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Union Sanitary District's Collection System Hydraulic Model and Pipe Condition Assessment Program – the ongoing evolution of a powerful planning tool

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ABSTRACT: Over 20 years ago, USD adopted a planning approach for its wastewater collection system that has been very effective in ensuring its ability to provide a high level of service to its customers. That planning approach includes inspecting and evaluating the condition of all sewers in the system on an approximate 6-year (72-month) cycle and maintaining an up-to-date hydraulic model to evaluate its capacity needs on an ongoing basis. As a result, the District has been able to ensure the timely identification of capital needs to maintain its sewer infrastructure in good condition and provide adequate hydraulic capacity to serve existing and new customers without risk of sanitary sewer overflows (SSOs).

To date, the District has completed two full cycles of the basin Master Plans and is poised to complete the third. Through this experience, the District has continually improved and adapted the master plan methodologies to reflect new information and changing conditions. The proposed paper would provide a history of these improvements, providing a glimpse of the model's origins, it's ever increasing detail and usefulness, and potential future enhancements.

1. INTRODUCTION

The Union Sanitary District (USD) provides wastewater collection, treatment, and disposal services for businesses and residents of the cities of Fremont, Newark, and Union City in southern Alameda County. The District operates a sanitary sewer system with over 1,100 kilometers (700 miles) of sewers. The District's service area is divided into three major drainage basins, Irvington, Newark, and Alvarado, corresponding to the three major pump stations that convey wastewater north through twin force mains to the District's Alvarado Wastewater Treatment Plant.

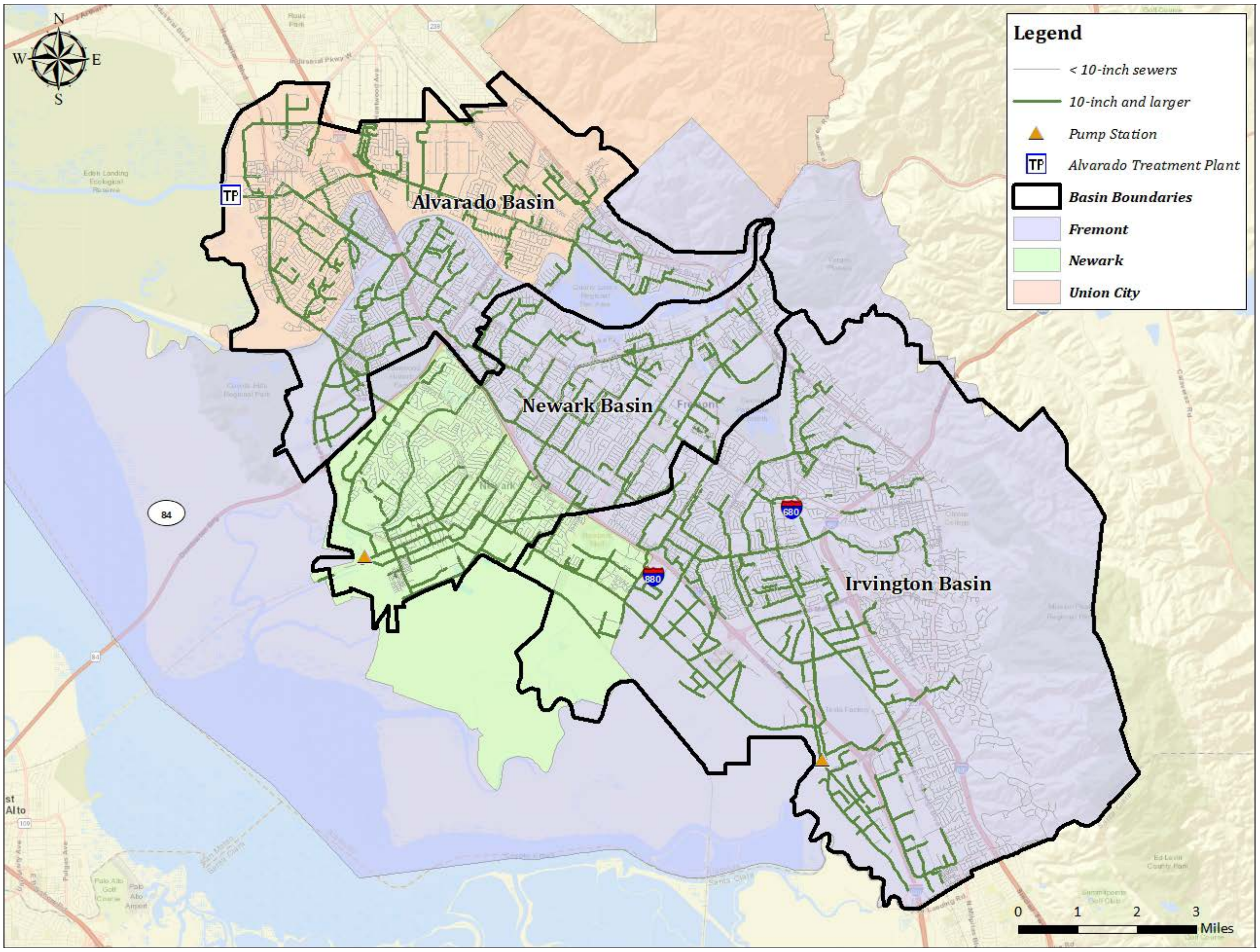

Figure 1. USD Overview

Over 20 years ago in 1989, USD adopted a planning approach for its wastewater collection system that has been very effective in ensuring its ability to provide a high level of service to its customers. That planning approach includes inspecting all sewers in the system on an approximate 6-year (72-month) cycle and maintaining an up-to-date hydraulic model to evaluate its capacity needs on an ongoing basis. As a result, the District has been able to ensure the timely identification of capital needs to maintain its sewer infrastructure in good condition and provide adequate hydraulic capacity to serve existing and new customers while minimizing the risk of sanitary sewer overflows (SSOs).

2. MASTER PLANNING PROCESS

The District prepares Sewer Master Plans for each of its three major drainage basins on a rotating basis, tied to the completion of each TV inspection cycle. The Master Plans have two key elements:

- A ***capacity assessment*** of the trunk sewer system based on flow monitoring and state-of-the-art hydraulic modeling to quantify existing flows and the needs for serving anticipated future development; and
- A ***condition assessment*** based on a risk analysis approach implemented through the District's Pipe Condition Assessment Program (PCAP) using current TV inspection data to prioritize sewers in need of repair, rehabilitation or replacement.

The results of the condition and capacity assessments are combined in a Master Plan report for each basin. The report contains detailed discussions of study methodology, results, and recommendations in the report chapters, and supporting documentation (flow data and model calibration graphs, land use planning information, model data and results tables, and PCAP reports) in appendices bound with the report. The Master Plan reports and accompanying appendices inform the District's sewer system capital improvement program.

3. CAPACITY ASSESSMENT METHODOLOGY

The capacity requirements of each basin are analyzed using a computer hydraulic model originally developed in the late 1980s and since significantly updated and expanded. The model is used to analyze the capacity of the District's sewers and to determine the required capacity for conveying existing and future peak design flows. To identify any capacity deficiencies in the system, peak design flows under each existing or future "scenario" are compared to a capacity criterion which defines the threshold for a sewer to be considered capacity deficient.

The approach for each basin capacity assessment is to update the previous master plan model based on the District's latest GIS data (e.g. asset data for pipes and manholes), operation data (e.g. pump station on/off set points, any diversions), and customer billing data; meet with the cities within the basin to obtain up-to-date development information and land use plans; and update model calibration based on new flow monitoring and rain gauge data. The model is then run for the District's design storm event to identify potential existing or future capacity deficiencies, reviewed and "ground-truthed" with District staff, and the results used to develop capacity improvement projects if needed.

If the updated model indicates that capacity improvements are needed in the basin, options for improvements, including upsizing existing sewers, flow diversions to other sewers that have available capacity, or potential construction of new relief sewers are evaluated to confirm constructability and cost-effectiveness. Information available from TV inspection is then incorporated to identify pipes that may need rehabilitation as well as increased capacity. To support the District's planning, priority rankings and planning level cost estimates are developed based on the most viable alignments and construction methods for each potential capacity improvement project.

4. HYDRAULIC MODEL EVOLUTION

The District's computer hydraulic model was originally developed for the 1989 Sewer Master Plan, which addressed the collection and transport systems for all three drainage basins. The 1989 study developed flow projections and identified required capacity improvements in the trunk sewer system (primarily those sewers 10 to 12 inches in diameter and larger). In 1993, the District completed a District-Wide Master Plan. Although the plan focused on the transport system and treatment facilities, it did include detailed analysis of historical wastewater flows to better define the projected design flows for the system. The 1993 refinement of flow projections marked the first such improvement to the hydraulic model. This refinement has continued over the course of the subsequent basin Master Plan cycles, primarily in the following areas:

- **Model Software:** Improved hydraulic modeling software
    - **1989** – District's "static" SNAP model developed, "static" meaning snapshot peak flows were computed based on peaking factors applied to average base wastewater flow with the addition of an allowance for ground water infiltration (GWI) and an assumed amount of rainfall-dependent inflow and infiltration (RDI/I)

    - **1999** – Upgrade to a "fully dynamic" HydroWorks^{TM} model, "fully dynamic" meaning the model can perform dynamic extended period simulation hydraulic analyses, provide hydraulic gradeline calculations, and perform "what-if" simulations without modifying the main model database. Separate, custom GIS application created to create input files for model and export results back to GIS.

- **2004** – Upgrade to GIS-integrated InfoWorks CS™ model
- **2017** – Upgrade to InfoWorks ICM™, the latest generation modeling software

- **Model Network:** Began in 1989 with most 10-inch and larger sewers modeled and gradually refined the network over time, adding additional pipes (newly constructed or targeted for further study) and refining subareas used to estimate flow allocation. In 2017, developed an approach for developing model "loads" on a parcel basis, which enabled redefining subareas based on parcels, resulting in a 10x increase in model resolution.

- **Land Use Data:** In 1995 aerial photos were used to delineate areas of existing development and itdentify vacant land available for future development. General Plan Land Use maps were then digitized in AutoCAD and overlaid with delineated areas to quantify existing and future land uses, further informed by interviews with City planning staff. Base wastewater flow estimates (model "loads") were developed according to the breakdown of land uses within a given model "subarea". Beginning in 2000, GIS mapping and information layers began to replace aerial photos and digitized AutoCAD maps allowing for increasingly detailed load estimates. In 2004, customer billing databases began to be used to inform parcel-level load estimates, significantly refining model loading.

- **Deisgn Flows:** Originally defined in 1989, appropriate design storms for the basin master plans have been coordinated with results of continuous simulation analysis for the District's transport and treatment system. RDI/I assumptions have also been refined signficantly, most noteably by using observed data from flow meters and rain gauges to adjust from conservative, generalized assumptions to empirical, USD-specific factors. Observed flow data has also been used since 2000 to refine flow factors used for model base wastewater flow loading, calibrate to actual use, and adjust for changes in use patterns over time.

One very significant change planned for the upcoming Master Plan is to expand the model to include all pipes in the basin collection system, not just the trunk sewers. This evolution will leverage the District's excellent GIS, in which virtually all pipes are attributed with invert elevations and the recently implemented approach of developing model "loads" on a parcel basis. An all-pipe model will provide a substantially greater level of information for the District to use in evaluating the potential impact of new developments and intensification on the smaller diameter mains in the system, as well as providing information to confirm capacity needs and determine appropriate construction methods (e.g., lining vs. pipe bursting or replacement, etc.) for smaller diameter sewers in need of structural rehabilitation. Overall, this improvement will increase detail and accuracy of flow routing in the model.

5. CONDITION ASSESSMENT METHODOLOGY

The approach that has been used in the basin Master Plans for the condition assessment involves analysis of TV inspection data and maintenance information in order to establish a "condition rating" for each sewer pipe (manhole-to-manhole reach) in the system. The TV data is also used to develop preliminary estimates of costs for rehabilitation of sewers with identified defects in order to identify the most cost-effective method of repair for each pipe.

In order to prioritize the sewers for rehabilitation work, the condition ratings are considered in conjunction with other factors, called "impact factors", which reflect an assessment of how "critical" each particular sewer is, i.e., the potential severity of the impacts should the pipe fail structurally or a blockage occur. The combination of the sewer condition rating and impact factors defines the overall "critical rating" of the sewer, which determines its relative priority for rehabilitation.

6. PIPE CONDITION ASSESSMENT EVOLUTION

The condition assessment methodology described above was programmed into a computerized database system originally developed in 1994 as part of the first Irvington Basin Master Plan. To build the database, data from the District's Hansen Computerized Maintenance Management System (CMMS) were transferred and reformatted for import into the PCAP database. The data include inventory information (pipe upstream and downstream map grid and manhole numbers, cleaning section number, street location, diameter, length, slope, and material); maintenance schedules; and TV inspection data summarized by the number of occurrences of each defect type. The PCAP database does not include the detailed footage location for each defect nor any specific comments noted by the TV operators.

Originally built in dBaseIV and shortly thereafter converted to Microsoft Access, the PCAP has the ability to attach tables in the Hansen Oracle relational database management system (RDBMS) and to extract pipe inventory, maintenance, and TV inspection data from these tables. The program allows the user to edit, add, or delete inventory, maintenance schedule, TV inspection, and impact factor data, as well as to modify the pipe defect point values and repair, rehabilitation, and replacement unit costs.

The program generated several types of output reports. In addition to standard data listings, there were a number of "analysis" reports" that provide the user with summaries of the TV inspection data, condition and critical ratings, and rehabilitation recommendations and costs. The program also provided "data filter" capabilities, giving the user the flexibility to edit data or generate reports for an entire basin or for portions of the basin as specified by cleaning section number, map grid, or street name.

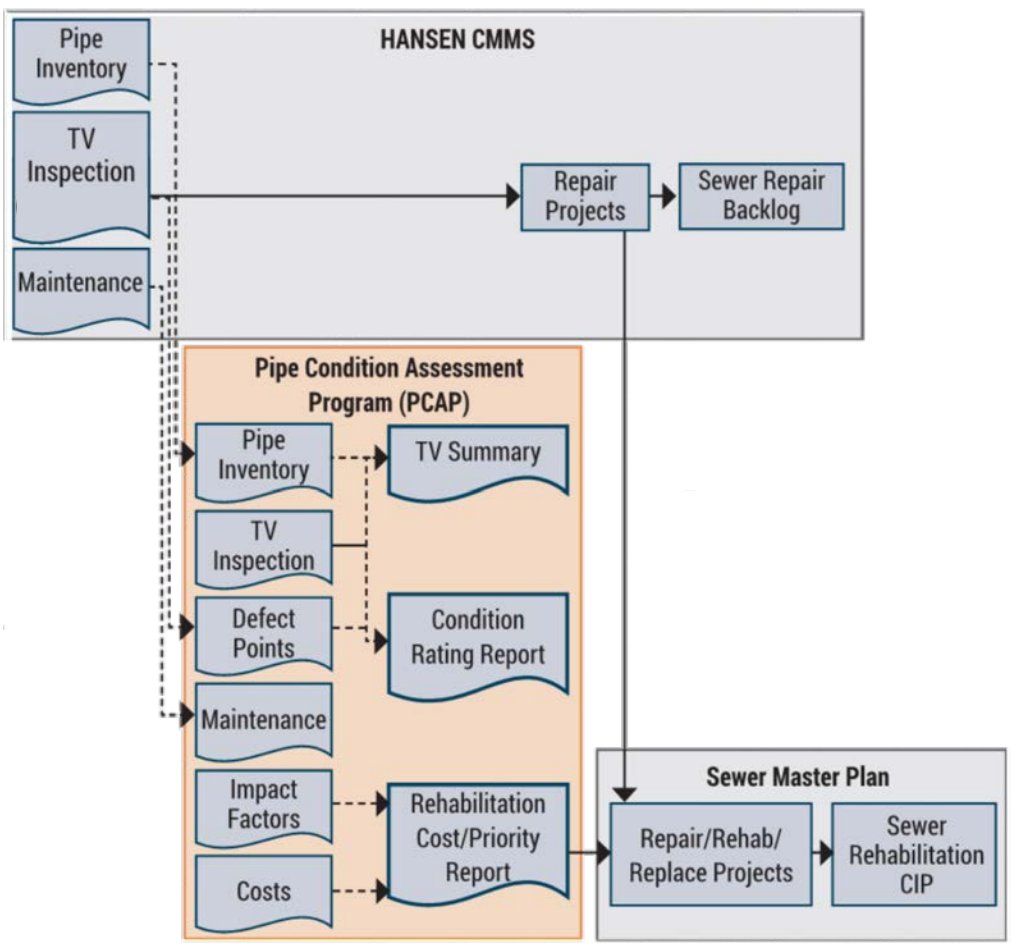

Figure 2. Condition Assessment Methodology

When the District's PCAP was developed in the mid-1990s, it was clearly ahead of its time in terms of using a computerized approach for analysis of TV inspection data and a risk-based methodology to develop rehabilitation priorities for system-wide planning. Over the years, the program has been updated and improved to accommodate new MS Access versions, as well as changes to the District's own data management systems (e.g., change from the original Geobase CMMS and associated TV codes to the Hansen CMMS, multiple upgrades to the Hansen software and database table structure, implementation of GIS, new manhole numbering format etc.) as well as industry thinking on approaches to rehabilitation planning. In 2012 a significant upgrade was made to the PCAP rehabilitation cost calculations, updating them to include a life-cycle cost analysis that incorporates the remaining service life and annual cost of ownership for different rehabilitation methods.

One future, significant improvement that has been initiated by the District in recent years is the adoption of the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP) standard for TV inspection, which will be incorporated into the ongoing update of the Newark Basin Sewer Master Plan. Though PCAP has evolved signficantly and been tailored to the District, there is now commercially available condition/risk assessment software on the market that is coming into more widespread use, as well as a trend to standardize condition assessment scoring using NASSCO PACP methodology. One such program is Innovyze's InfoMaster™, which can import TV inspection data in NASSCO PACP format, compute NASSCO PACP standard condition grades and scores, and perform risk analysis by applying customized likelihood and consequence of failure factors derived from various sources of data to prioritize needed repairs and rehabilitation. Thus, the condition assessment will be performed in InfoMaster™ for the upcoming basin master plan, and USD's pipe condition assessment methodology will continue to improve and evolve.

7. CONCLUSION

To date, the District has completed two full cycles of the basin master plans and the 2019 Newark Basin project will complete the third full master plan cycle. The master planning team has always strived to incorporate new, improved, and innovative technologies and methodologies into each update. Thus the master plan methodologies and tools have been continuously improved and adapted to reflect new information and changing conditions.

Through cyclic Master Plan updates, the District's hydraulic model and condition assessment program have continually improved in detail and usefulness. Through this cyclic master planning process, the District has been able to ensure the timely identification of capital needs to maintain its sewer infrastructure in good condition and provide adequate hydraulic capacity to served existing and new customers. USD serves as an excellent example of leveraging powerful planning tools in a systematic approach to quality public stewardship.

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