# 5. Storm Drain System Capacity Study

The analysis of stormwater quantity can be divided into two parts: hydrology and hydraulics. For the purposes of this study, hydrology is defined as the determination of the rate and volume of surface runoff from an individual catchment area. This involves analyzing the components of the hydrologic cycle such as precipitation, infiltration, depression storage, evaporation, and establishing the resulting surface runoff hydrograph from each catchment area based on the various parameters described in Section 3. In urban stormwater management, hydraulics can be defined as an analysis of the flow of water in pipes, open channels, storage basins, and other parts of the drainage system.

## Scope of Study

The purpose of this study is to identify drainage system modifications that would eliminate or minimize stormwater flooding within the City watershed in accordance with the County's policy on levels of flood protection. The primary goals of the Storm Drain Master Plan project were the following:

1. Primary Goal: Develop a hydrology and hydraulic model to determine the capacity and identify deficiencies of the existing storm drain system for the 10-year, 25-year (i.e. Urban Flood), and Capital Flood (i.e. 50-year) storm events.

2. Secondary Goal: Develop a CIP hydrology and hydraulic model with the focus on meeting requirements of the Urban Flood level of protection. Per the 2006 Los Angeles County Hydrology Manual, the Urban Flood is defined as runoff from a 25-year frequency design storm on a saturated watershed. This flow should be split to allow conveyance in the street and in the storm drain when flows exceed street capacity. To meet the Urban Flood level of protection, the existing storm drain system was modified (e.g. pipe upsized) for the 10-year CIP model so the peak water surface elevation in the storm drain system was below the rim elevation. The proposed improvements were then adjusted to keep the peak water surface elevation less than or equal to right-a-way elevations (roughly 0.5-ft above the rim elevation) during the 25-year storm event.

3. Tertiary Goal: The storm drain CIP model was then updated for the Capital Flood (i.e.50-year) storm event with the intent to keep the peak water surface elevation of the runoff within the public right-of-way. Furthermore, the improvements were to maintain passable street conditions for fire, police, and emergency vehicles, and protect property from flood damage.

The scope of the study included:

1. <u>Use a stormwater computer model to evaluate the existing drainage system and identify flooding problem areas</u>. The proprietary stormwater computer model *XP-SWMM 2D (version 2018.2.2)* was selected for this purpose. This tool was selected for several reasons including:

    - the software complies with the requirements from LACDPW
    - the software provides a fully hydrodynamic approach

- the model has been used in past County studies of the City's storm system, thus maintaining comparability to past studies;
- the model is designed to calculate runoff from urban areas;
- the model accounts for overland flow, infiltration, pipe flow, and open channel flow;
- the model can utilize synthetic design rainfalls and measured rainfall data; and
- the model can route water through stormwater management facilities and be used to help design stormwater management facilities.

2. Evaluate specific management measures aimed at reducing flooding. Management measures considered include detention basins, replacing / upgrading existing storm drains, adding new storm drains in a variety of alignments, and drywells.

## Vertical Datum

The hydrologic model was performed using the North American Vertical Datum of 1988 (NAVD 88). Storm drain data from record drawings and design plans were converted to NAVD88. If noted on drawings, vertical data was converted from National Geodetic Vertical Datum of 1929 (NGVD 29) to NAVD 88 with a vertical adjustment of +2.3 feet based on the LACPW benchmarks.

## XP-SWMM Model Setup

To conduct the hydrologic and hydraulic analysis of the City's drainage system the XP-SWMM 2D (version 2018.2.2) model was utilized. XP-SWMM is a dynamic model using a link-node representation for conduits and junctions. Links are used to represent the conveyance system elements, such as storm drains and drainage swales or ditches. Nodes are used to represent junctions, manholes, outfalls, and detention/sump areas. The model performs the hydrologic and hydraulic computations for complex stormwater drainage systems.

The XP-SWMM 2D model performs hydrologic calculations based on input parameters to develop runoff hydrographs from drainage areas. The hydrologic data is input into select nodes created in the model. A hydrograph describes the rate of stormwater runoff from a drainage area over time, during and after a storm event. The high point of the hydrograph represents the peak flow rate that must be conveyed and managed by the stormwater conveyance system. The area underneath the hydrograph is the total volume of stormwater runoff from that rain event.

Following the hydrologic calculations, the model then conducts hydraulic calculations by routing the runoff hydrographs through the drainage system. XP-SWMM 2D uses two different processes for the hydraulic calculations – 1D and 2D.

The subsurface conveyance infrastructure (storm drain pipes, manholes, etc.) were modeled in 1D using a system of links and nodes. The 1D process uses the St. Venant equations for gradually varied one-dimensional flow. This allows the model the ability to simulate complex hydraulic situations, including backwater effects and looped (interconnected) storm drain systems, which make it well suited for use within this watershed. The model allows for storm drains, open channels (drainage swales), and storage areas (sump basins) to be input as part of the drainage system. The 1D process of XP-SWMM calculates, and reports, water surface elevations at the system's nodes, and discharge hydrographs and velocities in the system's links.

The 2D process of the model was also used to simulate the flow of water that leaves the stormwater conveyance system. The 2D process uses a digital terrain model (DTM) of surface elevations to provide overland flow paths. The DTM allows flood waters to flow through streets, and in other locations, such as, through backyards, and also allow ponding of surface water in surficial low points. The 2D process calculates the water depth at points throughout the DTM. This information can be reported in either tabular or graphical formats.

## GIS Data Preprocessing and Asset Naming

GIS data received from the City was modified to build the hydraulic model, and the GIS data was preprocessed as described below to create network connectivity and unique asset ID identifier:

- Dummy nodes were created for connections and change in pipe characteristics where manholes are not present, i.e. pipes/laterals connections and pipe tie-ins.
- Storm pipes were split where existing GIS database had no node connection.
- Unique identifiers (IDs) were created for all nodes and pipes as shown in Table 4-1.

### Table 4-1: Storm Drain System GIS/Model IDs

| GIS Asset | Unique ID field |
|---|---|
| Storm Pipes | AEC_LNID |
| Manholes | AEC_MHID |
| Catch Basins | AEC_CBID |
| Outfalls | AEC_MFID |
| Dummy Nodes | AEC_DNID |

The storm pipes layer was updated with upstream and downstream node IDs in addition to unique link IDs. The label “US_NID” represents the upstream node ID of the storm drain pipe; “DS_NID” represents the downstream node ID of the storm drain pipe.

### Asset Naming Convention

The asset naming convention for the XP-SWMM model was kept in consistent with the County MBPS H&H model. The naming convention for the model is as follows:

**Pipe ID** – YYZZZXXXX where YY denotes Pipe Type, ZZZ denotes Owner, and XXXX denotes sequential number of storm drain system starting at 0001.

**Node ID** - YYZZZXXXX where YY denotes Node Type, ZZZ denotes Owner, and XXXX denotes sequential number of storm drain system starting at 0001. Node layers are storm manholes, catch basins and sd_outfalls.

## Hydraulic Analysis

Data provided by the City of Manhattan Beach and as collected specifically for this study was used to build the hydraulic portion of the XP-SWMM model. Data sources included the following:

- City GIS data for storm manholes, catch basins, outlets, storm drain pipes, length, material, and pipe size.
- The City provided record drawings and design plans for storm drain, water, development, and sewer projects.
- A digital terrain model (DTM) created from County LIDAR data used for surface characteristics to model two-dimensional overland flow. In addition, data was used to provide input data for overland flow routes and drainage ditches.

- City GIS data for building locations was used to provide areas on the DTM that is blocked off from 2D surface flow. These areas are known as "inactive" areas.
- City GIS data for roadway information was used along with the DTM to provide street inputs for overland flow along streets.
- Site visits conducted by AECOM staff to collect information on inlet characteristics.
- The Pacific Ocean Mean Higher High Water (MHHW) of 5.29-ft was incorporated into all design storm model runs at outfalls below this elevation.

The XP-SWMM model included all of the City and County owned storm drain infrastructure located within the City. The City's catch basin inlets were incorporated into the network by developing rating curves based on nomographs from the County Hydraulic Design Manual. The sumps and open channel conveyance systems were also included in locations where it was deemed important. Nodes were linked to the 2D surface and surface flow was able to pass through the 2D network into the 1D network. Nodes that represent catch basin inlets are linked to the 2D surface, allowing flow to be freely exchanged between the 2D surface flow and 1D storm drain system.

The XPSWMM 2D inflow capture approach is used in the analysis, which limits 2D surface water flow to enter catch basin based on inlet capacity. 2D surface water flow presents overflow from storm drain system due to its insufficient capacity. Although this modeling approach approach has its limitations, the predicted results appear reasonable for forecasting potential flooding for this level of study.

The model included a digital terrain model (DTM) of surface elevations to provide overland flow paths for stormwater that was not contained within the storm drain system. The DTM allowed flood waters to flow through streets, and in other locations, and also allowed ponding of surface water in surficial low points. A grid cell resolution of 10-feet was selected. This size of grid cells balances the models accuracy with duration of run time. The Manning's "n" values were determined using the County Hydraulic Design Manual (LACPW, March 1982). The Manning's "n" values used for the 2D grid were:

- Areas within of public right-of-way: 0.014
- Areas outside of the public right-of-way: 0.020.

Figure 4-1 shows the existing conditions storm drain network used in the analysis.

### Typical Assumption

- If the pipe was connected to a system with known data, the diameter was assumed to be the same size as the known system.
- For cases where the adjacent upstream or downstream pipes invert elevations were known, the slope was calculated and used for the portion of the storm drain system where data was unavailable.

## Existing Conditions Validation

Flood complaint reports from the storm event December 28, 2004 was used for a validation and verification of the existing conditions model. The December 28, 2004 storm was not incorporated into the model, however the reported flood locations were overlaid and compared with the model results for the 10- and 25-year storm events. The model results were similar flooding locations to the areas that reported flooding.

## Existing Conditions Model Results

The XP-SWMM was used to perform hydrologic and hydraulic calculations for three storm event simulations (i.e. 10-year, 25-year, and 50-year storms). The results of the existing conditions analysis revealed numerous areas that do not meet the flooding goals for the project. The existing conditions results for the 10-year, 25-year, and 50-year storm events are shown on Figures 5-1 through 5-3.

To assist in developing proposed infrastructure improvements for the CIP, the 10-year storm event existing condition results were coded with flood cause type, and flood locations were then coded with a Flood ID. Flooding was attributed to the following:

1 – Limited Pipe Capacity

2 – Curb Outlet Discharges

3 – High Tailwater Conditions for neighboring communities at the east and south limits of the City

4 – Limited Inlet Capacity

5 – Other/Combination

6 – Limited capacity of downstream storm drain system

The existing conditions results for the 10-year, storm event along with the Flood ID are illustrated on Figures 5-4. Table B-1 in Appendix B lists the Flood ID and Flood Type.

## Capital Improvement Project Storm Drain Model

Following the completion of the existing conditions analysis, potential alternatives to mitigate flooding were evaluated to meet the stormwater goals for the project. Flood relief alternatives included improving existing storm drains (increase sizing), adding new storm drain, and increasing sump areas. For example, a project may recommend upsizing an existing 24-inch pipe to a 36-inch pipe to provide more conveyance capacity, extend an existing storm drain line, and add volume within an existing detention basin to capture more stormwater.

Where possible, the goal was to eliminate the surface flooding for the 10-year storm event. Modifications were made to the systems until the goal was met.

The backbone of the Central and East watershed is a large diameter County owned system. This system collects flow from the City's tributary lines and outfalls into the Ocean. The County trunk line is surcharged during the 10-year storm event, which creates high tailwater conditions for the City's tributary lines. Much of the results were dependent on improving the system capacity of the County's trunk sewer. Because of this there were two scenarios that the proposed conditions were analyzed for, (1) with improvements to the County System and (2) without improvements to the County system.

### Improvements to the County Line

The first scenario was to include improvements to the County line. Improvements were made to the County trunk storm drain along with improvements to the City's tributary lines. The improvements in the surface flooding extents for the proposed conditions for this scenario are displayed on Figures 5-5 through 5-7 for the 10-year, 25-year, and 50-year storm events. Figure 5-8 illustrates the watershed improvements.

### No Improvements to the County Line

The second scenario was to remove the proposed improvements to the County line and replace it with the existing pipe characteristics. The improvements made to the tributary City systems remain in the model. The improvements in the surface flooding extents for the proposed conditions compared to the existing conditions for this scenario are displayed on Figures 5-9 through 5-11 for the 10-year, 25-year, and 50-year storm events. Figure 5-12 illustrates the watershed improvements.

Table B-1 in Appendix B lists the improvements made to each of the Flood ID locations.

## Compound Hazard Scenarios

The City is working to update the Local Coastal Program (LCP) to better plan for climate change in the Coastal Zone, particularly for sea level rise, extreme high tides, flooding, storm events, and coastal erosion. The goal of the City of Manhattan Beach's Coastal Resiliency and Climate Change Adaptation Project is to complete sea level rise (SLR) and climate change analyses and planning, thereby providing a strong scientific basis to inform and enhance the preparation and implementation of the City's Climate Action and Adaptation Plan and update to the LCP, General Plan, and Hazard Mitigation Plan. The City provided AECOM with a memorandum titled *Sea Level Rise Impacts and Baseline Conditions Memo* (City of Manhattan Beach, July 2019) that summarized Sea Level Rise projections and timelines.

AECOM used the SLR projection for the year 2060 (+0.75 meters or +2.46 feet) and higher precipitation depths (15% increase) for the 10-year event to create a simulation that depicts future climate change conditions. The results of this simulation for the 10-. 25-, and 50-year storm events are shown in Figure 5-13, 5-14, and 5-15, respectively. AECOM recommends that the next storm drain master plan update to incorporate sea level rise and climate change projections when developing storm drain improvement projects.