M E M O R A N D U M

DUBLIN SAN RAMON SERVICES DISTRICT
WASTEWATER COLLECTION SYSTEM MASTER PLAN UPDATE 2005

TECHNICAL MEMORANDUM No. 8

SUBJECT:	Review of O&M and System Replacement Criteria	**DATE:**	March 30, 2005 (draft) May 20, 2005 (final)
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This Technical Memorandum (TM) summarizes the findings and recommendations of Task 10 of the DSRSD Wastewater Collection System Master Plan Update, Review of O&M and System Replacement Criteria. The objectives of this task are to identify and assess regulatory requirements pertaining to sewer system management that may impact the District; review and recommend enhancements to current criteria and methods for inspection and rehabilitation of the sewer system, including design standards that impact system operation, maintenance, and condition; and review and recommend refinements to the District's current criteria for forecasting long-term collection system renewal/replacement needs.

This TM is organized into the following sections:

- Summary of Findings and Recommendations
- Regulatory Requirements
- Review of Existing Operations and Maintenance Criteria
- Review of Renewal/Replacement Criteria

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Regulatory Requirements

- The San Francisco Bay Regional Water Quality Control Board has recently promulgated new regulations requiring wastewater collection agencies to prepare Sewer System Management Plans (SSMPs). These plans include a number of required elements targeted at minimizing sanitary sewer overflows, providing adequate system capacity, and maintaining sewer infrastructure to provide reliable service. The State Water Resources Control Board will likely adopt similar statewide requirements in the future.

- DSRSD already has a number of the required SSMP elements in place. The District should carefully assess the new requirements and develop a plan for preparing the various elements of the SSMP along with a schedule for their implementation.

Operation and Maintenance Criteria

- The District currently inspects existing sewers in the collection system on an 8-year cycle using closed circuit television (CCTV). The collected data is recorded on videotape and input to the GBA Sewer Master computerized maintenance management system (CMMS). Inspection observations are rated based on severity, and the most severe defects (ratings of 3 or higher on a scale of 1 to 5) are identified for repair. Overall, the sewers are in good condition, and to date, relatively little rehabilitation work has been required.

- The District's frequency of inspection is comparable to other agencies that have implemented cyclic inspection programs. Many agencies are moving to digital video recording, use of CCTV software for direct data entry and data viewing, and use of pipe condition rating systems to prioritize rehabilitation efforts based on scoring the defects observed during inspection.

- It is recommended that the District develop a systematic approach to sewer condition assessment, including possibly modifying its observation coding system, future conversion to digital video recording, improvements to the data entry process, and development of a condition rating system for the pipes that will facilitate determination of repair and replacement needs and future prioritization of rehabilitation projects.

- The District's current standards relating to the design, construction, installation, and testing of sewer pipes, manholes, and service laterals have adequate provisions to minimize operation and maintenance problems in the collection system and comply with relevant SSMP requirements.

Renewal/Replacement Criteria

- Two previous District projects have developed renewal/replacement projections for sewer facilities: the 2000 Collection System Master Plan Update and the Replacement Planning Model developed in 2002. The basic approaches used by these two projects were similar: sewer inventory data (pipe length, diameter, and age) were developed from existing CMMS databases; assumptions were made with respect to expected useful service lives of the pipes; and unit costs based on pipe diameter and material were applied to forecast long-term renewal/replacement budgetary needs. However, the methods differed in several respects related to details about age of sewers, expected service life, and assumed renewal/replacement methods and costs.

- The following recommendations for enhancing the District's renewal/replacement methodology are suggested:
  - Update the sewer inventory database with more accurate age data.
  - Simplify expected service life assumptions initially; refine these assumptions over time based on actual field condition data and observed service lives for pipes of various ages and materials.
  - Establish a link between sewer inspection data and renewal/replacement projections by using pipe condition ratings based on CCTV inspections to adjust the remaining useful life of inspected pipes.
  - Incorporate risk factors (impact of failure) into renewal/replacement planning by adjusting predicted remaining useful lives based on these impact factors so that higher risk assets are replaced sooner.

Figure 1, at the end of this TM, presents a schematic flow chart for developing and updating timing and long-term cost projections for sewer renewal and replacement.

REGULATORY REQUIRMENTS

Until recently, regulation of public wastewater systems has focused primarily on wastewater treatment plants. While federal and State regulations prohibit discharge of untreated wastewater and impose fines for significant sanitary sewer overflows (SSOs), there have historically been no specific regulatory requirements addressing the operation, maintenance, and management of sanitary sewer collection systems. However, in recent years, increased awareness of the occurrence and potential impacts of SSOs throughout the U.S. has resulted in proposals to expand regulatory oversight to wastewater collection systems as well as treatment facilities.

In early 2001, the U.S. Environmental Protection Agency (USEPA) issued a draft Proposed Rule aimed at closer regulation of wastewater collection systems in order to minimize the impacts of SSOs in sewer systems across the country. This document, although never officially published in the Federal Register, represented USEPA's position resulting from stakeholder-based SSO Policy talks that had been ongoing since 1995. A key element of the draft Proposed SSO Rule included new requirements for sewer system owners/operators to develop and maintain a "Capacity, Management, Operation and Maintenance" (CMOM) program to control and mitigate the impacts of SSOs.

While the draft SSO Proposed Rule has stalled at the federal level, the State of California and several Regional Water Quality Control Boards (Regional Boards) have already taken steps to implement CMOM-type requirements in California. These requirements have been given the designation of "Sewer System Management Plans" (SSMPs). The San Francisco Bay Regional Board, which has regulatory oversight over DSRSD, has already initiated its SSMP program, and has conducted outreach workshops with Bay Area sewer system owners/operators to describe the specific requirements and time frame for implementation of the SSMPs. As stated, the objectives of the SSMPs are to 1) minimize the number and impact of SSOs, 2) provide sewer capacity to accommodate design storm flows, and 3) maintain or improve the condition of collection system infrastructure in order to provide reliable service into the future.

At the State level, the State Water Resources Control Board (SWRCB) adopted a resolution in November 2004 indicating its intent to develop SSMP requirements, with implementation over a two-year period beginning in about November 2005. The SWRCB requirements are likely to be similar to those issued by the San Francisco Regional Board, which include the following provisions:

1. **Goals.** Each collection system agency should develop goals for the SSMP that address proper management, operation, and maintenance of the system; provision of adequate capacity for conveying peak flows; and minimizing the frequency and impact of SSOs.

2. **Organization.** The SSMP should define organizational responsibilities, including staff responsible for implementing, managing, and updating the SSMP; and the chain of communications for responding to and reporting SSOs.

3. **Legal Authority.** The SSMP should describe the agency's legal authority (e.g., through sewer use ordinances or other legally binding procedures) to control I/I from satellite collection systems and service laterals; and require proper design, construction, installation, testing, and inspection of new and rehabilitated sewers and service connections.

4. **Measures and Activities.** Each agency should have measures and procedures in place to ensure proper management, operation, and maintenance of the collection system. These measures and activities include:

   a. Up-to-date mapping of the collection system.

   b. Adequate resources (staffing and equipment) to operate and maintain the system.

   c. A process for prioritizing preventive maintenance activities.

   d. A program to identify and prioritize repair of structural deficiencies.

   e. Routine preventive maintenance schedules.

   f. A process for assessing existing and future capacity requirements.

   g. Inventory of contingency equipment and spare/replacement parts.

   h. A program of regularly-scheduled staff training in operations, maintenance, and monitoring.

5. **Design and Construction Standards.** Each collection system agency should have adopted standards for design, construction, inspection, and testing of new or rehabilitated sewer system facilities.

6. **Monitoring, Measurement, and Program Modifications.** The agency should monitor the effectiveness of each SSMP element and perform periodic updates of the SSMP as needed to ensure that it is current, accurate, and available for audit.

7. **Overflow Emergency Response Plan.** Each agency should develop and have in place an emergency response plan to respond to possible SSOs. The plan must include notification, response, and reporting procedures and impact mitigation. Starting in December 2004, collection system agencies in the San Francisco Bay Region have been required to utilize the Regional Board's electronic reporting system for reporting of SSOs.

8. **Fats, Oils, and Grease (FOG) Control Program.** A FOG control program should be implemented by those agencies in which portions of the sewer system are subject to potential blockages due to fats, oils, and grease discharged to the sewer system. The program may include source control regulation, education and outreach, as well as frequent sewer cleaning.

9. **System Evaluation and Capacity Assurance Plan.** This element of the SSMP requires that each agency prepare and implement a capital improvement program to provide adequate hydraulic capacity for key sewer system elements under peak flow conditions.

10. **SSMP Audits.** Each agency will be required to conduct and submit to the Regional Board an annual audit of its SSMP that identifies deficiencies and steps to correct them.

The District has many of the programmatic elements in place to respond to the new SSMP requirements, and many of the efforts and products of this Master Plan can be directly applied to the development of SSMP documentation. For example, the hydraulic model and 5-year updates of the collection system master plan apply to the requirements of SSMP element 4f, Measures and Activities for capacity assessment; and the recommended improvement projects developed in this Master Plan Report, together with the District's adopted CIP, fulfill the requirements of element 9, System Evaluation and Capacity Assurance Plan. This TM presents additional information and recommendations that address other elements of the SSMP, including measures and activities to provide for regular inspection of the collection system and prioritize and budget for needed system repairs, rehabilitation, and replacement.

MWH recommends that the District carefully assess the new SSMP requirements and take proactive steps to ensure that it is developing or already has programs in place to meet those requirements. These steps should include establishing responsibilities for preparing the various elements of the SSMP, along with a schedule for their implementation that is consistent with the Regional Board and future SWRCB requirements.

REVIEW OF EXISTING OPERATION AND MAINTENANCE CRITERIA

This section of the TM reviews and makes recommendations for potential enhancements to the District's current criteria and practices for operation and maintenance (O&M) of the sewer collection system, with specific focus on system inspection, condition assessment, and rehabilitation. A more comprehensive assessment of the District's collection system O&M resources, practices, and procedures was conducted as part of the 2000 Master Plan Update and is documented in that report.

Current Practices

Sewer Inventory and CMMS. The District wastewater collection system currently includes over 170 miles of sewer pipelines, of which a significant portion is less than five years old. The oldest pipes in the system date to the early 1960s and are located primarily in central Dublin and San Ramon. The majority of the newer pipes are located in Eastern Dublin and Westside San Ramon.

The District's sewer system inventory is contained in the GBA Sewer Master® computerized maintenance management system (CMMS), which is maintained by staff located at the DSRSD WWTP. The manhole and pipe data in the GBA database are also linked to the District's Geographic Information System (GIS) AutoCAD Map files through use of common manhole and pipe IDs. Attribute information stored in the database includes basin (geographic areas used as the basis for scheduling system cleaning and inspection), GIS and sewer map manhole numbers, pipe diameters and lengths, manhole diameters, rim and invert elevations, pipe and manhole materials, manhole cover type, pipe year of construction, surface cover, address, and other notes such as if the pipe is included in the "six month trouble spots" cleaning schedule. The data are not complete (some pipes and manholes are missing various pieces of information); in particular, dates of construction are not entirely accurate, as over 50 percent of the pipes are listed with a construction date of 8/27/02. Data for the older sewers were transferred from the District's previous Hansen CMMS when the GBA CMMS was brought on line about five years ago.

The GBA CMMS includes modules for generating work orders, maintaining system inventory and inspection information, rating sewers based on inspection results, and identifying needed sewer repairs based on inspection results. It does not appear that maintenance history information about specific pipes, such as records of stoppages or follow-up CCTV from stoppages or other problems, are captured in GBA. Customer complaint data are stored separately in the District's customer service database.

Cleaning, Inspection, and Rehabilitation. The District currently has a two-year cycle for sewer cleaning, with a 1- to 6-month schedule used for specific known trouble spots that require more frequent cleaning. Sewer cleaning is performed within a six-month window starting in July and ending in January. In addition, the sewers located west of Dougherty Road (i.e., not including the newer pipes in Eastern Dublin) are inspected by closed circuit television (CCTV) on an eight-year cycle. This work is performed by District crews, who rotate into this task on a monthly basis. The District's CCTV equipment records to VHS tape and does not have the capability of capturing still image pictures. According to the District's field operations staff, the CCTV equipment will not likely be upgraded for a number of years.

The District's GBA system allows for computer data entry of CCTV observations directly in the field. However, because of problems with the computer systems, CCTV observation data are currently entered by operators onto paper forms using codes from the old Hansen CMMS. The codes are grouped into eight different categories (see attached copy of "TV Observation" form): cracks, joints, laterals, roots, debris/grease, I/I, alignment, and structure. A District staff person located at the DSRSD WWTP inputs this data into GBA by converting the recorded observation data to GBA codes and rating values (1 to 5) that are assigned for each entry in the eight categories based on their severity (see attached copy of "Code Sheet for CCTV Inspections). (With direct computer entry, the same GBA codes would be input directly by the CCTV operators.) This process generates a defects report that is reviewed by the collection system field supervisor, who also reviews the "raw" observation data on the forms recorded by the CCTV operators.

Records and observations from CCTV inspection have been input to the GBA database since about 2003. Some older CCTV inspection information from the Hansen system was also transferred over at the time of the CMMS conversion. As of April 2004, there were about 7,100 total records of CCTV inspections in the GBA database (with inspection dates up through January 2004), of which approximately 1,200 records appear to have GBA codes and ratings.

The CCTV reports and video are the basis for establishing needed system repairs. Needed repairs are identified for defects with severity ratings of 3 or higher. Repairs costing less than $15,000 are done by a local contractor under a District on-call service contract. For repairs estimated to cost between $15,000 and $25,000, three quotes are obtained. Larger repair projects are competitively bid. To date, sewer repair work has consisted primarily of spot repairs and pipe and manhole joint sealing. The District has also completed one pipe bursting project, but no sewer lining or entire main replacements have been done. The District may do lateral repairs if a connection breaks, but it does not maintain responsibility for service laterals.

Comparison to Other Agency Practices

The following paragraphs describe the typical criteria and practices used by other agencies for CCTV inspection and condition assessment. Comparison to other agency practices may suggest potential enhancements to the District's current program.

Inspection Frequency. The District's 2-year cycle for cleaning and 8-year cycle of CCTV inspection for the established portions of its collection system are comparable to other agencies who have implemented cyclic cleaning and inspection programs. For example, the Union Sanitary District (USD), an agency that has been often cited for its well-managed, proactive maintenance program, has established a 6-year cycle for cleaning and CCTV of its system, with portions scheduled for more frequent cleaning as needed for control of grease and roots. Central Contra Costa Sanitary District (CCCSD) has targeted a 7-year period for inspection of its sanitary sewer system, which is being done by geographical areas. After review of the first 7 years of data, CCCSD intends to adjust the CCTV frequencies (e.g., pipes found to be in good condition may be identified for less frequent inspections). County Sanitation District 1 (CSD-1) of Sacramento County initiated its system-wide inspection program in 2001 with the goal of inspecting its system on an 8- to 10-year cycle. The City of Palo Alto is starting a program to CCTV inspect its entire sewer system in one project to identify rehabilitation projects for its 5-year CIP, and the City of Roseville is now beginning the first year of its sewer rehabilitation program, which includes a planned 6-year cycle of CCTV inspections.

Resources and Equipment. Depending on available resources, agencies with CCTV programs may utilize their own in-house staff and equipment to conduct the inspections (e.g., USD, Roseville), or contract out the work (e.g., CCCSD, Palo Alto). Use of in-house capabilities offers certain advantages in terms of cost and efficiency (assuming that CCTV staff are not diverted to other activities because of limited resources) and in promoting greater consistency and quality of collected data and "ownership" of the program by agency staff. Most agencies utilize color video cameras with pan and zoom capabilities, which have now become standard. However, agencies that do their own CCTV work may not be able to afford the investment in new, constantly improving, state-of-the-art equipment and software that are increasingly available for CCTV inspection. Such improvements include cameras equipped with inclinometers that can measure the magnitude and extent of sewer sags; equipment that can inspect service laterals by launching a separate lateral camera during the mainline CCTV inspection; and various software packages that are available to record the data directly into computers residing in the CCTV truck, along with digital video and image captures, and include viewer programs to facilitate later review of the data concurrently with the video and still images.

Observation Coding. Most agencies who have implemented or are starting to implement system-wide CCTV inspection programs recognize the importance of utilizing a standard set of observation codes. There are a number of code systems available, and more recently, the National Association of Sewer Service Companies (NASSCO) has developed a standard coding and pipeline grading system, along with training and certification processes, with the goal of greater standardization and consistency of pipeline condition assessment throughout the country. Many agencies utilize codes that are built into their CMMS software, or coding systems that they have used for many years. Others have attempted to develop a specific set of codes that is tailored specifically to their needs, which may be a subset or modified version of some other standard set of codes.

Data Capture. Many agencies, and some contractors, still use hand-written field logs to record CCTV observations, which may then be manually input to a CMMS or other database for storage and analysis. Use of hand-written logs does have several advantages (in addition to avoiding the complications and extra costs of software and computer equipment), including providing a "comfort level" to CCTV operators who may not be used to computer data entry, as well as providing a possible QA/QC check if the data is later entered into CMMS (on the other hand, this "dual" data entry process may also induce additional errors). However, for system-wide programs in which a large amount of data is collected, computer data entry of CCTV observations directly by the CCTV operator is probably the most efficient means of data capture, and most agencies who are doing large-scale CCTV inspection programs have switched to this approach.

Along with electronic defect coding, many agencies and contractors have now switched to digital video recorded onto computer hard drives and/or CDs or DVDs. The advantage in terms of reduced storage space over traditional videocassettes is obvious, as well as the relative ease of viewing the video on computers and ability to move to specific footage locations when viewing without the need for "fast forwarding." Digital video can also be linked to observation data contained in a database to facilitate review of CCTV inspection results. However, one of the disadvantages of digital video is the possible reduced clarity, particularly for large diameter RCP sewers, where it is important to be able to clearly assess the extent of deterioration of the pipe wall.

Condition Assessment. Analysis of CCTV data through use of a CMMS or other software tools can assist in managing the data and prioritizing needed actions, such as increased cleaning or sewer rehabilitation or replacement. Many CMMS programs and CCTV software have built-in modules that assign scores to various observed defects based on their type and severity, and generate an overall condition rating for each inspected pipe, allowing comparisons to be made and repairs prioritized. Some agencies have developed separate condition assessment tools tailored specifically to their program needs. For example, USD utilizes a Pipe Condition Assessment Program (PCAP) written in MS Access®, developed by MWH about 10 years ago, which downloads current CCTV inspection data from USD's CMMS, computes condition ratings for the pipes based on the inspection data and other information such as scheduled maintenance frequencies, and generates reports with the condition ratings and preliminary rehabilitation methods and costs for each pipe. The reports can be sorted based on the ratings, providing a means of prioritizing repair work and estimating needed rehabilitation budgets. USD runs the program after each cycle of CCTV inspections for each of its three major drainage basins, and incorporates these results into its overall basin Master Plans, which are updated every 6 years in conjunction with the CCTV cycle.

DSRSD's GBA Sewer Master program includes a code and rating system that can generate condition ratings for pipes based on CCTV data. As with similar systems, the "scores" assigned for various defects can be user-modified, thereby allowing the condition ratings to be tailored to the needs and priorities of the specific agency. Currently, the District does not utilize the condition ratings generated by the GBA program. However, as the District's CCTV database expands with the collection of more data, use of such a system may be advisable to assist in evaluating changes in system condition, prioritizing needed repairs, and planning for long-term system renewal/replacement funding.

Potential Enhancements to Current Practices

As the District's system increases in size and the sewers continue to age, there will be a need for a more efficient and systematic process for capturing and evaluating data from CCTV inspections. The following potential enhancements to current practices are suggested for the District's consideration.

Observation Coding System. The District continues to utilize the old Hansen defect descriptions because of staff familiarity with that system and in order to provide continuity with historical inspection data. The system has a somewhat rigid structure, in that it includes eight predefined classes of observations with up to 15 different letter codes under each class to describe various types and severity of defects. A clock position can also be entered for each observation. The system is structured somewhat differently than the coding system used in the GBA Television Inspection module, which uses a set of individual numeric codes with associated descriptions for different types of defects, each of which is assigned a defect location (e.g., clock position) and a severity rating of 0 to 5. Therefore, the raw CCTV data must be converted to GBA format for input into the GBA program.

District staff have considered adding more individual codes to GBA to allow a one-to-one correspondence between the old codes and the GBA codes, thereby ensuring that the old defect descriptions would be shown on the GBA reports. However, MWH suggests that the number of codes could probably be reduced without sacrificing the detail and utility of the information collected, and the overall system could be simplified by switching to the GBA system of defect descriptions, codes, and ratings for coding the raw data rather than retaining the old defect descriptions. Some modifications to the GBA code descriptions could be made to make them more familiar and consistent with past practice. The GBA Users Manual includes a Television Inspection Form that could be used or modified for the District's purposes, or the District's current form could be modified to accommodate the GBA codes and ratings.

Data Capture Systems. District CCTV operators currently record data on paper forms (this is considered to be a temporary situation due to computer system problems that have not yet been corrected) and video on VHS tape. In general, the industry is now switching to computer data entry and digital video saved to CD or DVD (or in some cases, directly to removable computer hard drives). In the future, as part of the normal process of upgrading its CCTV equipment, the District should consider changing its current method of data capture. The District should determine if the GBA data entry system can be made to work and if it will meet their future needs, or possibly explore various other commercially available CCTV software systems. These systems can be programmed to accommodate any specific observation coding system, so the District could still use its own system of codes, and a process could be established to import the data directly into the GBA database. Most of these systems also provide viewer software that allow users and reviewers of the CCTV data to easily access the observation information and view the associated still images and/or portion of the CCTV video. If capturing digital video, it may also be advisable to establish a file naming convention for video and still image files (e.g., a file name that incorporates a pipe identifier such as upstream/downstream manhole numbers, plus the date and direction of inspection), to facilitate storage and retrieval of video data on a network server.

Training and QA/QC. Accuracy and consistency in recording CCTV observations is critical to being able to use the data to assess the condition of a pipe, compare the condition of different pipes, and track the changes in a pipe's condition over time. Adequate training (including refresher training) of CCTV operators in observation coding and audio commentary, as well as operation of the video equipment, including proper camera speed, lighting, and use of panning and zooming, are important for ensuring quality data and video. Aids such as a TV inspection manual (an example manual prepared by MWH for CSD-1 was provided to the District earlier in the project) and/or defect picture posters may be helpful to train new operators and ensure recording of consistent data by both new and experienced operators. A QA/QC program should also be established to ensure adequate review of recorded data and video for quality and accuracy.

Condition Assessment. As described previously, condition assessment is a systematic process used to rate the relative condition of the various pipes in the sewer system in order to identify and prioritize needed repair/ replacement projects and track trends in system condition (deterioration) over time. The condition assessment is typically conducted by assigning points to each pipe defect observed during CCTV inspection based on its type and severity. The points may vary depending on whether the defect is considered structural (e.g., a crack) and/or primarily related to maintenance issues (e.g., grease) or I/I contribution. The total points for each specific pipe are then normalized (usually by dividing by the inspected pipe length) to calculate a score or rating that can be used to compare its condition to that of other pipes or to previous inspections of the same pipe.

The Television Inspection module of the District's GBA program includes the capability of calculating structural, cleaning (maintenance), and flow ratings for each pipe based on points (called "numbers" in GBA) assigned to various defects. The District is not currently using this system to assess its pipes. However, in the future, as the CCTV database expands and data for more pipes and inspections are added to the system, a more automated and systematic way of reviewing and analyzing the data may be needed. If the District decides to utilize this system in the future, the point values assigned to various defects should be reviewed and modified as needed to ensure that the resultant condition ratings are appropriate for the District' system and needs.

Prioritization of Rehabilitation and Replacement. The primary purpose of condition assessment is to identify needed repairs, rehabilitation, or replacement of system facilities and to prioritize those projects. Presently, the District's collection system is in very good condition, and relatively few needed repairs have been identified through previous CCTV inspections. Thus, the District has been able to fund and construct all needed repairs as they are identified.

As the system increases in size and ages over time, the number of defects found will no doubt increase. There may be a point in time when it will be necessary to prioritize repair projects to better match available funding or to balance expenditures over time. There may also be a need to assess the cost-effectiveness of various repair and rehabilitation methods. For example, a rehabilitation method such as lining, or even complete replacement, may be advisable for an old pipe with multiple defects, as opposed to simply spot repairing only the few isolated severe defects in the pipe.

Prioritization of sewer rehabilitation and replacement should consider not only the condition of the pipe (i.e., its probability of failure) but also the relative criticality of the pipe (the potential impact or severity of failure). For example, failure of a pipe located under a major roadway would have more severe consequences in terms of repair cost and impact to the community than one in a quiet residential street. Therefore, given similar condition, the pipe under the major roadway should have a higher priority for repair. Incorporating such risk factors into the condition assessment process provides a means for an agency to make better decisions about capital expenditures. One simple method is to assign "impact factors" to each pipe based on its criticality, and to use those factors in conjunction with (e.g., as a multiplier of) the condition rating from CCTV inspection to compute a total "critical rating" for the pipe. **Table 1** presents an example of possible impact factors based on the system used by USD. Prioritization of rehabilitation and replacement work could then be based on the relative critical ratings of the inspected sewers.

TABLE 1
EXAMPLE IMPACT FACTORS

Type of Impact	Condition	Impact Factor (IF)*
Community	Creek or drainage channel	2
	Hospital	2
	School	1
Construction	Easement	1-2
	Traffic	1-2
Critical Crossing	Freeway/railroad	4
	Major water line	4
	Flood control channel or creek	3
	Major buried utilities	2
	Major overhead utilities	1
Affected Area	> 30-inch pipe	2
	15- to 30-inch pipe	1.5
	10- to 12-inch pipe	1
	8-inch pipe	0
	6-inch pipe	0.5

*Total IF = 1 + sum(IF)/10

The above discussions are presented to suggest tools and concepts that the District may want to incorporate into its future sewer inspection and rehabilitation efforts. It is recommended that the District carefully evaluate these suggestions and take steps to develop a systematic approach to condition assessment that can be used to identify and prioritize collection system repairs and replacement in the future.

Design Standards Review

The District's design and construction standards with respect to the sewer collection system are contained in Section III, Sewer System Requirements, of the District's "Standard Procedures, Specifications and Drawings for design and installation of potable water, recycled water and wastewater utilities." The design standards were reviewed to assess specific items that may impact operation, maintenance, and condition of the sewer system and compliance with SSMP requirements. A summary of these items is presented below.

Design Sewage Flow. The design standards provide flow factors to be used for sizing of sewer mains. These factors are somewhat simplified and more conservative than those used in the development of the hydraulic model for this Master Plan. However, the factors are considered appropriate for providing design guidance to developers. For any new major developments, the capacity of downstream trunk system facilities should also be verified by District staff through use of the hydraulic model.

Minimum and Maximum Slopes and Velocities. The District's standards provide for minimum slopes and velocities that provide for at least 2 feet per second (fps) flow velocity at half-full pipe. This minimum velocity is standard for most collection agencies to ensure adequate self-cleaning velocities in sewer pipes and to help minimize the possibility of odors in the collection system. Minimum slopes and velocities for pipes larger than 21 inches are not addressed in the standards since these are considered "major infrastructure," which is constructed by the District. Higher minimum velocities and associated slopes are recommended for pipes 24 inches and larger, as presented in Table 4 of TM 3.

Location and Construction of Sewer Mains and Manholes. The District's standards include comprehensive provisions to facilitate access to sewers for cleaning and inspection and prevent designs that could cause poor hydraulics, potential blockages, conditions conducive to odors or corrosion, or possible structural damage. The standards include minimum cover for sewer mains, specified pipe and manhole materials, placement of manholes at all bends and significant grade changes, maximum distances between manholes, minimum size of manhole covers and barrels, slope of manhole channels, and limitations on the use of drop manholes.

Service Connections (Side Sewers). The design standards specify the desired location of the service lateral with respect to the property lot line, the minimum pipe size based on type of use, minimum slope and depth, allowable pipe materials, type of fittings for connection to main line sewer, and requirements for cleanouts and backflow prevention. The objectives of these standards are to facilitate location and response to potential stoppages, prevent backup of sewage into buildings, and minimize I/I into the collection system.

Grease/Sand Traps and Interceptors. The District's standards require a grease and sand trap or grease interceptor for any building where wastewater with excessive grease, sand, or other harmful constituents may enter the sewer system. Minimum volumes and sizes for grease interceptors and storage tanks are specified in the standards.

Testing and Inspection for New Sewer Construction. Testing of sewer mains and laterals is required under the following five conditions:

- After all work is completed
- After installation of all other underground utilities
- After roadway base rock has been placed and compacted (in improved areas)
- After backfill has been compacted (in unimproved areas)
- After access to all manholes has been provided

The standard testing method for sewers is air testing. Deflection testing is also required for PVC pipe, and sewer cleaning and television inspection is required for all sewer mains prior to acceptance by the District.

REVIEW OF RENEWAL/REPLACEMENT CRITERIA

This section discusses recent methods the District has used to determine the expected timing and costs for collection system asset renewal/replacement. The key assumptions and considerations for projecting future renewal/replacement timing and costs and recommended enhancements to current practices are also presented here.

Collection System Inventory

There are currently over 906,000 feet of sewers in the DSRSD wastewater collection system. The system is divided into 144 sewer maintenance areas (basins). The majority of the sewers in system are comprised of vitrified clay pipe (VCP, 57%) or polyvinyl chloride pipe (PVC, 39%). The overall system is fairly young, with the oldest pipeline dating back to 1962, and an average pipeline age of approximately 20 years. As noted previously, some of the age data contained in the GBA CMMS database is likely to be inaccurately recorded, as over 50 percent of the pipes (over 450,000 feet) are listed as having an installation date of 8/27/02. Since the total system sewer length was estimated to be approximately 565,000 feet at the time of the 2000 Master Plan, it is likely that only approximately 350,000 feet of sewer have been added in the past five years, rather than the 450,000 feet currently indicated in the database. **Tables 2, 3, and 4** present more detailed summaries of the collection system inventory.

TABLE 2
DSRSD SEWER INVENTORY BY DIAMETER

Diameter (inches)	Total Length (feet)	Percent of Total
6	25,595	2.8
8	712,192	78.5
10	62,067	6.8
12	32,113	3.5
15	18,076	2.0
18	8,428	0.9
21	1,981	0.2
24	9,667	1.1
27	4,387	0.5
30	5,283	0.6
33	1,065	0.1
36	17,711	2.0
39	3,335	0.4
42	4,960	0.5
Total	**906,860**	**100**

Note: Footage based on inventory as of April 2004.

TABLE 3
DSRSD SEWER INVENTORY BY MATERIAL

Material	Total Length (feet)	Percent of Total
ABS	9,930	1.1
ACP	4,672	0.5
ASP	2,016	0.2
CIP	415	0.0
Concrete	1,003	0.1
DIP	2,702	0.3
NCP	1,040	0.1
PLP	640	0.1
PVC	349,615	38.6
RCP	14,111	1.6
Steel	184	0.0
VCP	520,532	57.4
Total	**906,860**	**100**

TABLE 4
DSRSD SEWER INVENTORY BY AGE

Age (years)	Total Length (feet)	Percent of Total
>40	60,867	6.7
30-40	150,581	16.6
20-30	82,691	9.1
10-20	95,678	10.6
<10*	515,351	56.8
Unknown	1,692	0.2
Total	**906,860**	**100**

* Over 50 percent of pipe records indicate a construction date of 8/27/02; some portion of these are likely older pipes.

Recent Methods Used to Project Collection System Renewal and Replacement Needs

As part of efforts conducted for the 2000 Collection System Master Plan Update and development of the Replacement Planning Model in 2002, the District has used two slightly different methods for projecting the timing and costs of renewal/replacement of its collection system assets. The key elements of each of these methods are discussed below and summarized in **Table 5.**

TABLE 5
COMPARISON OF RENEWAL/REPLACEMENT PROJECTION METHODS

Item	2000 Master Plan Update	Replacement Planning Model
Sewer Inventory	▪ Data from previous Hansen database ▪ Age determined by development tract building permit data ▪ 565,000 LF of sewers ▪ Average age = 26 years	▪ Data from current GBA database ▪ Age data from GBA; some inaccuracies for pipes with 8/27/02 construction dates ▪ 906,000 LF of sewers ▪ Average age = 15 years (29 years if 2002 data not included)
Expected Sewer Service Life	▪ Typical service life ranges assumed for different material types (e.g., PVC = 50-75 years) ▪ Assumed 20% would require replacement at low end of range and 80% at high end	▪ All pipes assumed to have expected service life of 75 years ▪ "Replacement factor" applied to adjust for early failures, results in increase in expected service life equal to 33% of current pipe age
Cost Assumptions	▪ Unit costs assigned for three types of renewal/replacement: replacement, pipe bursting, and in-situ lining ▪ Weighted unit costs applied based on combination of renewal/replacement methods assumed for different pipe sizes	▪ Unit costs assigned for pipe replacement only ▪ All pipelines up to 12-inch diameter to be replaced by PVC; all larger pipelines to be replaced by VCP

2000 Master Plan Projection Method. This method was utilized in the 2000 Collection System Master Plan Update prepared by MWH. Key elements of this method, including the development of the sewer system inventory, the estimated expected life of sewer assets, and renewal/replacement cost assumptions, are summarized below.

Sewer System Inventory. At the time of preparation of the 2000 Master Plan, the District was in the midst of converting from an older version of Hansen CMMS to GBA Sewer Master and linking the inventory data in the CMMS to its AutoCAD MAP GIS. Key data for the sewer system inventory were developed as follows:

- Sewer data were obtained primarily from the District's previous Hansen CMMS.
- Sewers were grouped by maintenance areas (total of 88 at the time).
- Sewer inventory data (length, diameter, material) were developed for each maintenance area based on the data from Hansen.
- Development tracts were identified and dated for each maintenance area from historical building permit data.
- Pipeline age was determined in each maintenance area by the age of the associated predominant development tract.
- Total sewer inventory was comprised of 565,000 feet of sewers, with pipeline ages ranging from 5 to 40 years (average 26 years).
- Predominant pipe materials were: VCP (75%), PVC (18%), RCP (3%), and ABS (2%).

Expected Service Life of Sewers. Service life was considered to be "the age at which the deterioration and defect accumulation may begin to affect the structural integrity of a pipe, or allow excessive infiltration to occur" or, alternately, "the point at which the present worth cost of maintaining and repairing the sewer exceeds the cost to rehabilitate or replace." The service life estimates were developed as follows:

- Typical service life ranges were assumed for each pipe material found in the DSRSD system, based on generally accepted values:
  - Unlined reinforced concrete pipe (RCP) and asbestos cement pipe (ACP): 25-50 years
  - Plastic pipe - PVC, polyethylene (PEP) and acrylonitrile butadiene styrene(ABS): 50-75 years
  - VCP with rigid joints: 50-75 years
  - Ductile iron pipe (DIP) and VCP with gasketed joints: 75-100 years
- In consideration of the range of service lives associated with each material, it was assumed that 20 percent of sewers would be rehabilitated or replaced at the lower service life and 80 percent would be rehabilitated or replaced at the upper service life.

Renewal/Replacement Cost Assumptions. Key elements of the cost assumptions included the following:

- Unit costs were assigned (on a dollar per lineal foot basis) for each of three methods of asset improvement: replacement, pipe bursting, and in-situ pipe lining.
- All 6-inch sewer lines were assumed to be replaced with 8-inch lines.
- For 8- to 15-inch lines, it was assumed that a combination of replacement, pipe bursting, and in-situ lining would be used.
- For 18-inch and larger lines, it was assumed that 25 percent would be replaced and 75 percent would be lined.

2002 Replacement Planning Model Projection Method. This method was utilized in the 2002 Replacement Planning Model developed by Brown and Caldwell. Key elements of this method are summarized below.

Sewer System Inventory. Key system inventory data for the Replacement Planning Model were developed as follows:

- Sewer data (pipe diameter, length, material) were extracted from the District's GIS/GBA database
- Age data for pipelines were included based on the date of construction data contained in the GBA database. As noted previously, a large group of pipes (more than 50 percent) have a listed constructed dates of 8/27/02, but it is likely that a portion of this group are actually much older.
- Average pipe age in the GBA database calculates to roughly 15 years. If 2002 data are not included, the average system age calculates to roughly 29 years.

Expected Service Life of Sewers. The Replacement Planning Model service life estimates were developed as follows:

- Baseline expected service life of all pipelines was assumed to be 75 years, regardless of material type.
- A "Replacement Factor" extension of expected service life was used "to adjust useful life for early failures." The replacement factor, which was set to 0.75 for all pipes, results in an increase in a pipe's assumed 75-year service life equal to 33 percent of its current age. For example, for a 40-year-old pipe with an assumed remaining service life of 35 years, the revised service life would be calculated as 40/0.75 + 35 = 88 years, so the pipe would have a remaining service life of 48 years rather than 35 years. A 5-year old pipe would be calculated to have a revised service life of about 77 years, or a remaining life of about 72 years.

Renewal/Replacement Methods and Cost Assumptions. Key elements of the Replacement Planning Model cost assumptions included the following:

- Unit costs were assigned (on a dollar per lineal foot basis) for pipeline replacement only. Alternate methods of asset renewal (e.g., lining) were not incorporated into the cost model.
- All pipelines up to 12-inch diameter would be replaced with PVC pipe; all larger pipelines (15- to 42-inch diameter) would be replaced by VCP.
- All 6-inch pipes were assumed to be replaced with 8-inch pipes (same replacement unit cost)

Renewal/Replacement Projection Results

The purpose of both projection methods is to forecast long-term financial needs for system renewal and replacement. The 2000 Master Plan projection addressed only sewer system pipes, and extended the projection out to the latest projected service life of all existing pipelines in the ground at the time (approximately year 2100). The forecast identified a significant increase in projected funding needs starting in about year 2035, with a major increase after the year 2059.

The Replacement Planning Model, however, addresses all utility assets (including structures, maintenance equipment, computers, vehicles, etc.). The study period is variable, but appears to have been applied for a 30-year period (through the year 2032).

Because of these differences, direct comparison of the results of the two methods cannot be made.

Key Elements and Shortcomings of Previous Renewal/Replacement Projection Methods

Based on the two renewal/replacement projection methods used previously by the District, as well as methods used at other utilities, certain key assumptions, distinctions, and shortcomings in previous projection methods are evident.

Assumed Ages of Collection System Assets. For pipelines of unknown age, the 2000 Master Plan utilized a method for estimating the approximate ages based on a review of historical building permit and development data. These data, while not perfect, were the best available data at the time for estimating the age of sewers. The current GBA database contains age data for most pipes. While some of the data do not appear to be correct, confirming and/or updating these dates would provide the most accurate data for replacement planning.

Expected Service Life. The 2000 Master Plan and the Replacement Planning Model utilized slightly different assumptions for the expected service life for the District's installed pipelines. The Master Plan assumed different ranges of expected service life based on type of pipe material and a certain distribution of expected service lives around these ranges (20 percent at low end and 80 percent at high end of range). The Replacement Planning Model assumed that all pipelines have the same expected service life of 75 years. In light of the relatively young age of much of the District's system, the fact that actual sewer service life is quite difficult to predict with any accuracy, and the fact that the predominant pipe materials in the collection system (VCP and PVC) have expected service lives between 50 and 100 years, the simple assumption of a single expected service life of 75 years may make the most sense right now for the District's planning purposes.

Replacement Factor. The Replacement Planning Model utilizes a "Replacement Factor" that results in an increased service life for older pipes based on the assumption that other pipes of similar age may have already failed and been replaced. This factor potentially accounts for the phenomenon that some pipelines may last much longer than the average expected service life. Using such a factor to extend expected service lives results in a less conservative projection of future replacement requirements (further deferment of costs). No such extension of expected service life was incorporated into the 2000 Master Plan projections. The District may want to eliminate this factor in the interest of simplicity and maintaining a more conservative projection (earlier timing) of future replacement needs. Use of a replacement factor may be more appropriate in later years when "early failures" can be better assessed.

Renewal and Replacement Technologies and Cost Assumptions. The 2000 Master Plan assumed that a blend of construction technologies (replacement, pipe bursting, and in-situ lining) would be used for future renewal/replacement needs, with the percentages of each technology dependent upon pipe size. In contrast, the Replacement Planning Model utilized a more simplistic assumption that all pipelines would be replaced at the end of their expected service lives, regardless of size or material. While the 2000 Master Plan assumptions are more reflective of actual practices by many utilities, the simpler, more conservative assumption that all pipelines are replaced may make more sense right now for the District's planning purposes.

Link Between Assumed and Measured Condition and Predicted Service Life. Neither the 2000 Master Plan nor the Replacement Planning Model incorporated a linkage between assumed or measured pipeline condition and the expected service life of a pipeline. In order to make the best use of pipeline CCTV inspection efforts, pipeline condition data should serve to refine the expected lives of individual pipes on an ongoing basis. Similarly, data on actual asset lives (time between installation and renewal/replacement) should be collected in order to refine the expected lives of other assets in the same area and/or of the same material or size.

Prioritization of Renewal/Replacement According to Risk. Neither the 2000 Master Plan nor the Replacement Planning Model incorporated any element of risk into the projected timing of asset renewal or replacement. Depending on the probability of asset failure (in part a function of age and condition), and the severity associated with that failure (e.g., potential public health or water quality impacts, community impacts, or liability costs), certain assets may warrant renewal or replacement prior to the expected end of their service lives. The District may want to place a higher priority on these "high risk" assets for earlier renewal/replacement (shorter projected useful lives) in order to minimize risk. The goal would be to set the "risk-based" renewal/replacement date at a point in time closer to where the avoided costs of mitigated risk would outweigh the increased costs of earlier asset replacement.

Potential Enhancements to Current Practices

The District should consider the following recommendations for enhancing its methodology for projecting future renewal and replacement costs.

- **Update Replacement Model Database with Better Age Data.** The District has relatively sound data on the age of its collection system assets. The age (year of construction) data in the GBA database should be verified (particularly for those pipes with construction dates of 8/27/02) and corrected as needed to improve the accuracy of the Replacement Planning Model.

- **Simplify Original Expected Life Assumptions and Refine with Data Over Time.** Each of the renewal/replacement methodologies previously used may be overcomplicating the projections with age ranges and replacement factors, and under-utilizing the condition data that is currently being collected through the District's cyclic CCTV inspection program. A more simple approach would be to use a single original expected service life of 75 years for all pipelines and eliminate the replacement factor adjustment that extends the service life. Instead, refinements to expected renewal and replacement dates should only be made based on actual field condition data and actual observed service lives of similar assets in the system.

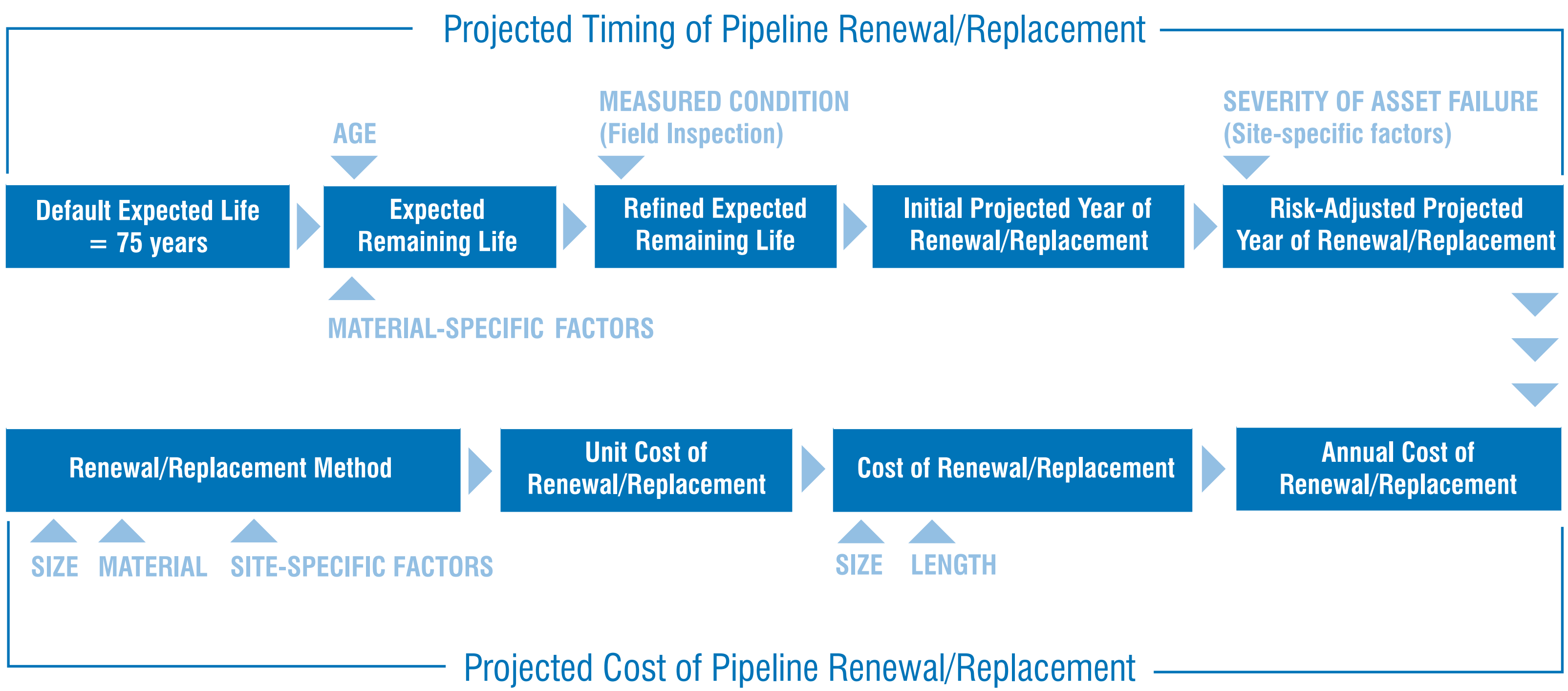
- **Establish Direct Data Linkage Between Field Condition Data and Renewal/ Replacement Projections.** A common data source for the District's CMMS and its Replacement Planning Model would enable the model and resultant renewal/replacement projection data to be updated automatically with new field condition data entries. A translation would need to be established between pipeline condition rating scores and expected remaining service life. While no established formula for this translation currently exists in the industry, such an approach would more closely connect observed field conditions to projected financial impacts. As actual service life data are collected over time, the relationship between historical observed field condition and remaining service life could be refined for specific areas and/or pipeline materials within the DSRSD system.

- **Adjust Projected Renewal/Replacement Timing According to Risk Factors.** The projected timing of renewal and replacement efforts should also incorporate the potential costs or impacts associated with a particular asset failing. A risk score, developed based on the severity of asset failure (e.g., an impact factor adjustment, as illustrated in Table 1) and the probability of failure (based on age/condition data) could be used to adjust the projected renewal/replacement timing such that higher risk assets are replaced sooner. Impact factors associated with each asset could be revisited on a periodic basis, and probability information could be updated automatically via age and condition data in the CMMS.

Figure 1 presents a schematic flow chart for developing and updating timing and cost projections for pipeline renewal and replacement. A similar methodology could be applied to other collection system or other utility assets.

Figure 1

Recommended Approach for Projecting Pipeline Renewal/Replacement Timing and Cost



ATTACHMENTS

1. **CCTV OBSERVATION FORM**
2. **CCTV CODE SHEET**

TV OBSERVATION

Basin Number: ___________________ **Tape/WO Number:** ______________________

Manhole No: ___________ to _________ TV Date: _______/_____ / _____ Total Feet: _________

UPS Address: ____

DWN Address: ____

TV Direction: ☐ Upstream to Downstream ☐ Downstream to Upstream

Project: __________________________ Location: _______________________________

Job #: ____________________________ Flow Level: __________________________ (in.)

Operator: _________________________ Pipe Width/Dia: ______________________ (in.)

Joint Length: ___________________ (ft.) Pipe Type: _____________________________

VTR Index Start: _________________________

VTR Index Stop: _________________________

Weather: ☐ Sunny ☐ Rainy ☐ Cloudy ☐ Foggy ☐ Clear ☐ Hot ☐ Cool ☐ Night

Surface Cover: ☐ Asphalt ☐ Rock ☐ Dirt ☐ Concrete
☐ Brush ☐ Easement ☐ Grass

Purpose: ☐ TV Existing Line ☐ TV New Line ☐ TV Rehabilitated Line
☐ Possible Collapsed Line ☐ Obstruction

Maintenance Prior to TV:
☐ Clean Prior ☐ Degrease Prior ☐ Point Repair Prior ☐ MH Replace Prior
☐ Root Cut Prior ☐ Root Chem Prior ☐ Other Maint. Prior ___________________________

Over-all Condition: ☐ Good ☐ Fair ☐ Poor ☐ Very Poor

Recommendations: ____

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____

Comments: ____

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TV OBSERVATION

Footage Reading	VTR Location	Clock Position	CRACKS		JOINTS		LATS	ROOTS	DEBRIS	I/I	ALIGN	STRUCTURE		
			RC	LC	MJ	BJ						DS	OS	CS
U D	S T A R T O F R U N													
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CODE SHEET FOR CCTV INSPECTIONS

CRACK - Radial (RC) & Longitudinal (LC)

CODE	DESCRIPTION	RATING	NOTES
A	< 1/2" W, < 1'L	1	
B	< 1/2" W, 1'-2' L	1	
C	< 1/2" W, > 2' L	2	
D	> 1/2" W, < 1' L	2	
E	> 1/2" W, 1'-2' L	3	
F	> 1/2" W, > 2' L	3	
G	Hole in Pipe- Small	4	
H	Pipe missing- < 60 degrees	4	
I	Pipe missing- > 60 degrees	5	

JOINTS -Misalign (MJ) & Broken (BJ)

CODE	DESCRIPTION	RATING	NOTES
A	DRP JT < 90% clear	1	
B	DRP JT 80-90% clear	3	
C	DRP JT < 80% clear	5	
D	SHF JT > 90% clear	1	
E	SHF JT 80-90% clear	3	
F	SHF JT < 80% clear	5	
G	WD JT 2" - 3"	1	
H	WD JT 3"- 4"	3	
I	WD JT > 4"	5	
J	BRK JT - Light	1	
K	BRK JT- Medium	3	
L	BRK JT- Heavy	5	
M	Typical Joint	0	
N	Visible Gasket	0	
O	Leaking at Joint	0	

LATERALS

CODES	DESCRIPTION	RATING	NOTES
A	Protruding Service 0"-1"	1	(Loc= lateral wye) (Description = protruding service)
B	Protruding Service 1"-2"	2	(Loc= lateral wye) (Description = protruding service)
C	Protruding Service 2"-3"	3	(Loc= lateral wye) (Description = protruding service)
D	Protruding Service 3' +	4	(Loc= lateral wye) (Description = protruding service)
E	Defect- Service Conn	5	(Loc= lateral wye) (Description = protruding service)
F	Dead/ Unused Service	0	
G	Factory Service	0	(Loc= clock positi (Description = Wye Service
H	Plumber Service	0	(Loc= clock positi (Description = Wye Service

ROOTS

CODES	DESCRIPTION	RATING	NOTES
A	Roots- Light	1	(Loc= clock position)
B	Roots- Medium	3	(Loc= clock position)
C	Roots- Heavy	5	(Loc= clock position)

CODE SHEET FOR CCTV INSPECTIONS

CODE	DESCRIPTION	RATING	NOTES
A	Debris- Light	1	(Loc= lateral wye/clock/other (Defect Descp. = Debris)
B	Debris- Medium	3	(Loc= lateral wye/clock/other (Defect Descp. = Debris)
C	Debris- Heavy	5	(Loc= lateral wye/clock/other (Defect Descp. = Debris)
D	Grease- Light	1	(Loc= lateral wye/clock/other (Defect Descp. = Grease)
E	Grease- Medium	3	(Loc= lateral wye/clock/other (Defect Descp. = Grease)
F	Grease- Heavy	5	(Loc= lateral wye/clock/other (Defect Descp. = Grease)

INFLOW/ INFILTRATION

CODES	DESCRIPTION	RATING	NOTES
A	I/I -Light (0-1 GPM)	1	(Loc= lateral wye/clock/other (Defect Descp. = Infiltration)
B	I/I- Medium (1-5 GPM)	3	(Loc= lateral wye/clock/other (Defect Descp. = Infiltration)
C	I/I- Heavy (> 5 GPM)	5	(Loc= lateral wye/clock/other (Defect Descp. = Infiltration)
D	I/I- Some Evidence	2	(Loc= lateral wye/clock/other (Defect Descp. = Infiltration)
E	I/I- Considerable Evidence	3	(Loc= lateral wye/clock/other (Defect Descp. = Infiltration)
F	I/I- Considerable Evidence	5	(Loc= lateral wye/clock/other (Defect Descp. = Infiltration)
G	I/I- No Evidence	0	

ALIGNMENT

CODE	DESCRIPTION	RATING	NOTES
A	Begin 1/4 Pipe Water (dist > 10)	1	(Loc= (8)other Descp= SAG)
A2	Begin 1/4 Pipe Water (dist > 20)	2	(Loc= (8)other Desc= SAG)
A3	Begin 1/4 Pipe Water (dist > 30)	3	(Loc= (8)other Desc= SAG)
A4	Begin 1/4 Pipe Water (dist > 40)	4	(Loc= (8)other Desc= SAG)
A5	Begin 1/4 Pipe Water (dist > 50)	5	(Loc= (8)other Desc= SAG)
B	Begin 1/2 Pipe Water (dist > 10)	1	(Loc= (8)other Desc= SAG)
B2	Begin 1/2 Pipe Water (dist > 20)	2	(Loc= (8)other Desc= SAG)
B3	Begin 1/2 Pipe Water (dist > 30)	3	(Loc= (8)other Desc= SAG)
B4	Begin 1/2 Pipe Water (dist > 40)	4	(Loc= (8)other Desc= SAG)
B5	Begin 1/2 Pipe Water (dist > 50)	5	(Loc= (8)other Desc= SAG)
C	Camera Submerged	NA	Location = 23 , no description'
D	Camera Emerged	NA	Location = 24, no description
E	End 1/2 Pipe Water		
F	End 1/4 Pipe Water		

STRUCTURAL CODE- Deterioration (DS) , Ovality (OS), Collapsed/ Crushed (CS)

CODE	DESCRIPTION	RATING	NOTES
A	Pipe Det (Point) - Light	1	(Loc=(8) other Desc= Cracked)
B	Pipe Det (Point) - Medium	2	(Loc=(8) other Desc= Cracked)
C	Pipe Det (Point) - Heavy	5	(Loc=(8) other Desc= Cracked)
D	Oval < 5%	1	(Loc=(8) other Desc= Pinched)
E	Oval > 5% & <10%	3	(Loc=(8) other Desc= Pinched)
F	Oval > 10%	5	(Loc=(8) other Desc= Pinched)
G	Collapsed	5	(Loc=(8) other Desc= Collapsed)
H	Heavy Overall Pipe Det	5	
L	Light Overall Pipe Det	1	
M	Medium Overall Pipe Det	3	
N	Pipe Det- None	0	
Z	At Manhole Number	0	