Stormwater Management Study
Arthur Capper/Carrollsburg Dwellings LID Project

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Table of Contents

1.0 INTRODUCTION

1.1 Background

The purpose of this modeling effort is to determine the feasibility of using LID stormwater management practices to address stormwater quality and stormwater quantity issues that could potentially be associated with the redevelopment of this approximately 120 acre tract. This information could be used by the developer and the planning department to address regulatory and community development issues. Also included is a task to determine the feasibility of diverting and/or retaining stormwater runoff to support the water budget needs of a park that would be along the western border of the development and would include a significant area of water features.

1.2 Executive Summary

This study, although limited in scope, demonstrates that there is potential for significant water quality improvements and reduction of stormwater volume that would potentially reduce the volume and amount of Combined Sewer Overflow (CSO) events to the Anacostia. The following are key findings from the study.

- Almost the entire runoff generated from the development could be disconnected from the combined sewer system. There is a large existing and under utilized trunk storm sewer line that runs through the development. As the streets and roads are reconstructed, the inlets could be connected to this system, rather than the existing combined system.
- Even a conservative number of LID practices, if placed strategically in front of inlets or incorporated into the design could have a significant effect on water quality. If the practices could be designed to completely retain the first ¼ inch of rainfall, then there would be approximately 15 to 20 less discharges per year of pollutants to the Anacostia. These systems could also be designed to treat and filter the pollutants from the remaining storm events.

- A preliminary assessment shows that approximately eight (8) acres of runoff area could easily be diverted to the canal park area. Using a conservative estimate of diverting 20 inches of the approximately 40 inches of average rainfall to the park, about 13.5 acre feet of water could be available on an annual basis for use in the canal park. This water may have to have some type of treatment (e.g. wetlands or other filter) to remove pollutants from the runoff if there is water contact use.

1.3 Problem Assessment

Combined sewer systems (CSOs) are used to transport both sanitary and stormwater runoff. During severe storm events, the addition of large stormwater flows can exceed the hydraulic capacity of the combined sewer interceptors and a mix of stormwater and sanitary sewage can be discharged into receiving waters. The area of this study (Arthur Capper / Carrolsburg Dwellings) is served with combined sewers that discharges excess stormwater into Anacostia River.

The Arthur Capper site is a high-density urban residential area and the land surface is highly impervious. Therefore, even minor rainstorms can result in excessive volumes of rainfall runoff. If this runoff, when mixed with the sanitary sewage, exceeds the capacity of the piping systems, combined sewage is discharged into the Tidal Anacostia River at multiple CSO overflow locations at the Washington Navy Yard. (See Figure 1-1.) In significant volumes, untreated combined sewage can have a detrimental impact on water quality conditions. The most severe water quality problems resulting from these discharges are:

? The depletion of dissolved oxygen due to the addition of oxygen consuming pollutants.
? Increased concentration of bacteria pathogens associated with sanitary sewage and stormwater.

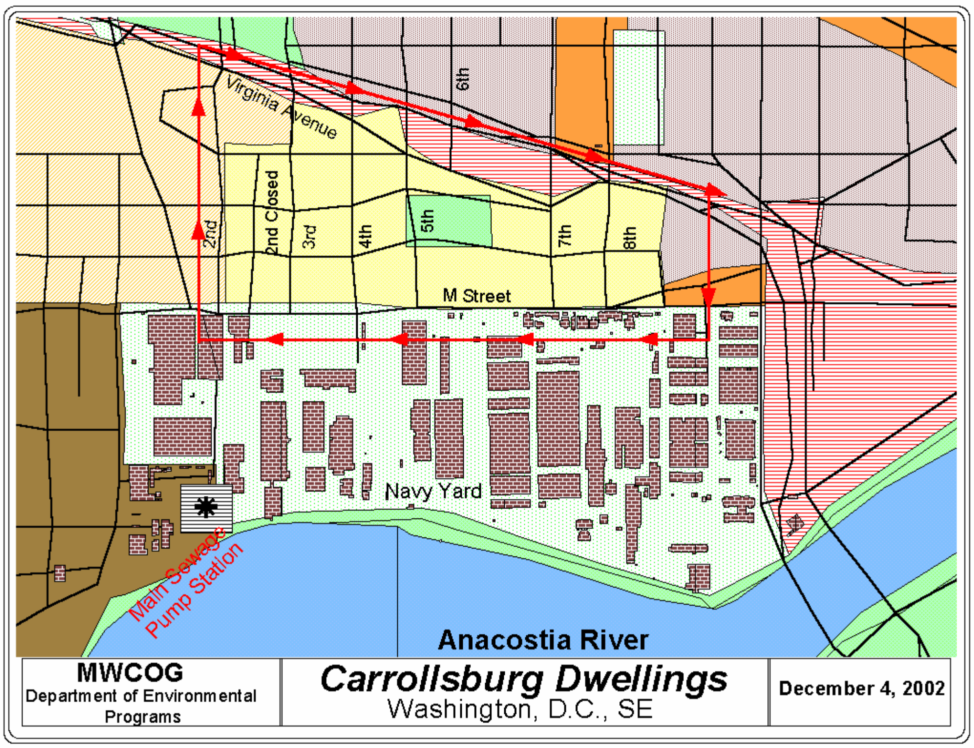


Figure 1-1: Arthur Capper Vicinity Map

2.0 SITE ASSESSMENT

This proposed project is located in the South East corner of the District of Columbia near the Navy Yard on the western bank of the Tidal Anacostia River. The site of the proposed separate storm sewer is located within a trapezoidal parcel of land bounded by Virginia Avenue from the north, M Street from the south, 2^{nd} Street on the west, and 8^{th} Street on the east (see Figure 2-1).

Figure 2-1 : Arthur Capper Site

3.0 ENGINEERING ANALYSIS

The physical characteristics of the proposed redevelopment site are just one part of the feasibility of this project. Even with LID, it was not clear whether a stormwater system could be modified to achieve the desired goals of the project. Therefore, a preliminary engineering assessment was required to ensure that these considerations were addressed in the feasibility analysis. The engineering analysis was comprised of a hydrologic and hydraulic engineering analysis.

3.1 Hydrologic Analysis

The hydrologic analysis was performed using the US EPA's RUNOFF block of the Stormwater Management Model (SWMM). Drainage area characteristics and precipitation data were input into this model for several storm conditions to generate runoff flows to the hydraulic system (described in Section 3.2). These analyses are described below.

3.1.1 Drainage Area Characterization

The land use for this drainage basin is high-density urban residential. The watershed contains some few parcels of open land, including the site of the proposed LID, a baseball field, and parking lots. Land use characterization is needed to provide an estimate of the area of the impervious and pervious land surfaces that drain to the storm water system in the watershed. In addition to the land use, other factors are used to characterize the drainage areas, including land slope, soil properties, and surface storage (puddles, etc.). The land slopes for subcatchments were determined using 100-ft scale DC-WASA sewer plates of the watershed. Overland flow paths were estimated using these maps and slopes were estimated using the flow path lengths, Streets and ground elevations. Soil properties (for infiltration parameters) were estimated from soil classification maps. Surface storage values were taken from literature values and estimated based on the slope of the catch basins (flatter subcatchments have greater storage potential.). The details of these values are presented in Section 3.1.3.

3.1.2 Rainfall

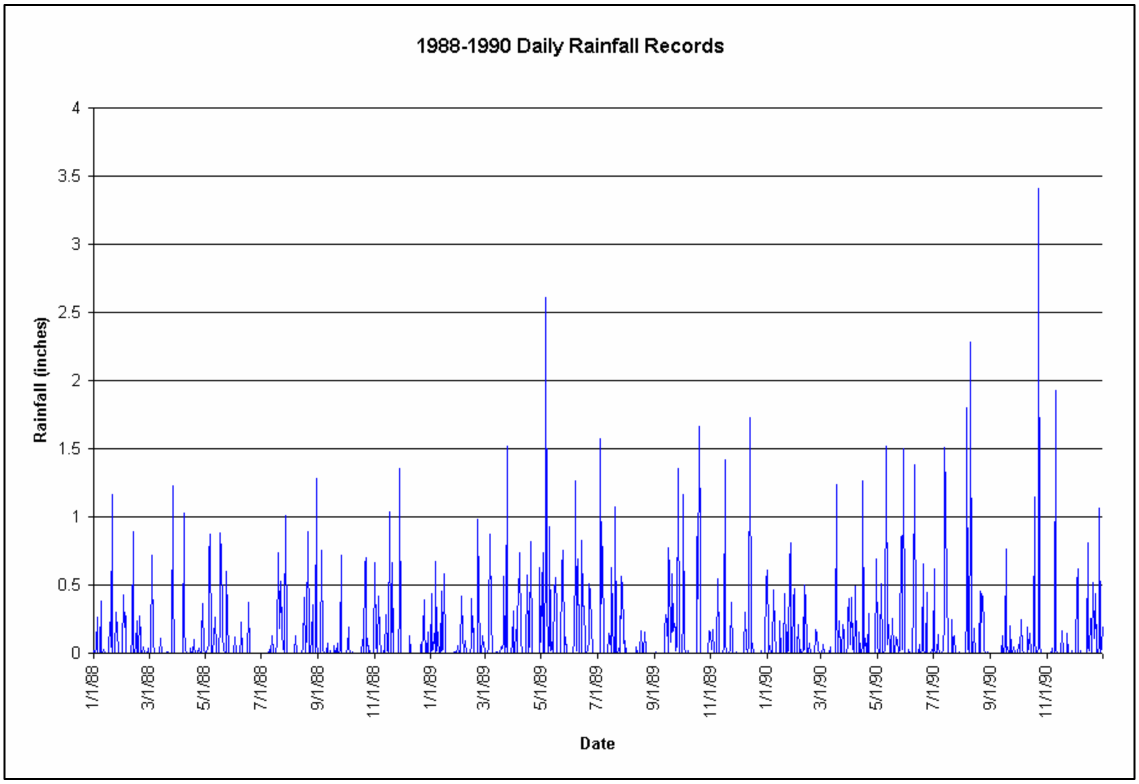
There are two methods typically used to generate rainfall patterns when designing stormwater systems. The first, and more traditional method is to generate a statistically based synthetic single-event hydrograph based on regional rainfall histories. The second method is to use a long-term historical rainfall database to generate runoff based on actual (rather than synthesized) data. The first method has the advantages of being widely accepted and relatively straightforward to compute. However some studies have shown that these regionally based hydrographs can differ widely from local conditions. Additionally, a single-event rainfall does not consider the conditions where two rainfalls occur within a short time period. The second method has the advantages of representing true rainfall conditions, which include the occurrences of consecutive rainfalls. However, a long period of detailed (at least hourly) rainfall is required to characterize the runoff at this scale.

For this analysis, both methods were considered. Three years record of hourly rainfall data between 1988 and 1990 was obtained and used as the primary input in the RAIN block of SWMM module to generate storm runoff flows. The primary reason for selecting the rainfall record between 1988-1990, was to obtain a combination of years that best represents system-wide, annual average rainfall conditions in the District (dry, average, and wet weather conditions). Table 3.1 shows the seasonal and annual rainfall for each of these years and Figure 3-1 shows the time series of rainfall during this time.

Table 3-1: Seasonal and Annual Rainfall (inches)

Year	Spring	Summer	Fall	Winter	Total Annual	Classification
88	9.93	8.246	9.1	6.541	33	Dry
89	17.304	12.72	13.357	8.686	52	Wet
90	13.666	15.244	9.145	11.54	49	Average

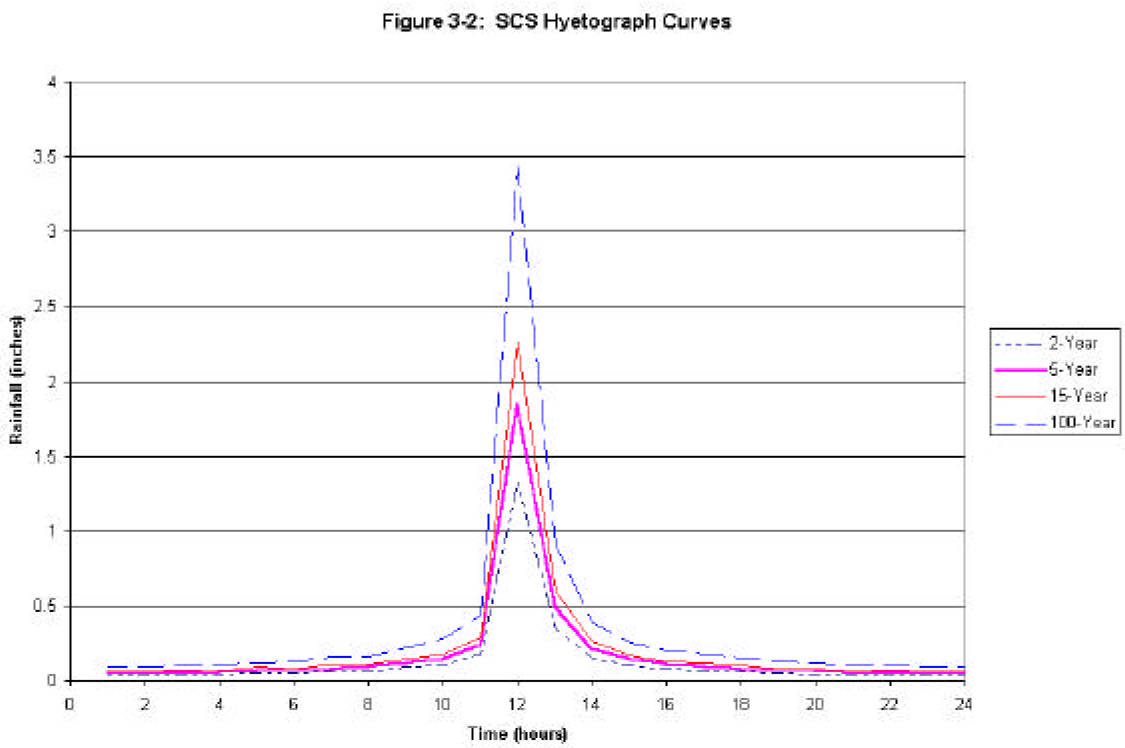
Figure 3-1: Daily Rainfall



In addition to a rainfall time-series, a range of rainfall return frequencies was analyzed using synthetic hydrographs. For these storms, the rainfall depth for a 24-hour storm was applied to a Type-II SCS curve. Note that for a Type-II SCS Curve, most of the rainfall occurs during a very brief time period around the 12th hour of the storm. Table 3-2 shows the rainfall summaries for the synthetic hydrographs, which are show in Figure 3-2

Table 3- 2: Precipitation Summary for 24-hour Storms

Return Period	Rainfall Depth (inches)	Peak Intensity (inches/hour)
2-Year	3.1	1.33
5-Year	4.27	1.84
15-Year	5.24	2.26
100-Year	7.95	3.43



3.1.3 RUNOFF Modeling

The first step in preparing a hydrologic model is to properly delineate the drainage basin and the subcatchments within that basin. Once these subcatchments have been delineated, hydrologic parameters are assigned to each of the basins. The RUNOFF model applies a rainfall pattern to each of these small basins and calculates a time-series of stormwater runoff flows. These flows are "loaded" into the hydraulic model that routes the flows downstream.

The drainage area was delineated for the entire Arthur Capper Carrolsburg Dwellings watershed. Subcatchments within these watersheds were delineated to most stormwater inlets using WASA's 100' scale sewer plats. Drainage areas were delineated and digitized into a GIS layer.

The following parameters were estimated for each of the subcatchments

? <u>Drainage Area</u>: The subcatchment area in acres. Calculated using GIS delineations.

? <u>Catchment Width</u>: The average width of the subcatchment in feet. Calculated by dividing the drainage area by the overland flow length.

? <u>Percent Impervious</u>: The estimate impervious area of the sub catchment. Estimated from land use plats, topographic survey maps, and field reconnaissance.

? Slope: Average overland flow slope of the subcatchment. Calculated by dividing the overland flow path by the change in ground surface elevation (from DC 200' scale topo)
? Impervious "n": An estimate of the "roughness" of the impervious ground surface used in the runoff equations.
? Pervious "n": An estimate of the "roughness" of the pervious ground surface used in the runoff equations.
? Impervious Depression Storage: An estimate of the ground surface storage (puddles, etc) for the impervious surfaces in each subcatchment. Estimated in inches, these parameters are used to estimate the amount of rainfall that must occur before runoff is generated from pervious surfaces
? Pervious Depression Storage: Same definition as above, except for pervious surfaces. This estimate includes the extraction of rainfall not just from surface puddles, but also from leaves, brush, etc.

The remaining three parameters are infiltration parameters. The Horton infiltration equation was used for these analyses, which assumes a maximum infiltration rate for dry conditions that exponentially gets smaller as the ground becomes saturated. Values were taken from literature sources for the soil type of the subcatchment.

? Maximum Infiltration: Maximum infiltration rate (feet/second) for the subcatchment pervious surfaces. This is the rate under dry conditions.
? Minimum Infiltration: Minimum infiltration rate (feet/second) for the subcatchment pervious surfaces. This is the rate when the ground becomes saturated.
? Decay Rate: Exponential factor to estimate how quickly the soil becomes saturated.

Table 3-3 presents the hydrologic parameters used to describe the drainage basins in the RUNOFF model.

Table 3-2: Sample of Hydrologic Parameters for RUNOFF model

Area ID	Width (ft)	AREA (acres)	Percent Imperv.	Slope (ft/ft)	Imperv. (n)	Perv. (n)	Imperv. Store. "in"	Perv. Store. "in"	Max. Infiltr (fps).	Min.Infil (fps)	Infiltr.Decay Rate
'A1'	337.5	2.58	95	0.006	0.013	0.2	0.03	0.07	1	0.04	0.00115
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
'A96'	270	6.07	95	0.008	0.013	0.2	0.03	0.07	1	0.04	0.00115

3.2 Hydraulic Analysis

The hydraulics of the Arthur Capper drainage systems was modeled using the EXTRAN block of the USEPA SWMM model. This model dynamically routes stormwater flows through the series of pipes and manholes. This model can simulate conditions when pipes are flowing under surcharge and changes in tidal elevations.

3.2.1 Hydraulic System Data

In order to accurately model the hydraulic system, it was necessary to characterize all the elements of the proposed storm drain system and drainage channels. These data include ground surface elevations, pipe diameters, invert elevations, lengths and slopes. The proposed system and drainage data were interpreted from 100' scale DC-WASA sewer plates.

3.3 Analytical Results

Two different scenarios were examined for this analysis. The first scenario was to work with the existing CSO system and add in low impact development type rain garden along the open area adjacent to South 2nd Street. Rainwater in adjacent blocks would be diverted into this facility, which would store the water and infiltrate it. For this scenario, only the hydrologic RUNOFF model was used because the design is primarily geared to the routing of surface water to a surface storage area. The second scenario was to examine complete sewer separation in this redevelopment area with routing of the storm water to an existing, but unused large elliptical pipe that runs along 6th Street. In this case new pipes were designed to convey this flow to the exiting elliptical pipe and the RUNOFF and EXTRAN models were used to analyze the system.

3.3.1 LID SCENARIO:

For the first scenario, the primary goal was to design a detention system that could collect diverted rainfall into a rain garden or similar structure. Rainwater would then be stored in this area and infiltrate or evaporate over time. Excess flow would be allowed to return to the CSO system.

To model this system, the depression storage depths for these drainage catchments were increased to 0.25 inches. This depth was chosen to simulate treating the first quarter-inch of rain with the basin. In addition, the pervious area was increased to 95% for the catchments where the LID would be located. Flows in adjacent basins were diverted into the LID basins for infiltration or overflow. The modified drainage areas totaled approximately 13.5 acres.

The three-year period of record between 1988-1990 was run and divided by three to estimate the average annual statistics. On average, 44.8 inches of rainfall each year generate 32.2 inches of runoff from the pervious and impervious areas during existing conditions. Under this LID scenario, the total runoff for the area was 15.5 inches. Therefore approximately 17 inches of rain each year falling on these 13.5 acres would be treated through the LID system.

3.3.2 SEWER SEPARATION SCENARIO

The data from 148 pipes and manholes were collected and stored in a database. Pipes and manholes were assigned IDs based on Street intersections from north to south, west to east, and east to west relative to the location of the main elliptical shaped separate storm sewer pipe that conveys upstream storm runoff flow from the intersection of 6th Street and Pennsylvania Avenue to the Anacostia River. In general, pipes and manholes between 2nd and 5th Streets were designed to transport stormwater flow from north to south and west to east. Pipes and manholes between 8th and 7th Streets were designed to carry flow from north to south and east to west. Figure 3-4 shows a schematic of the pipe system as modeled.

The proposed piping system was modeled to convey runoff flow from Arthur Capper study area into an existing deeply buried elliptical shaped 19 feet 6 inches diameter pipe that discharges storm flow into Anacostia River. The proposed system consists of 96 Street inlets, one in each corner of the Street intersections to convey storm runoff flow from each subcatchment area through a 10-inch diameter pipe into a junction box. A total of 52 main pipes with varying diameters were modeled beginning from an upstream junction chamber at each street intersection down to a junction chamber at the elliptical shaped pipe that discharge into the Anacostia River.

Using the synthetic hydrographs described above, the RUNOFF and EXTRAN models were run on this proposed sewer separation scenario. The primary goal was to determine whether the existing elliptical sewer had the capacity to convey the flows from Arthur Capper to the Anacostia, if sewer separation was part of the redevelopment plan.

The EXTRAN analysis concluded that the existing elliptical pipe has sufficient capacity to convey the flows from an Arthur-Capper sewer separation project, even during high tides. The relative size of the existing pipe would even allow for additional sewer separation projects north of the redevelopment site.

The figure below is a typical hydraulic profile from the proposed system.

Figure 3-3: Typical EXTRAN Hydraulic Profile

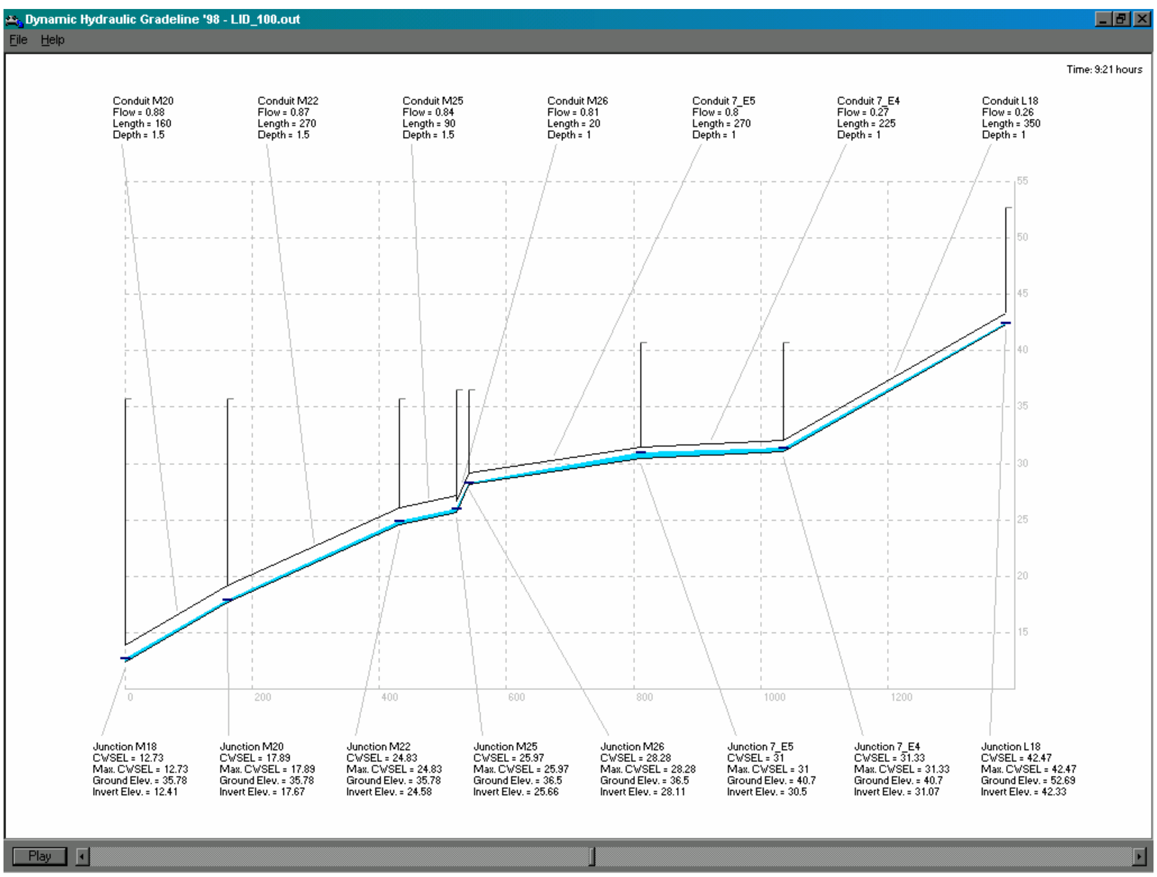


Figure 3-4 is a plan view of the sewer separation scenario that includes the diversion of stormwater to the canal park area. This scenario includes the capture and diversion of approximately eight (8) acres of runoff to the canal park area. This would generate approximately 13.5 acre feet of water that could be used to support water features. This number was arrived at by taking approximately 20 inches of rainfall, which is ½ the annual volume and diverting it to the park area. The 20 inches represents the volume, or depth, of rainfall that would most likely generate runoff from the urban areas. This water would most likely have to be filtered through a wetlands or other type of system to remove pollutants if contact with the water features is planned.

Figure 3-4: Potential Storm Drainage System Network