23.17	25.77	43.45	69.27	44.19	30.06	25.06	14.08	28.78	92.75	17.28	21.25	21.02	17.96	33.88	
Dry weather flow per lineal foot (gal.)	2.59	6.97	5.56	2.38	8.06	6.68	4	4	6	7	5	4	7	16	2	11	4	4	13	8	
Dry weather flow per in-mile (gal.)	1,711.54	4,309.03	3,042.88	1,160.28	4,845.39	3,883.62	2,794	1,864	3,681	4,141	3,160	2,873	4,973	10,390	1,294	6,946	2,494	2,379	6,681	4,692	
Peak day to dry Weather flow ratio	11	16	5	60	8	4	13	11	8	4	4	12	2	2	17	7	7	5	3	5	
Peak day flow (gpd)	977,000	570,000	1,034,000	2,100,000	1,490,000	360,000	960,000	880,000	1,990,000	760,000	370,000	860,000	140,000	560,000	1,980,000	800,000	370,000	250,000	360,000	730,000	
Peak day flow per lineal foot (gal)	28.47	110.38	26.26	142.67	66.38	26.73	57.01	46	47.03	28	19	47.57	14	30	40	73.14	26	19	39	38	
Peak flow per in-mile (gal)	18,788	68,226	14,367	69,617	39,887	15,534	37,253	20,254	28,729	17,199	12,308	34,313	9,946	19,460	21,348	46,304	17,413	11,895	20,043	21,544	
Basin peak day extraneous flow (gal)	888,000	534,000	815,000	2,034,400	1,309,000	270,000	888,000	799,000	1,735,000	577,000	275,000	788,000	70,000	261,000	1,904,000	680,000	317,000	200,000	240,000	571,000	
Peak 3 day avg to dry Weather flow ratio	10	13	4	43	6	3	10	9	7	3	3	10	2	2	14	5	5	4	3	4	
Peak 3 day avg. flow (gal)	888,000	450,000	980,000	1,500,000	1,010,000	293,000	730,000	730,000	1,700,000	640,000	300,000	720,000	110,000	530,000	1,630,000	610,000	260,000	210,000	300,000	590,000	
Peak 3 day avg. flow per lineal foot (gal)	25.87	87.14	24.88	101.91	44.99	21.75	43	38	40	24	16	40	11	28	33	56	18	16	33	31	
Peak 3 day avg. flow per in-mile (gal)	17,077	53863	13,617	49,726	27,038	12,643	28,327	16,802	24,542	14,484	9,980	28,728	7,815	18,417	17,574	35,308	12,236	9,992	16,703	17,412	

*Site 12 uses 11/28-11/30 data

EXTRANEOUS FLOW

CATEGORY 'A' REHAB.	2,568,400 (gal)		534,000		2,034,400																
CATEGORY 'B' REHAB.	2,985,000 (gal)					1,309,000		888,000					788,000								
CATEGORY 'C' REHAB.	4,319,000 (gal)								1,735,000						1,904,000	680,000					
CATEGORY 'D' REHAB.	1,370,000 (gal)							799,000												571,000	

Basin	Extran. Flow	Peak Flow/in-mile
1	0.888	18,788
2	0.534	68,226
3A	0.815	14,367
3B	2.034	69,617
4	1.309	39,887
5	0.270	15,534
6	0.888	37,253
7	0.799	20,254
8	1.735	28,729
9	0.577	17,199
10	0.275	12,308
10A	0.788	34,313
11	0.070	9,946
12	0.261	19,460
13	1.904	21,348
14	0.680	46,304
15	0.317	17,413
16	0.200	11,895
17	0.240	20,043
18	0.571	21,544