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9 December 2008

Mr. Michael Kang
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Department of Public Works/Sanitation
City of Simi Valley
500 West Los Angeles Avenue
Simi Valley, California 93065

Subject: Sewer Collection System Asset Evaluation and Rehabilitation Plan
Volumes 1 and 2
K/J 0689059

Dear Mr. Kang:

In accordance with your request, we are pleased to submit four (4) copies and one reproducible CD of the Final Sewer Collection System Asset Evaluation and Rehabilitation Plan (Plan) to the City of Simi Valley (City). The Plan is a compilation of the analysis and finding of our evaluation of the City's sewer system and incorporates the City's comments to previous submittals. This document and the accompanying digital files constitute the final deliverables for this project.

The Final Plan contains two volumes. Volume 1 is the primary report of findings, as it provides the background, objectives, approach, and results of the evaluation of approximately 50 miles of the City's sanitary sewer system. Volume 2 is provided to document detailed pipeline evaluation data and associated cost estimates to assist the City in the methodical implementation of the Plan. The data contained in both documents are generally referenced through common project or pipe segment identification numbers.

It has been a pleasure working with you and the other members of the City's staff on this important project and look forward to working with you in the future. Please contact us if you have any questions or need additional information.

Very truly yours,

KENNEDY/JENKS CONSULTANTS

Roger Null

Roger Null, V.P.
Project Manager

Enclosure

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Sewer Collection System Asset Evaluation and Rehabilitation Plan

Final Report

Volume 1
October 2008

Prepared for

City of Simi Valley
Department of Public Works/Sanitation
500 West Los Angeles Avenue
Simi Valley, CA 93065

K/J Project No. 0689059

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Executive Summary

Kennedy/Jenks Consultants (Kennedy/Jenks) has reviewed and coded defects according to the Pipeline Assessment Certification Program (PACP) guidelines for nearly 50 miles of video footage. The near 50 miles of video comprises only 13 percent of the City of Simi Valley's (City's) main collection system. However, the footage includes the larger pipelines in the main collection system and thus constitutes a substantial portion of the estimated cost for rehabilitation of the entire system (Figure 1-1). It also contains many of the older pipes that were constructed of asbestos cement or concrete pipe. These pipes are more susceptible to corrosion than new PVC piping systems.

The County started constructing the sanitary sewer system in 1961 and the City, after incorporation in 1969, continued expanding the system. Today the City has approximately 360 miles of mainline sanitary sewer piping according the City's GIS database. As the pipelines age, the risk of pipe failure increases. The City experienced one such failure located along Los Angeles Avenue. Pipeline failures, such as this, require emergency response and are costly to repair. They also often lead to sanitary sewer overflows (SSOs) which have both public health and environmental implications. The Los Angeles Avenue failure cost the City over $1 million and took over one month to repair. Pipeline failures and SSOs can often be prevented with proactive, rather than reactive, sewer pipeline rehabilitation.

Approaching improvements from a proactive perspective requires detailed knowledge of the existing pipelines accomplished by internal closed-circuit television (CCTV) inspections. These internal inspections record pipeline defects such as cracks, joint problems, and surface deterioration, which can lead to pipe failures. The internal inspections also identify maintenance concerns, such as intruding roots or grease build-up, that if corrected can prevent pipeline blockage and an SSO event. In the United States over the last 10 years, the approach to internal pipeline inspections has become standardized through the PACP.

After reviewing the internal CCTV footage, all sewer sections were ranked according to the PACP defect coding, pipe diameters, and materials of construction. Priority ranking was also given to each area based on a criticality evaluation (discussed in detail in Appendix A), including each area's proximity to major roadways, the railroad, known businesses, and tourist destinations. Volume 2 of this report includes a detailed schedule for sewer rehabilitation, indicating a range of years in which specific areas of concern are recommended for rehabilitation. Itemized estimates of probable cost are also included in Volume 2. This rehabilitation schedule is summarized in Figures 5-1 through 5-4 of this Volume 1. Information is also provided in this Volume 1 and also Volume 2 to distinguish pipe reaches requiring frequent routine cleaning and/or maintenance to prevent a SSO occurrence.

This thorough review has identified specific reaches of the piping system, which are recommended for improvement to prevent potential costly failures or SSO events. More importantly, however, these internal inspections have brought to light concerns involving one of the piping materials found extensively throughout the collection system. Between 30 and 45 years ago, the City invested in asbestos cement pipe (ACP) as the primary pipe material for new sewer installations. As a result, ACP makes up nearly one-third of the City's sanitary sewer

system (Figure 2-3) and it is generally the material found to be used for the larger diameter interceptor sewers in the system.

Based on historical evidence and video pipeline inspections, sewers in the highest risk areas of the City piping system are comprised of asbestos cement pipe (ACP). This type of pipe has an average life span of approximately 50 years. Unfortunately, while the extensive use of ACP might have lowered the costs to the City at the time of installation, over time this material has been found to be inferior. Where the appropriate conditions are present, deterioration and/or failure of the ACP piping system can occur prior to the 50-year average life span. This places the City in a unique position relative to other nearby communities whose initial investment was in pipe materials that can surpass 80- and 100-years of age. The City must begin reinvesting a significant sum of money into their sanitary sewer system at this time.

The longevity of ACP piping material is of concern because of its relatively low bearing strength, susceptibility to attack from internal sewer acids, and the subtle visual identification of deterioration during CCTV inspection. Therefore, the ACP is the most significant concern in this evaluation of the longevity of the City sewer system.

The internal inspections completed have revealed varying degrees of surface deterioration in ACP reaches, thus enabling the City to implement a phased rehabilitation schedule. Using a phased approach spreads out the cost of ACP rehabilitation that would otherwise occur over a short period of time when the pipelines reach the end of their useful life span (Figure 2-7). Fortunately, there were no pipe reaches found to have severe structural defects which would warrant pipe replacement and thus, the focus of this asset rehabilitation plan is based on rehabilitating the existing facilities whenever possible.

The estimated cost associated with rehabilitation of approximately 34 miles of sewers identified for rehabilitation within 20 years is approximately $90.5 million, at current construction costs (Table 5-1). Of this total, $14.4 million represents the probable cost for rehabilitation necessary in the next three years. Additionally, to support methodical construction, specific deficient pipeline segments have been grouped together into rehabilitation projects (Appendix B).

To assist the City with the programming of future capital improvement program costs, current costs and annual estimates are increased to future dollars to account for inflation and increasing construction costs. The resulting projected annual costs in both current and future dollars are derived (Table 5-2) and indicate that the City's twenty year program is projected to cost approximately $145 million. Moreover, the annual reinvestment in infrastructure could exceed $9 million in any given time frame. Given that there is some flexibility in annual programmed improvements, the specific facilities to be improved in conjunction with the level of annual investment should be reviewed annually as part of the City's ongoing capital improvement planning and budgeting.

It should be noted however, that there may be instances where pipe capacity limitations would warrant pipeline replacement. For this reason, the estimates of probable cost incorporate an allowance for potential pipe replacement as a function of the cost contingency factor. It is recommended that the City consider budgeting for a more comprehensive hydraulic capacity analysis and/or update the Sewer System Master Plan. This activity is also a requirement of the new State Waste Discharge Requirements as regulated by the State Water Resources Control Board.

It is recommended the City initiate a program for improving the segments identified in the immediate category and implement additional maintenance and cleaning as necessary in support of the City's SSO prevention program. It is also recommended the City consider the following:

- Incorporate the results presented in this evaluation into the City's existing maintenance/sewer database,
- Perform a flow monitoring study of areas of capacity concern,
- Conduct an overall hydraulic sewer capacity analysis and Master Plan Update,
- Continue with internal CCTV inspections of the sewer system,
- Develop a cleaning methodology tailored to protecting ACP, and
- Apply the approach developed in this evaluation to any future internal inspections.

Section 1: Problem Statement

1.1 Introduction

The City of Simi Valley's (City's) sanitary sewer system is comprised of approximately 360 miles of mainline gravity sewers according to the City's GIS database. This length does not include the private connection laterals. Construction of the sewer system began in 1961 (approximately 47 years ago) and continues as the city expands. A map of the City showing the approximate 50 miles of sewer main piping scheduled for video inspection is presented in Figure 1-1.

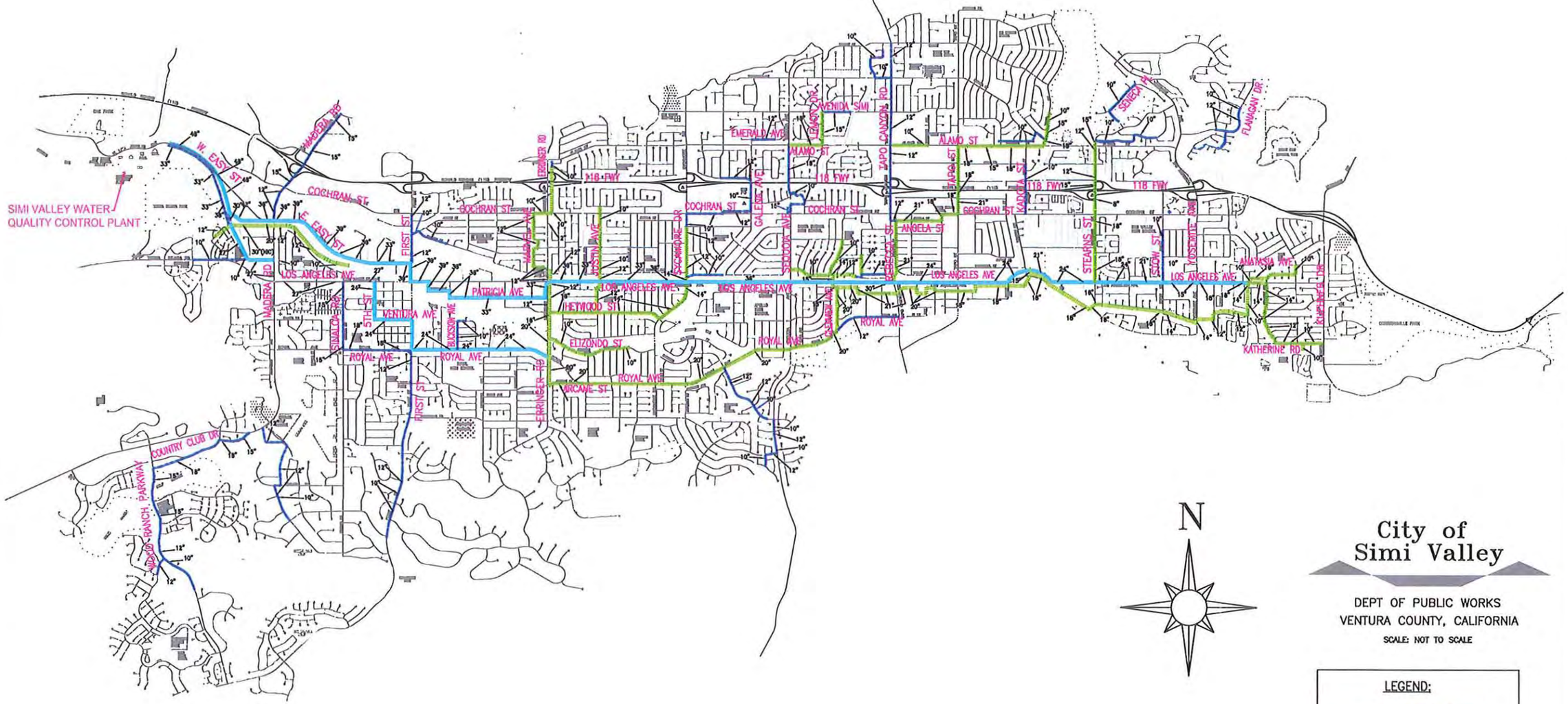
Due to state regulations, wastewater utilities are committed to a "no sewer system overflow" and "no pipeline collapse" mandate in the face of aging and deteriorating infrastructure. Prevention of pipeline failures and overflows will require evaluation of the condition of in-place sewers and rehabilitation of piping where failure is probable. This report summarizes the results of closed circuit television (CCTV) pipeline inspections, pipe defects, high risk locations, and recommendations for rehabilitation of concerned sections of sewer.

1.2 Problem Statement

The cost of pipeline failure in sanitary sewer systems serving municipalities is increasingly high. A failure where a collapse occurs typically causes a sanitary sewer overflow (SSO) and requires bypass pumping, public notification, and costly construction under emergency conditions. Other failures of sanitary sewers can cause soil collapse that result in a hazard to life and property. The liability associated with collapse increases in high density areas and heavily traveled roads.

Because of the environmental concern, liability, and high cost associated with pipeline collapse and SSO, the cost in dollars and loss of image from pipeline failure can be significant to the City. Based on historical evidence and video pipeline inspections, sewers in the highest risk areas of the City piping system are comprised of asbestos cement pipe (ACP). This type of pipe has an average life span of approximately 50 years and makes up many of the larger sewer interceptors that transport wastewater to the City's treatment facility. Unfortunately, while the extensive use of ACP might have lowered the costs to the City at the time of installation, over time this material has been found to be inferior. Where the appropriate conditions are present, deterioration and/or failure of the ACP piping system can occur prior to the 50-year average life span. This places the City in a unique position relative to other nearby communities whose initial investment was in pipe materials that can surpass 80- and 100-years of age. The City must begin reinvesting a significant sum of money into their sanitary sewer system at this time.

The longevity of ACP piping material is of concern because of its relatively low bearing strength, susceptibility to attack from internal sewer acids, and the subtle visual identification of deterioration during CCTV inspection. Therefore, the ACP is the most significant concern in this evaluation of the longevity of the City sewer system.



N

City of Simi Valley

DEPT OF PUBLIC WORKS
VENTURA COUNTY, CALIFORNIA
SCALE: NOT TO SCALE

LEGEND:

- FIRST PRIORITY
- SECOND PRIORITY
- THIRD PRIORITY

FIGURE 1-1
AREA MAP FOR SEWER SYSTEM TELEVISION INSPECTION

1.3 Objectives

The purpose of this study is to document the condition of approximately 50 miles of the City's sanitary sewer collection system using the National Association of Sewer Service Companies' Pipeline Assessment and Certification Program (PACP). A background on the City collection system, including a description of the location and composition of the piping materials, is provided in Section 2. Standardized PACP defect coding, presented in Section 3, is used in combination with a number of qualitative criticality factors to determine sections that require restoration and, once identified, these sections have been prioritized as further discussed in Section 4 and Appendix A. Recommended improvements to the sewer system and budgetary level estimates of probable cost are provided in Section 5 with a summary of conclusions and recommendations in Section 6.

Section 2: Background

2.1 Simi Valley Study Area

The City of Simi Valley is located in Ventura County approximately 30 miles north of Los Angeles and 30 miles east of Ventura. The study area is within the City limits. The City is approximately 9 miles long (east to west) between the Santa Susana Mountains on the North and Simi Hills on the south. The width of the Valley varies from approximately one to three miles. The valley floor rises in elevation from a low of 700 feet above mean sea level (MSL) at the western boundary to 1,100 feet MSL in the east. The Santa Susana Mountains rise to an elevation of approximately 3,000 feet MSL. To the south, the Simi Hills peak at an elevation of approximately 2,000 feet.

The depth to the groundwater surface varies throughout the service area from less than 20 feet to more than 100 feet. Water bearing sediments extend to several thousand feet in depth. Areas of the west and east ends of the Valley, shown in Figures 2-1 and 2-2, respectively, have been identified as the areas which contribute to the infiltration of groundwater into the sewer system. These areas generally correspond to portions of the community where the depth to groundwater is less than 20 feet.

The major surface drainage system in the City is the Arroyo Simi, which flows from east to west. It collects surface water from several canyon streams emerging from the surrounding hills and mountains. Most of these streams, including the Arroyo Simi at its eastern end, are intermittent during most of the year.

2.2 Sanitary Sewer System Summary

The backbone of the City's sanitary sewer system is comprised of the oldest and largest pipelines within the overall system. Much of this mainline runs along Los Angeles Avenue to the City's wastewater treatment plant. During the period in which the larger sewer lines were constructed, the materials in use were dominated by asbestos cement pipe (ACP), vitrified clay pipe (VCP), and reinforced concrete pipe (RCP). A small amount of ductile iron pipe (DIP) and cast iron pipe (CIP) was employed in the large diameter collection system where structural requirements called for the strength and flexibility of iron pipe. The largest mainline is comprised primarily of (ACP) and a small portion (less than 2 percent) of reinforced concrete pipe (RCP), and was constructed in the 1960s and 1970s in anticipation of growth within the city limits.

Since the early 1980's the City's sewer system has been constructed using predominantly plastic piping material such as PVC (polyvinyl chloride) and reinforced plastic (truss) pipe. PVC is used for a wide variety of pipe diameters, while truss pipe is most commonly used for smaller diameter pipe (12-inches or less). In locations where structural stability under dynamic load is critical, DIP is used as the conveyance sewer or a structural support outer sleeve/carrier pipe.

FIGURE 2-1
WEST AREA OF HIGH GROUNDWATER

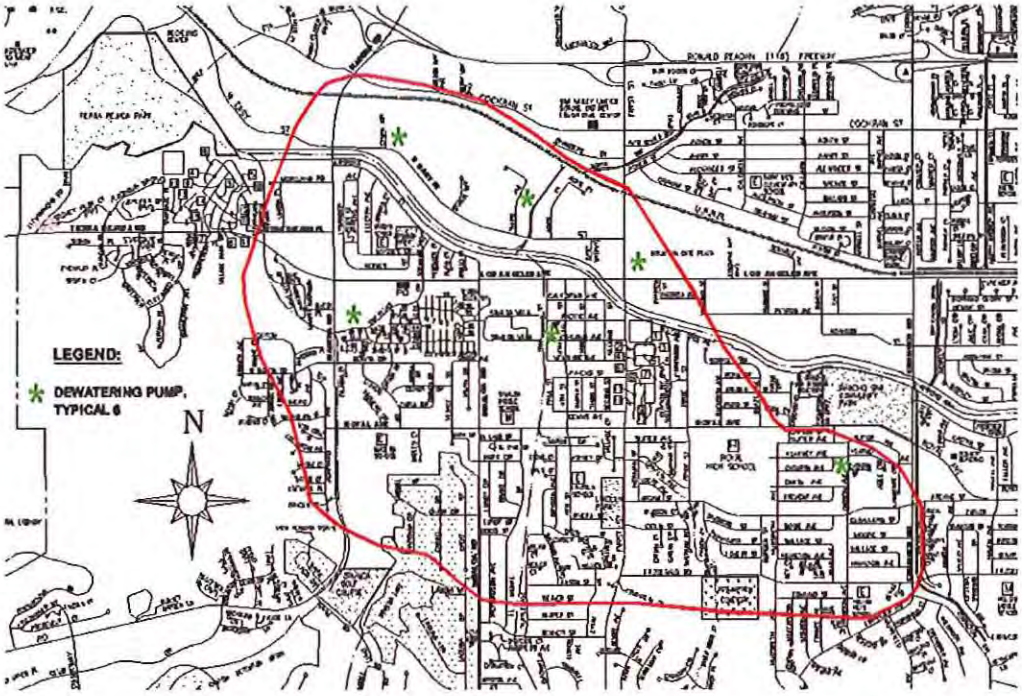
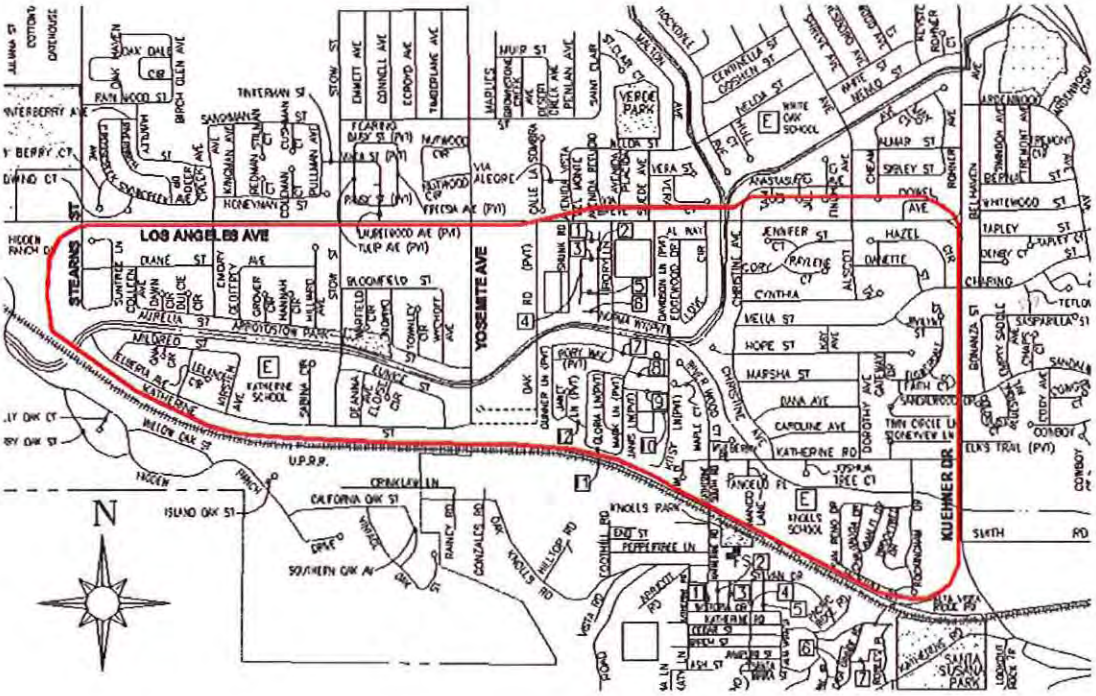


FIGURE 2-2
EAST AREA OF HIGH GROUNDWATER



The primary concern related to early construction of sewers in the City is the use of pipe materials that are subject to chemical attack by hydrogen sulfide. Materials susceptible to hydrogen sulfide attack are ACP, RCP, and DIP. Additional concern is for pipe material that is brittle and subject to cracking or breaking due to settling or poor construction practices. These issues are related to ACP, RCP, and VCP. PVC and truss pipe are not generally subject to chemical attack, and are somewhat flexible and are less likely to break due to inadequate compaction. In general VCP is known to have a long life span if installed and maintained properly, as it is not subject to chemical attack.

Visual inspection is the most common method of determining pipe condition; however, it is not applicable for some forms of damage that may affect the structural condition of pipe. For example, VCP failure is easily discernible by internal CCTV inspection, as cracks and breaks are the primary methods of failure. However, ACP structural failure is often more subtle and more difficult to identify by visual methods, as it is subject to chemical attack. To evaluate the condition of the ACP in the City, several factors were considered, including age, service, visual condition, deposits, and proximity to high risk areas.

2.2.1 Pipe Materials

The City's Geographic Information System (GIS) database (Atlas) was used to determine the lengths, ages, and diameters for the various materials of construction used in the overall collection system. The following data is based on information contained in the City's GIS database. This source data was not reviewed by Kennedy/Jenks for accuracy. Approximately half of the City's collection system in use today was constructed from 1961 until the late 1970s.

Figure 2-3 graphically summarizes the pipeline materials used in the City, as a function of the total length of 362 miles (1,912,300 feet) in the GIS database. As shown, plastic is the predominant material representing approximately 48 percent (174 miles) of the system. ACP, the pipeline material of greatest concern, comprises approximately 31 percent of the system or over 112 miles of pipe. VCP, RCP and DIP/CIP also exist in the system but only represent 14 percent, 1 percent, and 2 percent, respectively, of the mainline system. There is 4 percent of the system that is of unknown composition. Because the pipe material identified in the Atlas did not always correspond to the actual pipe material determined from the CCTV footage, the material percentages derived from the Atlas are not completely accurate.

The anecdotal performance history of PVC pipe over the last three decades indicates that there is little concern for its longevity. Therefore, it can be inferred from Figure 2-3 that approximately 48 percent of the City collection system is likely to be in good condition.

FIGURE 2-3
SIMI VALLEY COLLECTION SYSTEM:
PIPE MATERIALS – PERCENTAGE BY LENGTH

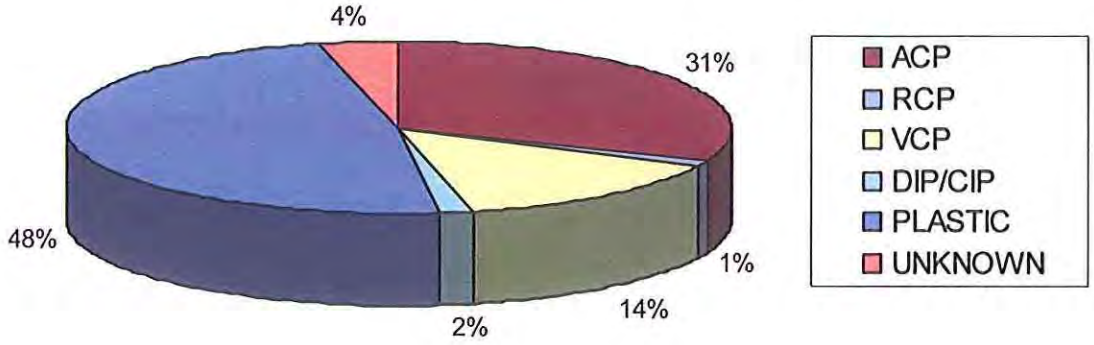
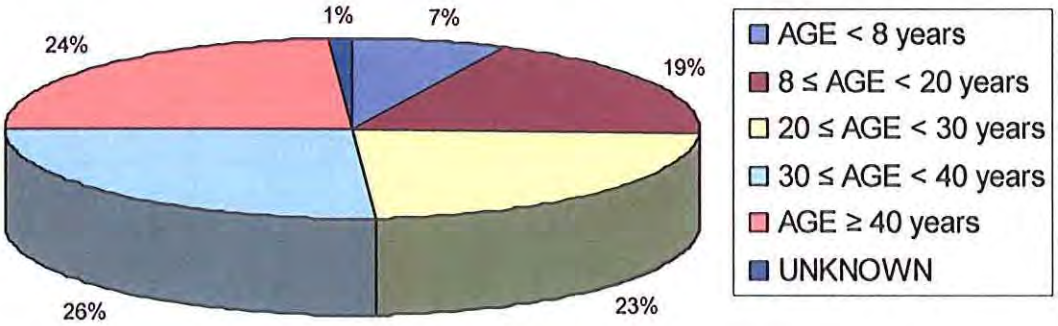


Figure 2-4 illustrates the age of pipe as a function of total footage for the City's collection system (362 miles) in the GIS database. The oldest pipe, according to the Atlas, was constructed in 1961, just over 45 years ago. Approximately 24 percent (87 miles) of the sewer main has aged between 40 and 45 years. A significant portion of this pipeline is ACP or VCP pipeline. Approximately 26 percent (94 miles) of sewer main has aged between 30 and 40 years. The total length of pipe constructed between 30 and 45 years ago is approximately 181 miles.

FIGURE 2-4
SIMI VALLEY COLLECTION SYSTEM: PIPE AGE



The combination of ACP and RCP pipe material totals approximately 116 miles (612,000 lineal feet) of pipe. Evaluation of the sewer mainline database developed from the City's GIS database indicates that 15.4 miles (81,350 lineal feet) is ACP sewer main constructed between 40 and 45 years ago. These ACP pipelines comprise many of the largest sewer interceptors in the City, and failure of any of these sections may result in substantial damage and cost.

2.2.1.1 CCTV Inspection Study Focus

Collecting and closely watching CCTV sewer footage is a very time-consuming and costly activity. Therefore, this study focused on interceptor pipelines 10 inches in diameter and greater. The pipeline length inspected for the study totaled 48.7 miles. Thus, the evaluation reported herein covers 48.7 miles of larger sewer pipelines out of the approximate 362 total miles of the City sewer network. Figures 2-5 and 2-6 depict the relative percentages in various age categories and material categories, respectively, for the 48.7 miles surveyed.

FIGURE 2-5
SIMI VALLEY COLLECTION SYSTEM:
PIPE AGE BY LENGTH (2006 CCTV STUDY)

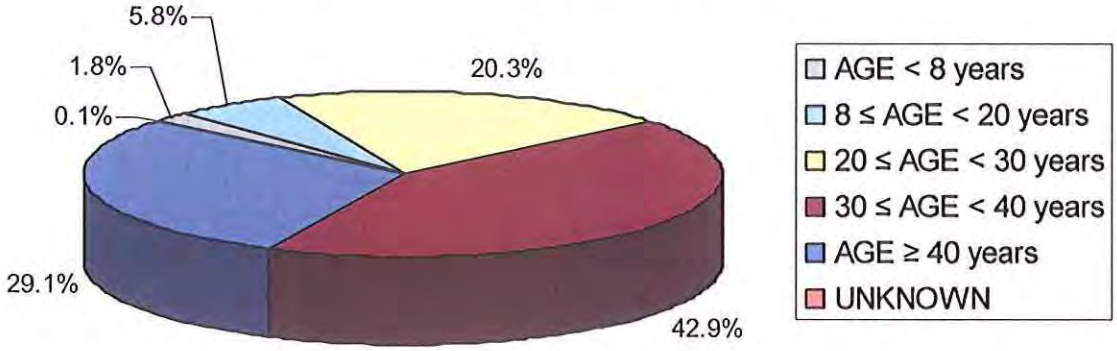


FIGURE 2-6
SIMI VALLEY COLLECTION SYSTEM:
PIPE MATERIAL BY LENGTH (2006 CCTV STUDY)

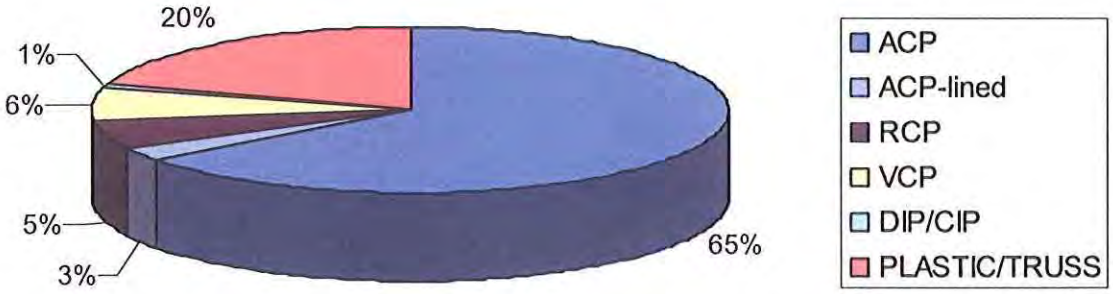


Figure 2-5 shows that 29 percent of the 48.7 miles of sewer inspected for this study in 2006 is greater than 40 years in age. With the oldest pipe in the system being 45 years in age, sewers between 40 and 45 years in age total approximately 74,800 feet (14.2 miles). An additional 43 percent of the City sewer mainline system is between 30 and 40 years in age, totaling 20.9 miles (110,500 feet). Together these two age groups represent 72 percent of the mainline system that was inspected by CCTV and are at least 30 years in age in 2006. By 2016 this same 72 percent will range in age from 40 to 55 years. Similarly in 2026, 72 percent of the piping will range from 50 to 65 years in age. Of the pipelines inspected, 28 percent is less than 30 years of age. These sewers were primarily constructed of PVC, which is generally high quality material with improved gaskets at the joints.

Figure 2-6 shows that ACP makes up 65 percent or 31.5 miles (166,520 feet) of the pipeline materials for sewers inspected in the 2006 study. Figure 2-7 indicates that 38.6 percent of ACP in the 2006 study is 40 years of age or older. It also shows that more than 91 percent of ACP pipe in the 2006 study is 30 years in age or greater. Therefore, approximately 66,864 feet of the ACP surveyed is between 40 and 45 years in age, and 92,250 feet of ACP is between 30 and 40 years of age. ACP makes up the greatest amount of pipeline materials used between 30 and 45 years ago, and it also represents the largest amount of pipeline with the greatest age in the study. Together Figures 2-6 and 2-7 demonstrate that the City's critical sewers (large diameter pipelines carrying relatively high wastewater flows) are also the oldest and are predominantly constructed of ACP.

FIGURE 2-7
SIMI VALLEY COLLECTION SYSTEM:
ACP AGE BY LENGTH (2006 CCTV STUDY)

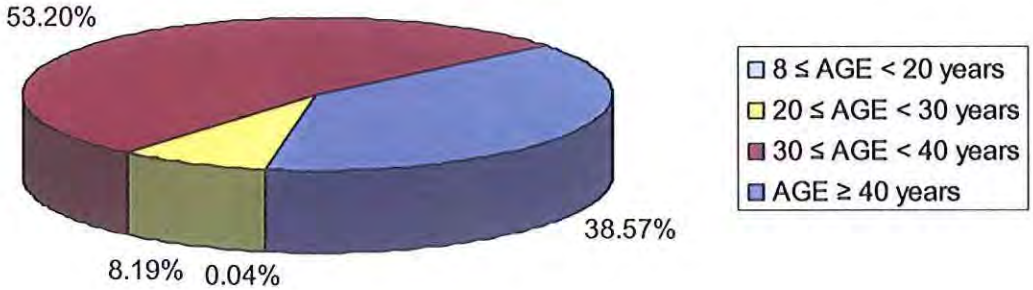
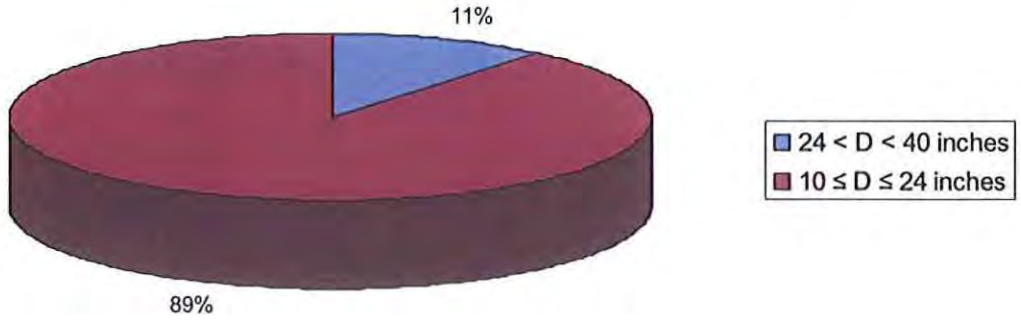


Figure 2-8 depicts the distribution of diameters for ACP sewers that are 40 years of age or older. The largest ACP sewer between 40 and 45 years of age is 40 inches in diameter. Pipes with diameters between 25 and less than 40 inches account for approximately 7,500 feet of the pipe in this age range. The largest percentage of ACP pipeline between 40 and 45 years in age is in the 10-inch to 24-inch diameter range, totaling nearly 59,500 lineal feet. No ACP sewers between 40 and 45 years of age included in this evaluation are smaller than 10 inches in diameter.

FIGURE 2-8
SIMI VALLEY COLLECTION SYSTEM:
ACP DIAMETER (D) FOR PIPE AGE 40 YEARS AND GREATER (2006 CCTV STUDY)



Together Figures 2-6, 2-7, and 2-8 indicate that pipelines in the City of 40 years of age or greater are dominated by the largest diameter ACP sewers in the City sewer collection system.

2.2.2 Causes of Potential Sewer Failures

The causes of sewer pipeline failures in the City fall into three major categories: poor construction practices, deteriorating pipe material condition, and operational and maintenance issues. Each of these categories has distinct defects or problems associated with them that can be identified from the review of the City's CCTV sewer footage.

2.2.2.1 Construction Practices

All types of sewer pipe are subject to failures related to poor construction practices. Improper pipe bedding, insufficient grades, and improper pipe assembly coupled with uneven or over compaction can result in deformed pipes, broken or misaligned joints, and the resulting accumulation of solids within the pipe.

Infiltration of groundwater through open joints, broken pipes, and bad service connections can result in soil entering the pipe and formation of voids around the pipe. These voids can result in collapse of soils around the pipe, and collapse of the pipe itself. Collapses can form holes in roadways or under structures leading to human health risks and property damage. Damaged sewers can also reduce conveyance capacity and is a common cause of sewer system overflows.

2.2.2.2 Deteriorating Pipe Material Condition

Pipe material may be subject to deterioration by exposure to chemicals or corrosive conditions. ACP, RCP, and DIP are generally subject to corrosion due to production of hydrogen sulfide. When flow through a reach of sewer pipe is slow (less than 1 ft/sec) organic solids may settle out, and anaerobic conditions can occur within the pipe. This can lead to formation of hydrogen sulfide which reacts with Portland cement in ACP and RCP, or iron in DIP and can ultimately lead to infiltration and structural failure of the pipeline.

Because of their non-reactive composition, PVC, truss, and VCP pipes are not subject to attack by hydrogen sulfide, therefore, chemical deterioration is not generally an issue for these types of pipes. On rare occasions, however, erosion due to grit may be a concern for these types of pipe.

2.2.2.3 Operation and Maintenance Issues

Operation and maintenance (O&M)-related issues primarily cause a decrease in pipe capacity, which may lead to an SSO. Loss of capacity is commonly caused by settled debris, accumulation of grease, root intrusion, infiltration, and objects protruding through the pipe wall. The effect is to obstruct a portion of the pipe cross section reducing flow through the pipe. These issues occur with all pipe materials and can be caused by poor design or poor installation. Typically O&M issues are ongoing, and repeated maintenance work is periodically required at these locations.

2.3 Identifying Failure Risk

The current regulatory environment in California requires that sewer system operators prevent or minimize SSOs by adequately maintaining the system and by repairing deficient portions of the system. To prevent failures it is necessary to conduct an internal pipeline assessment. Section 3 of this report includes a discussion of the internal assessment methodology used to assess 48.7 miles of the largest diameter sanitary sewers in the City.

Based on historical evidence and CCTV pipeline inspections, the highest risk pipes in the City's system are composed of ACP. This pipe material has an average life of approximately 50 years and composes many of the larger sewer interceptors that transport wastewater from the city to the treatment facility. Where the appropriate conditions are present, deterioration and/or failure of the ACP sewer system can occur prior to the 50-year average life span. As shown in Figure 2-3, ACP comprises nearly 31 percent or 112 miles of the City's mainline sanitary sewer system. Much of this ACP piping was constructed between 30 and 45 years ago. Where surface attack on the interior of ACP has occurred, the average life of this piping system (50 years) should be considered to be its maximum life. It is the ACP sewers that represent the most significant concern in this evaluation of the longevity of the City's collection system.

Section 3: Sewer Pipeline System Assessment

3.1 Sewer Pipeline System Assessment

Owners of wastewater collection systems have recognized for many years that pipelines deteriorate with time and have a finite life. To meet the public's expectations for a high level of service within a wastewater collection system, it is necessary to prevent SSOs, bypasses, and pipeline collapse. To provide a high level of confidence that the pipeline system is in sound condition requires performance of a periodic pipeline assessment.

3.1.1 National Association of Sewer Service Companies (NASSCO)

Until recently, owners and operators of wastewater collection systems in the United States lacked a systematic approach to assessing pipelines. These utilities, which today total approximately 19,000 separate organizations, were forced to develop their own internal pipeline condition assessment rating system. The National Association of Sewer Service Companies (NASSCO) offers the standardized pipe rating system known as the Pipeline Assessment and Certification Program (PACP). PACP establishes the condition of the sewer pipelines from the structural, maintenance, and physical dimension perspective, which is discussed in detail in the following section. The assessment is accomplished through the use of internal television inspection, termed closed circuit television (CCTV). The system provides standardization and consistency in the way we evaluate sewer pipeline condition and in how CCTV inspection data is managed.

The goal of NASSCO's PACP system is to develop a comprehensive and reliable database of information to describe sewer pipelines for use in prioritization, planning, and rehabilitation of wastewater collection systems.

3.1.2 Pipeline Assessment and Certification Program (PACP)

NASSCO developed PACP in cooperation with the Water Research Centre (WRc) of the United Kingdom. A CCTV inspection and defect coding system developed by WRc is recognized as the standard in the UK and much of Europe. In the United States NASSCO and WRc worked together to update the European codes to develop PACP, providing enhancements that more accurately address the needs for sewer pipeline assessment in the United States.

The prior lack of standards in the United States has complicated the understanding of how and why pipelines deteriorate. Wastewater utilities across the country lacked standards to benchmark the condition of sewer pipelines. Each utility or inspection contractor developed its own coding system that was not compatible with other systems. The inconsistencies made standardization necessary.

The adoption of PACP, with its standard codes and data management practices, allows benchmarking of sewer pipeline conditions within the utility. It also allows the comparison of future sewer pipeline inspections and comparison of inspections between separate utilities.

PACP incorporates a training and certification program. The cornerstone of the training is a reference manual, which includes approximately 275 pages of text. Certified instructors provide training in the use of PACP during a 2 to 3 day intensive workshop. At the end of the instruction an examination is administered and passing students are issued a certification number.

3.2 General Approach to TV Inspection Using PACP

The PACP details the requirements for the collection of sewer video and for identifying and coding the defects. The following are some of the standards that CCTV operators are required to adhere to:

- Pipeline must be free of debris and obstructions that prevent the visibility of the entire interior pipeline surface,
- All reasonable efforts must be made to fully inspect the entire pipeline segment,
- The camera must be ideally located within the pipe invert and move less than 30 feet per minute,
- The camera must stop while viewing defects,
- The lighting must be sufficient to fully illuminate the entire pipeline, but not overly illuminate it, and
- The video must correctly reflect the true colors within the pipeline.

A CCTV inspection form is used to document information required by the PACP format for each pipeline segment. This inspection form includes 39 fields that can be used by the CCTV operator or defect coder to describe the pipeline segment. These fields include physical features such as location, type of pipe, length, diameter, depth, year constructed, purpose of the survey, date cleaned, and weather. The form also includes fields to document pipeline defects observed during the internal CCTV inspection. These fields allow the coding of both point and continuous defects. The objective of coding defects is to document structural deficiencies and construction features, as these will have the greatest long term influence on pipeline integrity. Defects that are cosmetic in nature are not to be coded. A sample NASSCO CCTV inspection form is attached as Figure 3-1.

3.3 PACP Defect codes

The PACP system has defined five categories of codes used to identify internal pipeline defects:

- Continuous Defect Coding
- Structural Defect Coding
- Operational and Maintenance Defect Coding
- Construction Features Coding
- Miscellaneous Features Coding

Figure 3-1

C.C.T.V. Inspection Form

Surveyors name (1) and Certificate number (1a) System Owner (2) Survey Customer (3) Drainage Area (4) Sheet No. (5)

P/O No. (6) Pipeline Segment Reference (7) Date (8) CCYY/MM/DD Time (9) Location (Street Number and Number) (10) Locality (10a)

Further Location details (11) Upstream Manhole Number (12) Rim to Invert (13) Grade to Invert (14) Rim to Grade (15)

Downstream Manhole Number (16) Rim to Invert (17) Grade to Invert (18) Rim to Grade (19) Use of Sewer (20) Direction (21) Flow Control (22) Height (23)

Width (24) Shape (25) Material (26) Ln. Method (27) Pipe Joint Length (28) Total Length (29) Length Surveyed (30) Year Laid (31) Year Rehabilitated (32) Tape / Media Number (33)

Purpose (34) Sewer Category (35) Pre-Cleaning (36) Cleaned 36a) CCYY/MM/DD Weather (37) Location Code (38) Additional Information (39)

Distance (Feet)	Video Ref.	Code		Continuous defect	Value				Joint	Circumferential Location		Image Ref.	Remarks
		Group/ Descriptor	Modifier/ severity		S/ M/ L	Inches 1st	Inches 2nd	%		At/ From	To		
•													
•													
•													
•													
•													
•													
•													
•													
•													

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Figure 3-2 provides a reference sheet for the defect categories listed above. Figure 3-2 provides a readily accessible reference for operators cataloging defect codes using PACP. It also provides a ready reference to in-depth information for each defect code found in the PACP Training Manual in Sections 4 through 8.

3.4 WinCan® Software

WinCan® is a computer software package that supports PACP standardized pipeline inspection coding. This software received PACP certification from NASSCO in 2004. The software provides built-in support for:

- PACP header fields (including mandatory header fields);
- Overall pipeline ratings for structural and O&M conditions;
- Observation descriptions with ratings, includes all descriptions as defined by PACP; and
- Export of data to a PACP Database Format.

Utilities, contractors, and consultants have invested substantial time and expense in training and certification in PACP protocol. This investment is strengthened by PACP Certified Software like WinCan®, which systematizes and streamlines CCTV data collection and analysis. The result is a consistent, defendable product that can be used by utilities to assess risks of failure.

The WinCan® software package can assist utilities in emergency situations to rapidly provide inspection records when issues occur. In addition, this database tool of internal inspections allows the city to develop timelines for rehabilitation and an associated capital improvement program (CIP). The software also allows City Staff to review pipeline segments to confirm rehabilitation has been completed. This is accomplished by using a feature of the software that allows comparative review on-screen of current and historical inspection images.

WinCan's® analysis tools can provide the City and its consultants with easy-to-learn reporting capabilities that summarize internal sewer pipeline inspection data. These tools can assemble summary reports containing information on multiple inspections or customize reports to provide needed information to develop capital improvement plans or provide other management information.

WinCan® Versions 7 and 8 can interface with Hansen/Neztek's Data Exchange Utility. This feature allows for bi-directional communication between WinCan® and Hansen/Neztek, including checking the integrity of the data and generating reports.

3.5 Collection System Reviewed

Kennedy/Jenks has reviewed CCTV inspection video for the 48.7 miles of sewer pipelines in the 2006 survey. These pipelines are 10 inches in diameter and larger and constitute the sewer interceptors that transport large wastewater volumes to the City's wastewater treatment facility. The standardized PACP defect coding system provided the methodology for the review.

The City divided the collection system into three categories based on age, diameter, and material for the sewers where the CCTV work will be completed. The three categories were designated "Priority 1," "Priority 2," and "Priority 3." Figure 1-1 is a map of the collection system indicating these three categories. The most critical sewer lines, including the largest diameter ACP sewers in the city were designated as Priority 1 and are shown in red. Priority 2 contained smaller AC segments and Priority 3 consisted of non-AC segments as identified by the Atlas.

Figure 3-2

NASSCO'S PIPELINE ASSESSMENT & CERTIFICATION PROGRAM (PACP)©

Section 4—Continuous Defect Coding

"TRULY" 4-1
"Truly" continuous defects run along the sewer without any interruption for more than 3 feet.
Examples:
- Longitudinal Fractures
- Cracks

"REPEATED" 4-1
"Repeated" continuous defects occur at regular intervals along the sewer. These occur at pipe joints and include:
-Encrustation
-Open Joints
-Circumferential Fractures

Section 5—Structural Defect Coding (Module 6A)

C CRACK 5-1
CL Longitudinal 5-2
CC Circumferential 5-2
CM Multiple 5-2
CS Spiral 5-2

F FRACTURE 5-7
FL Longitudinal 5-7
FC Circumferential 5-7
FM Multiple 5-7
FS Spiral 5-7

B BROKEN 5-14
BSV -Soil Visible Beyond Defect 5-14
BV V -Void Visible Beyond Defect 5-14

H HOLE 5-16
HSV -Soil Visible Beyond Defect 5-16
HV V -Void Visible Beyond Defect 5-16

D DEFORMED 5-18
DV Deformed Vertically (brick) 5-18
DH Deformed Horizontally (brick) 5-18

X COLLAPSE 5-22
XP Pipe Collapse 5-22
XB Brick Collapse 5-22

J JOINT 5-25
JO Joint Offset (Displaced) 5-25
JS Joint Separated (Open) 5-25
JA Joint Angular 5-25

S SURFACE DAMAGE 5-30
SRI Roughness Increased 5-30
SRIM -Mechanical 5-31
SRIC -Chemical Attack 5-31
SRIZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SAV Aggregate Visible 5-30
SAVM -Mechanical 5-31
SAVC -Chemical Attack 5-31
SAVZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SAP Aggregate Projecting 5-30
SAPM -Mechanical 5-31
SAPC -Chemical Attack 5-31
SAPZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SAM Aggregate Missing 5-30
SAMM -Mechanical 5-31
SAMC -Chemical Attack 5-31
SAMZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SRV Reinforcement Visible 5-30
SRVM -Mechanical 5-31
SRVC -Chemical Attack 5-31
SRVZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SRP Reinforcement Projecting 5-30
SRPM -Mechanical 5-31
SRPC -Chemical Attack 5-31
SRPZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SRC Reinforcement Corroded 5-31
SRCM -Mechanical 5-31
SRCC -Chemical Attack 5-31
SRCZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SMW Missing Wall 5-31
SMWM -Mechanical 5-31
SMWC -Chemical Attack 5-31
SMWZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SSS Surface Spalling 5-31
SSSM -Mechanical 5-31
SSSC -Chemical Attack 5-31
SSSZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SZ Other 5-31
SZM -Mechanical 5-31
SZC -Chemical Attack 5-31
SZZ -Not Evident 5-31

S SURFACE DAMAGE 5-30
SCP Corrosion (metal pipe) 5-31

LF LINING FAILURE 5-44
LFD Detached Lining 5-44
LFDE Defective End 5-44
LFB Blistered Lining 5-44
LFCS Service Cut Shifted 5-44
LFAC Abandoned Connection 5-44

LF LINING FAILURE 5-44 (continued)
LFOC Overcut Service 5-44
LFUC Undercut Service 5-44
LFBK Buckled Lining 5-44
LFW Wrinkled Lining 5-44
LFZ Other 5-44

WF WELD FAILURE 5-56
WFL Longitudinal 5-56
WFC Circumferential 5-56
WFM Multiple 5-56
WFS Spiral 5-56
WFZ Unidentified 5-56

RP POINT REPAIR 5-62
RPR Pipe Replaced 5-62
RPRD -Defective 5-62
RPP Patch Repair 5-62
RPPD -Defective 5-62

RP POINT (cont) REPAIR 5-62
RPL Localized Lining 5-62
RPLD -Defective 5-62
RPZ Other 5-62
RPZD -Defective 5-62

BRICKWORK 5-68
DB Displaced 5-68
MB Missing 5-68
DI Dropped Invert 5-68

BRICKWORK 5-68 (continued)
MM Missing Mortar 5-68
S -Small 5-68
M -Medium 5-68
L -Large 5-69

Updated June 2005

Figure 3-2

NASSCO'S PIPELINE ASSESSMENT & CERTIFICATION PROGRAM (PACP)©

Section 6—Operational and Maintenance (Module 6B)

D	DEPOSITS	6-1
DA	Attached	6-1
DAE	-Encrustation	6-2
DAGS	-Grease	6-2
DAR	-Ragging	6-2
DAZ	-Other	6-2

D	DEPOSITS (continued)	6-1
DS	Settled	6-1
DSF	-Fine	6-2
DSGV	-Gravel	6-2
DSC	-Hard/Compacted	6-2
DSZ	-Other	6-2

D	DEPOSITS (continued)	6-1
DN	Ingress	6-1
DNF	-Fine Material (silt & sand)	6-3
DNGV	-Gravel	6-3
DNZ	-Other	6-3

R	ROOTS	6-7
RF	Fine	6-7
RFB	-Barrel	6-7
RFL	-Lateral	6-7
RFC	-Connection	6-7

R	ROOTS (continued)	6-7
RM	Medium	6-7
RMB	-Barrel	6-7
RML	-Lateral	6-7
RMC	-Connection	6-7

R	ROOTS (continued)	6-7
RB	Ball	6-7
RBB	-Barrel	6-7
RBL	-Lateral	6-7
RBC	-Connection	6-7

R	ROOTS (continued)	6-7
RT	Tap	6-7
RTB	-Barrel	6-7
RTL	-Lateral	6-7
RTC	-Connection	6-7

I	INFILTRATION	6-13
IW	Weeper	6-13
ID	Dripper	6-13
IR	Runner	6-13
IG	Gusher	6-13

OB	OBSTACLES/ Obstructions	6-19
OBB	Brick or Masonry	6-19
OBM	Pipe Material in Invert	6-19

OB	OBSTACLES/ Obstructions (cont)	6-19
OBI	Object protruding through wall	6-19
OBJ	Object wedged in joint	6-19

OB	OBSTACLES/ Obstructions (cont)	6-19
OBC	Object through connection/junction	6-19
OBP	External Pipe Cable	6-19

OB	OBSTACLES/ Obstructions (cont)	6-19
OBS	Built into structure	6-20
OBN	Construction Debris	6-20
OBR	Rocks	6-20
OBZ	Other	6-20

V	VERMIN	6-31
VR	Rat	6-31
VC	Cockroach	6-31
VZ	Other	6-31

Section 7—Construction Features Coding (Module 6C)

T	TAP	7-1
TF	Factory Made (junction)	7-1
TFA	-Active	7-2
TFB	- Abandoned	7-2
TFC	-Capped	7-2
TFD	-Defective	7-2

T	TAP (continued)	7-1
TB	Break In/Hammer (connection)	7-2
TBI	-Intruding	7-2
TBA	-Active	7-2
TBB	-Abandoned	7-2
TBC	-Capped	7-2
TBD	-Defective	7-2

T	TAP (continued)	7-1
TS	Saddle (connection)	7-2
TSI	-Intruding	7-2
TSA	-Active	7-2
TSB	- Abandoned	7-2
TSC	-Capped	7-2
TSD	-Defective	7-2

IS	INTRUDING SEAL MATERIAL	7-8
ISSR	Sealing Ring	7-8
ISSRH	-Hanging	7-8
ISSRB	-Broken	7-8

IS	INTRUDING SEAL MATERIAL (continued)	7-8
ISGT	Grout	7-8
ISZ	Other	7-8

L	LINE (of sewer)	7-11
LL	Left	7-11
LLU	Left & Up	7-11
LLD	Left & Down	7-11
LR	Right	7-11

L	LINE (of sewer) (continued)	7-11
LRU	Right & Up	7-11
LRD	Right & Down	7-11
LU	UP	7-11
LD	Down	7-11

A	ACCESS POINT	7-13
AMH	Manhole	7-13
AWA	Wastewater Access	7-13
ADP	Discharge Point	7-13
ATC	Tee Connection	7-13

A	ACCESS POINT (continued)	7-13
AOC	Other Special Chamber	7-14
AM	Meter	7-14
AWW	Wet Well	7-14
AJB	Junction Box	7-14

A	ACCESS POINT (continued)	7-13
ACO	Clean Out	7-14
ACOM	-Mainline	7-14
ACOP	-Property	7-14
ACOH	-House	7-14

A	ACCESS POINT (continued)	7-13
ACB	Catch Basin	7-14
AEP	End of Pipe	7-14

Section 8—Miscellaneous Features Coding (Module 6D)

M	MISC. FEATURES	8-1
MCU	Camera Underwater	8-1
MGO	General Observation	8-1
MGP	General Photograph	8-1

M	MISC. FEATURES (cont)	8-1
MSC	Shape/Size Change (Sewer Dims/ Vertical/ Horizontal)	8-1
MJL	Joint Length Change	8-1

M	MISC. FEATURES (cont)	8-1
MLC	Lining Change	8-1
MMC	Material Change	8-2
MSA	Survey Abandoned	8-2
MWL	Water Level	8-2
MWLS	-sag	8-2

M	MISC. FEATURES (cont)	8-1
MWM	Water Mark	8-2
MY	Dye Test	8-2
MYV	-Dye Visible	8-2
MYN	-Not Visible	8-2

Updated June 2005

Section 4: Pipeline Improvement Methodology

4.1 Improvement Approach

Pipelines in need of improvements could require one-time/point-repair maintenance, routine maintenance, rehabilitation, or replacement. The observations from the review of CCTV footage determined which type or types of improvements are necessary. Fortunately, there were no instances where structural deterioration warranted replacement, as lining techniques are able to provide the necessary structural strength. However, for some pipe segments replacement may be preferred over rehabilitation to increase the pipe's capacity. This can only be determined with knowledge of existing flows and identification of areas anticipated for growth. This is discussed further in Section 6.

The ACP sewers, a small number of point defects, and areas of severe O&M impact comprise the elements of the City's sewer system to be considered for improvements. There are three kinds of improvements the City should consider undertaking to maintain a functioning sewer system:

- Correction of Point Structural Defects: These repairs include cracks in pipelines, fractures of the pipe barrel, open pipe joints, and other structural deficiencies at discrete locations in a pipeline segment. The installation of a pipe liner can correct these defects.

- SSO Prevention Repairs: Prevention of SSOs include increased operation and maintenance frequency in problem areas of the sewer system. Where operation and maintenance requirements are significant or where the risk of overflow is great, a structural repair of the sewer system to alleviate the defect should be accomplished. Any point defects that cause SSOs will be addressed. Many point defects will be corrected during the cleaning and preparation for lining. For segments not to be lined in the near future, planned maintenance prior to rehabilitation is necessary.

- Continuous Defect Correction: Erosion of the interior surface of ACP piping constitutes a continuous defect of concern for structural stability. All ACP pipelines where deterioration has been observed should be rehabilitated before the material has reached an age of 50 years. Where practical, trenchless methods should be utilized to minimize disturbance of friable asbestos-containing material and reduce costs associated with traffic control and restoration of surface features (including landscaping and road surfaces). A rehabilitation liner can correct these continuous defects.

4.1.1 Improvement Schedule

Subsequent sections of this report identify the need to begin improvements of significant portions of the City's sanitary sewer system. The capital expenditure to replace deteriorated piping in a short period of time is significant. While many of the point defects should be repaired as soon as possible and non-ACP pipelines should be rehabilitated in a timely fashion, their financial impact is minor in comparison to the extensive rehabilitation of ACP that will likely be necessary.

A significant expenditure of funds is necessary in the near term to extend the life of a major portion of the City's ACP sewer system. If the collection system is allowed to deteriorate to the point of failure, it will impact the entire community, requiring emergency repairs that may result in significant community disruptions and excessive costs. For this reason we recommend a phased multi-year rehabilitation program for the ACP piping system throughout the City.

Figure 4-1 identifies a symbolic Bell Curve comparing ACP sewer pipe life in years on the horizontal axis with the annual cost of sewer rehabilitation on the vertical axis. This symbolic Bell Curve is used to indicate that piping systems of a similar age, undergoing a similar degree of deterioration will require rehabilitation in a similar time frame. In general, this figure demonstrates that ACP pipelines will require rehabilitation over a short time frame surrounding its projected life of 50 years, and in some instances even earlier. To avoid large expenditures of funds during this short window of years requires the early initiation of rehabilitation. This approach allows smaller annual expenditures over a longer period of years, effectively reducing the number and cost of "peak" year rehabilitations.

Establishing the time frame for improvement of areas of the City's sanitary sewer system should be based on:

- Internal sewer defect assessment,
- Pipeline age and material characteristics, and
- Distributing the cost of improvements over multiple years to meet funding capabilities.

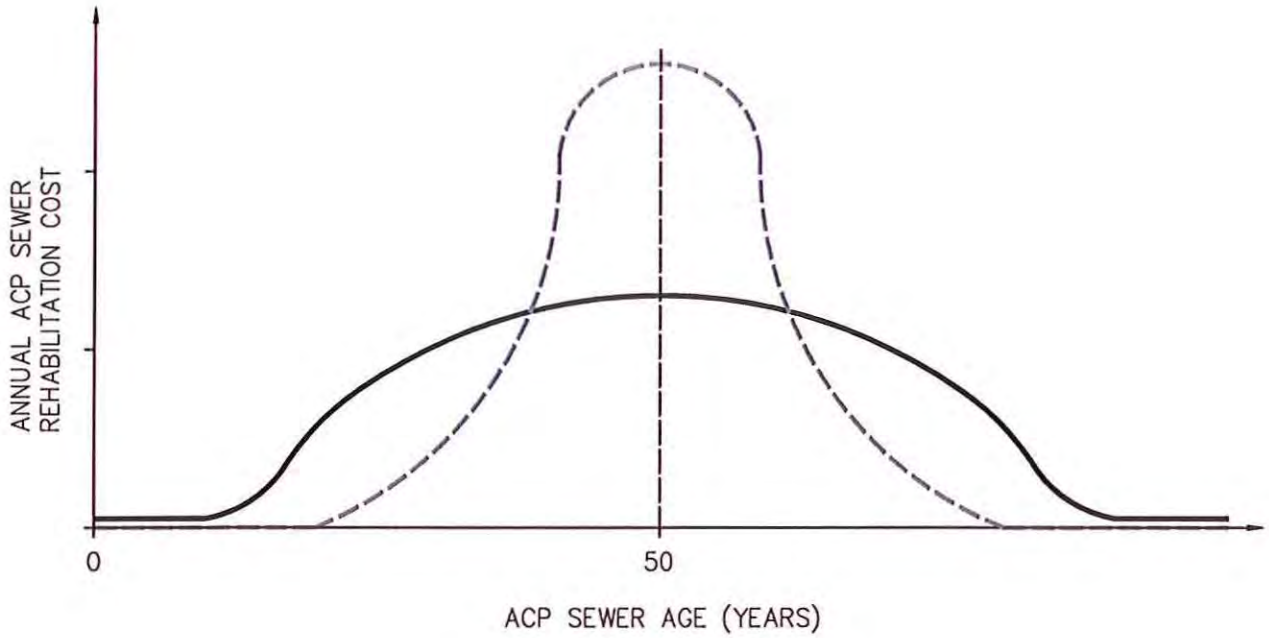
The prioritization approach, discussed in the following section, allows the costs of the extensive ACP rehabilitation to be spread out over the next 20 years while giving priority to segments with visible surface deterioration and/or segments located in high risk areas.

4.2 Criticality and Prioritization

To create a Capital Improvements Plan (CIP) for the City and establish which sewers should be improved first, it is necessary to account for other factors beyond the current condition of the pipes as determined by the PACP coding system. The identity of these other factors, termed criticality factors, and how they were used to modify the PACP coding system is presented in detail in a technical memorandum included as Appendix A.

Physical factors such as pipe material, diameter, and age, as well as maintenance considerations such as pipe sag were evaluated. Additional factors such as sewer location relative to other critical infrastructure (roads and railways) and proximity to tourism and commerce centers were included, among others. The City's GIS database proved to be a useful tool for applying these criticality factors.

Based on the results of the PACP coding system and the applied criticality factors, each pipe segment received at total score and was ranked according to this score to determine rehabilitation priority. The pipelines were then assigned to a rehabilitation time frame as discussed in the technical memorandum (Appendix A). The cutoff values for these time frames were set by the following criteria:



NOTE:
LIFESPAN OF ACP SEWER PIPE
IS APPROXIMATELY 50 YEARS.

LEGEND

———	COST CURVE WITH PROACTIVE CAPITAL IMPROVEMENTS PLAN IN PLACE TO GRADUALLY REHABILITATE ACP SEWERS.
- - - - -	COST CURVE FOR REACTIVE PIPE REHABILITATION BASED ON DETERIORATION OF ACP SEWERS.

Kennedy/Jenks Consultants

CITY OF SIMI VALLEY
VENTURA COUNTY, CALIFORNIA
WASTEWATER COLLECTION SYSTEM

ANNUAL REHABILITATION COST COMPARISON

K/J 0689059

FIGURE 4-1

- To set the score limit for pipes to be rehabilitated within 20 years, all AC pipe greater than 40-years old would be rehabilitated within 20 years. This was decided because the average life of asbestos cement (AC) pipe is 50 years, thus, 50 percent of pipes will tend to fail before 50 years, and 50 percent will tend to fail after 50 years.

- To set the score limit for pipes requiring rehabilitation in less than 10 years, all structural defects with a rating of 4 out of 5 (a Modified PACP Score of 400 or greater) must be rehabilitated within 10 years.

- To set the score limit for pipes to be rehabilitated within 5 years, all pipe segments that were assigned the most severe structural score (i.e., had a Modified PACP score greater than or equal to 500) must be rehabilitated within 5 years.

- To set the score limit for pipes requiring immediate rehabilitation (1 to 3 years), all pipe segments assigned the most severe structural score as a result of holes, missing walls, or broken pipes (i.e., not corrosion) were to be rehabilitated.

Once these score boundaries were set for the rehabilitation time frames, the other pipe segments fell into place with their relative scores. This approach successfully distributes the extensive rehabilitation of ACP over the next 20+ years while simultaneously prioritizing all non-ACP sections.

Once these scores were distributed, the City developed a total of 39 projects for rehabilitation, linking pipes of similar diameters, location, and scores together. The 39 projects were distributed into 3 groups – with 11 projects to be completed within 1 to 3 years (highest priority), 6 projects to be completed within 4 to 6 years (moderate priority), and 22 projects being completed within 7 to 10 years. Priorities were based on pipe diameter and critical scores, with larger pipe diameters and higher scores receiving the highest priority. Project locations are shown in Appendix B.

4.3 Rehabilitation Method Selection

Many rehabilitation methods exist, including, but not limited to PVC liners, segmented liners, spiral wound pipe, deformed pipe, and cured-in-place-pipe. The selection of the best method for rehabilitation is dependent on a number of factors such as the pipe size reduction that would occur, the need for structural support, the resistance to chemical attack, the cost, and the ease of installation. The different rehabilitation methodologies all have advantages and disadvantages. The recommended rehabilitation method for the portion of the City's sewer system considered in this evaluation is cured-in-place-pipe (CIPP).

CIPP generally does not require excavation, installs rapidly, maximizes capacity of the pipe, and does not require grouting. The method is suitable for pipe diameters between 4 inches and 108 inches and has a projected life of 50 years. Before CIPP can be implemented, the pipeline must be sufficiently cleaned and the wastewater by-passed. A resin saturated material is inserted through a maintenance manhole or other convenient entry point. The material, once in the existing pipeline, is heated to cure the resin. This forms a hard, impermeable pipe within the old pipe. Service connections or laterals are then identified by dimpling that occurs in the lines at each connection location.

CIPP is generally considered to be the most cost effective trenchless pipelining method when the sewer is located in high traffic areas or where numerous sewer lateral connections exist, such as many of the segments comprising the main trunk line and interceptors considered in this evaluation. We recommend installing CIPP with a minimum default wall thickness greater than SDR 35 (Standard Dimension Ratio) in accordance with the ASTM F 1216 formula for a fully deteriorated condition. This thickness provides the structural support the existing segment may lack. In addition to providing structural support, liners can reduce the surface roughness, eliminate infiltration, and eliminate the need to make any spot repairs of holes or cracks.

Other feasible rehabilitation alternatives exist. We recommend that City consider fold and form liners for small-diameter (8-inch to 12-inch) pipes. The cost estimates for CIPP, as described below, also hold for the fold and form method. Additionally, for larger pipes (greater than 30-inches), we recommend the City consider using a slip-lining technique. This technique could reduce the costs, as bypass pumping may not be necessary, but also reduces the pipe capacity more significantly than CIPP and is best when three to four continuous pipe sections are to be rehabilitated. Therefore, this technique may not be ideal in all situations and the cost estimate provided below will err on the high-side if this approach is used. We observed a number of pipe segments which did not have service lateral connections. Other lining methods which would generally require excavation of lateral connections to reestablish them might be ideal for these segments. One such approach is the Tite-Liner HDPE lining system by Insituform; however, this is a fairly new product and is not yet approved in the LA Sanitary District Greenbook.

4.4 Estimates of Probable Cost Estimation

Estimates of probable cost for rehabilitation were based on information provided by CIPP installers and/or other service providers. Table 4-1 shows the estimated unit costs for rehabilitation and all determinable cost modifiers. The base-level costs include mobilization, cleaning, root removal, and televising before and after lining. In some cases the cost modifiers increase with the pipe diameter, the volume of flow, and/or length. For these modifiers, costs are presented as a percentage of the CIPP cost. In other cases, the cost modifiers are presented as a cost per occurrence. The base cost modifiers for CIPP include:

- Bypass pumping: The costs for bypass pumping are, in general, the most variable costs associated with CIPP installation. Because we cannot define the specific conditions for each bypass needed, the costs are more general than some of the other factors. The estimated costs were developed from discussions with bypass pumping companies. Bypass requirements at major roads are assumed to cost more, as the bypass will likely require trenching. The major roads were identified by the City Staff as Alamo, Cochran, Erringer, First, Fitzgerald, Kuehner, Los Angeles, Madera, Royal, Sequioa, Stearns, Stow, Sycamore, Tapo, Tapo Canyon, and Yosemite. Bypasses of major lines were also assumed to cost significantly more, as pumping would be required 24-hours per day, with pumps ramping up and down based on diurnal flows. Major lines were considered to be pipelines over 16-inches in diameter.

- Utility and Traffic Control: Utility and traffic control costs vary depending on the type of streets near the pipe in question. Therefore, the costs for utility and traffic control were divided into two categories: major and typical. Pipe segments passing under any of the

TABLE 4-1
UNIT COSTS FOR CIPP REHABILITATION

Pipe Diameter, inches	Base CIPP Cost, $/linear ft	Modifiers*									Engineering and Adminstrative Costs	Contingency Costs	Risk Assessment Cost Factors for Bypass Pumping and Traffic Control				
		Bypass Pumping		Utility and Traffic Control		Ground-water	Laterals		Spot repairs								
		Major Streets	Typical Streets	Major Streets	Typical Streets	if high GW	$/ lateral	$/ intruding lateral	$/ obstruction	if infiltration, $/linear ft			1	2	3	4	5
	a	b		c		d	e	f	g	h	i	j	k.				
8	$50	10%	5%	15%	5%	0%	$300	$400	$6,000	$0	20%	20%	0%	10%	25%	37%	50%
10	$60	10%	5%	15%	5%	0%	$7,500	$400	$6,000	$0	20%	20%	0%	10%	25%	37%	50%
12	$65	10%	5%	15%	5%	0%	$7,500	$400	$6,000	$0	20%	20%	0%	10%	25%	37%	50%
14	$112	30%	20%	15%	5%	5%	$7,500	$400	$6,000	$10	20%	20%	0%	10%	25%	37%	50%
15	$120	30%	20%	15%	5%	5%	$7,500	$400	$6,000	$10	20%	20%	0%	10%	20%	30%	40%
16	$128	30%	20%	15%	5%	5%	$7,500	$400	$6,000	$10	20%	20%	0%	10%	20%	30%	40%
18	$144	60%	40%	15%	5%	5%	$7,500	$400	$6,000	$10	20%	20%	0%	10%	18%	25%	30%
20	$160	60%	40%	15%	5%	5%	$7,500	$400	$6,000	$10	20%	20%	0%	10%	18%	25%	30%
21	$168	60%	40%	15%	5%	5%	$7,500	$400	$6,000	$10	20%	20%	0%	10%	18%	25%	30%
24	$192	60%	40%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	18%	25%	30%
27	$216	70%	40%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	15%	18%	20%
30	$240	70%	40%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	15%	18%	20%
33	$264	80%	50%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	15%	18%	20%
36	$360	80%	50%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	13%	15%	18%
39	$390	80%	50%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	13%	15%	18%
42	$420	80%	50%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	13%	15%	18%
48	$480	80%	50%	15%	5%	10%	$7,500	$400	$8,000	$10	20%	20%	0%	10%	13%	15%	18%

Notes:

a. Based on cost values provided by CIPP installers' recommendations.

b. Bypass pumping is a percentage of total base costs estimated from information provdided by bypass pumping companies. Costs are assumed to be higher for pipes under major roadways as trenching is likely required for the bypass.

c. Traffic & utility control depends on whether the pipe is under a major roadway or a typical roadway. The major roads were identified by the City. Costs are a percentage of total base costs.

d. Pipes located in high groundwater areas require extra cure time. High groundwater areas were identified by the City. Costs represent a percentage of the total base costs.

e. Cutting out laterals adds to the cost of CIPP. Cost estimates per lateral were provided by CIPP installers.

f. Grinding down intruding laterals before lining has additional costs.

g. Spot repair of obstructions (Object protruding through wall, Obstruction: external pipe cable, and Obstruction built into structure) will require additional work to be subcontracted out.

h. Infiltration (runners and gushers) will require installing a preliner before lining for larger diameter pipe. Smaller diameter pipe already has the preliner incorporated.

i. Engineering and Adminstrative Costs are estimated to be 20% of the Total Rehabilitation Cost (Base Cost plus all modifiers).

j. Allowance for Contingencies is estimated to be a function of the Total Rehabilitation Cost (Base Cost plus all modifiers). Larger pipe rehabilitation has a number of factors that can more greatly affect the costs and, therefore, larger costs are assigned.

k. Risk Factor Assessment is based on low risk to high risk, with lowest risk being level 1 and highest risk being level 5

l. Based on cost values provided by slipliner installers' recommendations.

* Depth, although another factor affecting the cost, cannot easily/reliably be determined with the available data.

major streets identified above were assumed to have a larger cost associated with utility and traffic control than pipes under typical streets.

- Groundwater: There are two areas in Simi Valley with high groundwater (see Figures 2-1 and 2-2). High groundwater affects the CIPP installation process by requiring a thicker liner (i.e., more resin) and a hot water cure rather than steam requiring a longer cure time.

- Laterals: After installing the CIPP liner, the service lateral connections must be reestablished. Because some pipe segments considered in this evaluation had greater than fifteen lateral connections, we considered the costs associated with cutting open each of these service connections. Additionally, laterals that protrude into the pipe (PACP-termed "intruding taps") need to be ground down before the liner can be installed. This estimate of probable cost accounts for the costs associated with correcting each protruding lateral.

- Spot Repairs: There are two kinds of spot repairs which influence the costs of CIPP installation. First, large obstructions need to be removed. These large obstructions were identified from PACP defect codes. The specific codes are: (1) Obstruction: object protruding through wall, (2) Obstruction: external pipe cable, and (3) Obstruction: built into structure. These specific occurrences can be identified in the tables provided in Volume 2 and should be corrected as soon as possible. For each of these occurrences, an additional cost was added. Also, installation of CIPP where major infiltration of groundwater exists (as defined by PACP codes of runner and weeper) requires a preliner. The liner for small-diameter pipes already includes this preliner, but this adds to the installation cost for pipes greater than 12 inches in diameter

- Sag Costs: The City may want to remove and replace short sections of pipe with severe sag. Nearly 50 percent of the pipes were determined to have sag (as defined by an increase of at least 10 percent in the water level followed by a decrease of at least 10 percent). Sag is more critical in smaller diameter pipes (12-inches in diameter or less) than larger diameter pipes as flow in larger diameter pipes is usually more constant in trunk sewers, and the velocity and constant flow of trunk sewers will usually prevent solids from settling in the bottom of sags. Deposits of grease will be a problem with both large and small diameter pipes that have sags. The City determined which segments will require sag removal and the distance to be removed. Sag costs were reviewed by the City for pipes less than 18-inches in diameter. A base cost was determined at $1000 per linear foot of sag, with the length of sag determined by the City from review of the sewer video of the affected pipelines.

- Risk Factors: This was a catchall factor to try to take into account the difficulty of the rehabilitation work for each individual segment. A risk factor of 1 through 5 was assigned for each segment, with 1 meaning lowest difficulty (0% included in the costs, not counting Engineering and Contingency Costs) to 5 meaning highest difficulty or working conditions (50% additional to the costs). A number of various factors were reviewed to make a risk determination for each segment, and included items like the location of the sewer in the street, commercial, industrial, or residential driveways, major or minor intersections, and crossing or located near major facilities such as railroad tracks, freeway interchanges, or flood control channels. Photos and GIS survey from the

City, as well as Google Maps and other sources of aerial photography were used to help identify problem locations. Normally, low traffic residential areas had the lowest risk factors, where major intersection in the middle of a commercial area had the highest ratings. Risk factors for larger diameter pipe were reduced compared to smaller diameter pipe as the initial cost of installing the liner in larger diameter pipe was significantly larger, and would seriously skew costs if the same proportional risk percentages were used for the larger pipe. Mitigation of some ratings may be possible if the contractor is allowed to work at night in commercial or industrial areas that shut down at night.

- Engineering and Administrative Costs: A cost allowance of 20 percent is included for engineering and administrative services required for the final design and construction management.

- Contingency Costs: An additional cost for contingencies is made for uncertainties unavoidably associated with estimates of probable cost in this budgetary-level evaluation. The necessity for special construction methods, required heavy cleaning, and large pipe depth are a few of the many circumstances which may increase the contract costs and for which some allowance must be made. A base cost allowance of 15 percent is included as a contingency factor for all pipeline segments, based on standard cost estimating procedures.

  Upon evaluation of pipeline capacity, pipe replacement may be preferred over pipe rehabilitation. Because capacities are not known at this time, the applied contingency factor is inflated an additional 5 percent to account for potential replacement of a limited number of pipe segments.

In the development of these costs, some of the factors, such as laterals and groundwater, represented very minor contributions to the total segment rehabilitation cost. However, the reason for reporting this information is twofold. First, it provides an increased level of detail in the cost estimate. And perhaps more importantly, reporting this information will serve as a helpful guide to the City Staff when moving forward with rehabilitation design. Pipe segments requiring the removal of an obstacle or installation of a preliner in cases of infiltration can be identified and budgeted for in advance.

The costs provided in this collection system improvement plan are not definitive values of project cost. At all levels of design, from the conceptual-stage to the design-stage, there is an assumed accuracy for any estimate of probable cost. For this evaluation, the estimates of probable cost have an accuracy range of +15% to -15%. This range of values is consistent with the level of accuracy developed by the Association for Advancement of Cost Engineering (AACE) for the preliminary design level.

Section 5: Results

5.1 Prioritization

To graphically present the finding of this study, the City has been divided into three regions: Eastern, Central, and Western. The recommended rehabilitation time frames for all pipe segments included in the 48.7 miles are presented in the geographic areas on Figures 5-1 through 5-3. Additional cut-out areas are presented on Figure 5-4. The assignment of rehabilitation time frames provides a planning period estimate based on the internal inspections and criticality factors. For budgeting and rate adjustment purposes, it may be necessary to repackage specific projects so that portions of the capital improvement program costs can be shifted over time from one year to the next.

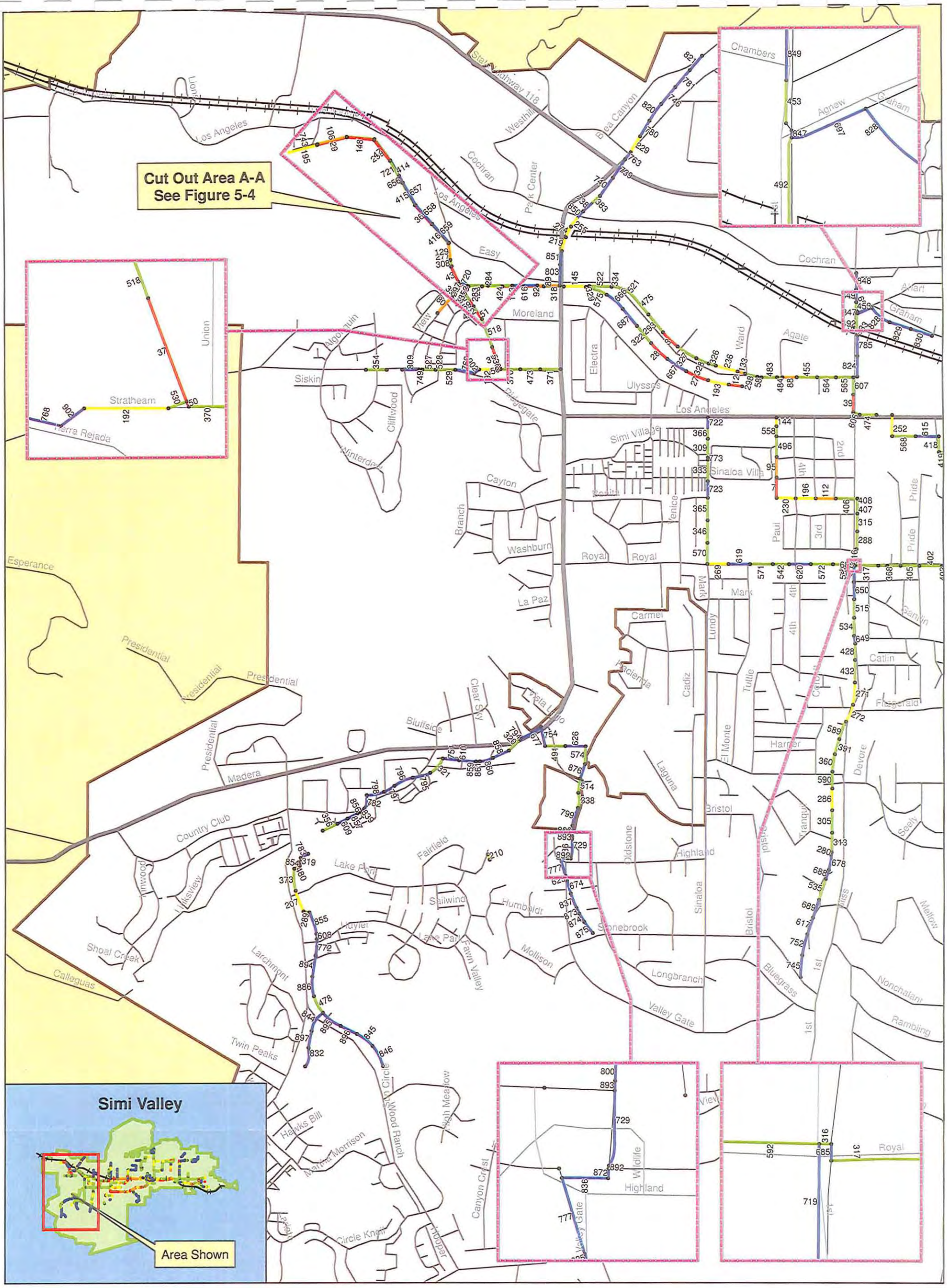
Figures 5-1 to 5-4 were generated in a manner to facilitate ease of creating specific rehabilitation projects. The pipe identifiers in the figures refer to data tables provided in Volume 2 of this report. This information will enable City Staff to graphically determine rehabilitation priority, and obtain appropriate details such as the pipe length, material, number of service connections, etc from the corresponding data tables. With the figures and tables linked in this way, the City can effectively coordinate their pipe rehabilitation efforts with that of other City development or construction.

Pipe sections identified for rehabilitation in greater than 20 years, although included in the calculations for the estimations of probable cost, may not need rehabilitation for 30 or more years. These pipe sections had very minor or no significant structural defects.

5.2 Estimates of Probable Cost

Table 5-1 provides a summary of the detailed tables found in the Volume 2 report by displaying the total estimated length and probable cost of rehabilitation for each time frame and the annual allocation of cost, should the rehabilitation efforts and costs be equally distributed within those periods. It should be noted that the cost estimates provided in Table 5-1 represent current construction costs.

As shown, the City should program for the rehabilitation of approximately 25,000 feet of pipe in the next three years. This initial program will cost approximately $14.4 million. During the balance of the 20-year period, it is projected that an additional $76.1 million will be necessary to rehabilitate an additional 155,000 feet of pipe identified for rehabilitation from the extensive video inspection program. Based on current dollars, implementation of this plan suggests that the City should plan to reinvest between $3.8 million and $5.6 million annually to rehabilitate the collection system.



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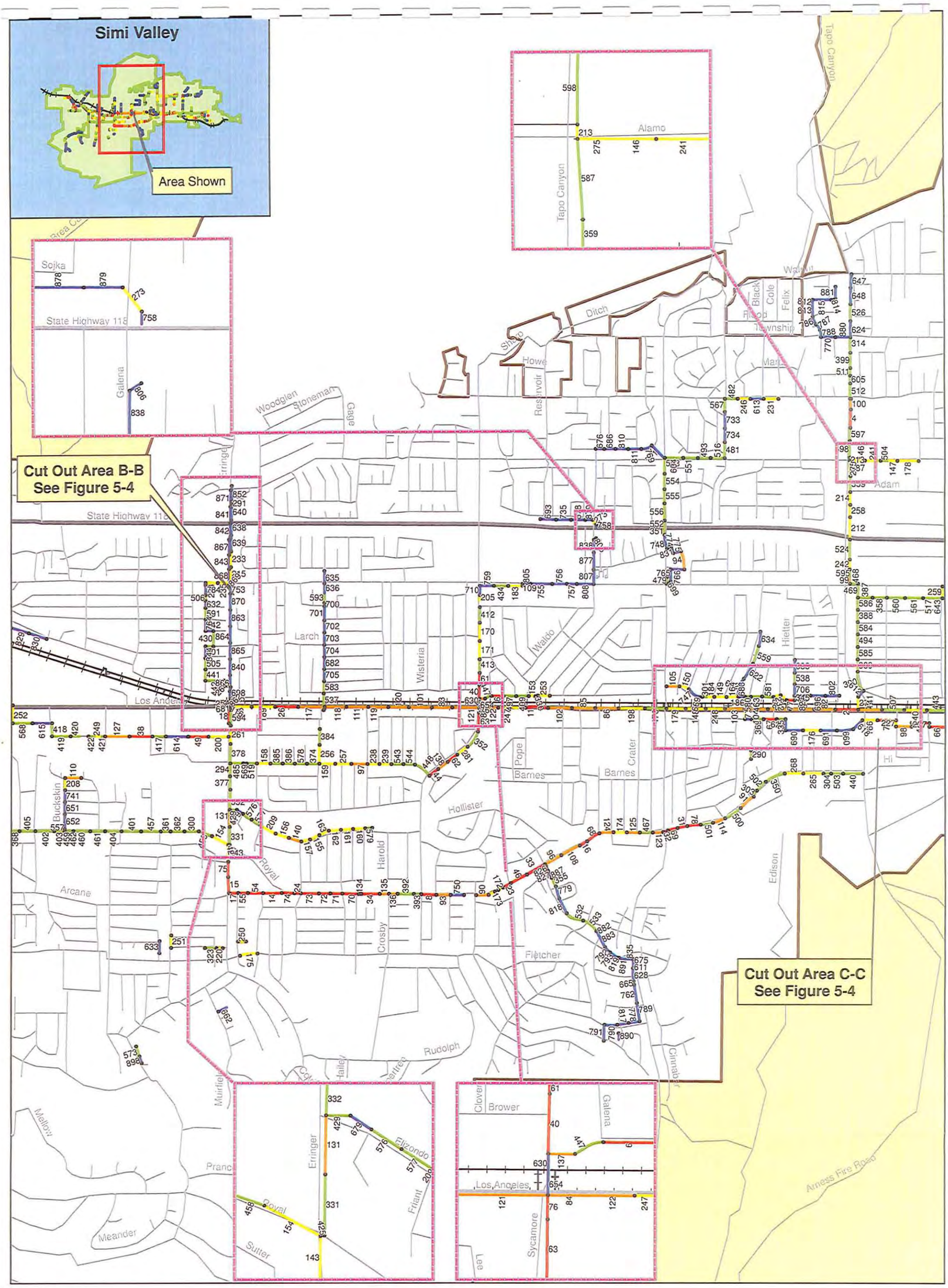
Prioritization of Pipelines in Western Region of Simi Valley

City of Simi Valley

Figure 5-1



Legend

- Local Road
- Highway
- Manhole
- City Boundary

PRIORITY

- Immediate
- 3-5 yrs
- 5-10 yrs
- 10-20 yrs
- > 20 years

N W E S

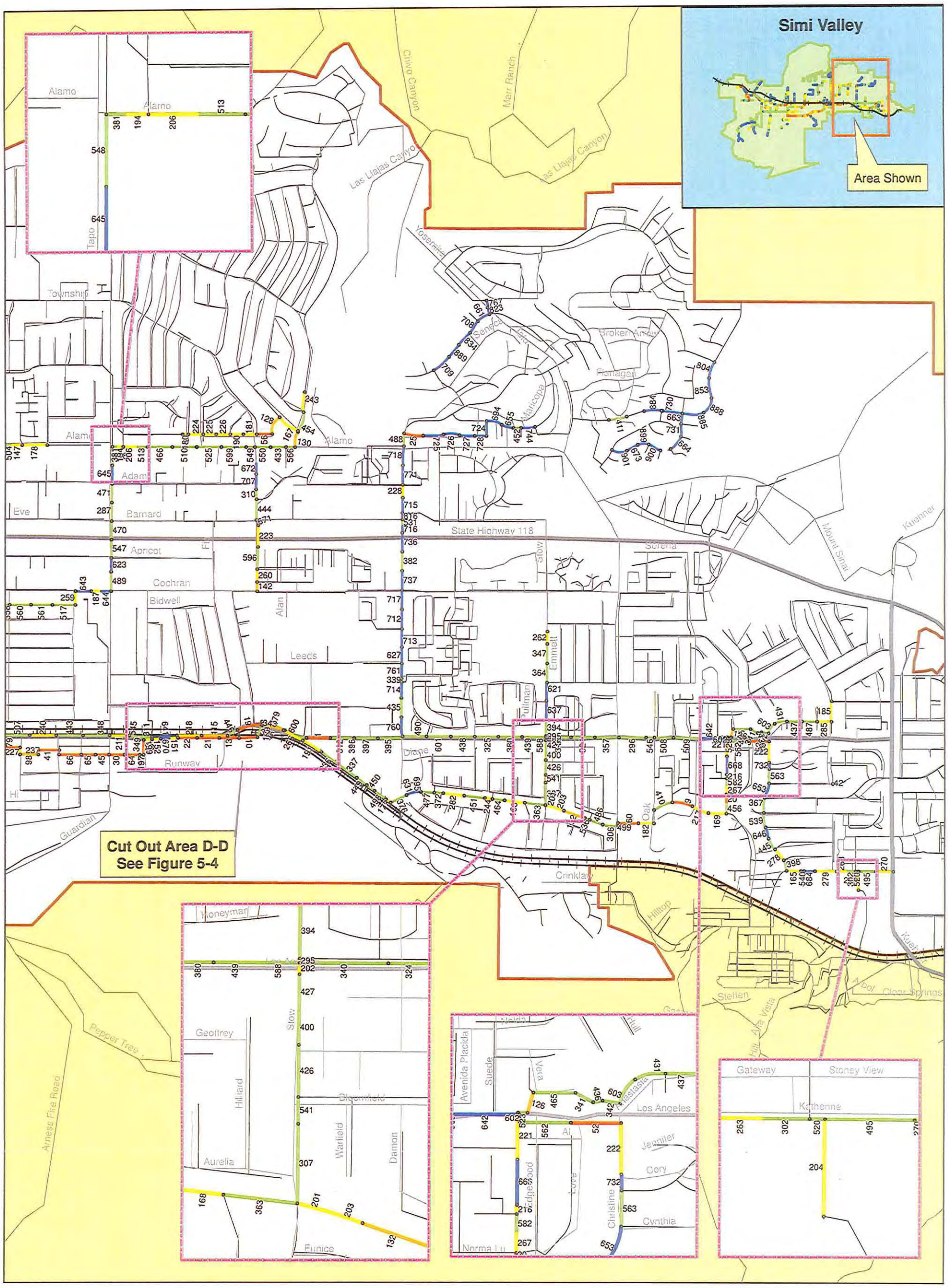
0 0.25 0.5 1 Miles

Kennedy/Jenks Consultants

Prioritization of Pipelines in Central Region of Simi Valley

City of Simi Valley

Figure 5-2



N
W E
S

0 0.25 0.5 1 Miles

Legend

- Local Road
- Highway
- City Boundary
- Manhole

PRIORITY

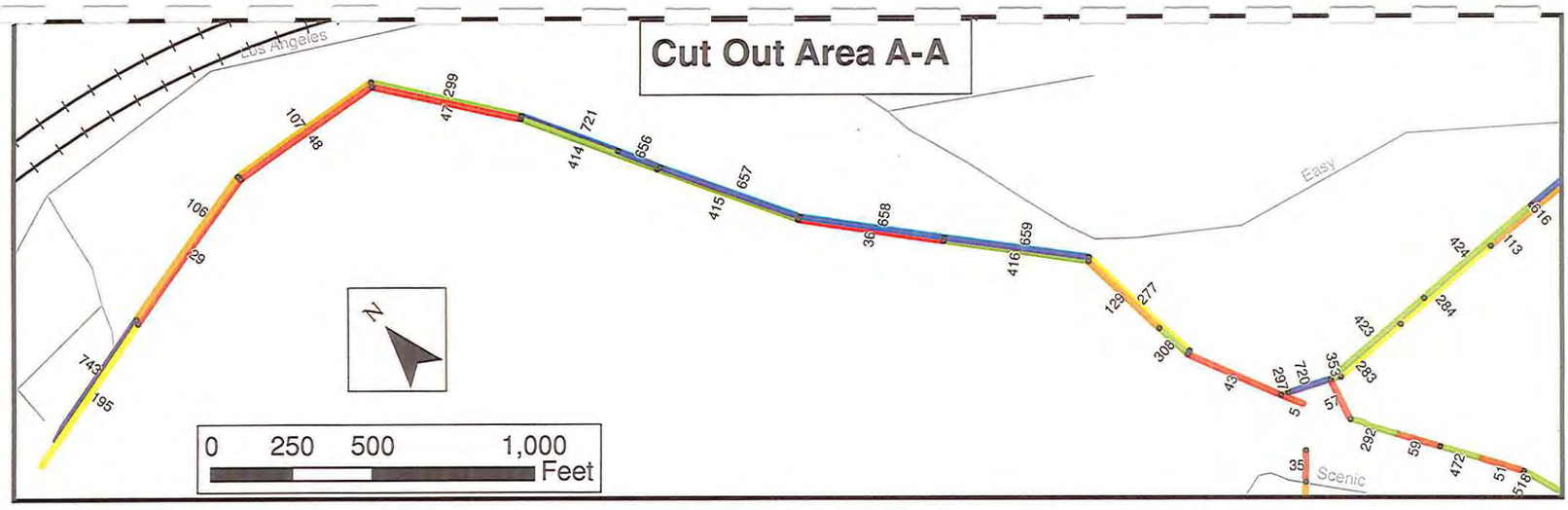
- Immediate
- 3-5 yrs
- 5-10 yrs
- 10-20 yrs
- > 20 years

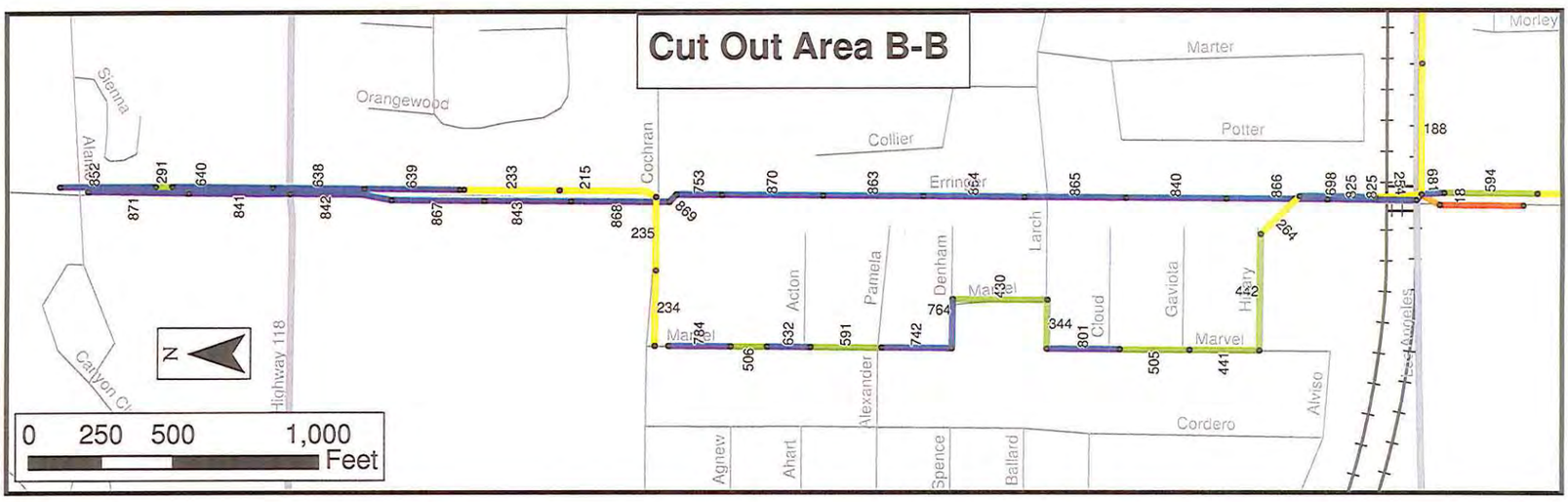
Kennedy/Jenks Consultants

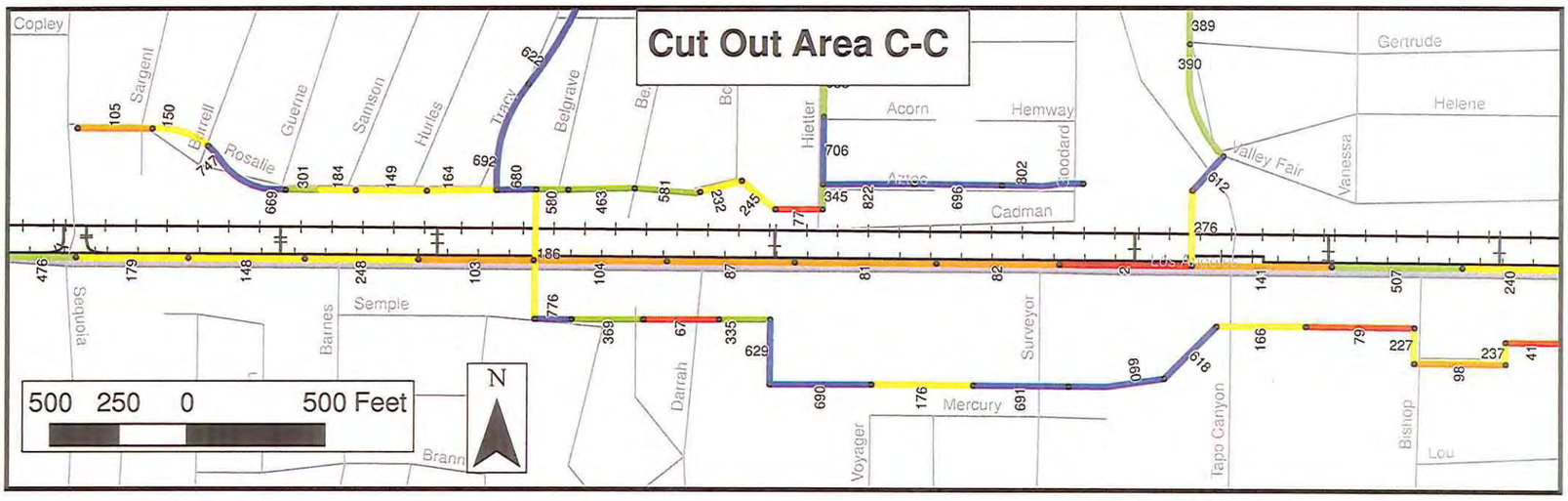
Prioritization of Pipelines in Eastern Region of Simi Valley

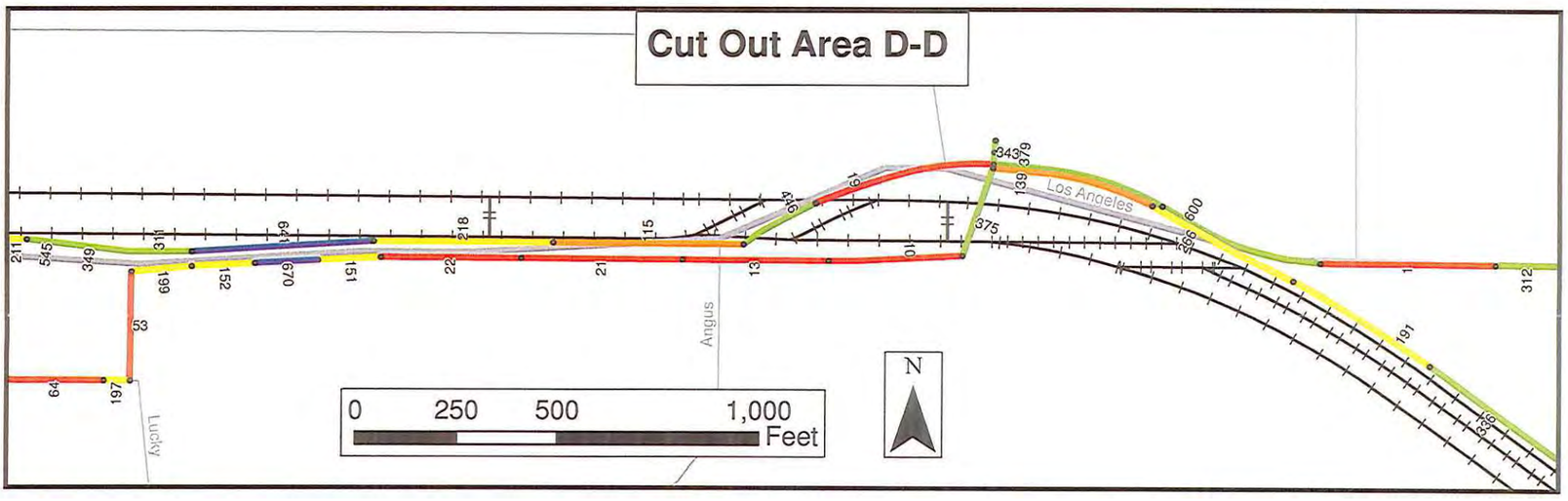
City of Simi Valley

Figure 5-3









Kennedy/Jenks Consultants

Prioritization: Additional Cut-Out Areas

City of Simi Valley

Figure 5-4

Legend

Highway

Local Road

Manhole

PRIORITY

Immediate

3-5 yrs

5-10 yrs

10-20 yrs

> 20 years

TABLE 5-1
SUMMARY OF ESTIMATES OF PROBABLE COST

Time Frame	Number of Segments	Total Length (feet)	Total Cost ($)	Segments per year	Total Length per Year (feet/yr)	Total Cost per year ($/yr)
Immediate (1-3 years)	82	25,280	$14,410,000	27	8,427	$4,800,000
4 - 6 years	54	19,680	$15,450,000	18	6,560	$5,150,000
7 - 10 years	149	43,165	$22,440,000	37	10,791	$5,610,000
11 - 20 years	321	92,596	$38,200,000	32	9,260	$3,820,000
> 20 years	295	76,317	<not included>	na	na	n/a
TOTAL	**901**	**257,038**	**$90,500,000**			

To assist the City with the programming of future capital improvement program costs, the current costs and annual estimates shown in Table 5-1 are increased to future dollars to account for inflation and increasing construction costs. The resulting projected annual costs in both current and future dollars are shown in Table 5-2.

Table 5-2 clearly indicates the implications of deferring capital investment. Integrating a 5 percent annual inflationary increase in the projected capital improvement costs of Table 5-1 indicates that the City's twenty year program is projected to cost approximately $145 million and the annual reinvestment in infrastructure could exceed $9 million in any given time frame.

TABLE 5-2
PROJECTED CAPITAL IMPROVEMENT BUDGET

Year	Estimated Annual Cost[a]	Projected Estimated Annual Cost[b]
1	$4,800,000	$4,800,000
2	$4,800,000	$5,040,000
3	$4,800,000	$5,292,000
4	$5,150,000	$5,962,000
5	$5,150,000	$6,260,000
6	$5,150,000	$6,573,000
7	$5,610,000	$7,518,000
8	$5,610,000	$7,894,000
9	$5,610,000	$8,289,000
10	$5,610,000	$8,703,000
11	$3,820,000	$6,222,000
12	$3,820,000	$6,534,000
13	$3,820,000	$6,860,000
14	$3,820,000	$7,203,000
15	$3,820,000	$7,563,000
16	$3,820,000	$7,942,000
17	$3,820,000	$8,339,000
18	$3,820,000	$8,756,000
19	$3,820,000	$9,193,000
20	$3,820,000	$9,653,000
TOTAL	**$90,500,000**	**$144,596,000**

Notes:

a. Annual Cost is based on the total cost per time frame shown in Table 5-1, divided by the number of years. Costs are rounded.

b. Projected Annual Cost is the annual cost inflated at a rate of 5 percent to keep pace with inflation and construction costs. Costs are rounded

To maximize its return on investment, the City should generally program its rehabilitation projects in groups. There can be two approaches to grouping the pipes: (1) three to four pipes can be grouped as one continuous reach needing rehabilitation or (2) individual pipe segments of the same or similar size, with similar flows, and in roughly the same area (not necessarily contiguous) can be grouped.

Attached in Appendix B is a geographical demonstration of pipeline segments that the City of Simi Valley has grouped into capital projects for rehabilitation. Capital Projects (CP) 1 through 11 are scheduled for rehabilitation during years 1 through 3 of the Capital Improvement Program (CIP). CPs 12 through 17 are scheduled for years 4 through 6 of the CIP. CPs 18 through 39 are scheduled for years 7 through 10 of the CIP. Kennedy/Jenks has reviewed the City's recommended projects and believes that the projects are properly balanced, with segments that require high priority improvements close to the proximity of other segments with similar diameters and priorities so that overall construction efficiencies can be realized.

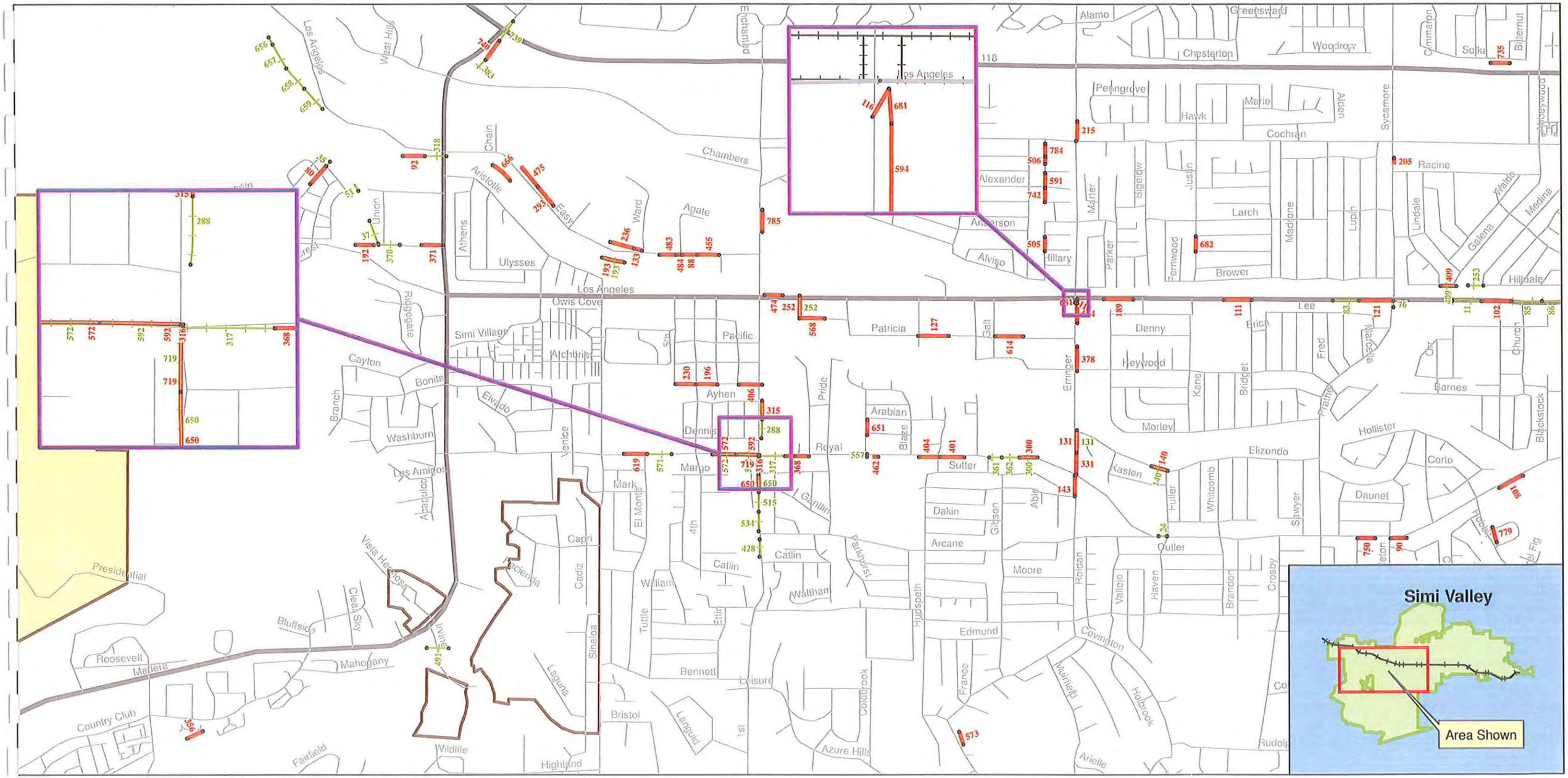
5.3 Operations and Maintenance Impacts

5.3.1 Cleaning

As a result of the internal inspections, pipe segments likely to require frequent cleaning were identified. Figures 5-5 and 5-6 present the 96 segments with observations of sag(s) and accumulation of grease or deposits. A detailed table of these pipe segments is provided in Volume 2. According to discussions with the CIPP installers, once a pipe has been lined, it generally has less friction and does not provide the same opportunity for grease accumulation that the joints or sags in unlined pipes provide. For this reason, it is expected that the increase in operations and maintenance costs for these segments will be offset by the reduced maintenance required for the newly rehabilitated pipe segments.

During the review of the internal inspection footage of ACP segments, delamination patterns similar to the spacing of jets on the cleaning device were observed. This pattern took the form of distinct bands that run the length of the pipe, an example is shown in Figure 5-7. Often the surface peeling that was prevalent in ACP segments occurred in these bands. Although it is difficult to confidently attribute this observation to the cleaning device, given the amount and age of ACP throughout the City, the City may want to further evaluate its O&M practices for these facilities. The revised practices may include: cleaning frequency, type of equipment and level of pressure for scouring.

The City's normal practice for cleaning pipe is once every two years. Sections of pipe that are considered troublesome due to sag or accumulations of grease and/or deposits are cleaned more frequently, from once a year to once every six months, depending on the sizes of the pipe and the level of sewage flow. Kennedy/Jenks recommends that the City continue with this schedule, with several caveats. Sections of pipe that will be rehabilitated in the next five to ten years that are considered troublesome should be closely monitored to prevent additional damage to the pipe. As noted above, there are patterns of delamination on ACP segments of sewer that should be carefully managed by either CCTV efforts or by measuring internal diameters every year to determine the rate of deterioration. Reducing the pressure of cleaning equipment on the sewer walls would be the first recommended method of reducing deterioration, with either a reduction in cleaning frequency or a change in cleaning equipment if deterioration continues to be a problem. Other non-destructive methods may include flushing the pipe with water (usually good for 12-inch and smaller diameter pipes), or chemical treatment to dissolve grease buildup. If necessary, the City can adjust the rehabilitation priorities of certain pipe sections; moving up the priority of those sections with a combination of troublesome flows and deterioration ahead of those sections demonstrating better performance.

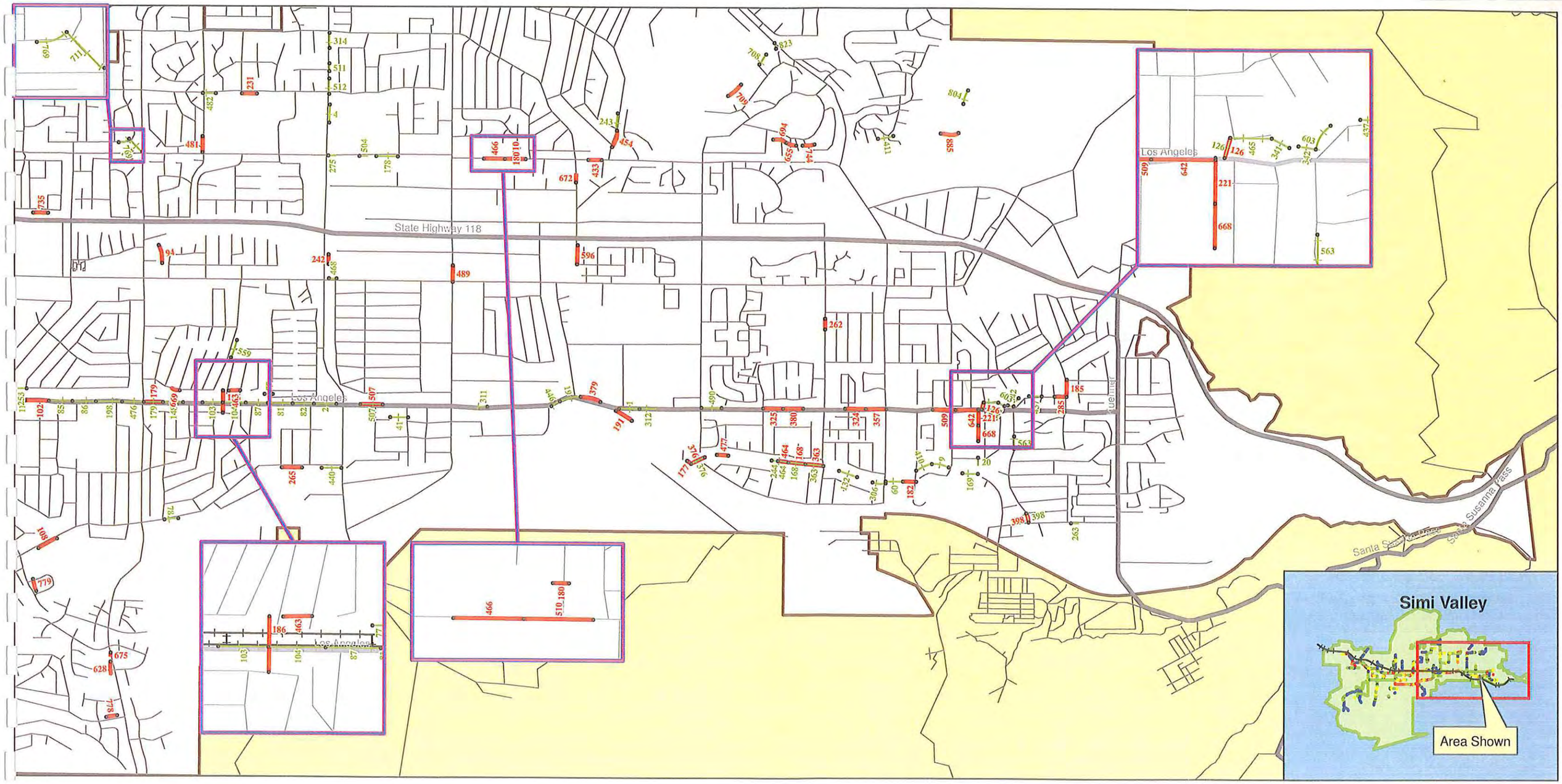


Kennedy/Jenks Consultants

Routine Cleaning and SSO-Prevention Maintenance Requirements
West Region

City of Simi Valley

Figure 5-5



Legend

- Sections for cleaning
- Sections for spot repair
- Manhole
- Highway
- Local Road
- City Boundary

N
W E
S

0 0.5 1 2 Miles

Kennedy/Jenks Consultants

Routine Cleaning and SSO-Prevention
Maintenance Requirements
East Region

City of Simi Valley

Figure 5-6

FIGURE 5-7
EXAMPLE OF BANDED DELAMINATION IN ACP

5.3.2 SSO-Prevention Maintenance

In addition to specific pipe segments identified for frequent, routine cleaning, some pipe segments will require maintenance or spot repairs to reduce the risk of an SSO event. This maintenance activity may be needed for root removal, obstruction removal, infiltration patches, or correction of defective service lateral connections. These segments are also shown in Figures 5-5 and 5-6. In general, root removal and obstruction removal are required before the pipe can be lined and costs associated with these types of maintenance are incorporated into the estimates of probable cost for rehabilitation. However, many of these point repairs should be corrected earlier than the recommended rehabilitation time frame for the segment.

Volume 2 of the report contains the detailed table indicating what was specifically observed in each of the 114 pipe segments highlighted in Figures 5-5 and 5-6 and also includes a prioritization of the segments based on the severity of the O&M defect and the risk and probability of failure. This additional maintenance will have an impact on the City's maintenance costs and should be integrated in future sewer system operating budgets.

Section 6: Conclusions and Recommendations

This section of the report summarizes the findings of the CCTV inspection and pipeline assessment of the 48.7 miles of sewer pipeline evaluated in this collection system asset rehabilitation plan. The report identifies areas within the City's sanitary sewer system that require rehabilitation in the near future, and provides a preliminary estimate of probable cost for the recommended work.

6.1 Conclusions

Figures 5-1 to 5-4 display all of the pipe segments reviewed in this study and the estimated time frame recommended for rehabilitation of each pipe segment. Table 5-1 summarizes the costs for each rehabilitation time frame, assuming current construction costs. The total cost for rehabilitation of the 34 miles of sewer scheduled for rehabilitation within the next 20 years is approximately $90.5 million at current construction costs. Estimates of probable cost of this stage of design assume an accuracy level of +15% to -15%.

The annual estimated costs for the capital improvements are presented in Table 5-2 and are projected to account for inflation and increasing construction costs. Based on an annual increase of 5% per year, it is recommended the City plan to reinvest approximately $145 million to improve pipe segments identified for rehabilitation within 20 years. Given that there is some flexibility in annual programmed improvements, the specific facilities to be improved in conjunction with the level of annual investment should be reviewed annually as part of ongoing capital improvement planning and budgeting.

6.2 Additional Considerations and Further Work

It should be noted that the focus of this asset rehabilitation plan is based on rehabilitating the existing facility whenever possible. As such, there may be instances where pipeline replacement is warranted due to individual pipeline capacity considerations. In these cases, pipe rehabilitation would not be appropriate as pipe lining would not provide additional capacity and may even decrease the capacity of the pipe due to the thickness of the liner.

The City should consider budgeting for this analysis and/or Sewer System Master Plan Update in an upcoming budget. This hydraulic capacity analysis is also an element of the new State regulations.

6.3 Recommendations

Volume 2 of this report includes schedules for sewer improvements, indicating a range of years in which specific reaches are recommended for rehabilitation and which reaches need routine cleaning or spot repair. It is recommended the City program for improving the segments identified in the immediate category, implement the appropriate maintenance to support the prevention of SSO events, and continue regular pipe cleaning with an emphasis on the sections identified for frequent cleaning.

Based on the findings derived during the conduct of this study, it is also recommended that the City consider the following:

- Incorporate the results of this evaluation into the City's existing maintenance/sewer database. The rehabilitation time frames, PACP scores, total scores, specific defects coded, and even photos and video are possible to join with the existing database.

- Perform a flow monitoring study of specific areas of capacity concern. This information will provide the direct support for selecting replacement over rehabilitation of the near-term improvement program and can be useful to determine bypass pumping requirements.

- Conduct an updated overall sewer capacity analysis and Master Plan Update. Proceeding in the manner, current and projected dry and wet weather flows can be derived and simulated through the collection system with a computerized hydraulic model. This effort is a requirement of the current State Waste Discharge Requirements for a Sewer System Management Plan and, in combination with the flow monitoring program, can be used to identify those facilities that should be replaced rather than rehabilitated.

- Continue with the internal inspections. Approximately 87 percent of the mainline sewer system was not evaluated in this study. The City can prioritize the remaining pipes, similar to the Priorities 1, 2, and 3 created for this study. In addition, the segments evaluated in this study may need to be inspected again prior to rehabilitation depending upon the assigned rehabilitation time frame.

- Carefully select the cleaning methodology for ACP. It was observed in the internal inspection footage that ACP surface delamination occurred at times in patterns similar to the spacing of jets on the cleaning device. Given the high percentage of ACP in the City's system, it is recommended the City review its O&M practices in this area and consider alternative approaches and scouring pressures to cleaning these ACP segments.

- Apply the approach developed in this evaluation to any future internal inspections. This includes PACP defect coding and application of criticality factors to continue prioritization of the remaining 87 percent.