City of Seattle

201 FACILITY PLANNING

INFILTRATION INFLOW ANALYSIS CARKEEK PARK SYSTEM

August, 1979

SEATTLE ENGINEERING DEPARTMENT

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CHAPTER I

INTRODUCTION

SUMMARY, CONCLUSION & RECOMMENDATION

INTRODUCTION

Sewage collection and transport systems are frequently subjected to infiltration of groundwater and inflow of surface water or stormwater. Infiltration is the water which enters a sewer system, including sewer service connections, from the ground, through such means as, but not limited to, defective pipes, pipe joints, connections, or manhole walls. Inflow is the water discharged into a sewer system, including service connections from such sources as, but not limited to, roof leaders, cellar, yard, and area drains, foundation drains, cooling water discharges, drains from springs and swampy areas, manhole covers, cross connections from storm sewers and combined sewers, catch basins, stormwaters, surface run-off, street wash waters, or drainage.

Extraneous flows reduce the capability of the sewerage facilities to accommodate domestic and industrial wastewaters. The elimination of infiltration/inflow by sewer system rehabilitation can often substantially reduce the cost of wastewater collection and treatment. However, a systematic evaluation of the sewer system is necessary to determine the cost-effectiveness of such undertakings, on a system-by-system basis. Infiltration/inflow is excessive when the following condition prevails: The cost to construct and operate wastewater collection, transport and treatment facilities to accommodate the infiltration/inflow over the planning period (twenty years) is greater than the cost to remove the infiltration/inflow from the system.

Recognition of extraneous flow as a major concern, is evident by the inclusion of a section dealing with Infiltration/Inflow in Public Law 92-500. This act requires that municipalities and sewerage authorities evaluate the integrity of their sewer system as part of the overall facilities planning process for new or upgraded

wastewater treatment facilities. The Federal Government, through a program administered by E.P.A., will provide matching funds for facilities planning, design and construction. As a prerequisite for receiving Federal funding under this program, the municipality must first conduct an Infiltration/Inflow study of their sewer collection system.

All applicants for grant assistance awarded after July 1, 1973, must demonstrate to the satisfaction of the EPA Regional Administrator that each sewer system tributary to the collection, transport or treatment works project for which grant application is made is not or will not be subject to excessive infiltration/inflow.

The determination whether or not excessive infiltration/inflow exists will generally be accomplished through a sewer system evaluation consisting of (1) certification by the State agency, as appropriate; and, when necessary (2) an infiltration/inflow analysis; and, if appropriate, (3) a sewer system evaluation survey followed by rehabilitation of the sewer system to eliminate an excessive infiltration/inflow defined in the sewer system evaluation. Because of the age of much of the City sewage collection system, an extensive infiltration/inflow analysis was necessary.

This report presents the results of our analysis of the infiltration/inflow characteristics of the sewerage system tributary to the METRO Carkeek Park Wastewater Treatment Plant. The purpose of this analysis is to establish whether or not there is excessive infiltration/inflow in the trubutary sewer system.

This analysis was conducted in accordance with the guidelines developed in the U.S. Environmental Protection Agency's "Handbook for Sewer System Evaluation and Rehabilitation, January 1975," and this document is prepared as part of the Seattle METRO 201 Wastewater Facility Plan. The Seattle, METRO 201 Wastewater Facility Planning Study is the first step of a three part program culminating in implementation of a wastewater management program for the METRO service area through the year 2005.

On October 1976, The City of Seattle, using its own staff, was given the responsibility of completing a detailed Infiltration/Inflow analysis of the Carkeek Park sewer system. The purpose was to determine quantity of extraneous flows and if any portions of the excessive flows in the existing sewer systems can be removed more economically than it can be transported and treated at the METRO Carkeek Treatment Plant.

SUMMARY

The area served by the Carkeek Park Wastewater Treatment Plant is located in the northwest corner of the City of Seattle. It serves a primarily residential area. The sewer collection system in the area is basically a sanitary only system, however, much of the storm water in the area finds its way into this system and overtaxes its pipe capacity and often exceeds the capacity of the treatment plant.

Information concerning rainfall, sewage flow, overflows, bypasses, age of sewers, maintenance programs, new connections and storm drains were acquired from available records within Seattle Engineering Department. Information relating to the Carkeek Park Treatment Facilities, its transport and treatment cost, and its expected capital cost to construct secondary treatment facilities, were acquired from METRO.

The infiltration/inflow analysis consists of five basic steps. The first was evaluation of flow, rainfall, and water use date to identify infiltration and inflow characteristics for the total system and system subareas. The second step was to allocate the identified infiltration/inflow to the system components namely service laterals and main line. The third step was to develop and cost a sewer system rehabilitation program to eliminate the identified extraneous flows. The forth step was to develop costs of transporting and treating infiltration/inflow. Finally, the costs developed in step 3 and 4 are compared to determine if any elements of the infiltration or inflow are economically excessive.

The Carkeek Park area with a population of 24,495 and a service area of 2,658 acres, is served by a separate sanitary system. For this analysis, the service area was considered as two principal systems; the areas tributary by gravity to the North Beach pump station, and the areas tributary by gravity to the Carkeek Treatment Plant. These two principal systems were further subdivided into a total of 14 sub-areas, three at North Beach and 11 at Carkeek. However, due to difficulties in finding acceptable monitoring manholes, flow measurements were not obtained on two sub-areas. For the sub-areas monitored, flow recorders were installed in key manholes to determine infiltration/inflow characteristics.

Water use and diurnal flow characteristics were analyzed to determine base wastewater flows. Total base wastewater flow from the 12 monitored sub-areas came to 1.42 M.G.D. based on population of 21,285 from the 12 sub-areas, the per capita water consumption ~~came to~~ 66.7 gallons per day.

Infiltration was estimated as the difference between measured flows on nonstorm days and the base wastewater flow. For dry season flow, the average daily infiltration was found to be 1.98 M.G.D. For wet season flow, the average daily infiltration during rainy season came to 4.4 M.G.D. Total annual infiltration volume came to 757.71 million gallons.

Inflow was estimated by taking the difference between storm flows and wet season nonstorm flows. Inflow rates varied with the intensity of specific storms. The maximum rate of inflow observed from the 12 monitored sub-areas was determined to be 18.01 M.G.D. Adjusting maximum observed inflow to an equivalent 5 year storm, resulted in calculated peak inflow of 28.6 M.G.D. These figures were derived from the summation of flow data collected from each of the 12 sub-areas. Total annual inflow volume came to 155.8 million gallons. Annual inflow was calcuated by setting up a ratio of measured flow volume during a specific period, times the annual rainfall in the area, divided by actual rainfall recorded during the flow monitoring period.

Infiltration was allocated to the two system components, namely collector sewers (main line) and service laterals based on the analysis of flow data from nonstorm periods and periods just after a storm. It was assumed that most of the infiltration occurring during extended periods of no rain occurred within the deeper main line pipes since these are more likely to be submerged by groundwater than the service laterals. The increase in infiltration following a storm was allocated both to service laterals and local agency pipes. Inflow was allocated by assuming 80 percent came from sources such as roof drains or catch basins connected to the sanitary system and 20 percent came from service laterals.

Infiltration/Inflow ranking as developed in METRO I/I analysis was used to provide a systematic approach to the sewer system evaluation. Rankings of 1 through 5 were established with the highest number reflecting the most excessive infiltration/inflow quantities. Sub-areas with infiltration in excess of 7,500

gallons/day/inch diameter mile, and or inflow in excess of 9,000 gallons/day/acre would be ranked 5. Analysis of infiltration data resulted in two sub-areas being ranked 5, one ranked 4, and seven sub-areas ranked 3. Inflow ranking based on 5 year rainfall resulted in seven sub-areas being ranked 5, and the remaining five sub-areas ranked 4.

Having assessed the quantities of infiltration and inflow that are in the system and allocated them to the particular system elements, an economic evaluation was undertaken to determine costs for eliminating each element of infiltration/inflow and costs for transporting and treating the infiltration/inflow.

Cost to conduct sewer system evaluation survey of the entire Carkeek Park area (12 sub-areas) came to a total of $229,616. Rehabilitation costs to remove excessive infiltration from the same 12 sub-areas came to $2,406,141 for main lines, and $4,558,246 for service laterals.

Evaluation of flows of the 12 sub-areas monitored indicated a high inflow into the system. This resulted in ranking of 4 or greater for all sub-areas. However, in evaluating the Carkeek Park area, with its steep slopes, irregular terrain, lack of storm drains, ditches and its slide potential, it was determined that inflow rehabilitation would require not only a downspout removal program, but also the installation of a storm drain piping system. Storm drains would insure safe removal of undesirable runnoff and remove the potential of claims or law suits.

Downspout removal cost for the entire 12 sub-areas came to $4,556,160, with an equivalent annual cost of $528,589. Cost to build necessary storm drains where needed in the Carkeek Park area came to $15,276,000, which is equal to an equivalent annual cost of $1,772,260. Combining the cost of both downspout removal and storm drains resulted in total cost of $19,832,160 and a equivalent annual cost of $2,300,858.

Transport and treatment cost which includes capital cost to construct necessary secondary treatment facilities were extracted and updated from the following METRO reports:

Carkeek Park Infiltration/Inflow Analysis	1977
Systemwide Facility Plan Vol. 11	1977
Facility Plan of Carkeek Treatment Plans	1979

Updating of operation and maintenance cost to ENRCI 3000, produced an annual cost of $375 per million gallons for the flows pumped from North Beach, and $346 per million gallons for the flows entering by gravity to the Carkeek Park Treatment Facilities. Cost of operation and maintenance of all the measured infiltration/-inflow from North Beach system came to $119,288 annually, and from the remaining Carkeek Park area, $206,358 annually. Capital cost of updating existing treatment plant to handle infiltration/inflow to a peak of 30 million gallons per day and to construct necessary secondary treatment facilities, produce an incremental annual cost of $1,765,077. This capital cost combined with operation and maintenance cost produced a total transport and treatment cost of $2,168,200 annually.

To determine whether infiltration/inflow is non-excessive or possibly excessive in any of the individual sub-areas of this study, a cost-effective analysis was made to determine the cost of removing different percentages of infiltration/inflow from the system and compare it to the cost to transport and treat the same. From these costs, two curves were plotted and the total cost curve developed by the summation of the two curves. See Figure 6-2. These curves reflected the cost effective analysis of all sub-areas examined and evaluated in this study. Plotted points which fall to the left of the low point identifies those sub-areas that have excessive infiltration and are cost-effective to rehabilitate.

CONCLUSION

Of the 12 sub-areas analyzed in the Carkeek Park area, 9 were found to have excessive infiltration in the main line sewers and therefore found cost effective to rehabilitate. Total estimated cost to rehabilitate these nine sub-areas came to $2,260,409. The expected infiltration removed would be approximately 62.7% of the total infiltration of 757.7 million gallons annually. Rehabilitation of service laterals was found not to be cost effective to remove excessive infiltration. As for inflow, it was also found not cost effective to remove. This was due to the fact that rehabilitation cost to remove inflow included storm drain construction as well as downspout removal program. Storm drain construction estimated at $10,000/-acre, added $15,276,000 to the cost of inflow removal.

RECOMMENDATION

It is recommended that the City of Seattle conduct a Sewer System Evaluation Survey of all nine (9) sub-areas identified as having excessive infiltration. This survey should consist of physical inspection, cleaning, smoke testing and T.V. inspection to determine specific areas of excessive infiltration. The estimated cost to carry out the Sewer System Evaluation Survey is $205,757. The pipe to be inspected in these nine (9) sub-areas totals 308,866 feet or 58.5 miles. Once the Sewer System Evaluation Survey is accomplished, a sewer system rehabilitation program should be undertaken to reduce infiltration based upon the finding of the survey. The estimated cost to remove approximately 62.7% of the identified infiltration within the Carkeek Park Study Area is 2,260,049. Rehabilitation based on the methods and parameters set forth in this report ~~is~~ appears to be cost-effective and will reduce an annual infiltration of 467 million gallons. Annual savings in transport and treatment cost of $1,338,690 will be realized if the infiltration reduction program is carried out. ~~Actual savings to METRO will be $1,062,646 annually.~~

As the SCTS [illegible] to define the [illegible] necessary to eliminate excessive infiltration, it is recommended that inflow be examined as well. It is very possible that there may be small areas where inflow control may be cost effective even though this analysis shows that, in general, inflow correction will not be cost effective.

CHAPTER 2

BACKGROUND INFORMATION

The City of Seattle is currently conducting a 201 Facility Plan for the 20-year period 1985-2005 to develop a program for the transport, treatment and disposal of wastewater flows received from tributary component agency sewer systems. The Facility Plan is being conducted to address requirements of Section 201 of Public Law 92-500. The Infiltration/Inflow Analysis is an integral part of this plan, and its purpose is to determine if portions of extraneous water in the existing sewer systems can be reduced more economically than they can be transported and treated at METRO facilities. Specifically this analysis addresses the City of Seattle sewerage system that is tributary to the METRO Carkeek Park Treatment Plant.

Sewer systems throughout the nation are plagued by the problem of extraneous water entering the system. Many systems have reduced ability to carry sewage due to water entering the sewer systems through faulty joints, broken pipe, cross-connections to storm sewers, roof drain connections, and numerous other system defects. The traditional solution of providing more collection and treatment capacity is not always the most economical solution to this problem. In many instances, rehabilitating existing sewer systems may be more economical.

Physical Geography

The area served by the Carkeek Park plant encompasses the northwest corner of the City of Seattle that has a natural drainage to Puget Sound. For this analysis, it is assumed the Carkeet Park service area will remain as existing through the planning period.

Topography

Topography, as related to groundslope and natural drainage features, determines the route, size and slope of collection sewers and drainage basin configuration. It impacts requirements of and location of pumping stations. In the same manner, it affects natural drainage patterns and localized groundwater levels.

The upland areas of the Carkeek Park service area are typical of the extended gently rolling plains that predominate in the Puget Sound area, affording ideal conditions for gravity collection systems. The steep banks and rugged terrain along Puget Sound and Piper Creek have generally restricted residential development. The area southwest of Piper Creek drains to a local pumping station for transfer to the Carkeek Park plant.

Geology and Soils

The geology of an area is significant in the provision of wastewater facilities in terms of structural stability of pipelines and major structures. Soils formations, both surface and subsurface, have a direct effect on wastewater collection facilities. Subsurface characteristics dictate pipe bedding requirements and groundwater levels. If surface soils are imprevious in nature this reduces the potential of storms as an infiltration source, but increases the likelihood of stormwater ponding and therefore inflow.

Upland hills and areas consists of a shallow weathered soil from two to six feet in depth and underlain with hard cement fill of firm compact clay and hard pan. High groundwater heads have built up in local areas along the banks facing Puget Sound due to the low permeability of underlying subsoils. This high pressure has resulted in bank erosion and slides along Sound frontage property.

Morainic deposits of sand and gravel and recessional outwash deposits are also found over much of the uplands, extending in some instances to great depths and over a considerable area. Peat deposits have accumulated along courses of past and existing small creeks draining the uplands area as well as in local kettle-like depressions. Groundwater tables vary seasonally, with the high water table usually found in late Spring and the low water table found in late Summer.

Peat deposits and water bearing sand and gravel pockets are encountered in many areas, both uplands and lowlands. These soils contain large quantity of water, often creating a subterranean pocket or reservoir of water. Sewer pipes laid near of through these soils are susceptible to high infiltration if pipe joints are not tight. Based on age of most of the Sewer Systems found in Seattle and the type joint material used prior to the 1950's, infiltration can be expected to be high in these soils.

The low land soils usually consist of alluvial deposits of soft clay silts, and fine to coarse sands intermixed with gravel. The higher level sandy soils are easily drained. Peat up to 12 feet deep is encountered throughout the lowlands. In most areas of the lowlands, high groundwater tables are encounter-with water found at depths of 2 feet to 6 feet in the summer months and above the ground surfaces during the winter. These areas as well as those highland pockets of peat and gravel can be considered as the primary source of water infiltration into the sewer system..

Slide Areas

Soil conditions which could have a pronounced effect on the amount of extraneous flows in the City's sewer system are those areas identified as slide areas. Generally, the cause of sliding may be ascribed to as water percolating downward through the sand deposits to the upper face of the clay layer where it becomes entrapped and slowly brings a large volume of impervious ground along the steep slopes to a condition of saturation and suspension. On the event of heavy rainfall, the thoroughly dissolved ground is forced out and away from its place of lodgement and a slide occurs. In the Carkeek Park area several slides have been noted along the high cliff facing Puget Sound. Other slides have been recorded along the steep slope of Piper Creek Canyon. Many of these slides were triggered from manmade earth fills in an effort to reclaim more useable land for development.

Seismology

The Pacific Northwest area is considered to be seismically active. Earthquakes can rupture or weaken pipelines and structures, and the slow continuous movement that occurs along an active fault line can also rupture pipelines if provision for this movement is not considered in the original installation. No specific fault lines have been identified within the Carkeek Park service area; however, measurable tremors have been recorded. In 1970 a tremor of intensity V on the modified Mercalli Scale and magnitude 3.9 on the Richter scale had its epicenter only a few miles north of Carkeek Park. One therefore can assume that some structural damage may have occurred to the collection system, specifically sewers with rigid joint construction, providing access both for groundwater infiltration and sewage exfiltration.

Climate

The climate of Seattle is predominately a mid-latitude, west-coast, marine type. Marine air from the Pacific Ocean has a moderating influence in both winter and summer. Only occasionally does dry continental air from the north and east reach Puget Sound. The orographic lifting and cooling of the air masses moving inland results in persistent cloudiness and widespread precipitation. The general pattern of precipitation in the Seattle area is light in the summer, moderate in the spring and fall, and heavy in the winter. The 10 year average annual rainfall determined from the rain gauge located in the Carkeek study area produces an annual rainfall of 37.03 inches. See Figure 4-2 for Rain Gauge Locations. This precipitation falls on the land, and that which is not lost to evaporation, food supply for trees and plants, and runoff, percolated into the soil to resupply the groundwater. The level of groundwater fluctuates from season to season, attaining its highest level in mid spring and its lowest in late fall. Sewer constructed below this groundwater level increases the potential for infiltration. Flow monitoring carried out in this program has verified a substantial difference in infiltration between the wet season and the dry season. This substantiates the effect rainfall has on the watertable.

The percipitation which collects on the surface is another source of extraneous flows in the City's sewer systems. In Carkeek Park Study Area, many illegal connections and residential downspouts are connected directly into the sewer system. In some areas excessive inflow is beyond the pipes' capacity and often leads to overflows of sewage to the nearest body of water.

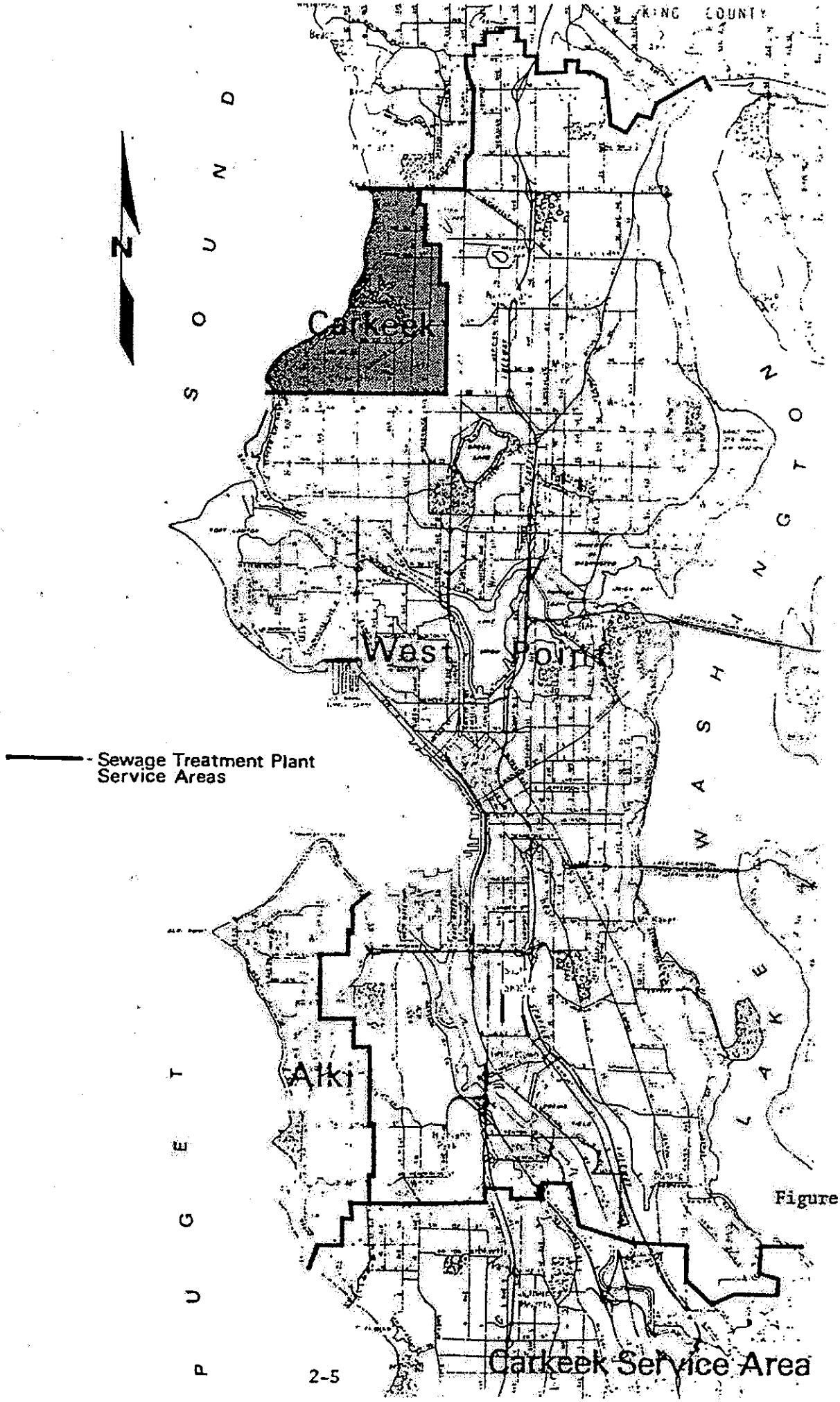


Figure 2-1

Carkeek Service Area

CHAPTER 3

EXISTING CONDITIONS

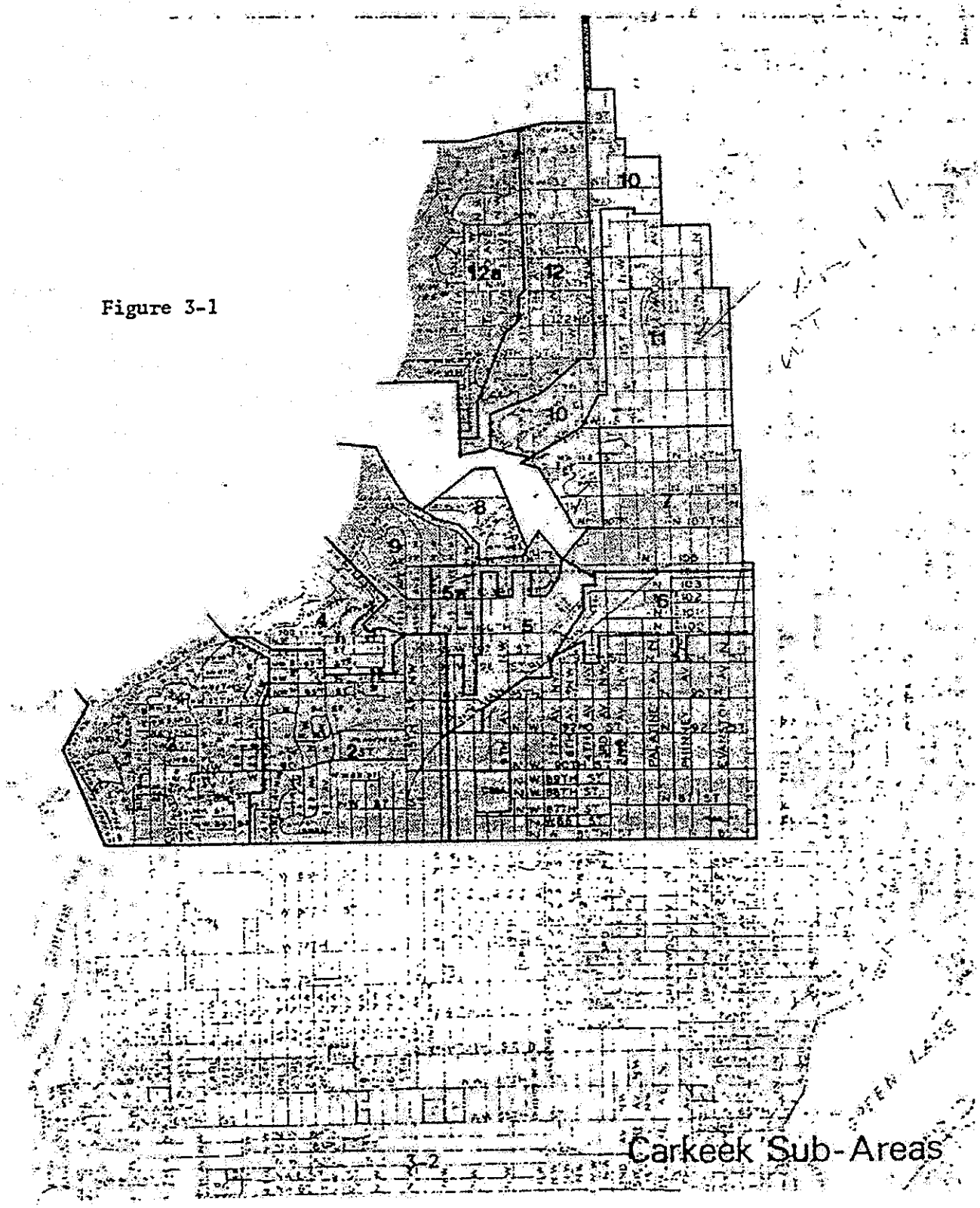
The Carkeek Park Wastewater Treatment Plant serves a residential area of 2658 acres located in the northwest corner of the City of Seattle. The service area is bounded by Puget Sound on the west, 85th Street on the south, Fremont Avenue on the east, and 145th Street on the north. See Vicinity Map Page 3-2. For this analysis, the total area was divided into 14 sub-areas, as shown in Figure 3-1. Three areas flow by gravity to the North Beach pump station and are then pumped to Carkeek Treatment Plant, and the other 11 sub-areas flow by gravity to the METRO interceptors leading to the plant.

The current population of the service area is 24,495. Population distribution and levels were obtained from the City of Seattle 1975 estimate of population and housing tracts, and the 1970 and 1990 population DOT maps prepared by Department of Community Development. This information provided means to determine the number of house connections per sub-area. This was accomplished by taking the estimated household size divided by the population of the sub-area. Population data was also used to estimate base wastewater flow.

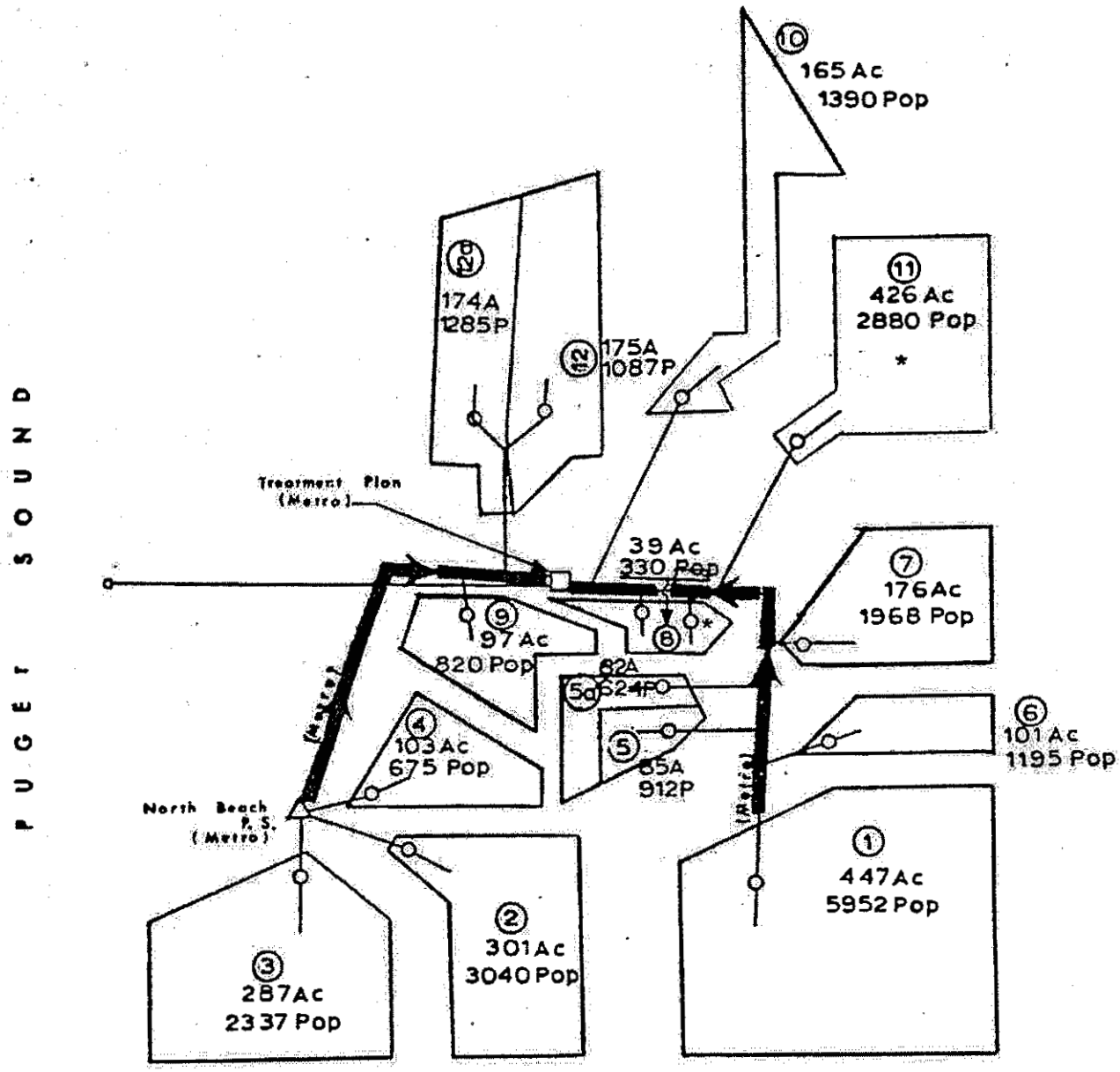
Drainage Basins

In an attempt to be more precise in pinpointing the areas of greatest infiltration/-inflow, the study area was divided into 14 sub-areas identified on the Flow Diagram. See Figure 3-2. These sub-areas were then monitored by installing flow monitoring recorders in carefully selected manholes that would reflect sewage flow for the entire area tributary to a specific sub-area. In all, some 94 flow charts were collected and evaluated on the 12 sub-areas that were monitored. Two sub-areas identified as number 8 and 11 on the Flow Diagram were not monitored due to the lack of suitable manholes for installing flow equipment.

Figure 3-1



Carkeek Sub-Areas



CARKEEK PARK FLOW DIAGRAM

FIGURE 3-2

LEGEND:

-o- Key Manhole

* Area Not Monitored

An inventory of sewers by sub-areas, including length of each, diameter size, acreage of sub-area, tributary population and service connections were tabulated and shown on Table 3-1 and 3-2.

Approximately 630 acres of the system drain by gravity to the North Beach pump station located at N.W. 100th Street and Triton Drive N.W. This area is characterized by steep ravines and steep bluffs along the waterfront. Three small local pumping stations serve portions of the areas along the waterfront in addition to METRO's North Beach station, which serves all the 630 acres. The flows are pumped from North Beach via a 14-inch diameter force main along the waterfront and up Piper Creek Canyon to the treatment plant. The 4.5 mgd capacity of the North Beach pumping station is exceeded during rainy periods resulting in combined sewer overflows through an outfall discharging to Puget Sound.

The area not served by North Beach flows by gravity to the METRO interceptor or force main which runs through Piper Creek Canyon. Most of the sub-areas which flow by gravity to the treatment plant have moderage slopes except near Carkeek Park where slopes are steeper. A bog area exists in a region of mild slope between Northwest 85th and Northwest 97th Streets and 6th Avenue Northwest and Greenwood Avenue North.

CITY OF SEATTLE

CARKEEK PARK

INFILTRATION/INFLOW STUDY

201 TASK B2b

August 1979

ENGINEERING DESIGN DIVISION
SEATTLE ENGINEERING DEPARTMENT

STUDY CONTRIBUTORS

The study was conducted by the 201/208 Planning Group of the Seattle Engineering Department's Design Division. Staff personnel involved in the major efforts in completing the study and report under the direction of Joe Talbot, Senior Engineer, are listed below.

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TABLE 3-1

CARKEEK PIPE INVENTORY

Sub Area No	Acres	Main Line Sewer Length (Feet)									Total	
		6"	8"	10"	12"	15"	18"	21"	24"	30"	Ft.	In.Di.Mi
1	447	21,275	56,915	1,270	2,620	340	1,665	670	200	0	84,955	129.0
2	301	0	44,930	5,125	265	985	0	0	0	0	51,385	81.2
3	287	2,680	32,460	3,930	1,310	935	1,830	0	220	0	43,365	72.1
4	103	415	9,630	1,570	825	580	850	0	0	0	16,770	24.2
5	85	2,977	11,216	0	0	0	0	0	0	0	14,193	20.4
5a	82	2,872	10,164	0	0	0	0	0	0	0	13,036	18.7
6	101	4,200	15,605	830	0	0	0	0	0	0	20,635	30.0
7	176	5,260	23,410	3,920	0	0	0	0	0	0	32,590	48.9
8	39	200	5,550	1,070	90	140	1,900	310	360	150	9,770	21.5
9	97	0	10,450	3,355	1,905	480	320	0	0	0	16,510	28.9
10	165	2,305	9,625	0	8,775	0	0	0	0	0	20,705	37.1
11	426	6,830	36,470	1,835	0	0	0	0	0	0	45,135	66.5
12	175	1,455	18,575	0	350	0	0	0	0	0	20,380	30.5
12a	174	3,795	19,575	2,740	0	0	0	0	0	0	26,110	39.2
	2,658	54,264	304,573	25,645	16,140	2,980	6,565	980	780	150	415,456	648.2

TABLE 3-2

SUB-DRAINAGE BASIN CHARACTERISTICS

Sub-Area No.	Sewered Area, acres	Population	Side Sewers	Main Line in.dia.miles	Side Sewers in.dia.miles
1	447	5,952	2,449	129.0	185.5
2	301	3,040	1,139	81.2	86.3
3	287	2,337	906	72.1	68.6
4	103	675	253	24.2	19.2
5	85	912	326	20.4	24.7
5a	82	624	223	18.7	16.9
6	101	1,195	492	30.0	37.3
7	176	1,968	703	48.9	53.3
8	39	330	118	21.5	8.9
9	97	820	307	28.9	23.3
10	165	1,390	615	37.1	46.6
11	426	2,880	1,274	66.5	96.5
12	175	1,087	354	30.5	26.8
12a	174	1,285	419	39.2	31.7
Total	2,658	24,495	9,578	648.2	725.6

Sewer System

Sewers in this area were first constructed in 1930 with most of the system being built in the 1950's and early 1960's. One of the first major sewer construction projects in the nation after the Second World War was the construction of sewers in this area under the jurisdiction of the Greenwood Sewer District. Pipes used in sewer construction up to and including most of the construction in this area were made of concrete with mortar joints. However, in the flat area south of Holman Road from Northwest 97th Street to Northwest 85th Street and from Greenwood Avenue to 7th Avenue Northwest., the soil is a fibrous, wet and highly compressible peat ranging from zero to 18 feet in depth. Sewers constructed by the Greenwood Sewer District in this very wet and spongy area utilized corrugated steel pipes. Records are not clear as to how much corrugated pipe was used, however, it is believed that at least 10,000 feet was installed in this area. Little is known about the type of joints used with the corrugated metal pipe, however, it has been reported that little if any testing was required to determine tightness of the corrugated metal pipe. Since the watertable in this area is just below the surface, infiltration could be expected to be high the year around.

Pump Station and Force Main

The North Beach pumping station at Northwest 100th Street and Triton Drive was constructed in 1962/63. Prior to this time a small primary treatment plant served this area. The digester and sedimentation tank were converted into the wet well and pump room. The flows enter the wet well through an 18-inch gravity sewer and leave the station via a 14-inch force main. The station had 4 pumps with a combined capacity of 4.5 mgd. When the capacity is exceeded, the sewage overflows through the old treatment plant's 15-inch outfall into Puget Sound. The force main extends in a northeasterly direction along the waterfront about 5,000 feet before turning up Piper Canyon another 2,500 feet to the treatment plant. One sewer connects to the force main along the waterfront and three along the canyon.

Treatment Facility

The Carkeek Park treatment plant was constructed during the same period as the North Beach pump station. The plant provides primary treatment with a design average dry weather flow of 3.5 mgd and a design peak wet weather flow of 20 mgd. The plant peak capacity is exceeded several times each year, depending upon particular storm characteristics. To meet the legal requirements of Public Law 92-500, secondary treatment facilities will be required. It has been assumed for this analysis that this will be accomplished by the addition of an air activated sludge biological treatment system at the Carkeek Park site.

Groundwater

Groundwater as an established groundwater table, a temporary perched table or percolating through the soil during and as a result of storms, is a potential infiltration source. A knowledge of the extent and level of groundwater relative to the sanitary sewer system can identify those areas subject to infiltration. For dry season periods, assuming no yard irrigation, the established groundwater table is the only infiltration source and only those sewers below the table, regardless of open joints or other structural defects, will be subject to infiltration. However, during the rainy season, percolating groundwater and temporary perched tables confuse the issue, making the identification of infiltrating sewers much more difficult. Typically through the rainy season established groundwater levels rise covering more of the sewer system and increasing the hydrostatic head on previously submerged areas. The direct influence of the seasonal fluctuating groundwater table in the Carkeek Park service area is well illustrated in the proceeding chapter.

Analysis of available established groundwater level data indicated that during the summer season those areas adjacent to streams and the area south of Holman Road between 8th Avenue Northwest and Greenwood Avenue Northwest have sewers below the groundwater table. During the wet season all the collection system is subject to percolating, temporary perched and rising established groundwater to some degree.

Stormwater Drainage

Stormwater ponding and leaking stormwater transfer lines are potential sources for both inflow and infiltration. The provision of efficient stormwater collection facilities and sealed stormwater transfer lines and ditches will reduce the possibility of these waters entering the sanitary sewer system. Points at which storm sewers and surface drainage ditches cross sanitary sewers have historically been sources of infiltration/inflow. Localized ponding, in addition to being a potential inflow source, feeds upper groundwater tables to become a potential infiltration source.

Most of the Carkeek Park service area has a storm drainage system consisting of open ditches alongside roads. The only area with an extensive storm sewer system is the area south of Holman Road between 8th Avenue Northwest and Greenwood Avenue Northwest. This area is boggy and has poor natural drainage. The storm drain system in this area is unique in that the collection system was constructed with perforated metal catch basins. The reason for the perforation in the catch basin was to allow storm water to percolate out and maintain the high water table. Dewatering of this area could cause serious settlement problems with all buildings built over the peat. The storm sewers in this area transport the flow along 8th Avenue Northwest to Northwest 105th Street where it discharges into Piper Creek, which then flows to Puget Sound. Piper Creek has had about 15 rock dams placed in the stream to help dissipate energy and reduce erosion. Several other short stretches of storm sewers exist between Northwest 105th Street and Carkeek Park, and in the North Beach area. These storm sewers, except North Beach storm sewers, also discharge to Piper Creek.

Sewer Maintenance

The Carkeek Park treatment plant service area sewers are maintained by the City of Seattle. The City currently has two TV inspection systems with two full time crews of 3 men systematically inspecting the entire City. In this way, the entire City is inspected once every 10 to 15 years with problem areas monitored more frequently when necessary. Even though over 40 percent of the sanitary and combined sewers in the City have been inspected in the past 10 years, very few obvious sources of infiltration have been identified. The primary purpose of the TV inspection thus far has been to locate structurally damaged pipe and places where sand and grit enter the system. About 50 maintenance persons are employed by the City to inspect, maintain, and repair the system. The most frequent maintenance problem in the Carkeek area is root intrusion with grease buildup being a close second.

The City of Seattle is divided into a north and a south district for sewer maintenance, with Denny Way as the dividing line. The north district has two patch crews, two sewer rodder crews, one water jet crew, and one sewer drag crew. The patch crews perform physical inspection of the sewers and repair minor problems. A separate sewer repair crew makes the major repairs.

METRO Facilities

The METRO interceptor picks up City of Seattle flows at the corner of Northwest 100th Street and 7th Avenue Northwest through a 21-inch pipe. The interceptor then runs north into Carkeek Park and down Piper Creek Canyon, at first decreasing to 15 inches, then gradually increasing in size as City of Seattle pipes are intercepted until it enters the treatment plant as a 24-inch pipe. The interceptor was constructed of reinforced concrete pipe with flexible "O" ring joints. Manholes were constructed of precast concrete walls and cast in place bases. Original construction was inspected and air tested by METRO's consultants prior to acceptance.

Summary

To more precisely define infiltration/inflow sources, the Carkeek Park service area has been divided into 14 sub-drainage basins previously identified in Figure 3-1. Three of the sub-areas flow to the North Beach pump station. Sub-drainage basin characteristics based on the data developed for each sub-area are shown in Table 3-2. The extent of the City of Seattle sewer for each sub-area has been expressed in terms of inch-diameter-mile of sewer. Side sewers have also been expressed in these units assuming each side sewer is equivalent to 100 feet, 30 feet of 6-inch and 70 feet of 4-inch pipe.

CHAPTER 4

METHODOLOGY

GUIDELINES

Work consisted of a systematic analysis of the 78 miles of pipe within the City's Carkeek Park sewer system to establish the existence or non-existence of excessive infiltration/inflow. Guidelines followed in preparing this report were the Environmental Protection Agency (E.P.A.) Handbook for Sewer System Evaluation and Rehabilitation, and the Systemized Approach to Infiltration/Inflow, prepared for Municipality of Metropolitan Seattle.

DIRECTION

Although the City Engineering Department has involved itself in many studies, reports and designs in expanding and improving the existing sewer system, no large scale study or effort was made to analyse the infiltration/inflow of its system other than the two most recent studies covering areas known as Lake Union South and Empire Way South. Municipality of Metropolitan Seattle (METRO) has completed its Infiltration/Inflow Analysis of the Carkeek Park System, and their report was used as a guide to completing the City's report. The preliminary task of this study was to set up a program of obtaining the flow data necessary to complete this study. The direction decided upon was to divide the Carkeek Park into very small units, called sub-areas, select a suitable manhole at the downstream point of each particular sub-area, and install monitoring equipment to gather flow data that could be analyzed for infiltration/inflow.

SEWER MAPS

An essential step required to accomplish the infiltration/inflow analysis was acquiring flow data through manhole monitoring, was to have maps showing existing sewer system. The Engineering Department's up-to-date 200 scale topographic sewer maps were found suitable for this purpose. These topography maps, covering one square mile of the City's sewer system, provided such information as pipe location and size, manhole elevations and the file number of the as-built construction plans. In order to provide a more practical map size for combining to make a composite map of a planned study area, all 200 scale section maps were reduced to 400 scale. These composite maps were then used as base maps in determining the boundary, size and number of sub-area, as well as assisting in selecting the manhole for installing flow monitoring equipment. From these maps, 14 sub-areas were originally established. The 400 scale sub-area maps provided all information necessary to complete the inventory of the sewer system. To assist in understanding the interconnection between sub-areas, a vector flow diagram was prepared as shown on Figure 3-2.

Table 4-1 gives an example of form used to record sewer characteristics and to inventory existing piping system.

Other records besides the as-built plans used extensively in this study, were the sewer cards which show side sewers connections from existing building to the main line. These records were helpful in establishing sub-area boundaries, number of buildings on the service, and approximate length of side sewer per block or main line sewer.

TABLE 4-1

DATA SHEET	INFILTRATION/INFLOW
AREA	Carkeek
SUB-AREA	1
POPULATION	5952
SIZE IN ACRES	447
NUMBER OF OVERFLOWS	0
NUMBER OF PUMP STATIONS	0
SOIL CONDITION	See Chapter 2, "Geology of Soils"
WATER TABLE	75% of Area Low, 25% High
NUMBER OF CONNECTIONS	2449

PIPE INVENTORY

4" x 244,900'/5280 (ft/mi) = 185.5

PIPE DIA.	Length of M.L. (Ft)			S.S.* Connection (Ft)	Total Pipe (Ft)	TOTAL In. Dia. Mi.
	Under 10 yr	10-20 yrs.	20yr & Over			
4"				244,900	244,900	185.5
6"			21,275		21,275	24.2
8"	175		56,740		56,915	86.2
10"			1,270		1,270	2.4
12"			2,620		2,620	2.4
15"			340		340	1.0
18"			1,665		1,665	5.7
21"			670		670	2.7
24"			200		200	0.9
27"						
30"						
36"						
42"						
TOTAL	175	0	84,780	244,900	329,855	
TOTAL MAIN LINE SEWER →			84,955	Total In. Dia. Mi. →		314.5

* Assume 100 feet per connection

MANHOLE SELECTION

Sub-area boundaries and selecting manholes for monitoring sewer flow were often conducted together. The most essential item to recording the flow of a sub-area was to find a manhole where all the flow tributary to the sub-area could be measured. The manhole selected had to be accessible, have straight through piping, no change in pipe size, uniform slope in and out of manhole, and be free of bends and side flows that would cause turbulence. Once the manhole was chosen, it was given a number that would prevail throughout the program and be used to record data taken at different time periods.

EQUIPMENT USED

Lacking equipment to monitor sewer flow, the City made arrangements to lease eleven (11) Manning Dipper Level Recorders with the understanding that lease fees could be credited toward purchase of the instruments. Two bubbler recorders and one water current meter which could not be leased, was purchased outright. After several months of evaluating the leased equipment and analysing the cost to determine whether it was more advantageous for the City to lease or buy, a decision was made to buy 12 Manning Dipper Level Recorders. This brought the total to 15 flow level instruments for use in this study.

EQUIPMENT INVENTORY

6	Manning Dipper Recorder	Type L2015
6	Manning Dipper Recorder	Type L3048
1	Volume Measuring Inst.	Type F3048
2	Bubbler Level Recorder	
1	Water Current Meter	
2	Flumes	

RAINFALL DATA

Both infiltration and inflow are affected by rainfall. The amount of inflow to a sewer system is directly related to rainfall. On the other hand, direct relationships between rainfall and infiltration are not so apparent. However, it is a fact that the groundwater table rises during the wet season and this increases the hydraulic head above the sewer pipe and causes more water to enter the sewer through defective joints, cracks or deteriorated manholes. Analysis of flow data taken in this study have shown wet weather infiltration is substantially higher than the dry weather readings.

Since the City Engineering Department has an on-going rain-gaging program, the rainfall data collected from 18 stations scattered throughout the City were used in this study. Computer print-out sheets provided daily and hourly rainfall as well as accumulation of rainfall in 5 minute, 10 minute, 20 minute, 30 minute and 45 minute periods. Following map, Figure 4-1 shows approximate location of rain gauges throughout the City. The recorders using a standard tilting-bucket with magnetic tape recorder, measured each 0.01 inch of rainfall and the time recorded at 1 minute intervals. Data is then fed into digital computers which summarize data of rainfall characteristics on computer print-out sheets. Table 4-2 shows the monthly and annual average rainfall recorded in Seattle area. A Rainfall-Intensity-Duration Curve is shown on Figure 4-3.

POPULATION DETERMINATION

A necessary element in completing the infiltration/inflow analysis for each designated sub-area in this study is to determine the population of those sub-areas. A standardized procedure of obtaining this data was established. Population distribution and levels were obtained from the City of Seattle 1975 estimate of population and housing tracts, and the 1970 and 1990 population DOT maps prepared by Department of Community Development. Physical check of an area to determine the degree of new development or community change assisted in determining which DOT map must be used. After the most appropriate DOT map had been selected for each census tract in a sub-area, the population was then determined for that sub-area.

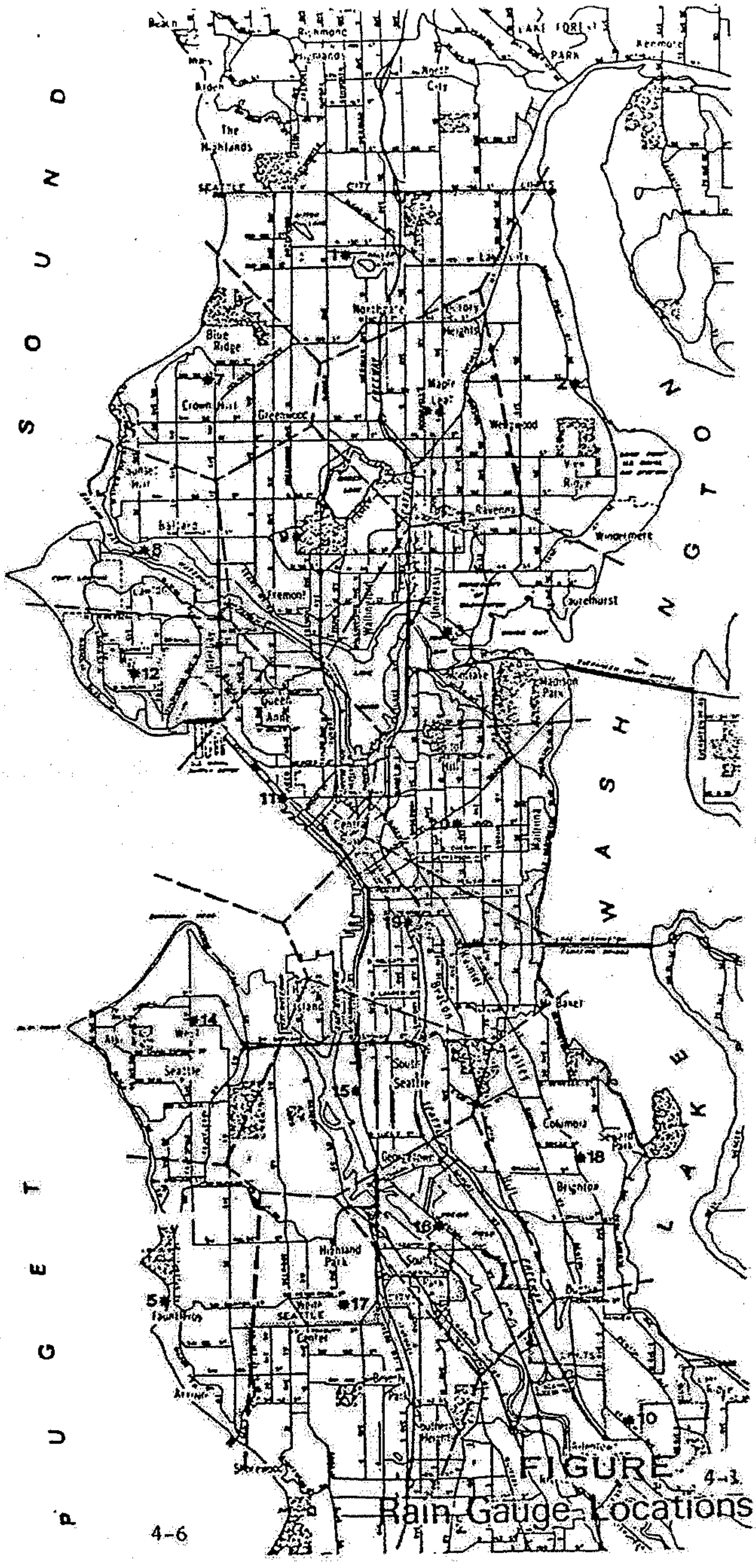


FIGURE 4-3
Rain Gauge Locations

Figure 4-2

RAINFALL - INTENSITY - DURATION - FREQUENCY CURVES

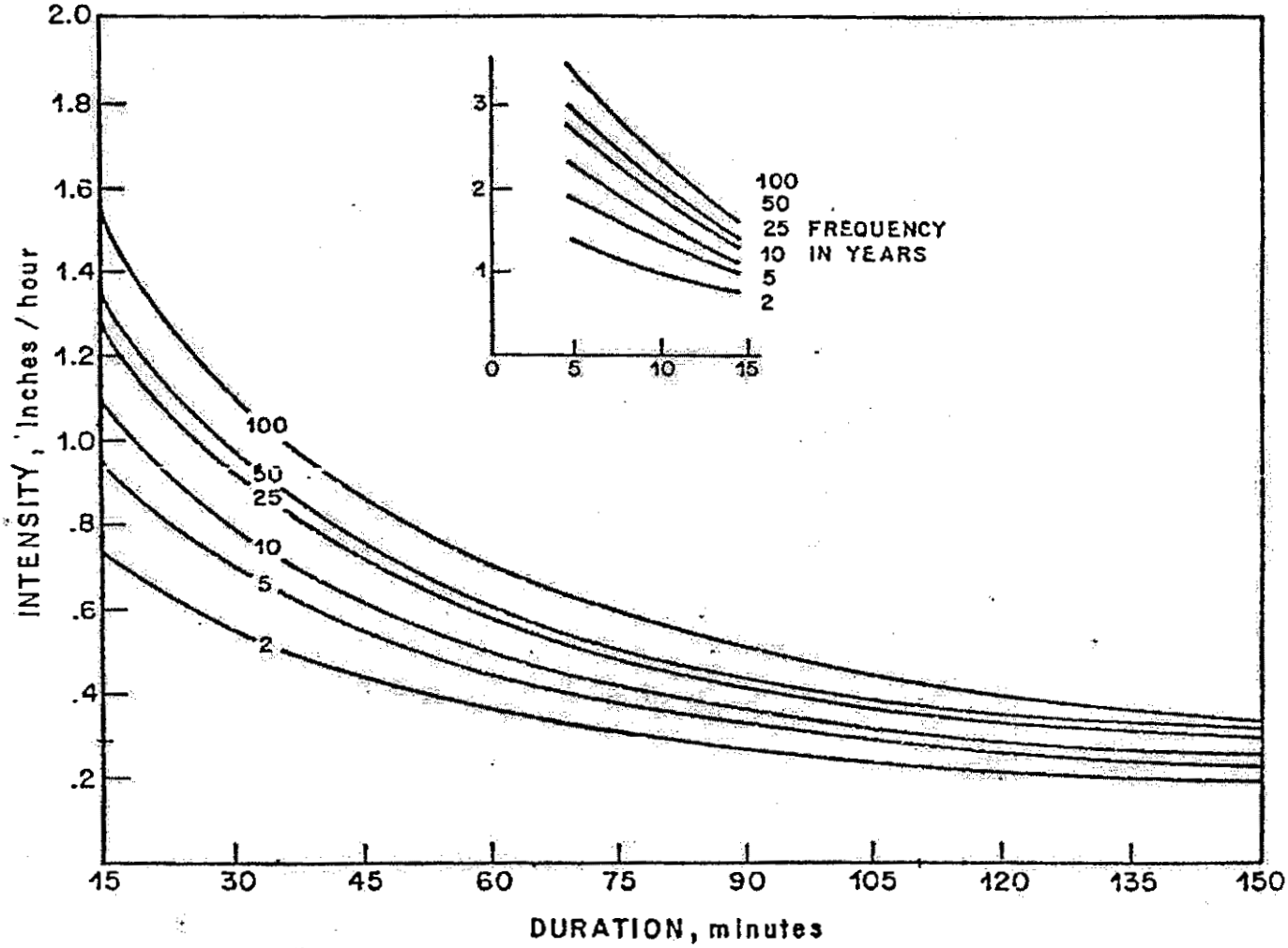


TABLE 4-2
CARKEEK PARK

RAINFALL, 10 YEAR MONTHLY AVERAGE

Month	Average
January	5.23
February	3.79
March	4.42
April	2.44
May	1.68
June	1.54
July	0.71
August	1.71
September	1.87
October	2.19
November	4.62
December	6.83
TOTAL ANNUAL AVERAGE	37.03

WATER CONSUMPTION

Considerable data obtained from the Water Department assisted in determining water consumption per capita per day. This data which included register of water bills and comparative report of metered water, showed that residential consumption ranges from 60 to 70 gallons per capita per day.

This was compared to water consumption rate determined by taking the wastewater flow measured in the entire Carkeek Park area and dividing it by its population. ~~Results here also support to~~ the use of 66.7 gallons per capita per day for water consumption.

DIFFICULTIES ENCOUNTERED

Many large projects requiring extensive amounts of data to be collected often encounter problems during the early stages that have to be overcome before consistent and acceptable data is developed. This infiltration/inflow study was no exception. Difficulties immediately came to light in our attempt to gather satisfactory information. Most of these difficulties could be attributed to manhole location, system design and problems associated with use of new monitoring equipment.

MANHOLES

Manholes selected for particular sub-areas were often found unsatisfactory during the field installation of the flow monitoring equipment. In many instances the suitability of the manhole was not questioned until the result of the flow measurements were evaluated. Where manholes selected were found unsuitable, another was chosen. This of course caused the sub-area boundaries to be altered and necessitated a correction of the total acreage, pipe inventory and population figure of the sub-area. This took time to correct and definitely had an effect on the project schedule. Realizing the need to correct the situation, procedures for selecting and monitoring manholes were revised to include field examination and a closer review of as-built plans to determine their suitability.

Some of the characteristics found in existing manholes that impair their use for obtaining accurate flow measurements are listed below.

1. Change in slope across manhole channel,
2. Slope change between incoming and outgoing pipe,
3. Rough and irregular constructed channels,
4. Change in size between incoming and outgoing pipe,
5. Drops in manhole,
6. Abrupt change in flow direction,
7. Manholes with more than one incoming flow source,
8. Steep pipe grades, and
9. Channel does not approximate shape of pipe.

SYSTEM PROBLEMS

Other problems encountered in gathering flow data was with the system itself. Many planned sub-areas were found impossible to monitor unless the sub-area was divided into many smaller units. Time and equipment available required, made it unfeasible to monitor these smaller units. Most often this situation was found where numerous separate small lateral systems, running parallel to each other, connected to a major trunk sewer and where flow level in the trunk was often controlled by a regulator. In this case, measurements along the trunk could not produce satisfactory flow results - and likewise, the laterals systems were too small to be measured individually. Where this situation was found, there was no choice but to exclude the area from further consideration. Sub-areas 8 and 11 were excluded due to these problems. See Figure 3-1.

EQUIPMENT

As new monitoring equipment was acquired and installed, results were evaluated to determine whether equipment was functioning properly. On numerous occasions flow recording equipment malfunctioned and this was clearly shown on the recording charts. Some of the problems experienced with the new monitoring equipment were such items as follows:

1. Loss of battery charge,
2. Probe stuck,
3. Recording device malfunction,
4. Out of ink, and
5. Instrument malfunction.

As soon as the chart revealed a problem, the equipment was readjusted. When equipment could not be corrected by mere adjustments, it was removed and taken to the shop for repair.

CHAPTER 5

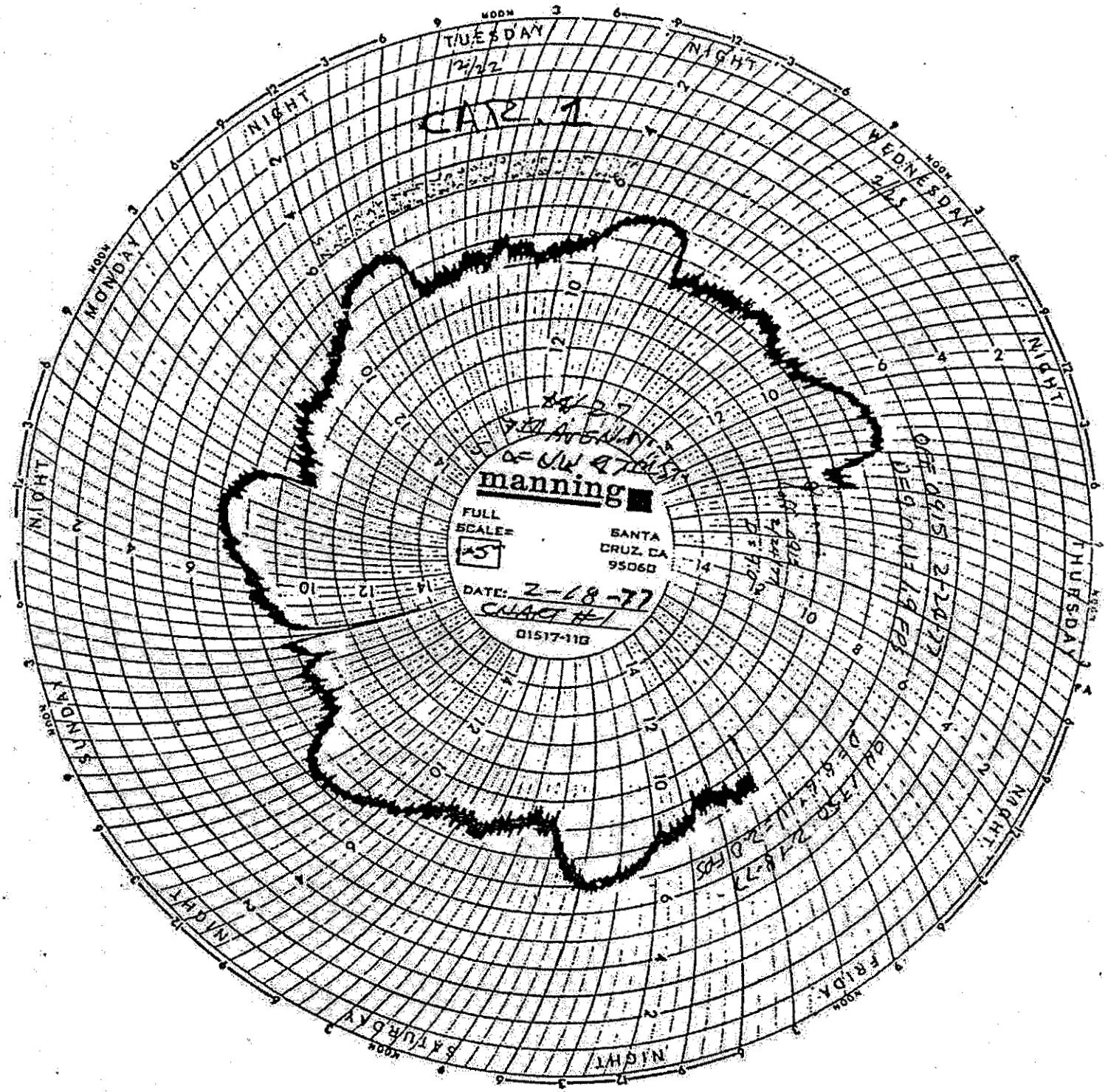
INFILTRATION/INFLOW DETERMINATION

An essential step in the infiltration/inflow analysis is to quantify total system infiltration/inflow and by sub-area analysis identify the extraneous flow contribution of discrete areas. The following flow information is required to conduct the cost effective analysis:

1. Base wastewater flow
2. Annual infiltration
3. Annual inflow
4. Annual infiltration/inflow
5. Peak infiltration
6. Peak inflow
7. Peak infiltration/inflow

Infiltration and inflow into sewerage systems are affected by rainfall, groundwater levels, soils, standard of sewer construction, degree of sewer maintenance, use of sewers for sub-surface drainage connections. The accurate determination of the quantities and location of infiltration and inflow within a sewer system is dependent on reliable flow and rainfall data. METRO maintains continuous flow records of wastewater influent flows at the Carkeek Park wastewater treatment plant and pump station hour-meter data at the North Beach pump station. However, in this study, all low data for each sub-area was obtained from the use of flow meters installed in carefully selected manholes. From these key manholes, sufficient data was collected to cover dry and wet weather flow as well as storm flows. The City of Seattle began monitoring manholes in the Carkeek Park Sewer System in November, 1976, and took its last readings in March, 1978. Lack of flow monitoring equipment prevented the collection of continuous year around flow readings, however, sufficient data was collected to make proper analysis of the system. In all, 94 flow level charts were collected. Figure 5-1 shows an example of the many flow level charts obtained from monitoring the 12 sub-areas in Carkeek Park. Rainfall records were obtained from data collected at Rain Gauge Station No. 3 located at Whitman Junior High School.

Flow data collected from each sub-area was tabulated in Table 5-1 for all dry weather flow, and in Table 5-2 for wet weather flows. All flow monitoring was accomplished from key manholes located in close proximity of each sub-area. Sub-areas in the North Beach area were monitored upstream from the METRO pump station. Sub-areas draining by gravity to the Carkeek Park Treatment Plant were monitored before flows entered the trunk line. Flows of sub-area 8 and 11 were not obtained because manholes could not be located or were found unsuitable for monitoring. Average daily flow taken from the twelve monitored sub-areas indicated a dry weather flow of 3.1 million gallons per day, and a wet weather flow of 3.7 million gallons per day. These figures would be slightly higher if all 14 sub-areas were included in the study. Analysis of storm flows showed a peak observed inflow of 18.01 million gallons per day. Calculation of peak inflow for 5 year design storm resulted in a peak flow of 28.60 million gallon per day.



Flow Level Chart
sub-area No. 1.

TABLE 5-1

DRY SEASON FLOWS (FROM MONITORING CHARTS)

SUB COMP NO	AVERAGE FLOW M.G.D.	MINIMUM FLOW M.G.D.	INFILTRATION (90% of Q Min.) M.G.D.
1	1.401	1.099	0.989
2	1.175	0.056	0.050
3	0.927	0.737	0.663
4	0.017	0.011	0.010
5	0.017	0.003	0.003
5a	0.061	0.034	0.031
6	0.113	0.068	0.061
7	0.113	0.045	0.041
9	0.084	0.020	0.018
10	0.035	0.002	0.002
12	0.059	0.030	0.027
12a	0.097	0.045	0.041
TOTAL	3.123	2.197	1.978

TABLE 5-2

WET SEASON FLOWS (FROM MONITORING CHARTS)

SUB. COMP NO.	AVERAGE FLOW M.G.D.	MINIMUM FLOW M.G.D.	INFILTRATION (90% of Q Min) M.G.D.
1	1.460	1.125	1.012
2	0.231	0.083	0.075
3	1.112	0.779	0.701
4	0.027	0.017	0.015
5	0.032	0.014	0.013
5a	0.075	0.040	0.036
6	0.163	0.118	0.106
7	0.146	0.064	0.058
9	0.150	0.0763	0.069
10	0.062	0.024	0.022
12	0.096	0.062	0.056
12a	0.147	0.093	0.084
TOTAL	3.701	2.495	2.247

BASE WASTEWATER FLOW

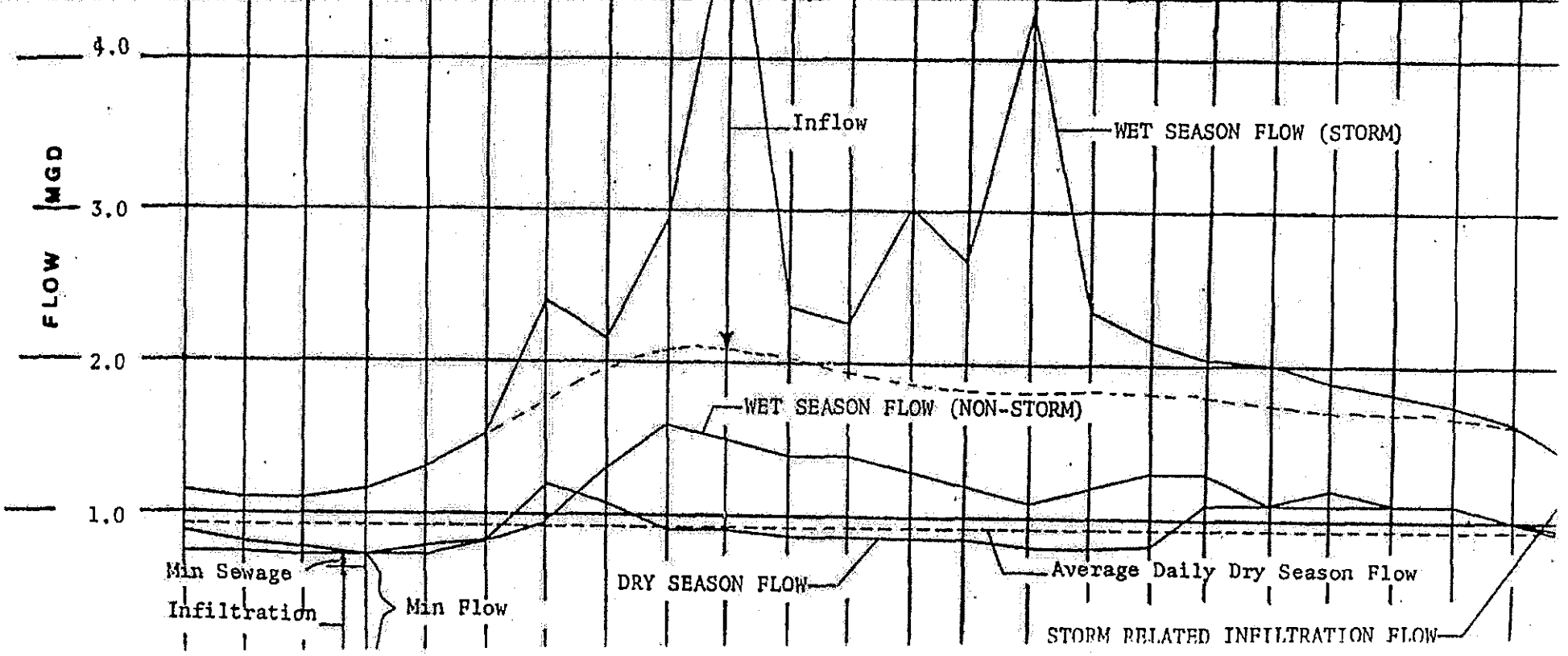
Wastewater flows attributable to residential, commercial and industrial uses are related to water consumption data collected from the Seattle Water Department for water consumption figures showed that residential consumption ranged from 60 to 70 gallons per capita per day. An average water consumption rate of 68 gpcd was determined for analytic purposes. Another method to estimate domestic wastewater base flows is to analyze early morning flows, a time when wastewater discharge is at a minimum, and compare with daily average flows for non-storm influenced days. Minimum flows are made up of infiltration plus minimum wastewater flows.

Analysis of the early morning wastewater flows that were recorded on the weekly flow charts were then compared to the average daily wastewater flow for non-storm periods. Assuming that 90 percent of the early morning flow is infiltration, the daily average wastewater flow can be determined. Ninety percent of the minimum wastewater flow is deducted from the daily minimum wastewater flow to obtain the amount of dry season infiltration. The dry season infiltration is deducted from the average dry season wastewater flow to determine the base sewage wastewater flow. See Figure 5-2. This base sewage wastewater can then be compared to results achieved through analysis of water use data. For the current tributary population of 24,495, winter water consumption is equivalent to 66.7 gallons per capita per day.

CARKEEK SUB. COMP. #3 FIGURE 5-2

Recorded Data

time	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	24
DATE	FEBRUARY 22, 1977 Tuesday										Dry Weather													
in. depth	3.6	3.6	3.5	3.5	3.5	3.7	4.4	4.3	3.9	3.9	3.8	3.8	3.8	3.8	3.7	3.7	3.7	4.3	4.3	4.5	4.2	4.3	4.1	4.
mgd flow	0.78	0.78	.74	.74	.74	.82	1.2	1.1	0.92	.92	.87	.87	.87	.87	.82	.82	.82	1.1	1.1	1.2	1.1	1.1	1.0	.
DATE	NOVEMBER 19, 1977 Saturday										Wet Season (non storm)													
in. depth	3.8	3.7	3.6	3.6	3.6	3.7	4.0	4.6	5.1	5.0	4.9	4.8	4.7	4.5	4.3	4.5	4.6	4.6	4.3	4.2	4.2	4.2	4.1	3.
mgd flow	.87	.82	.78	.78	.78	.82	.96	1.3	1.6	1.5	1.4	1.4	1.3	1.2	1.1	1.2	1.3	1.3	1.1	1.1	1.1	1.1	1.0	.
DATE	NOVEMBER 25, 1977 Friday										Wet Weather (storm)													
in. depth	4.4	4.3	4.4	4.4	4.7	5.0	6.4	6.0	7.1	10.0	6.3	6.2	7.2	6.7	8.8	6.3	6.0	5.8	5.8	5.6	5.5	5.4	5.2	4.
mgd flow	1.16	1.1	1.16	1.16	1.3	1.5	2.4	2.13	2.92	5.29	2.34	2.23	3.0	2.62	4.28	2.34	2.13	2.0	2.0	1.87	1.80	1.74	1.62	1.
0.91" rain	.01	0	.01	.02	0	.08	.07	.13	.19	.05	.02	.09	.08	.12	.03	0	0	0	.01	0	0	0	0	0



An alternate method of determining infiltration and base wastewater flow is listed as follows:

$$Qmin = Q_{w\ min} + \text{infiltration} \quad (1)$$

Average daily flows are made up of wastewater flows plus infiltration:

$$Q_{av} = Q_{w\ av} + \text{infiltration} \quad (2)$$

The relationship of average wastewater flow to minimum flow on the basis of tributary population has been documented by a number of researchers. Using data developed by Metcalf and Eddy in "Wastewater Engineering", a typical relationship is:

$$Q_{w\ min} = Q_{w\ av} \times f \quad (3)$$

where $f = \frac{(P)}{5}^{0.2}$ where (P = population in thousands)

By substituting equation (3) in (1) above, the following expression is developed:

$$Q_{min} = Q_{w\ av} \times f + \text{infiltration} \quad (4)$$

Infiltration and base wastewater flow can be estimated by the analysis of any 24 hour period by applying equations (2) and (4). Table 5-3 and Table 5-4 tabulate Infiltration and Wastewater (Qw Min) for Dry and Wet Seasons respectively.

[illegible]

TABLE 5-3

DRY SEASON FLOWS

(M.G.D.)

No.		From Monitoring Charts		Qw Ave.	Qw Min	Infiltration		f
Sub Comp	M.H.	Q Ave.	Q Min.			*	90% of Q Min.	
1	27	1.401	1.099	0.425	0.123	0.976	.989	.29
2	7	0.175	0.056	0.159	0.040	0.016	.050	.25
3	28	0.927	0.737	0.250	0.060	0.677	.663	.24
4	29 A	0.017	0.011	0.007	0.001	0.009	.010	.18
5	31	0.017	0.003	0.017	0.003	0.000	.003	.20
5a	30	0.061	0.034	0.033	0.006	0.028	.031	.18
6	6	0.113	0.068	0.057	0.012	0.056	.061	.21
7	5	0.113	0.045	0.088	0.020	0.025	.041	.23
9	8	0.084	0.020	0.079	0.015	0.005	.018	.19
10	34	0.035	0.002	0.042	0.009	0.007	.002	.21
12	58	0.059	0.030	0.036	0.007	0.023	.027	.20
12a	59	0.097	0.045	0.066	0.014	0.031	.041	.21
	TOTAL	3.123	2.197	1.242	0.304	1.892	1.978	

* I = Q Min. - Qw Min.

TABLE 5-4

WET SEASON FLOWS

(M.G.D.)

No.		From Monitoring Charts		Qw Ave	Infiltration			f
Sub. Comp.	M.H.	Q Ave.	Q Min.		90% of Q Min.	Storm Related+	*	
1	27	1.460	1.125	0.472	1.012	0.800	0.988	.29
2	7	0.231	0.083	0.197	0.075	0.290	0.034	.25
3	28	0.112	0.779	0.438	0.701	0.540	0.674	.24
4	29 A	0.027	0.017	0.012	0.015	0.084	0.015	.18
5	31	0.032	0.014	0.022	0.013	0.016	0.009	.20
5a	30	0.075	0.040	0.043	0.036	0.108	0.032	.18
6	6	0.163	0.118	0.057	0.106	0.012	0.106	.21
7	5	0.146	0.064	0.106	0.058	0.218	0.039	.23
9	8	0.150	0.0763	0.091	0.069	0.095	0.059	.19
10	34	0.062	0.024	0.048	0.022	0.018	0.014	.21
12	58	0.096	0.062	0.0421	0.056	0.025	0.053	.20
12a	59	0.147	0.093	0.068	0.084	0.020	0.079	.21
TOTAL		3.701	2.495	1.596	2.247	2.226	2.102	

+ From Charts
* I = Q Min - Qw Min.

The infiltration volume from each sub-area was determined by tabulation of daily infiltration flows recorded during dry, wet non-storm, and storm seasons. The resulting flow volumes were then distributed on a proportionate basis to mainline and side sewer systems. Peak infiltration flow and total annual infiltration flow values were then developed by summing related proportionate flow from dry, wet non-storm, and storm season readings. Page 5-12 illustrates an example form used to tabulate peak and annual infiltration. All infiltration values tabulated on these forms are then summarized on Tables 5-6 and 5-6A.

The following flow system characteristics were obtained by relating the infiltration values to each of their specific tributary characteristics:

1. Within sub-area - infiltration (gallon/day/identified source).
2. Main line system - infiltration (gallons/day/inch diameter mile).
3. Side Sewers - infiltration(gallons/day/inch diameter mile).

Typical sewer construction specifications have accepted infiltration rates in a range of 250 to 750 gallons/day/inch diameter mile. With the advent of improved jointing materials, and an increased emphasis on minimizing infiltration, most new sewer construction specifications have required that the 250 gallons/day/inch diameter mile criteria be met.

EXAMPLE

TABULATION OF PEAK AND ANNUAL INFILTRATION

Area CARKEEK - 1 Mainline 129.0 Inch Dia. Mile

Water Table 2/3 Low Side Sewer 185.5 Inch Dia. Mile

1/3 High Total 314.5 Inch Dia. Mile

Total Daily Infiltration: Dry .989 M.G.D. Wet-Dry= .023 M.G.D

Wet 1.012 M.G.D.

Storm Related 0.80

Distribution of Infiltration to Mainline and Side Sewer:

Dry Weather Infiltration: M.L. S.S.

Low Water Table: 100% 0%
High Water Table: 70% 30%

Wet Weather Infiltration: Measured difference between dry and wet infiltration is pro-rated between Mainline and Side Sewer on the Ratio of Inch Dia. Mile.

Storm-Related Infiltration: Storm -related infiltration shall be pro-rated in ratio to the Inch Dia. Mile of Mainline and Side Sewer (For peak infiltration only).

$\frac{\text{Total Mainline}}{\text{Total S.S. \& M.L.}}$ In. Dia. Mile = 41.02 % to M.L.

$\frac{\text{Total Side Sewer}}{\text{Total S.S. \& M.L.}}$ In. Dia. Mile = 58.98 % to S.S.

Peak Infiltration:

	Dry		Wet-Dry		Storm-Related				
M.L.	.8901	+	.00943	+	.32816	=	1.22769 M.G.D.	= 9,517	G/D/In.Di. Mi.
S.S.	.0989	+	.058333	+	.47184	=	.62907 M.G.D.	= 3,391	G/D/In.Di. Mi.

Ranking: M.L. 5

S.S. 3

Annual Infiltration:

$$\text{M.L.}\left(\frac{\text{Wet}^{*}\ .009435 + \text{Dry}^{*}(.8901)\ 2}{2}\right) \times 365 = 326.61 \text{ M.G./Yr.}$$

$$\text{S.S.}\left(\text{Wet}^{*}\ .058333 + \text{Dry}^{*}\ .0989\right) \times 182.5 = 28.69 \text{ M.G./Yr.}$$

TOTAL ANNUAL INFILTRATION = 355.30 M.G./Yr.

* These are the pro-rated values.

TABLE 5-6

Infiltration Summary

Area CARKEEK

Sht. 1 of 2

Sub-Area				1	2	3	4	5	5a	6	7
Basic Sewage				0.123	0.040	0.060	0.001	0.003	0.006	0.012	0.(
Dry Average				1.401	0.175	0.927	0.017	0.017	0.061	0.113	0.:
Wet Average				1.460	0.231	1.112	0.027	0.032	0.075	0.163	0.:
Infiltration	Wet	MGD		1.012	0.075	0.701	0.015	0.013	0.036	0.106	0.(
		GPD/ In Dia Mile		3218	448	4982	346	288	1011	1575	568
	Dry	MGD		0.989	0.050	0.663	0.010	0.003	0.031	0.061	0.(
		GPD/ In Dia Mile		3145	298	4712	230	66	871	906	402
	Storm	MGD		0.800	0.290	0.540	0.084	0.016	0.108	0.012	0.:
		GPD/ In Dia Mile		2544	1731	4122	1935	355	3034	178	2135
	Peak	Main Lines	MGD	1.228	0.203	1.002	0.060	0.015	0.090	0.087	0.
			GPD/ In Dia Mile	9517	2497	13904	2065	723	4830	2888	3140
		Side Sewer	MGD	0.629	0.175	0.302	0.039	0.014	0.054	0.032	0.
			GPD/ In Dia Mile	3391	2029	4396	2049	577	3176	854	2297
	Annual	Main Lines		326.61	20.46	249.75	4.16	1.92	11.79	25.93	16.
		Side Sewers		28.69	2.35	3.38	0.40	1.00	0.43	4.55	1.
Ranking		Main Line		5	3	5	3	2	4	3	3
		Side Sewers		3	3	4	3	2	3	2	3

TABLE 6A

Infiltration Summary

Area CARKEEK

Sht. 2 of 2

Sub-Area				8*	9	10	11*	12	12a	TOTAL
Basic Sewage				--	0.015	0.009	--	0.007	0.014	0.304
Dry Average				--	0.084	0.035	--	0.059	0.097	3.123
Wet Average				--	0.150	0.062	--	0.096	0.147	3.701
Infiltration	Wet	MGD		--	0.069	0.022	--	0.056	0.084	2.247
		GPD/ In Dia Mile		--	1322	263	--	977	1185	14377
	Dry	MGD		--	0.018	0.002	--	0.027	0.041	1.978
		GPD/ In Dia Mile		--	345	23.9	--	471	578	12048
	Storm	MGD		--	0.095	0.018	--	0.025	0.020	2.226
		GPD/ In Dia Mile		--	1820	215	--	436	282	18787
	Peak	Main Lines	MGD	--	0.099	0.019	--	0.056	0.076	3.087
			GPD/ In Dia Mile	--	3422	508	--	1827	1935	47656
		Side Sewer	MGD	--	0.065	0.021	--	0.025	0.028	1.507
			GPD/ In Dia Mile	--	2795	454	--	943	888	23849
	Annual	Main Lines		--	11.73	2.35	--	12.67	19.30	703.12
		Side Sewers		--	4.15	2.03	--	2.48	3.51	54.59
Ranking		Main Line		--	3	2	--	3	3	--
		Side Sewers		--	3	1	--	2	2	--

* Did not monitor

Substituting data for February 23, 1977, from Sub-area No. 1, where average daily flow was 1.4 mgd and minimum flow 1.1 mgd, in equations (2) and (4) indicates that infiltration is approximately 0.98 mgd for that day. Thus the per capita sewage contribution for Sub-area No. 1 with a population of 5,952 is:

$$Qw\ Ave = \frac{Q\ ave - Q\ min}{1-f} \quad 1 \times 10^6 \div 5{,}952 = 71 \text{ gallons/capita/day}$$

where $f = \frac{(P)^{0.2}}{5}$ and P = Population in thousands.

INFILTRATION ALLOCATION

The volume of infiltration occurring with the mainline and side sewer systems have been identified for each sub-area. Infiltration allocation between the mainline, side sewers, and known sources directly affects the effectiveness of any sewer system rehabilitation program. The potential infiltration sources for non-storm periods are groundwater, yard irrigation, and for storm periods, groundwater and rainfall percolating through the ground. For this analysis, the infiltration in each sub-area has been allocated to mainline sewers and side sewers according to the extent of their respective inch diameter mile. Maximum infiltration values for both mainline and side sewers are expressed in terms of gallons/day/inch diameter mile and have been determined for each sub-area. For example and from the Infiltration Summary Sheet for Sub-area No. 1 these values range from 508 to 13,600 gallons/day/inch diameter mile for the mainline sewers and 454 to 4,112 gallons/day/inch diameter mile for the side sewers. Ranking of each sub-area was determined from these figures. In all cases, mainline sewer were allocated higher percentage of infiltration and therefore produced the highest ranking.

TOTAL SYSTEM INFILTRATION

Infiltration characteristics were determined by analysis of each sub-area monitored data. Continuous weekly flow recording were evaluated to produce a graph which reflected as near as possible, the flow variations found in each sub-area. Flow data taken at different seasons permitted the collecting and charting of both wet and dry weather sewage flow. Infiltration for both dry and wet weather was established and varified as being approximately 90 percent of the minimum flow recorded at 3:00 a.m. to 6:00 a.m. Tables 5-3 and 5-4 tabulate the amounts of infiltration found to be in each sub-area for dry and wet seasons respectively. For storm days, infiltration was calculated by analysis of the non-storm days immediately following the storm and applying the value to the preceeding storm day to determine storm infiltration effect. The data analyzed from the 12 sub-areas monitored indicate a maximum infiltration flow of 4.5 million gallons per day occurring during height of the wet season, and a minimum infiltration of 1.98 million gallons during the summer months. Total annual infiltration came to 757.7 million gallons.

Table 5-5 tabulates Infiltration/Inflow values in million gallons for each sub-area.

TOTAL SYSTEM INFLOW

By definition, inflow is limited to storm periods. Inflow characteristics were determined by analysis of each sub-areas monitored flow data. First, the flow recording of a storm, was evaluated and plotted on chart along with a curve produced from a wet weather non-storm day. See Figure 5-2. From these two curves the net rate of inflow and storm related infiltration were determined. Peak observed inflow from the 12 monitored sub-areas came to 18.01 million gallons per day. In order to reflect the inflows of a particular type of storm, the peak inflow was adjusted to a 5 year design storm. This was accomplished by setting up a ratio of the design and observed rainfall intensities with the determined peak inflow to produce the expected flow for a 5 year design storm. This resulted in an adjusted peak inflow rate of 5.30 million gallons per day for sub-area 1, and 28.60 million gallons per day for all 12 sub-areas. Inflow peaks with a return frequency of occurrence of one in five years were estimated by the following relationship:

$$\frac{\text{Max. Rainfall Accumulation}}{\text{5-year Storm Rainfall Accum.}} = \frac{\text{Observed Peak Storm.}}{\text{5 year Peak}}$$

Annual inflow was determined for each sub-area, then summed to give total annual inflow. Annual inflow was calculated by multiplying the observed inflow with the 10 year average rainfall for Carkeek Park area which is 37.03 inches, and dividing this value by the sum of all rainfalls which occurred during the inflow measurement period. Total annual inflow came to 155.8 million gallons. Equation for estimating annual inflow was by following relationship.

$$\text{Yearly Inflow} = \frac{\text{(Measured Inflow) (Yearly Rainfall)}}{\text{Rainfall during measuring period.}}$$

MANHOLE MONITORING - FLOW DETERMINATION

The Manning Dipper Level Recorders were installed by City of Seattle personnel in key manholes. Each manhole was monitored for several weeks during dry and wet seasons from November 1976 through March 1978.

Flow characteristics were determined by interprinting recorded flow depths into m.g.d. by using the following Manning equation:

$$Q = \frac{k^1 \ d^{8/3} \ s^{1/2}}{n}, \quad \text{where } k^1 = \frac{D}{d}, \ D = \text{depth of water}, \ d = \text{diameter of}$$

channel, s = slope in pipe, and n = coefficient of channel roughness.

Inflow peaks for storms that occurred during the monitoring period were determined by subtracting the flows of wet season non-storm days from flows of wet season storm days.

Infiltration sources for non-storm periods are groundwater and yard irrigation and for storm periods, groundwater and rainfall percolating through the ground.

Inflow sources are roof drains, surface drainage and near surface open joints in the sewer system.

Roof and surface drain sources can be eliminated by disconnection or relocation to storm sewers. Elimination of inflow from near surface side sewers requires either replacement or rehabilitation.

Peak infiltration values for both mainline and side sewers expressed in terms of gallons/day/inch diameter mile are given for each sub-area on Infiltration Summary Sheets. Peak inflow values for direct connection and side sewers are given in Table 5-7 in million gallons per day.

TABLE 5-7

INFILTRATION - INFLOW VALUES

SUB AREA NO.	SEWERED AREA ACRES	WASTEWATER BASE FLOW MGD	INFILTRATION		INFLOW+		
			PEAK * WET SEASON MGD	ANNUAL MG	PEAK RATE MGD		ANNUAL MG
					OBSERVED	5 YR STORM	
1.	447	0.425	1.812	355.3	2.18	5.30	36.6
2.	301	0.159	0.365	22.81	2.58	2.47	12.6
3.	287	0.250	1.241	253.13	2.99	4.95	19.6
4.	103	0.007	0.099	4.56	2.53	2.43	9.4
5.	83	0.017	0.029	2.92	0.27	0.43	1.8
5a.	82	0.033	0.144	12.22	0.32	0.42	3.6
6.	101	0.057	0.118	30.48	1.06	1.02	2.9
7.	176	0.088	0.276	18.07	1.20	1.15	20.2
9	97	0.079	0.164	15.88	2.74	4.90	25.0
10.	165	0.042	0.040	4.38	0.42	1.28	2.5
12.	175	0.036	0.081	15.15	0.27	2.16	11.0
12a.	174	0.066	0.104	22.81	1.45	2.09	10.6
TOTAL	2,193	1.242	4.473	757.71	18.01	28.60	155.8

*Wet Season Non-storm Infiltration plus Storm-Related Infiltration

+ For Derivation of Inflow Values see Computation Sheet Page 5-20

EXAMPLE

COMPUTATIONS

OBSERVED PEAK INFLOW:

From Monitoring Chart #2 sub. comp. #1

Observed Peak Inflow = 2.18 M.G.D.

ANNUAL INFLOW:

For sub. comp. #1 and for the storm on March 2, 1977

Total Inflow = $(23.21)\ \frac{(1)}{24} = 0.968$ M.G.D.

Total Annual Inflow = $\frac{(0.968)\ (37.031)}{0.98} = 36.6$ M.G.Y.

5-YEAR PEAK INFLOW:

For sub. comp. #1 and for storm on March 2, 1977

Rainfall for 6-hr storm = 0.44 inch

Peak Inflow = 2.18 MGD

5-year Storm 6-hr Rainfall Accumulation = 1.07

X = 5-Year Storm

$\frac{0.44}{2.18} = \frac{1.07}{X}$ X = 5.30 M.G.D.

TABLE 5-8

INFLOW RATE DETERMINATION AND RANKING

SUMMARY

SUB AREA NO	ADJUSTED [a] PEAK INFLOW MGD	ADJUSTED PEAK INFLOW RATE	INFLOW RANKING
1	5.30	11,857	5
2	2.47	8,206	4
3	4.95	17,247	5
4	2.43	23,592	5
5	0.43	5,059	4
5a	0.42	5,122	4
6	1.02	10,099 gpad	5
7	1.15	6,534	4
9	4.9	28,893	5
10	1.28	7,758	4
12	1.82	10,400 gpad	5
12a	2.09	12,011	5

[a]Based on 1 in 5 year storm

CHAPTER 6

COST EFFECTIVE ANALYSIS

A cost-effectiveness analysis has been conducted to determine whether the infiltration/inflow is possibly excessive or non-excessive. Infiltration/inflow is defined as being excessive if the estimated total costs for the correction of infiltration/inflow conditions are less than the total costs for transportation and treatment of these flows.

Infiltration/Inflow Removal

Infiltration/inflow sources are removed from a sewer collection system by rehabilitating the sewer pipes and disconnecting non-wastewater discharges. This rehabilitation work can upgrade a sewer system to reduce infiltration to the level of a new sewer line (250 gallons per day per inch diameter mile). The disconnection of non-wastewater sources can reduce all inflow allocated to these sources. In most systems, the elimination of all inflow would also require rehabilitation of service laterals.

Two major tasks will have to be conducted in order to accomplish correction of excessive infiltration/inflow conditions. These major tasks are a sewer system evaluation survey and a sewer system rehabilitation program.

In developing an effective sewer system rehabilitation program, the first phase is to conduct a Sewer System Evaluation survey of the sewer collection system. The data and information collected in conducting this survey is used to prepare a sewer system rehabilitation program which will propose to eliminate all defined excessive infiltration/inflow. The cost of the evaluation survey will depend upon the extent of the field investigations, accumulated flow data records, and data that may identify specific problem areas.

All cost estimates for rehabilitating the sewer system are directly related to the length of existing sewers, structural conditions of the sewer lines, number of manholes requiring repair, and the number of stormwater cross connections. The rehabilitation work will be at a minimum scope if infiltration/inflow is concentrated in a small area.

The following infiltration/inflow ranking method has been developed to provide a systematic approach to the sewer system evaluation survey and rehabilitation program for infiltration/inflow reduction. This infiltration and inflow ranking method is used as a basis for developing the sewer system evaluation survey and rehabilitation program. Actual inflow values are utilized for a program to reduce inflow.

The adopted infiltration and inflow rankings are as follows:

Ranking	Infiltration, gallons/day/ inch diameter mile	Inflow Gallons/day/acre
1	0-500	0-750
2	500-1500	750-2000
3	1500-4000	2000-5000
4	4000-7500	5000-9000
5	7500	9000

The infiltration and inflow ranking for each of the sub-areas tributary to the Carkeek Park plant are shown in Table 6-1. For the economic analysis, costs are based on an Engineering News Record Construction Cost Index (ENR-CCI) of 3,000. To account for the different effective lives of rehabilitation components, costs are compared on the basis of equivalent annual cost and calculated from conversion factors shown on Table 6-2.

Sewer System Evaluation Survey

The sewer system evaluation survey is a systematic examination of the sewer system which is comprised of five basic steps. These five steps are physical inspection, smoke testing, preparatory sewer cleaning, television inspection and a sewer report that documents development of a recommended rehabilitation program.

The extent of the survey is dependent on the infiltration/inflow levels determined in this report. In general the extent of each step with exception of physical inspection and smoke testing, will decrease as each task is completed and as problem areas become more specifically defined with each step of the evaluation survey.

In Table 6-3 for each infiltration/inflow ranking, the percent of sewer lines involved in each task is shown. The maximum ranking of either infiltration or inflow indicates the extent of the sewer system evaluation survey. The percentage factor is multiplied by the length of sewer within the particular sub-area to obtain the pipe length to which the particular function is applicable. Task costs are calculated by applying the unit cost data values as shown in Table 6-4 to the pipe length applicable for each task.

TABLE 6-1

INFILTRATION/INFLOW RANKING

SUB AREA NO.	INFILTRATION				INFLOW	
	GALLON/DAY/INCH DIA. MILE		RANKING		GALLONS/ ACRE/DAY	RANKING
	MAIN LINE	SIDE SEWER	MAIN LINE	SIDE SEWER		
1.	9,517	3,391	5	3	11,857	5
2.	2,497	2,029	3	3	8,206	4
3.	13,620	4,112	5	4	17,247	5
4.	2,469	2,049	3	3	23,592	5
5.	723	577	2	2	5,059	4
5a.	4,830	3,176	4	3	5,122	4
6.	2,888	854	3	2	10,099	5
7.	3,140	2,297	3	3	6,534	4
9.	3,422	2,795	3	3	28,893	5
10.	508	454	2	1	7,758	4
12.	1,827	943	3	2	10,400	5
12a.	1,935	888	3	2	12,011	5

TABLE 6-2

EQUIVALENT ANNUAL COST

ITEM	USEFULL LIFE	PLANNING PERIOD	SALVAGE VALUE (SV) (a)	PRESENT WORTH (PW) (b)	EQUIVALENT ANNUAL COST EAC	CONVERSION FACTOR WITH CONST. COST (I.C)	EAC
S.S.E.S.	20	20	0	ICx1	PW x .09349	P.C. x	0.09349
Sewer Chemical Grouting	10	20	0	ICx1+RC[c] x 0.51456	PW x 0.09349	I.C. x 0.141597	0.207303
Engr &				0.4 ICx1	PW x .09349	I.C. x 0.037396	
Contingency	--	--	-	0.2 ICx1	PW x .14157	I.C. x 0.028310	
Sewer Polyethylene Lining	30	20	$\frac{10}{30}$ x IC	IC x 1-SV x 0.26508	PW x .09349	I.C. x .085229 I.C. x .037396	0.122625
Engr & Cont.			0	0.4ICx1	PW x .09349		
Sewer				ICx1 -SVx	PW x .09349	I.C. x .078620	0.116016
Replacement	50	20	$\frac{30}{50}$ x IC	0.26508	.84095 .09349	I.C. x .037396	
Engr. & Cont.				0.4IC-x1	PW x .09349		

[a]Assumes straight line depreciation

[b]Interest 6 7/8 percent 20-year planning period

[c]Assume replacement cost (RC) equals initial cost (IC)

I.C. = Initial Cost (construction cost w/o engr & cont.)

TABLE 6-3

EXTENT OF SEWER SYSTEM EVALUATION SURVEY

INFILTRATION/ INFLOW RANKING (a)	PERCENT OF LINES AFFECTED				
	PHYSICAL INSPECTION (b)	SMOKE TESTING (c)	CLEANING (b)	T.V. INSPECTION (b)	CONCURRENT FLOODING (b)
1	0	0	0	0	0
2	100	100	10	20	0
3	100	100	20	30	0
4	100	100	30	40	5
5	100	100	40	60	10

(a) Maximum Ranking of Infiltration or Inflow

(b) Main Lines Only

(c) Side Sewers and Main Line

TABLE 6-4

UNIT COST DATA - SEWER EVALUATION SURVEY

Item	Unit Cost[a] dollars/linear foot
Physical survey, flow monitoring and groundwater monitoring	.12
Smoke testing	0.15
Sewer cleaning	
6-10 inch diameter	0.25
12-18 inch diameter	0.30
21-27 inch diameter	0.35
30-36 inch diameter	0.40
42 inch diameter & over	0.45
Television inspection including video tape recording	0.40
Flooding concurrent with television inspection	0.50
Report preparation, management of evaluation survey and coordination with funding agencies	25 percent of above costs

[a] All costs adjusted to an ENR Index of 3000

Survey Costs

Survey costs for each sub-area were developed on the approach described above and are summarized in Table 6-5. The total sewer system evaluation survey costs are shown and these costs are then expressed in terms of equivalent annual costs to allow comparison with treatment costs expressed on an annual basis. For the purposes of the analysis, the survey is assumed to have a useful life equivalent to the 20 year planning period. Sample survey cost calculations for sub-area No. 2 are shown below:

Infiltration Ranking: Mainline 5

Length of Mainline = 84,955 l.f.

		Footage		Percent		Unit Cost		
Physical Inspection		84,955	x	1.0	x	.12	=	$ 10,195
Smoke Testing		84,955	x	1.0	x	.15	=	12,743
Cleaning	6 - 10 Inch	79,460	x	0.4	x	.25	=	7,946
	12 - 18 Inch	4,625	x	0.4	x	.30	=	555
	21 - 27 Inch	870	x	0.4	x	.35	=	122
	30 - 36 Inch	0	x	0.4	x	.40	=	0
	42 Inch & Over	0	x	0.4	x	.45	=	0
T.V. Inspection		84,955	x	0.6	x	.40	=	20,389
Concurrent Flodding		84,955	x	0.1	x	.50	=	4,248

Sum of Survey Costs	=	$ 56,198
Engineering and Administration 25%	=	14,049
Total Cost	=	$ 70,247
EQUIVALENT ANNUAL COST	=	$ 6,567

TABLE 6-5
SUMMARY OF COSTS

SEWER SYSTEM EVALUATION SURVEY

AREA CARKEEK

Sub-Area	Infiltration Ranking	Length of M.L. Sewer	Total Cost	E.A.C.
1.	5	84,955	70,247	6,567
2.	3	51,305	28,235	2,640
3.	5	43,365	35,759	3,343
4.	3	13,490	7,447	696
5.	2	14,193	6,652	622
5a.	4	13,036	7,536	704
6.	3	20,635	11,349	1,061
7.	3	32,590	17,924	1,676
9.	3	16,510	9,112	852
10.	2	20,705	9,760	912
12.	3	20,360	11,236	1,050
12a.	3	26,110	14,359	1,342

Total Area Cost → $ 229,616

Total Area E.A.C. → $ 21,465

E.A.C. = Total Cost x 0.09349

Sewer System Rehabilitation

The correction alternatives which are available for infiltration control are replacement of sewers, replacement of broken sections, insertion of liners, internal sealing with gels or slurries and external sealing by injection grouting. Selection of any specific method is dependent upon the efficiency and cost of the method for actual pipe and soil conditions that are encountered. The accepted methods for repair of leaking sewers are internal sealing that uses chemical grouts, lining with polyethylene pipe and pipe replacement.

The selection of particular inflow correction measures is dependent on the specific source of inflow. Source of inflow are manhole cover lids, direct storm drainage corrections and illegal storm drainage connections.

Infiltration Reduction

The extent of rehabilitation required to reduce infiltration levels to that of a new system (250 gallons/day/inch diameter mile) is dependent on the magnitude of the infiltration and the condition of the sewers. Based on the infiltration ranking and age of the system, the extent of sewer system rehabilitation required to reduce infiltration in the sewerage system to that of a new system is shown on Table 6-6. For each specific ranking, the extent of sewer rehabilitation can then be determined by applying the indicated percentage factor. The mode of rehabilitation is listed across the top and the percentage factors which define the extent of each rehabilitation method for each ranking is listed below each specific task. To obtain the length of pipe to which the particular rehabilitation method is applicable, the percentage factor is multiplied by the length of sewer within the particular sub-area. Table 6-8 is an example form used to determine total rehabilitation cost for a particular sub-area using data taken from Table 6-6 and 6-7.

TABLE 6-6

EXTENT OF SEWER REHABILITATION TO REDUCE INFILTRATION IN MAIN LINE

INFILTRATION RANKING	Pipe Age 0 - 20 Years			Pipe Age 20 Years and Older		
	Chemical or Cement Grouting	Polyethylene Lining Percent	Replacement Percent	Chemical or Cement Percent	Polyethylene Lining Percent	Replaceme Percent
1						
MAIN LINE	0	0	0	0	0	0
S.S.	0	0	0	0	0	0
2						
MAIN LINE	25	0	0	25	0	0
S.S.	0	20	0	0	30	0
3						
MAIN LINE	35	0	0	30	5	0
S.S.	0	30	0	0	40	0
4						
MAIN LINE	45	5	0	35	10	5
S.S.	0	40	0	0	50	0
5						
MAIN LINE	55	5	0	40	10	10
S.S.	0	50	0	0	60	0

This Table assumes that after smoke testing and T.V. inspection, the extent of rehabilitation work in any particular area, will not be greater than 60% on the average.

Identified extraneous flows to service laterals are infiltration through pipe cracks and defective joints and inflow through service lateral cleanouts and near surface open joints. Rehabilitation options available to eliminate extraneous flows in service laterals are either polyethylene lining or replacing the service lateral. Chemical sealing with current technology is not practical.

Once the length of specific rehabilitation methods has been determined, costs can be developed based on the unit cost data shown in Table 6-7.

A relationship between the percent of infiltration flow removed to the percent of area to be rehabilitated according to infiltration ranking has been established. See Figure 6-1. Corresponding percentages of infiltration reduced are then used for each sub-area for determination of the area cost benefit curves.

Infiltration Reduction Costs

Unit costs for developing sewer system rehabilitation costs which are based on the above described approach have been developed for infiltration control of main line and side sewers. These unit costs are given on Table 6-7. Summary costs for rehabilitating main line and side sewers for each sub-area are listed on Tables 6-9 and 6-11 respectively,and are expressed in equivalent annual costs.

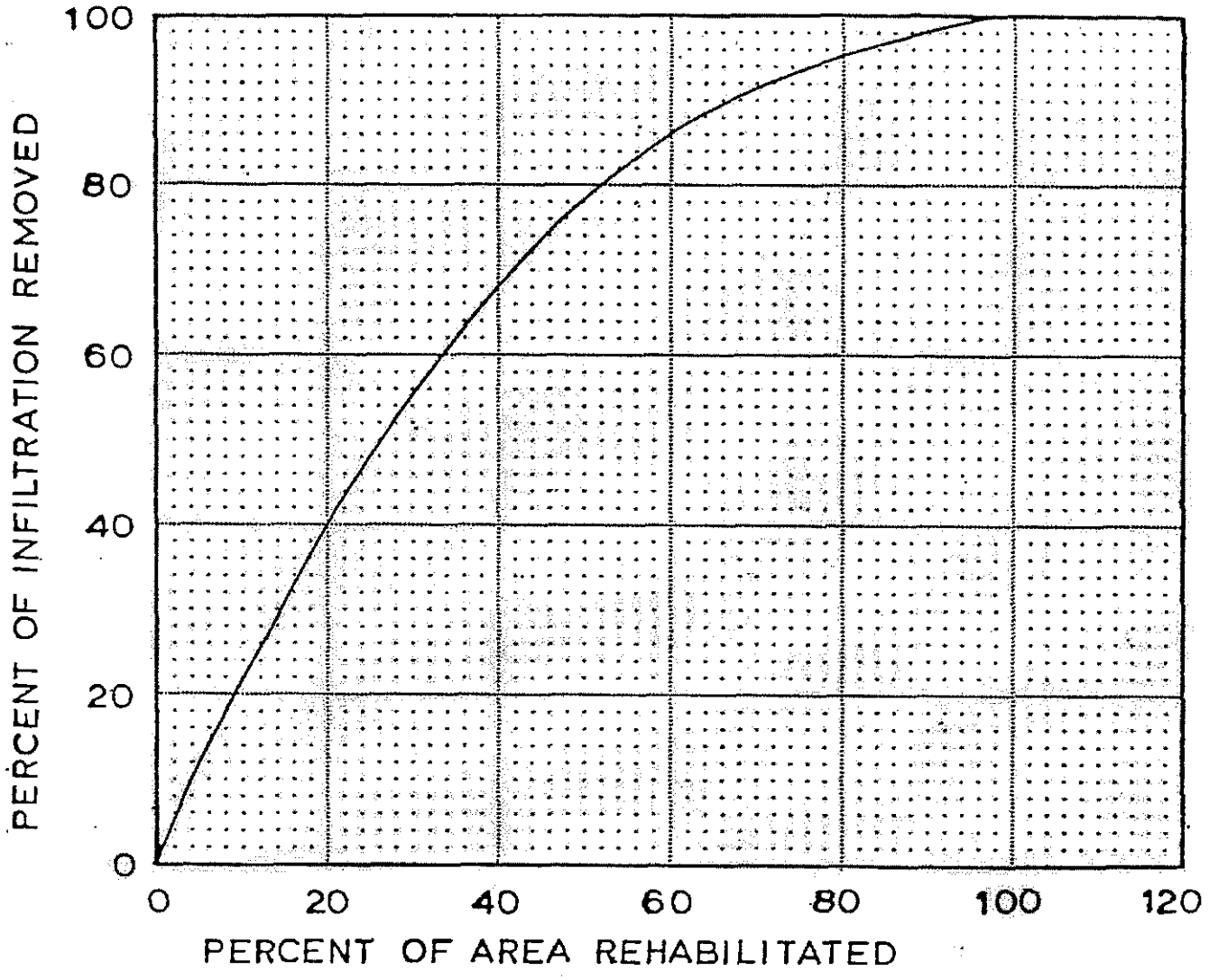
Table 6-10 and 6-10a summarizes costs of rehabilitating service connections (side sewers). Procedure for rehabilitating service connections is limited to polyethylene lining. Pressure grouting has not been found practical. Total project cost is estimated at $4,558,246.

Table 6-12 summarizes infiltration rehabilitation costs for both main line and side sewers. Total project costs and E.A.C. for each noted at bottom ofthe table.

Table 6-13 and 6-13a summarizes and combines cost of sewer system evaluation survey and rehabilitation of infiltration for each sub-area.

Figure 6-1

INFILTRATION RANKING CURVE



RANKING	PERCENT AREA REHABILITATED	PERCENT FLOW REMOVED
1	0	0
2	25	47
3	35	61
4	50	77.5
5	60	85

TABLE 6-7

UNIT COST DATA
SEWER REHABILITATION TO REDUCE INFILTRATION

PIPE SIZE	REHABILITATION METHOD (a)			
	CHEMICAL OR CEMENT GROUTING (b)	POLYETHYLENE LINING (c)	REPLACEMENT (d) (e) IMPROVED STREET AREA	REPLACEMENT (d) (e) UNIMPROVED STREET AREA
6"	$ 6.70	$16.15 d	$40.75	$25.00
8"	6.80	19.60 d	48.75	36.25
10"	7.15	24.25 d	58.75	42.50
12"	7.75	20.75 g	68.75	47.75
15"	8.45	25.40 g	82.50	53.75
18"	9.15	31.15 g	96.25	62.50
21"	9.95	38.00 g	110.00	72.50
24"	10.85	46.15 g	125.00	82.50
27"	11.35	52.85 g	140.00	92.50
30"	12.35	58.85 g	155.00	102.50
36"	13.85	77.30	189.00	126.00
42"	15.35	99.25	226.00	150.50
48"	16.85			
54"	18.35			
60"	21.00			
66"	24.00	All pipe over 42 inch dia. will be rehabilitated by chemical or cement grouting only.		
72"	27.00			
78"	30.00			
84"	35.50			
90"	42.00			
96"	47.00			
102"	53.00			
108"	60.00			
SIDE (f) SEWER 100'		$1100	1500	1000

(a) All costs adjusted to engr. index 3000 (1978)
(b) Costs include line cleaning
(c) Costs include line cleaning, television inspection (excluding side sewer pipe) and use of SDR 21 polyethelene pipe.
(d) Costs for connections to side sewer is included.
(e) Costs for trenching in stable ground.
(f) Assumes 30 feet 6" pipe and 70 feet of 4" pipe/connection.
(g) Add $7.00 for pipes in combined sewer areas for side sewer connections.

JJC:ms
3/21/78

EXAMPLE SUBAREA - INFILTRATION REHABILITATION COSTS

AREA Carkeek SUB-AREA 1

AGE OF PIPING 20 Yrs. & Older

RANKING 5

0 - 20 Yrs. *

TABLE 6-8

ITEMS			6"	8"	10"	12"	15"	18"	21"	24"	27"	30"	36"	42"	SUM
Pipe Length, ft.			21,275	56,915	1,270	2,620	340	1,665	670	200	0				
MAIN LINES	Replacement	10 %	2127.5	5691.5	127	262	34	166.5	67	20	0				
		Unit Cost $/ft	25.00	36.25	42.50	47.75	53.75	62.50	72.50	82.50	92.50				
		Constr. Cost	53,187	206317	5,397	12510	1,827	10406	4857	1650	0				296,151
		Project Cost [1]													414,611
		EAC [2]													34,358
	Polyethylene Lining	10 %	2127.5	5691.5	127	262	34	166.5	67	20	0				
		Unit Cost $/ft	16.15	19.60	24.25	20.75	25.40	31.15	38.00	46.15	52.85				
		Constr. Cost	34,359	111,553	3,080	5,436	864	5,186	2,546	923	0				163,947
		Project Cost [1]													229,526
		EAC [3]													20,104
	Chemical Grouting	40 %	8,510	22,766	508	1,048	136	666	268	80	0				
		Unit Cost $/ft.	6.70	6.80	7.15	7.75	8.45	9.15	9.95	10.85	11.35				
		Constr. Cost	57,017	154809	3,632	8.122	1149	6,094	2,667	868	0				234,358
		Proj. Cost [1]													328,101
		EAC [4]													48,583
														TOTAL PROJECT COST	972,238

[1] Project Cost = Construction Cost x 1.4 Engr. & Contingencies

[2] EAC = Const. Cost [illegible]

[3] EAC = Const. Cost x 0.122625

[4] EAC = Const. Cost x 0.207303

SUMMARY OF COSTS

INFILTRATION REHABILITATION COSTS

AREA CARKEEK

Sub-Area	Infiltration Ranking	Length of M.L. Sewer	Total Project Costs	Total E.A.C.
1	5	84,955	972,238	103,045
2	3	51,305	199,807	25,944
3	5	43,365	496,892	52,958
4	3	13,490	60,303	7,986
5	2	14,193	33,674	4,986
5a	4	13,036	108,495	11,977
6	3	20,635	86,440	11,132
7	3	32,590	138,151	17,752
9	3	16,510	68,302	9,114
10	2	20,705	52,115	7,717
12	3	20,360	84,437	10,969
12a	3	26,110	105,287	13,918

Total Project Cost → $ 2,406,141

Total Area E.A.C. → $ 277,234

E.A.C. = Replac. const. cost x 0.116016 + Poly. Lining const. cost x 0.122625 + Grouting const. cost x o.207303

INFILTRATION REHABILITATION COSTS

AREA Carkeek

TABLE 6-10

(SIDE SEWERS ONLY)

Sheet 1 of 2

POLYETHYLENE LINING

SUB AREA	1	2	3	4	5	5a	6	7	TOTAL
RANKING	3	3	4	3	2	3	2	3	
AGE GROUP	20 & over	20 & over	20 & over	20 & over	20 & over	20 & over	20 & over	20 & over	
NO. OF CONNECTIONS	2,449	1,139	906	253	326	223	492	703	
% REHAB.	40	40	50	40	30	40	30	40	
* QUANTITY REHAB. (Connections)	979.6	455.6	453	101.2	97.8	89.2	147.6	281.2	
UNIT COST $/Connection	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	
CONST. COST $	1,077,560	501,160	498,300	111,320	107,580	98,120	162,360	309,320	
PROJECT COST $	1,508,584	701,624	697,620	155,848	150,612	137,368	227,304	433,048	
EAC $	132,136	61,455	61,104	13,651	13,192	12,032	19,909	37,930	

PROJECT COST = CONSTRUCTION COST x 1.4

EAC = Const. Cost x 0.122625

* ASSUMED 100 L.F. PER CONNECTION (30' of 6" PIPE & 70' of 4" PIPE)

INFILTRATION REHABILITATION COSTS

AREA Carkeek

TABLE 6-10a

(SIDE SEWERS ONLY)

Sheet 2 of 2

POLYETHYLENE LINING

SUB AREA	9	10	12	12a					TOTAL
RANKING	3	1	2	2					
AGE GROUP	20 & Over	20 & Over	20 & Over	20 & Over					
NO. OF CONNECTIONS	307	615	354	419					8,186
% REHAB.	40	0	30	30					
*QUANTITY REHAB. (Connection)	122.8	0	106.2	125.7					
UNIT COST $/Connection	1,100	1,100	1,100	1,100					
CONST. COST $	135,080	0	116,820	138,270					3,255,890
PROJECT COST $	189,112	0	163,548	193,578					4,558,246
EAC $	16,564	0	14,325	16,955					3,399,253

PROJECT COST = CONSTRUCTION COST x 1.4

EAC = Const. Cost x 0.122625

* [illegible]

TABLE 6-11

SUMMARY OF COSTS

INFILTRATION REHABILITATION COSTS

(SIDE SEWERS ONLY)

AREA CARKEEK

Sub-Area	Ranking	Length of Side Sewer	Project Costs	E.A.C.
1	3	244,900	1,508,584	132,136
2	3	113,900	701,624	61,445
3	4	90,600	697,620	61,104
4	3	25,300	155,848	13,651
5	2	32,600	150,612	13,192
5a	3	22,600	137,368	12,032
6	2	49,200	227,304	19,909
7	3	70,300	433,043	37,930
9	3	30,700	189,112	16,564
10	1	61,500	0	0
12	2	35,400	163,548	14,325
12a	2	41,900	193,578	16,955

Total Project Cost → $ 4,558,246

Total Area E.A.C. → $ 399,253

E.A.C. = Construction Cost x 0.122625

TABLE 6-12

SUMMARY OF

INFILTRATION REHABILITATION COSTS

SUB AREA	INFILTRATION RANKING		REHABILITATION COST		E.A.C.	
			MAIN LINE	SIDE SEWER	M.L.	S.S.
	M.L.	S.S.	$	$	$	$
1	5	3	972,238	1,508,584	103,045	132,136
2	3	3	199,807	701,624	25,944	61,455
3	5	4	496,892	697,620	52,958	61,104
4	3	3	60,303	155,848	7,722	13,651
5	2	2	33,674	150,612	4,986	13,192
5a	4	3	108,495	137,368	11,977	12,032
6	3	2	86,440	227,304	11,132	19,909
7	3	3	138,151	433,048	17,752	37,930
9	3	3	68,302	189,112	9,114	16,564
10	2	1	52,115	0	7,717	0
12	3	2	84,437	163,548	10,969	14,325
12a	3	2	105,287	193,578	13,918	16,955
SUM			2,406,141	4,558,246	277,234	399,253

SSES AND REHABILITATION (INFILTRATION)
COST SUMMARY

TABLE 6-13
AREA Carkeek

SUB AREA	PIPE SYST.	Total Project Costs				EAC			
		S.S.E.S.	REHAB.	TOTAL M.L.	TOTAL S.S.	S.S.E.S.	REHAB.	TOTAL M.L.	TOTAL S.S.
1	M.L.	70,247	972,238	1,042,485		6,567	103,045	109,612	
	S.S.	0	1,508,584		1,508,584	0	132,136		132,136
2	M.L.	28,235	199,807	228,042		2,640	25,944	28,584	
	S.S.	0	701,624		701,624	0	61,455		61,455
3	M.L.	35,759	496,892	532,651		3,343	52,958	56,301	
	S.S.	0	697,620		697,620	0	61,104		61,104
4	M.L.	7,447	60,303	67,750		696	7,722	8,418	
	S.S.	0	155,848		155,848	0	13,651		13,651
5	M.L.	6,652	33,674	40,326		622	4,986	5,608	
	S.S.	0	150,612		150,612	0	13,192		13,192
5a	M.L.	7,536	108,495	116,031		704	11,977	12,681	
	S.S.	0	137,368		137,368	0	12,032		12,032
6	M.L.	11,349	86,440	97,789		1,061	11,132	12,193	
	S.S.	0	227,304		227,304	0	19,909		19,909
7	M.L.	17,924	138,151	156,075		1,676	17,752	19,428	
	S.S.	0	433,048		433,048	0	37,930		37,930

SSES AND REHABILITATION (INFILTRATION)
COST SUMMARY

TABLE 6-13a
AREA CARKEEK

SUB AREA	PIPE SYST.	TOTAL PROJECT COSTS				EAC			
		S.S.E.S.	REHAB.	TOTAL		S.S.E.S.	REHAB.	TOTAL	
				M.L.	S.S.			M.L.	S.S.
9	M.L.	9,112	68,302	77,414		852	9,114	9,966	
	S.S.	0	189,112		189,112	0	16,564		16,564
10	M.L.	9,760	52,115	61,875		912	7,717	8,629	
	S.S.	0	0		0	0	0		0
12	M.L.	11,236	84,437	95,673		1,050	10,969	12,019	
	S.S.	0	163,548		163,548	0	14,325		14,325
12a	M.L.	14,359	105,287	119,646		1,342	13,918	15,260	
	S.S.	0	193,578		193,578	0	16,955		16,955

Inflow Reduction Costs

Three categories of inflow have been identified; nonspecific inflow sources tributary to service laterals, other nonspecific inflow sources, and direct connection of inflow sources to the sanitary sewers. Twenty percent of the nonspecific inflow was identified as being from service laterals. Service lateral inflow can be eliminated by rehabilitating the service lateral, costs of which were developed in the section on infiltration.

The following approach has been developed for a basis of determining the scope and cost of reducing the remaining nonspecific inflow. The scope of sewer modification is based on an inflow source equivalent to a typical single-family home roof drain connection. Assuming a roof area of 1,200 square feet, inflow per equivalent source is calculated by the following steps.

1. Determine the average time of concentration from the source to the treatment facility; this can be approximated by analysis of the hydraulic characteristics of the specific collection system to determine an average time of travel from the tributary area to the treatment facility, or comparing plant flow records with hourly rainfall data and determining the time delay between the peak of the storm and peak influent flow.

2. Determine the rainfall intensity of the storm frequency selected for the inflow analysis with a duration equal to the system time of concentration.

3. From this rainfall intensity the inflow per equivalent roof drain is calculated as follows:

   Peak flow rate/source, gallons/day = Roof area, ft^2 x inch/hour rainfall intensity, x 7.48 x 24 hours x 90 percent (effective runoff)

By analysis of rainfall records, the time of concentration of the Carkeek Park service area was found to be approximately 90 minutes. For the storm which produced the observed inflow of 19.41 mgd, the intensity of the 90 minute time of concentration was 0.35 inches/hour. Thus the peak inflow per equivalent source is

$$= 1200 \times \frac{0.35}{12} \times 7.48 \times 24 \times \frac{90}{100} = 5650 \text{ gallons/day/equivalent source}$$

The equivalent number of sources per acre can be determined by dividing the sub-area inflow value by the 5,650 gallons/day equivalent source value. The relationship between inflow and equivalent sources per acre is shown in Figure 6-2. This will be a linear relationship. To account for the probability that there will be larger inflow sources in areas of higher inflow an adjustment has been made to the basic equivalent source value as shown in Figure 6-2. From the plotted relationship the number of equivalent inflow sources per acre was determined in Table 6-12. Note that 5 year peak inflow was used in determining inflow sources.

Since a judgement was made that inflow control must include a separate storm drain system, along with downspout removal, cost for storm drain construction for each sub-area had to be prepared. Table 6-15 summarizes capital cost and equivalent annual cost to construct necessary storm drains for each sub-area. Each sub-area was evaluated to determine approximate acerage needing storm drains.

Table 6-16 summarizes the total capital cost and equivalent annual cost of a combined downspout removal program and the storm drain construction project. Total combined capital cost comes to $19,832,160, with an E.A.C. of $2,300,858.

Table 6-17 summarizes the analysis that leads to determining the cost of flow removal per 1000 gallons and the percentage of inflow removed to the total inflow. Cost ranking is determined from the flow removal cost of each sub-area.

Combined Infiltration/Inflow Ranking

Table 6-18 and 6-18a reflects the cost ranking or prioritizing of both infiltration and inflow data together. Main line sewer and side sewer infiltration, as well as inflow into the system are tabulated and ranked from 1 through 35. Total I/I was 913.51 M.G. annually.

Table 6-19 is the tabulation of data required to develop the plotting data necessary to set up the correction cost curve shown on Figure 6-5.

Sewer System Rehabilitation Cost/Benefit

For each sub-area, and collection system component of the sub-area, maximum infiltration values and peak inflow values and the costs to reduce these identified extraneous flows have been estimated. Thus for each identified system element the benefit of rehabilitation can be expressed in terms of dollars expended per 1000 gallons of extraneous flow eliminated.

For the cost/benefit portion of the analysis, the North Beach sub-areas and Carkeek sub-areas were treated separately. This was necessary because the treatment and transport cost for the North Beach areas was higher than the other sub-areas due to the extra cost of enlarging and operating the pump station. Therefore a separate cost effective analysis was done for each group of sub-areas.

The present capacity of the North Beach pump station, 4.5 mgd, is often exceeded during rainy periods and overflows into Puget Sound. During periods of high flow at the treatment plant, it has been assumed that the contribution from North Beach is 4.5 mgd and the rest of the peak comes from Carkeek sub-areas. For this reason the flow at the treatment plant does not always equal the sum of the sub-area flows.

Figure 6-2

INFLOW SOURCES

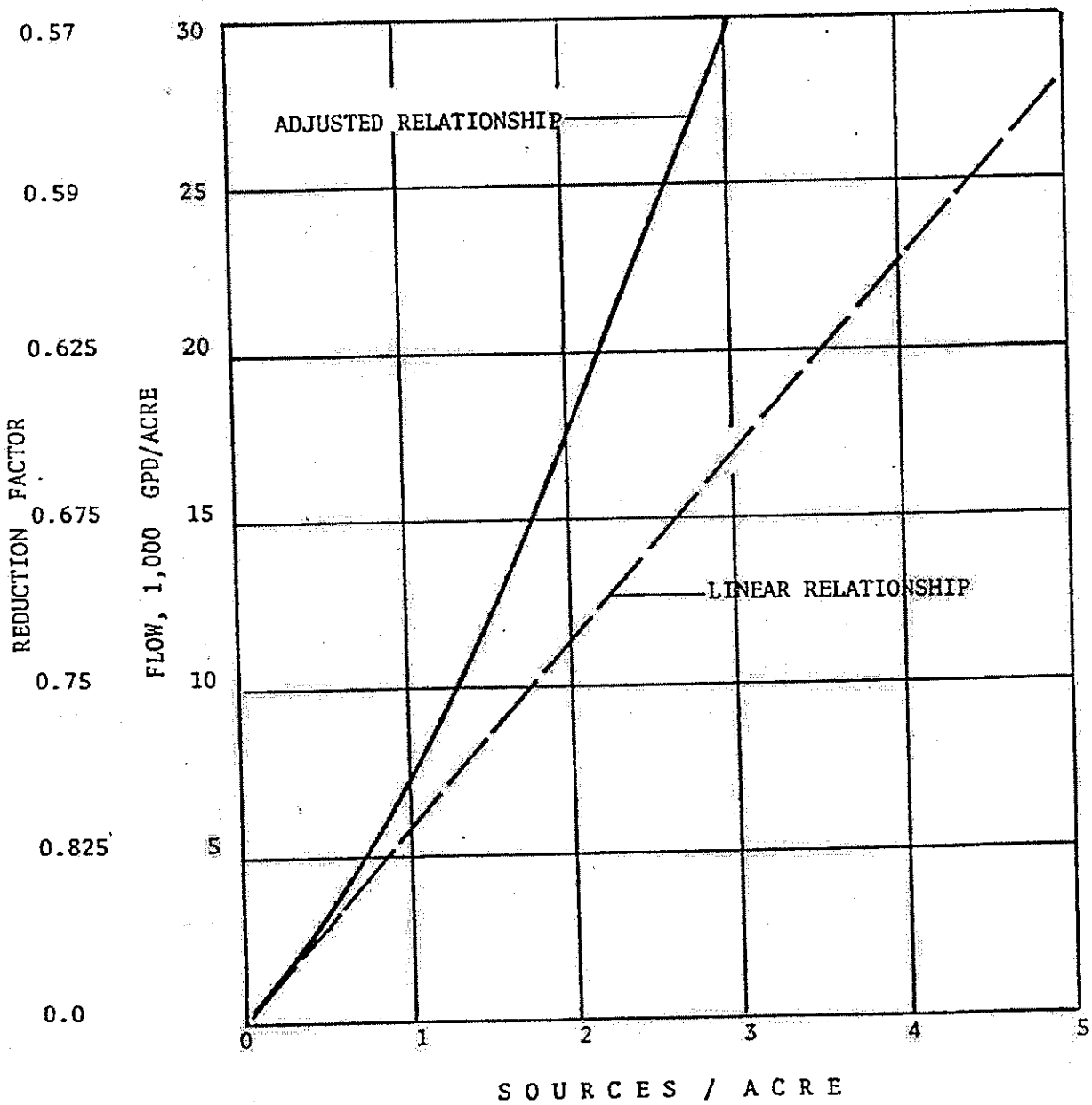


TABLE 6-14

INFLOW REDUCTION SCOPE AND COSTS

SUB AREA NO.	ACREAGE	INFLOW*				COST	
		MGD* 5 YR PEAK	GALLONS/ACRE	SOURCES/ACRE	TOTAL SOURCES	CAPITAL+ DOWNSPOUT REMOVAL	E.A.C.
1.	447	4.24	9,485	1.25	559	939,120	108,953
2.	301	1.97	6,545	0.90	271	455,280	52,830
3.	287	3.96	13,798	1.25	359	603,120	69,972
4.	103	1.94	18,835	2.10	216	362,880	42,100
5.	85	0.34	4,000	0.60	51	85,680	9,940
5a.	82	0.34	4,146	0.60	49	82,320	9,550
6.	101	0.82	8,119	1.11	112	188,160	21,830
7.	176	0.92	5,227	0.75	132	221,760	25,728
9.	97	3.92	40,412	3.8	369	619,920	71,921
10.	165	1.02	6,182	0.85	140	235,200	27,287
12.	175	1.73	9,886	1.30	228	383,040	44,439
12a.	174	1.67	9,598	1.30	226	379,680	44,049
TOTAL	2,193	22.87*	136,233	15.81	2,712	4,556,160	528,589

* 80% of non-specific Inflow
\+ Assuming $1,680 construction cost per source including Engineering & Contingencies
E.A.C. = Capital Cost x 0.116016

TABLE 6-15

STORM DRAIN COSTS

SUB AREA NO.	TOTAL ACREAGE	ACREAGE WITH STORM DRAIN	ACREAGE WITHOUT STORM DRAIN	COST PER ACRE	COST	
					CAPITAL COST	E.A.C.
1.	447	270	177	10,000	1,770,000	205,348
2.	301	216	85	10,000	850,000	98,614
3.	287	23	264	10,000	2,640,000	306,282
4.	103	44	59	10,000	590,000	68,449
5.	85	12	73	10,000	730,000	84,692
5a.	82	11	71	10,000	710,000	82,371
6.	101	46	55	10,000	550,000	63,809
7.	176	0	176	10,000	1,760,000	204,188
9.	97	12	85	10,000	850,000	98,614
10.	165	3	162	10,000	1,620,000	187,946
12.	175	10	165	10,000	1,650,000	191,426
12a.	174	18	156	10,000	1,556,000	180,521
TOTAL	2,193	700	1,958		15,276,000	1,772,260

E.A.C. = Capital Cost x 0.116016

TABLE 6-16

TOTAL INFLOW REDUCTION COST

(COMBINED COST)

SUB AREA NO.	INFLOW CONTROL				TOTAL	
	DOWN SPOUT REMOVAL		STORM DRAIN			
	CAPITAL COST	E.A.C.	CAPITAL COST	E.A.C.	CAPITAL COST	E.A.C.
1.	939,120	108,953	1,770,000	205,348	2,709,120	314,301
2.	455,280	52,830	850,000	98,614	1,305,280	151,444
3.	603,120	69,972	2,640,000	306,282	3,243,120	376,254
4.	362,880	42,100	590,000	68,449	952,880	110,549
5.	85,680	9,940	730,000	84,692	815,680	94,632
5a.	82,320	9,550	710,000	82,371	792,320	91,922
6.	188,160	21,830	550,000	63,809	738,160	85,638
7.	221,760	25,728	1,760,000	204,188	1,981,760	229,916
9.	619,920	71,921	850,000	98,614	1,469,920	170,534
10.	235,200	27,287	1,620,000	187,946	1,855,200	215,233
12.	383,040	44,439	1,650,000	191,426	2,033,040	235,865
12a.	379,680	44,049	1,556,000	180,521	1,935,680	224,570
TOTAL	4,556,160	528,589	15,276,000	1,772,260	19,832,160	2,300,858

E.A.C. = Capital Cost x 0.116016

INFLOW CONTROL

CARKEEK

DETERMINATION OF COST RANKING
FOR EVALUATION SURVEY

TABLE 6-17

SUB AREA	PIPE SYSTEM	ANNUAL INFLOW M.G.	EXPECTED INFLOW REMOVAL %	INFLOW REMOVED M.G.	E.A.C.*	COST FLOW REMOVAL ($/1000 GAL.)	COST RANKING	% INFLOW REMOVED TO TOTAL AREA INFLOW
1		36.6	80	29.28	314,301	10.734	2	18.793
2		12.6	80	10.08	151,444	15.024	5	6.470
3		19.6	80	15.68	376,254	23.996	6	10.064
4		9.4	80	7.52	110,549	14.701	4	4.827
5		1.8	80	1.44	94,632	65.717	11	0.924
5a		3.6	80	2.88	91,922	31.917	9	1.848
6		2.9	80	2.32	85,638	36.913	10	1.489
7		20.2	80	16.16	229,916	14.227	3	10.372
9		25.0	80	20.0	170,534	8.527	1	12.837
10		2.5	80	2.0	215,233	107.617	12	1.284
12		11.0	80	8.8	235,865	26.803	7	5.648
12a		10.6	80	8.48	224,570	26.482	8	5.443

* Down Spout Removal and Storm Drain Costs Combined

+Total Area Inflow = 155.8 MGY

CARKEEK

DETERMINATION OF COST RANKING
FOR EVALUATION SURVEY

TABLE 6-18

SUB AREA	PIPE SYSTEM	ANNUAL I/I M.G.	EXPECTED I/I REMOVAL %	I/I REMOVED M.G.	E.A.C*	COST FLOW REMOVAL ($/1000 GAL.)	COST RANKING	% FLOW + REMOVED TO TOTAL AREA I/I
1.	M.L.	326.61	85	277.62	109,612	0.395	2	30.390
	S.S.	28.69	61	17.50	132,136	7.551	13	1.916
	Inflow	36.6	80	29.28	314,301	10.734	18	3.205
2.	M.L.	20.46	61	12.48	28,584	2.290	9	1.366
	S.S.	2.35	61	1.43	61,455	42.975	31	0.156
	Inflow	12.6	80	10.08	151,444	15.024	22	1.103
3.	M.L.	249.75	85	212.29	56,301	0.265	1	23.239
	S.S.	3.38	77.5	2.62	61,104	23.322	23	0.287
	Inflow	19.6	80	15.68	376,254	23.996	24	1.716
4.	M.L.	4.16	61	2.54	8,418	3.314	10	0.278
	S.S.	0.40	61	0.24	13,651	56.879	33	0.026
	Inflow	9.4	80	7.52	110,549	14.701	21	0.823
5.	M.L.	1.92	47	0.90	5,608	6.231	11	0.098
	S.S.	1.00	47	0.47	13,192	28.068	27	0.051
	Inflow	1.80	80	1.44	94,632	65.717	34	0.158
5a	M.L.	11.79	77.5	9.14	12,681	1.387	5	1.000
	S.S.	0.43	61	0.26	12,032	46.277	32	0.028
	Inflow	3.60	80	2.88	91,922	31.917	28	0.315
6.	M.L.	25.93	61	15.82	12,193	0.771	3	1.732
	S.S.	4.55	47	2.14	19,909	9.303	16	0.234
	Inflow	2.90	80	2.32	85,638	36.129	29	0.254
7.	M.L.	16.45	61	10.03	19,428	1.937	8	1.098
	S.S.	1.62	61	0.99	37,930	38.313	30	0.108
	Inflow	20.20	80	16.16	229,916	14.227	20	1.769
9.	M.L.	11.73	61	7.15	9,966	1.394	6	0.783
	S.S.	4.15	61	2.53	16,564	6.547	12	0.277
	Inflow	25.00	80	20.00	170,534	8.527	15	2.189

CARKEEK

DETERMINATION OF COST RANKING
FOR EVALUATION SURVEY

TABLE 6-18a

SUB AREA	PIPE SYSTEM	ANNUAL I/I M.G.	EXPECTED I/I REMOVAL %	I/I REMOVEL M.G.	E.A.C*	COST FLOW REMOVAL ($/1000 GAL.)	COST RANKING	% FLOW + REMOVED TO TOTAL AREA I/I
10.	M.L.	2.35	47	1.10	8,625	7.844	14	0.120
	S.S.	2.03	0	0	0	0	0	0
	Inflow	2.50	80	2.00	215,233	107.616	35	0.219
12.	M.L.	12.67	61	7.73	12,019	1.555	7	0.846
	S.S.	2.48	47	1.17	14,325	12.244	19	0.846
	Inflow	11.00	80	8.80	235,865	26.803	26	0.963
12a	M.L.	19.30	61	11.77	15,260	1.296	4	1.288
	S.S.	3.51	47	1.65	16,955	10.276	17	0.181
	Inflow	10.60	80	8.48	224,570	26.482	25	0.928

Total Monitored Area Infiltration = 757.71 M.G.Y.
Total Monitored Area Inflow = 155.80 M.G.Y.
+Total Monitored Area I/I = 913.51 M.G.Y.
* SSES and Rehabilitation Costs Combined

AREA CARKEEK

PLOTTING DATA

TABLE 6-19

COST RANKING	SUB AREA NO.	% FLOW REMOVED TO TOTAL AREA I/I	E.A.C.	PLOTTING DATA ACCUM. % FLOW REMOVED	PLOTTING DATA ACCUM. E.A.C.
1.	3 ML	23.239	56,301	23.239	56,301
2.	1 ML	30.390	109,612	53.629	165,913
3.	6 ML	1.732	12,193	55.361	178,106
4.	12a ML	1.288	15,260	56.649	193,366
5.	5a ML	1.000	12,681	57.649	206,047
6.	9 ML	0.783	9,966	58.432	216,013
7.	12 ML	0.846	12,019	59.278	228,032
8.	7 ML	1.098	19,428	60.376	247,460
9.	2 ML	1.366	28,584	61.742	276,044
10.	4 ML	0.278	8,418	62.020	284,462
11.	5 ML	0.098	5,608	62.118	290,070
12.	9 SS	0.277	16,564	62.395	306,634
13.	1 SS	1.916	132,136	64.311	438,770
14.	10 ML	0.120	8,625	64.431	447,395
15.	9 I	2.189	170,534	66.620	617,929
16.	6 SS	0.234	19,909	66.854	637,838
17.	12a SS	0.181	16,955	67.035	654,793
18.	1 I	3.205	314,301	70.240	969,094
19.	12 SS	0.128	14,325	70.368	983,419
20.	7 I	1.769	229,916	72.137	1,213,335
21.	4 I	0.823	110,549	72.960	1,323,884
22.	2 I	1.103	151,444	74.063	1,475,328
23.	3 SS	0.287	61,104	74.350	1,536,432
24.	3 I	1.716	376,254	76.066	1,912,686
25.	12a I	0.928	224,570	76.994	2,137,256
26.	12 I	0.963	235,865	77.957	2,373,121
27.	5 SS	0.051	13,192	78.008	2,386,313
28.	5a I	0.315	91,922	78.323	2,478,235
29.	6 I	0.254	85,638	78.577	2,563,873
30.	7 SS	0.108	37,930	78.685	2,601,803
31.	2 SS	0.156	61,455	78.841	2,663,258
32.	5a SS	0.028	12,032	78.869	2,675,290
33.	4 SS	0.026	13,651	78.895	2,688,941
34.	5 I	0.158	94,632	79.053	2,783,573
35.	10 I	0.219	215,233	79.272	2,998,806

Infiltration/Inflow Transport and Treatment

Costs related to transporting and treating infiltration/inflow include cost for constructing facilities sized to handle peak storm flows and operation and maintenance costs of transporting and treating the volume of infiltration/inflow is necessary to complete a cost effective analysis. For this report, treatment costs are based on secondary treatment requirements consistent with Public Law 92-500.

All transport and treatment cost which includes transportation of sewage, pumping, treatment, operation and maintenance, and capital cost of secondary treatment facilities were extracted from METRO's two facilities report, The Systemwide Facility Plan, Volume II, 1977, and METRO's Facility Plan of Carkeek Treatment, 1979.

From METRO's report, the cost to build a facility with capacity of 30 million gallons/day would cost $23,227,000. This cost to update the Carkeek Park plant is found on Table 6 of METRO's Facility Plan of Carkeek Park, June 1979.

Cost of transport and treatment of sewage was extracted from METRO's I/I report and updated to ENRCI 3000 to correspond with index used for rehabilitation costs. This resulted in use of transport and treatment cost of $375 per million gallon for flow from North Beach and $346 per million gallons for flows arriving by gravity to the treatment facilities.

Capital cost of updating and constructing secondary treatment facilities that can be attributed to infiltration and inflows was estimated by taking the cost difference between a 2 million gallon facility with a 6 million gallon peak capacity, and a 30 million gallon treatment facility. Cost based on ENRCI of 3000 produced the following costs.

30 M.G.D. Plant	$	21,775,300
2/6 M.G.D. Plant		2,895,450
Incremental Cost	$	18,879,850
E.A.C.	$	1,765,077

This capital cost was proportioned between North Beach and Carkeek areas on the basis of actual measure infiltration and inflow. Capital cost attributed to North Beach came to $613,717, and to the remaining Carkeek area as $1,150,830. Figure 6-3 and 6-4 summarize the combination of capital cost and the cost of transport and treatment.

Determination of Excessive Infiltration/Inflow

Excessive infiltration/inflow by definition is determined solely on the basis of cost. Infiltration/inflow is excessive if the estimated costs of transporting and treating a particular element of infiltration/inflow exceed the estimated costs of rehabilitating the collection system to remove it.

By summing the estimated cost of removing incremental percentages of infiltration/inflow from the collection system, and the cost required to transport and treat the remaining flows, the excessive infiltration/inflow can be identified. The point of minimum costs identifies the increment of infiltration/inflow that is cost effective to eliminate. If the minimum cost point corresponds to zero percent infiltration/inflow reduction, then infiltration/inflow is not excessive. This is illustrated from the tabulation of data found on Table 6-21 and the resulting curves in Figure 6-5.

Cost Effective Sub-Areas

Evaluation of data on Table 6-21 and the points on the total cost curve on Figure 6-5 indicates that 9 elements or sub-areas have excessive infiltration and are cost effective to remove. Table 6-22 and 6-23 lists the cost effective sub-areas and summarizes the costs of the sewer system evaluation survey and the cost of rehabilitation.

FIGURE 6-3
NORTH BEACH (SUBAREAS 2,3,4)
TREATMENT & TRANSPORT COSTS

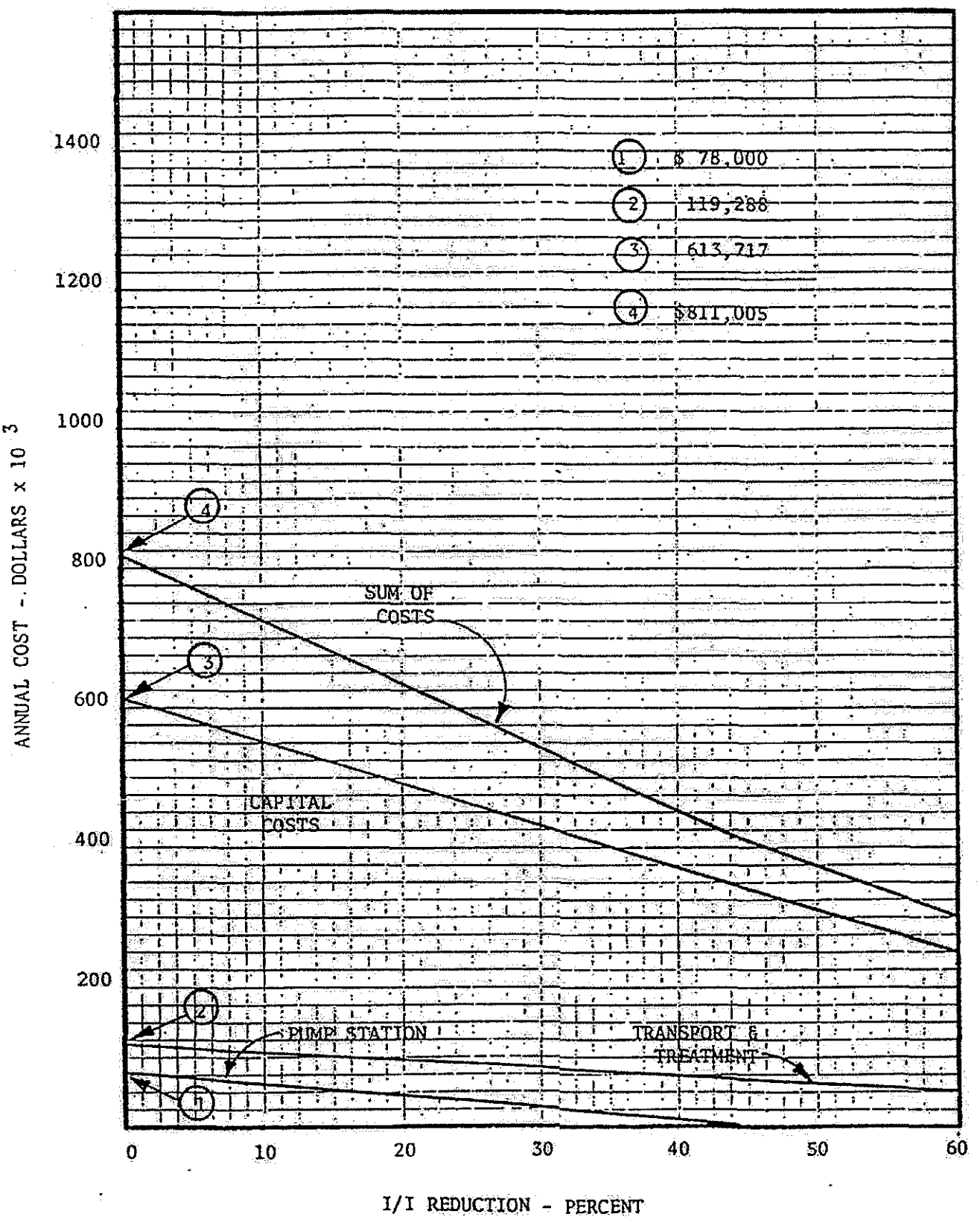


FIGURE 6-4
CARKEEK PARK SYSTEM
TREATMENT & TRANSPORT
SUBAREAS 1,5,5a,6,7,9,10,12,12a

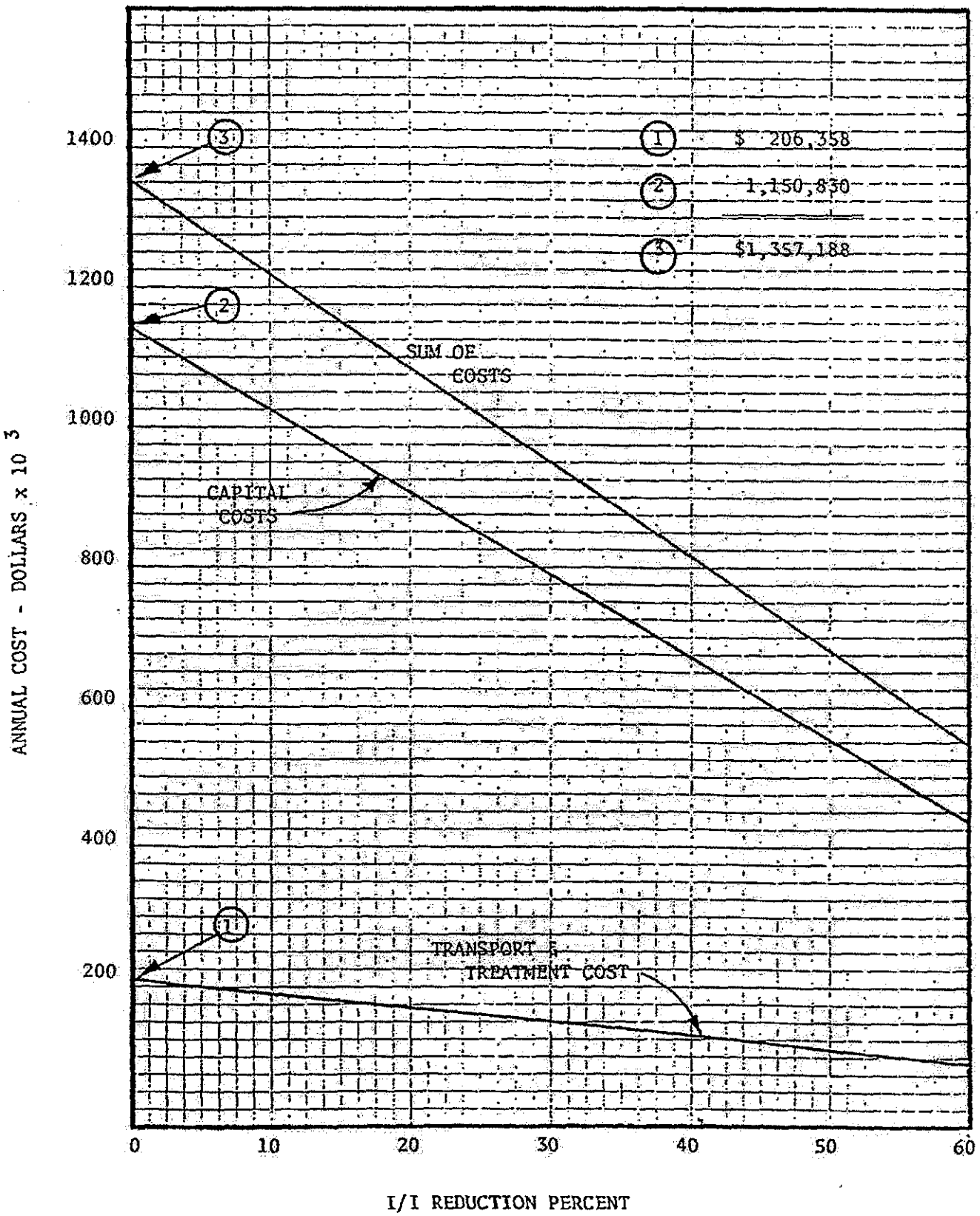


TABLE 6-20

CARKEEK SYSTEM

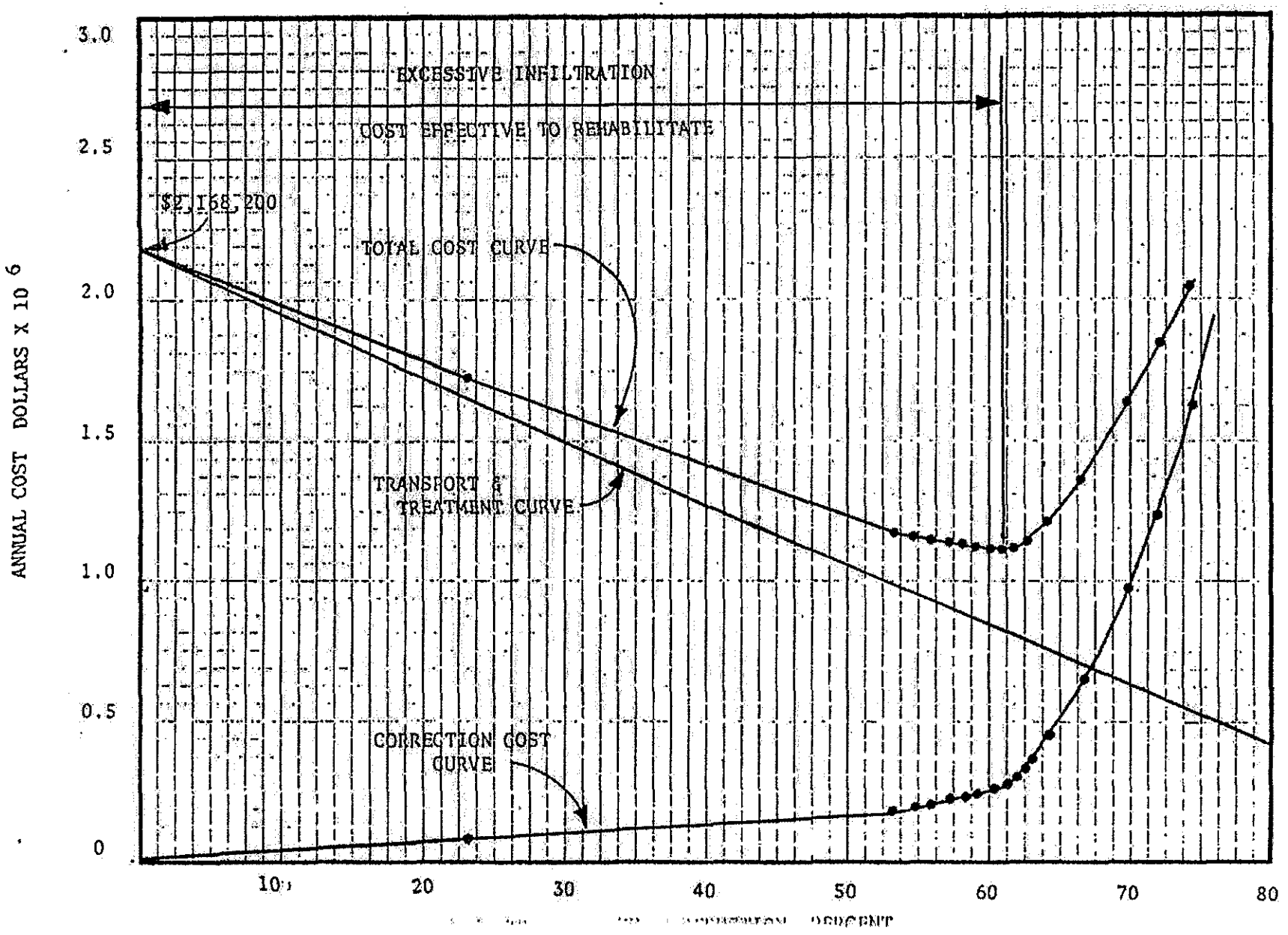
DETERMINATION OF I/I - COST EFFECTIVE SUB-AREAS

Cost Ranking	Area - Sub Area	Percent Remvl Accum.	Rehab Cost, EAC	Accum Rehab Cost, EAC	Transp & Treatment Cost	Composite Costs Annual
					2,168,200	2,168,200
1.	3 ML	23.239	56,301	56,301	1,664,332	1,720,633
2.	1 ML	53.629	109,612	165,913	1,005,416	1,171,329
3.	6 ML	55.361	12,193	178,106	967,863	1,145,969
4.	12a ML	56.649	15,260	193,366	939,936	1,133,302
5.	5a ML	57.649	12,681	206,047	918,254	1,124,301
6.	9 ML	58.432	9,966	216,013	901,277	1,117,290
7.	12 ML	59.278	12,019	228,032	882,934	1,110,966
8.	7 ML	60.376	19,428	247,460	859,128	1,106,588
9.	2 ML	61.742	28,584	276,044	829,510	1,105,554
10.	4 ML	62.020	8,418	284,462	823,482	1,107,944
11.	5 ML	62.118	5,608	290,070	821,358	1,111,428
12.	9 SS	62.395	16,564	306,634	815,352	1,121,986
13.	1 SS	64.311	132,136	438,770	773,809	1,212,574
14.	10 ML	64.431	8,625	447,395	771,207	1,218,602
15.	9 I	66.620	170,534	617,929	723,745	1,341,674
16.	6 SS	66.854	19,909	637,838	718,672	1,356,510
17.	12a SS	67.035	16,955	654,793	714,747	1,369,540
18.	1 I	70.240	314,301	969,094	645,256	1,614,350
19.	12 SS	70.368	14,325	983,419	642,481	1,625,900
20.	7 I	72.137	229,916	1,213,335	604,126	1,817,461
21.	4 I	72.960	110,549	1,323,884	586,281	1,910,165
22.	2 I	74.063	151,444	1,475,328	562,366	2,037,694
23.	3 SS	74.350	61,104	1,536,432	556,143	2,092,575
24.	3 I	76.066	376,354	1,912,686	518,937	2,431,623
25.	12a I	76.994	224,570	2,137,256		
26.	12 I	77.957	235,865	2,373,121		
27.	5 SS	78.008	13,192	2,386,313		
28.	5a I	78.323	91,922	2,478,235		
29.	6 I	78.577	85,638	2,563,873		
30.	7 SS	78.685	37,930	2,601,803		
31.	2 SS	78.841	61,455	2,663,258		
32.	5a SS	78.869	12,032	2,675,290		
33.	4 SS	78.895	13,651	2,688,941		
34.	5 I	79.053	94,632	2,783,573		
35.	10 I	79.272	215,233	2,998,806		

FIGURE 6-5

TOTAL CARKEEK PARK SYSTEM

COST BENEFIT CURVE



SUMMARY OF COSTS

SEWER SYSTEM EVALUATION SURVEY

FOR

COST EFFECTIVE SUB-AREAS

Sub-Area	I/I Ranking	Length of M.L. Sewer	Total Sub-Area Costs	E.A.C.
3 M.L.	5	43,365	35,759	3,343
1 M.L.	5	84,955	70,247	6,567
6 M.L.	3	20,635	11,349	1,061
12a M.L.	3	26,110	14,359	1,342
5a M.L.	4	13,036	7,536	704
9 M.L.	3	16,510	9,112	852
12 M.L.	3	20,360	11,236	1,050
7 M.L.	3	32,590	17,924	1,676
2 M.L.	3	51,305	28,235	2,640
Nine of twelve sub-areas were				
found cost effective to				
rehabilitate to remove excess				
infiltration in main line				
		308,866		

Total Area Cost → $ 205,757

Total Area E.A.C. → $ 19,235

SUMMARY OF COSTS

INFILTRATION REHABILITATION COSTS

FOR

COST EFFECTIVE SUB-AREAS

Sub-Area	I/I Ranking	Length of M.L. Sewer	Total Sub-Area Costs	E.A.C.
3 M.L.	5	43,365	496,892	52,958
1 M.L.	5	84,955	972,238	103,045
6 M.L.	3	20,635	86,440	11,132
12a M.L.	3	26,110	105,287	13,918
5a M.L.	4	13,036	108,495	11,977
9 M.L.	3	16,510	68,302	9,114
12 M.L.	3	20,360	84,437	10,969
7 M.L.	3	32,590	138,151	17,752
2 M.L.	3	51,305	199,807	25,944

Total Area Cost → $ 2,260,049

Total Area E.A.C. → $ 256,809

CHAPTER 7

DETAILED PLAN STUDY AND SCHEDULE

Plan of Study Action

In order to proceed with a sewer system evaluation survey program a detailed plan of action, a budget and a time table needs to be established for execution.

This detailed plan for a systematic sewer system evaluation survey for the Carkeek Park System cost-effective sub-areas will be divided into six plases:

1. Physical Survey and Ground Water Analysis
2. Rainfall Simulation (Smoke Testing and Dyeing)
3. Initial Engineering Report, Analysis and Time Table
4. Preparatory Cleaning
5. Television Inspection
6. Survey Analysis and Report.

1. Physical Survey and Ground Water Analysis

The physical survey will encompass a field investigation of the entire sewer system in each of the nine sub-areas that have been determined as being cost-effective for infiltration control rehabilitation work. This field investigation will involve the descent into every manhole and observing the degree and nature of any deposition in all lines coming into and out of the manhole. Leakage and any sign of high water marks in the manhole will be noted. Each sewer line will be lamped and investigated for existing physical conditions and structural defects or deficiencies. Field log notes will be taken of actual conditions in each manhole and sewer line.

Groundwater evaluation is planned as part of the physical survey. Where found essential, groundwater gauges or gauge holes may be installed in or close to selected key manholes as a means of correlating the impact of static heads in sewage flows. This procedure may be necessary to determine the relative significance of infiltration to the total infiltration/inflow problem.

Flow monitoring work will be conducted at selected key manhole locations to more accurately determine and identify the areas when infiltration/inflow problems exist. Flow depths will be measured and recorded in each manhole during the progress of the physical survey.

The total length of the main line sewers in the nine sub-areas is 308,866 feet. The cost of the physical survey was estimated to be $43,710. A time element of 62 working days or 13 calendar weeks would be required to perform the physical survey task operation. This time element can be reduced with the use of more than one crew. With the use of two crews performing the survey work on a concurrent basis, the physical survey could be conducted through 31 working days or approximately 7 calendar weeks. Each crew, including a project observer working a full 8 hour day, is estimated to survey 5,000 feet per day.

2. Rainfall Simulation (Smoke Testing and Dyeing Tests)

Smoke testing operations are planned to be conducted throughout the nine sub-area sewer systems in order to detect infiltration/inflow sources. The smoke testing procedure will consist of forcing smoke emitted from special smoke bombs by using gasoline driven blowers into two adjoining main line sewer sections at one manhole set-up. The smoke testing operation between two manholes will require about 10 to 15 minutes. This method will be best used to detect inflow sources such as roof leader, cellar, yard and area drains, foundation drains, abandoned building sewers, faulty connections, illegal connections and storm drain cross connections. Structural damages and leaking joints in sewer pipes and overflow points in the sewer system can also be detected by the smoke tests.

Observation will be made of any smoke appearance at any and all locations. These smoke observations will be recorded by camera photography and the photographs will be kept for permanent documentation of the infiltration/-inflow sources. Data log sheets will be recorded with the dates, locations and situations of the results.

The total length of main line sewers to be smoke tested is 308,866 feet. Estimated cost of conducting the smoke tests through the total length is in the amount of $31,564. The number of working days estimated to perform the smoke testing work is 52 days, based on the use of a single man crew with a project observer, working an eight hour day and testing 6,000 feet per day. Smoke testing operations will provide best results on calm clear days, therefore, testing on rainy, windy or snowy days should be avoided. Due to the uncertainty of steady continuous testing operations, the time length of testing may be extended for a longer period of time. The smoke testing operations should be expedited by using several crews on a concurrent basis during the summer and fall seasons from June through September. The use of two crews working on a consistent basis and having favorable weather could perform smoke testing operations in 5 to 6 weeks through the nine sub-areas.

Dyed water testing may be utilized to determine whether storm drain sections, stream sections, ditch sections and ponding areas which are located near or above the sewer sections are contributing any infiltration/inflow to the sewers. This method is more expensive and time consuming than the smoke testing technique, and is limited to locations where large quantities of water are available for the test. No cost estimate or work time period has been developed for any anticipated use of dye testing in the survey schedule.

3. Initial Engineering Report, Analysis and Time Table

An initial engineering report shall be prepared which summarizes and evaluates all of the findings of the physical survey, groundwater analysis and rainfall simulation studies. The report will itemize the infiltration/inflow findings by sub-area system which would then be correlated to the total infiltration/inflow volume.

The general conditions of the nine sub-area sewer systems can be determined after completion of the physical survey and the rainfall simulation tasks. Sewer sections which present an obvious potential for excess infiltration/-inflow are then selected for internal inspection to pinpoint the causes, sources and magnitude of infiltration/inflow before being recommended for rehabilitation. Sewers found with accumulation of deposited material blocking or partially reducing the capacity of the sewer, will be first cleaned before any internal inspection is performed. Necessary preparatory cleaning and internal television inspection schedules will be established. The precise locations for televising can be determined and the exact cost of these television inspections can be established along with the required cost of necessary preparatory cleaning activities. Completion dates and the end results can be predicted. This report will present economical justification for any future work and conclusions that infiltration/inflow problems will be brought under control if the work is carried out as recommended. The cost estimate for preparing and providing the initial engineering report is in the amount of $8,000 based on the project engineer's development time of 40 days at $200 per day.

4. Preparatory Cleaning

The preparatory cleaning operation should remove all sludge, mud, sand, gravel, rock, bricks, grease and roots from the sewer pipes, manholes and sewer structures to be inspected. This cleaning action is normally more thorough than that work done for routine maintenance. Thorough cleaning of sewers will permit optimum viewing with television cameras. The performance of the cleaning operation is usually far more time-consuming than the actual internal inspection. For this reason, television camera work will not be on-site while the cleaning crews are working.

A complete sewer cleaning operation involves the following four tasks: 1) dislodging the materials, 2) transporting the materials to a point of access, 3) removing the materials from the sewer system and 4) disposing of the materials. Usually more sewers will be cleaned than are televised. Being dependent on the findings of the physical survey there are times when extra cleaning is necessary to avoid the reclogging of sewers prior to televising. This action will assure that the sewers will remain clean long enough for television inspection work.

The total length of main line sewers that has been determined for preparatory cleaning is estimated at 969,950 feet for the nine sub-areas. This estimate of footage is not exact however, and will be subject to revision after the physical survey work is completed. The number of working days estimated to perform the cleaning activities is 97 days. This time is based upon the use of three man crew with necessary cleaning equipment and a project observer working an 8-hour day, and being able to clean 1,000 feet of sewer pipe daily. The cost estimate for cleaning work would be in the amount of $45,590, with crew costs at $470 per day.

5. Internal Television Inspection of Preselected Sewers

Following the preparatory cleaning, the preselected sewers are internally inspected to determine the location, condition and estimated flow rate for each source of infiltration/inflow. During the inspection, all of the infiltration/inflow sources, structural defects, service connections, abnormal conditions and other pertinent observations are recorded. This information documented during the inspection operation can be used to locate the pipelines and problem sections in the pipes during actual rehabilitation. The results from the inspection will provide a factual base for the cost-effectiveness analysis to determine the lines which can be cost-effectively rehabilitated and for the selection of the most suitable methods for rehabilitation.

The sewer inspection will be accomplished by television camera inspection. This technique utilizes a closed circuit television camera to observe the conditions in the sewer lines. The results are shown on the television monitor screen. Documentation is made with video tapes or photographs of the monitor. All conditions will be recorded on television log sheets. The locations of all conditions, observations, flow rates and recommended correction actions will be noted on the log sheets.

The total length of mainline sewers that has been established for internal television inspection is estimated at 143,493 feet from the nine sub-area systems. This estimate of footage is not exact, and will be subject to revision after the physical survey work is completed. The number of working days estimated to conduct the televising operations is 144 days. This time is based upon the use of a three man crew with all necessary television equipment and vehicles and a project observer working an 8 hour day and being able to televise 1,000 feet of sewer pipe daily. The cost estimate for televising work would be in the amount of $69,120 with a crew cost at $480 per day.

6. Survey Report and Analysis

A complete survey report has to be prepared which contains a description of all the tasks performed, a summary of all the results gathered during the investigation, a cost-effectiveness analysis necessary to determine the portion of sewer sections which can be cost-effectively rehabilitated and the infiltration/flow which is expected to remain in the sewer system after rehabilitation, a proposed sewer system rehabilitation program and its related costs, and a documentation of all the field data gathered during the investigation. The results, conclusions and recommendations are to be summarized in tabulated forms and illustrated on maps. Detailed sewer maps will be included in the report which will show all the manholes, pumping stations, by passes, overflows and sewer lines in the survey sub-areas. The development time for data compilation and analysis, report preparation and production is estimated at 50 days. Estimated cost for preparation of final report is $20,000 based on the engineer labor cost of $200 per day per engineer.

The evaluation survey cost estimate total for the six phases is in the amount of $217,984. With the inclusion of survey project contingency cost of 10 percent for the amount of $21,798, the total estimated survey cost would be $239,782. The survey phase costs are based on current 1979 labor and equipment charges and include Seattle Engineering Department overhead costs. Survey phase cost estimates for labor and time requirements are tabulated and summarized on Table 7-1.

In regard to the subject of providing approximate starting date estimates and the time period duration of each phase, a tentative evaluation survey schedule has been developed and illustrated in bar chart form on Figure 7-1. The time periods which have been determined for the physical survey, rainfall simulation, preparatory cleaning and television inspection phases are based on the use of one crew performing concurrent work operations. By taking the climatological restrictions into account along with the use of three survey crews, the evaluation survey could be conducted on a time schedule of thirteen months. No starting calendar date has been established for the schedule at this time.

TABLE 7-1

SEWER SYSTEM EVALUATION SURVEY

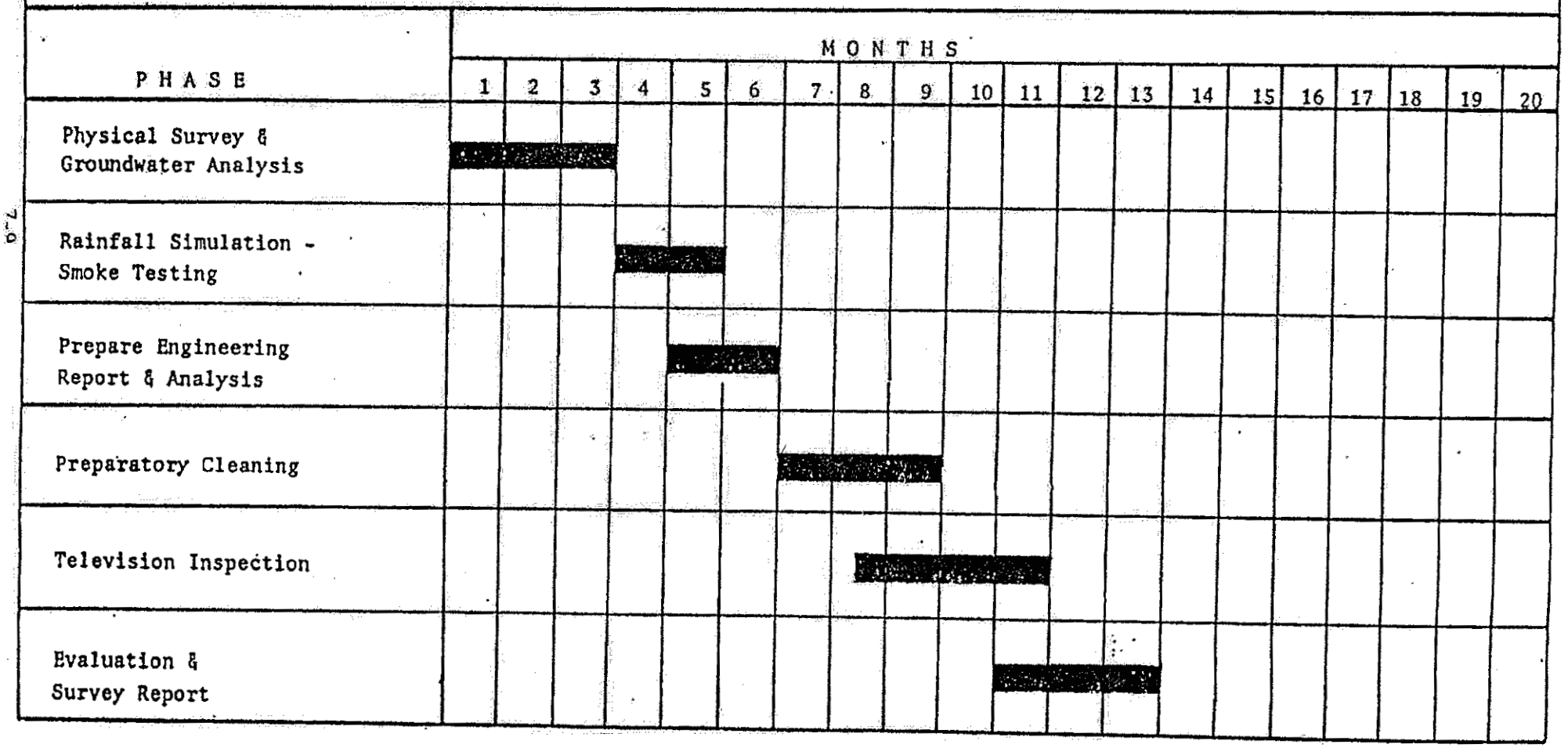
COST ESTIMATE - 1979

Phase	Length	Rate Per Day	Crew Cost Per Day	Number Working Days	Cost in Dollars
Physical Survey Four Man Crew + Observer (8 hr.)	308,866	5,000 ft	$705	62	$ 43,710
Rainfall Simulation - Smoke Testing - Three Man Crew + Observer (8 Hr.)	308,866	6,000 ft	$607	52	$ 31,564
Engineering Report (Selective Cleaning and Televising)	-	-	$200	40	$ 8,000
Cleaning Three Man Crew + Observer (2 hr.)	96,950	1,000 ft	$470	97	$ 45,590
Televising Three Man Crew + Observer (2 hr.)	143,493	1,000 ft	$480	144	$ 69,120
Collection & Interpretation, Cost Effective Analysis, Outline Rehab. Program, Maps, Schedule, Compilation & Preparation of Report Resources 2 Engr/Day	-	-	$400	50	$ 20,000
Sub-Total					$217,984
Survey Project Contingency @ 10%					$ 21,798
TOTAL					$239,782

Note: Crew costs per day are based on June 1979 labor and equipment costs and include City of Seattle overhead charges. Wage increase for 1979, not included.

FIGURE 7-1
201 TASK INFILTRATION/INFLOW STUDY
CARKEEK PARK SYSTEM

SEWER SYSTEM EVALUATION SURVEY SCHEDULE
(TENTATIVE)



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