CHAPTER 5
STORMWATER SYSTEM
HYDROLOGIC AND HYDRAULIC MODELING

5.1 INTRODUCTION

One of the primary objectives of the City in updating its Stormwater Comprehensive Plan (SCP) was the creation of a list of needed stormwater capital improvement projects and resulting Capital Improvement Program (CIP) to address flooding concerns throughout the City. The updated drainage CIP for the City was developed by identifying problem locations using two different methods and integrating the results into one master list. The first method used a drainage needs inventory developed by surveying City staff and the public for observed nuisance drainage problems. The second method analyzed selected drainage problem areas within the downtown portion of the City, and then used computer models to identify problem locations and design solutions. Results of these two methods were integrated and used to form the City's updated drainage CIP, with a prioritization of the needed capital improvement projects and cost estimates for each, as presented in Chapter 6.

This chapter presents the approach, methodology, and results used for the development and implementation of the modeling that was used to evaluate the capacity of some of the City's worst flooding problem areas and design solutions. The result is an updated CIP and list of needed drainage projects that was derived from 54 identified drainage problem areas located throughout the City. The top ten (10) highest priority drainage problems were selected for the computer modeling analysis.

5.2 MODELING ANALYSIS TO ACHIEVE DESIRED LEVEL OF SERVICE

Locations within the City's drainage system were identified as problems if they did not meet the following two-part performance standard. The first part of the standard specifies what water levels in the stormwater system are considered contained within the system (without any major flooding). For the purposes of this plan, the stormwater system is considered flooding if:

- Water levels within the stormwater pipe network exceed the elevation of a catch basin or manhole rim, causing ponding or flooding in the street; or
- Water levels within an open channel system exceed the banks and cause nuisance flooding or property damage.

The second part of the standard specifies how frequently the stormwater system can flood and not be considered a failure. This is commonly called the *flood frequency return interval* and is calculated as one divided by the probability of occurring in any given year. For example, the 2-year flood has a 50% chance of occurring in any given year, and the 25-year flood has a 4% chance of occurring in any given year. For the purposes of this plan, the system is considered to be failing if the system floods during the 25-year return interval flood.

5.3 DEVELOPMENT OF THE STANWOOD STORMWATER MODEL

5.3.1 Selection of Areas for Modeling

The areas identified for stormwater modeling are located within the downtown core where an aged stormwater system and capacity limitations routinely cause chronic flooding. The identified areas include four sub-areas on the west side of town between 93rd Drive NW and 104th Drive NW, and one area to the east of 94th Drive NW that includes drainage from 92nd Avenue NW and 271st Street NW. The four sub-areas on the west side of town are *headwater basins*, meaning there are no pipes or ditches adding flows from outside the basin. The east downtown area that was modeled receives runoff from Douglas Creek via the ditch on Lover's Lane Road and 92nd Avenue NW. Because flows from Douglas Creek are tidally influenced, the hydrology of that modeling area is substantially more complicated than that of the four more western modeling sub-areas between 93rd Drive NW and 104th Drive NW.

The five areas selected by the City for stormwater modeling were based on need and available resources and, in general, followed the recommendations provided by NHC in the March 31, 2014, memorandum (see Appendix A.8). These five areas are displayed in Figure 5-1, titled Stormwater Model Areas.

- *Model Areas #1 – 3: Augusta Street** –The first three drainage basins flow from the Stormwater Model Outfall down into the area affected by the Irvine Slough Stormwater Separation Project (ISSSP). (Note: Model Areas #1-3 include three smaller systems that were combined for the purposes of modeling and were analyzed as a single system, as shown in Figure 5-1.)
  **Augusta Street is located between 270th Street NW and 268th Street NW, just to the west of the intersection of Camano Street with 268th Street NW.*
- *Model Area #4: 94th Drive NW* – Stormwater Model Outfall to Irvine Slough Stormwater Separation Project (ISSSP) from 94th Drive NW.
- *Model Area #5: 92nd Avenue NW* – Stormwater Model Outfall to Irvine Slough Stormwater Separation Project (ISSSP) from 92nd Avenue NW.

5.3.2 Irvine Slough Stormwater Separation Project

The City's stormwater system currently routes runoff via gravity from all of the modeled areas to Irvine Slough where it is pumped into the Old Stillaguamish River Channel through the Irvine Slough Pump Station. However, the City is planning a major stormwater system improvement, called the Irvine Slough Stormwater Separation Project (ISSSP), that may potentially include construction of a new stormwater system along the north side of SR 532. The primary objectives of the ISSSP are to prevent flooding of downtown Stanwood by separating flows from the City's stormwater system from the elevated flows of the

Stillaguamish River, and to increase the flood carrying capacity of Irvine Slough in order to reduce flood levels of the Stillaguamish River.

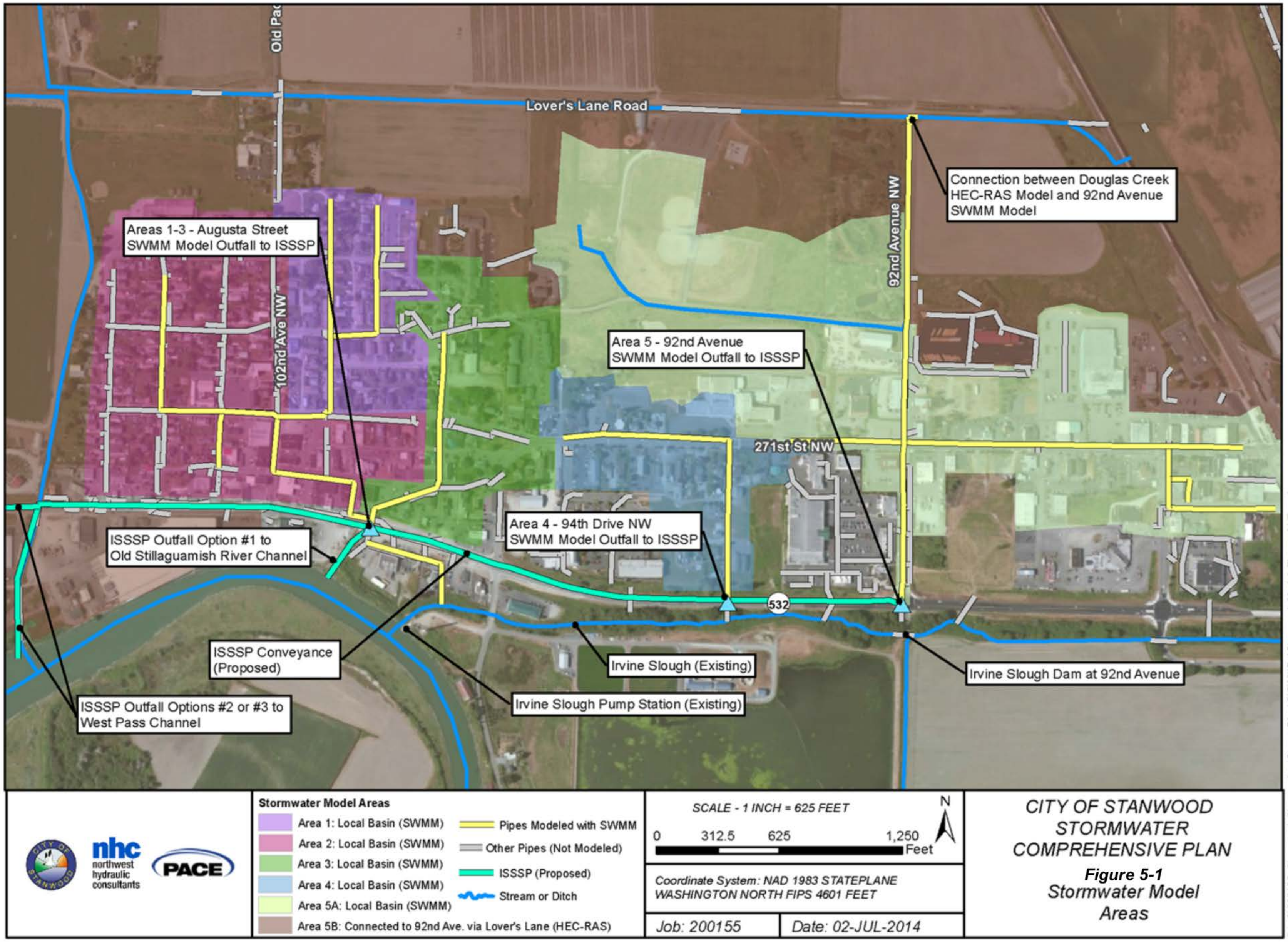
This project will look at flood reduction options, including reducing flooding within the low-lying downtown areas by conveying stormwater runoff west to a new outfall to the river at West Pass, located west of the Irvine Slough Pump Station. The outfall may include a new pump station, similar to the Irvine Slough Pump Station. At this point in time, prior to conducting the ISSSP modeling and design study, it is not immediately clear what role the existing pump station might play in the new configuration of pump and conveyance facilities that may come out of the ISSSP study. It could be moved, abandoned, or incorporated into a new flow reduction plan for the area.

Three potential outfall routes for the new ISSSP conveyance system are shown in Figure 5-1. (Note: This ISSSP drainage study is discussed in additional detail in Chapter 6, and is one of the highest ranked CIP projects in terms of priority. No detailed design is included here because the design options will be thoroughly investigated during the upcoming regional ISSSP study.)

For the purposes of modeling and this drainage CIP project development process, it has been assumed that this proposed ISSSP will be completed, and will be designed to prevent stormwater from backing up into the City's network of piped conveyances and outfalls. As a result, system failures (i.e., localized flooding) were only identified if the problem occurs in one of two reduced hypothetical ISSSP configurations that would have reduced backwater effects relative to the existing Irvine Slough. Those configurations include: 1) freely discharging outfall pipes, with no restriction from the downstream collection system, and 2) a static four-foot water level elevation in the downstream collection system. The four-foot water level threshold was selected by reviewing project monitoring data collected upstream of 92^{nd} Avenue NW on Irvine Slough. That data showed that the water level in Irvine Slough frequently reaches a depth of four feet during concurrent small winter storms and high-tides. Based on that data, it was assumed that the ISSSP should be able to at least keep water levels below those routinely controlled at Irvine Slough. Application of these modeling assumptions regarding the outfall water levels to the development of drainage CIP project solutions is discussed further in Chapter 6.

5.3.3 Modeling Approach

The approach applied to the hydraulic modeling of the City's stormwater system follows the Snohomish County Hydrologic Modeling Protocols, developed by NHC and others (Snohomish County, 2001). Runoff from the land surface was calculated using Hydrologic Simulation Program Fortran (HSPF) and Stormwater Management Model (SWMM) to calculate water levels within the City's stormwater system (EPA, 2005 and 2007). Additionally, inflows into Area 5, the 92^{nd} Street NW system, were calculated using a HEC-RAS (HEC, 2010) model of Douglas Creek. Both the HSPF model and HEC-RAS model were originally developed and calibrated by NHC for Snohomish County Surface Water Management as part of the Douglas Creek Basin Characterization Project (NHC, 2014). That project is still underway, but the model was calibrated to observed flow and water level data collected from Douglas Creek, Lover's Lane Road, and Irvine Slough before the models were applied to this project. Complete documentation of the Douglas Creek HSPF and HEC-RAS model development will be provided in the County's report when it is completed, but an overview of relevant information is briefly summarized within this section of the City's updated SCP.


Old Pac
Lover's Lane Road
Connection between Douglas Creek HEC-RAS Model and 92nd Avenue SWMM Model
92nd Avenue NW
Areas 1-3 - Augusta Street SWMM Model Outfall to ISSSP
102nd Ave NW
Area 5 - 92nd Avenue SWMM Model Outfall to ISSSP
271st St NW
Area 4 - 94th Drive NW SWMM Model Outfall to ISSSP
ISSSP Outfall Option #1 to Old Stillaguamish River Channel
532
ISSSP Conveyance (Proposed)
Irvine Slough (Existing)
Irvine Slough Dam at 92nd Avenue
Irvine Slough Pump Station (Existing)
ISSSP Outfall Options #2 or #3 to West Pass Channel
Stormwater Model Areas
Area 1: Local Basin (SWMM)
Area 2: Local Basin (SWMM)
Area 3: Local Basin (SWMM)
Area 4: Local Basin (SWMM)
Area 5A: Local Basin (SWMM)
Area 5B: Connected to 92nd Ave. via Lover's Lane (HEC-RAS)
Pipes Modeled with SWMM
Other Pipes (Not Modeled)
ISSSP (Proposed)
Stream or Ditch
SCALE - 1 INCH = 625 FEET
0 312.5 625 1,250 Feet
N
Coordinate System: NAD 1983 STATEPLANE WASHINGTON NORTH FIPS 4601 FEET
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CITY OF STANWOOD STORMWATER COMPREHENSIVE PLAN
Figure 5-1
Stormwater Model Areas

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Outlined below, in steps #1 through #8, is how the suite of models was applied to Areas 1 through 4 (Area 5 is discussed separately below):

1. Pipe network geometries were developed for SWMM models. All of the models were terminated at SR 532, the approximate location of the outfalls when the ISSSP is constructed.
2. The HSPF model representation of the conveyance system was updated with flow rate and system storage volumes from SWMM, and assumed a free outfall condition at the ISSSP.
3. The HSPF Model was run to simulate flows under existing conditions in the drainage system for the period 1949 through 2013.
4. A flood frequency analysis was performed to identify the 25-year flows at each of the two stormwater system outfalls (see item 6).
5. A historic storm event, October 1960, was identified as having a similar peak discharge as the statistical 25-year storm.
6. The land surface runoff rates, calculated with HSPF for the October 1960 event, were scaled to match the statistical 25-year storm discharge. The needed scaling factors were 0.989 in modeling Areas 1 through 3 – Augusta Street, and 0.916 in modeling Area 4 – 94th Drive NW.
7. This scaled October 1960 storm event was applied to the SWMM models for simulation of water levels throughout the modeled portions of the stormwater system. These water level simulations were used to identify which locations in the stormwater system experience flooding with the ISSSP constructed, but without any other CIP projects in place.
8. The SWMM model was run iteratively to identify CIP projects needed to eliminate street flooding within the modeled portions of the stormwater system. These runs were made for both a free outfall condition at the ISSSP and fixed outfall water level of 4 feet NAVD 1988 within Irvine Slough.

For Area 5, along 92nd Avenue NW, the models were applied in a similar fashion as applied to areas 1 through 4, except that the inflows from Lover's Lane Road had to be accounted for through application of the Stillaguamish River and Douglas Creek HEC-RAS models. Steps #1 through #3 are identical to those listed above for Area 5, but steps #4 through #12 included some additional steps that were not needed for Areas 1 through 4.

The additional modeling steps needed to model Area #5 include the following:

1–3. Same as the first three listed above.

4. The Stillaguamish River HEC-RAS model was run for the period 1960 through 1961, and 1980 through 2012, to calculate a time-series of water levels at the outfall from Douglas Creek into the Stillaguamish River. The model run utilized HSPF simulated runoff from Step #3, USGS observed Stillaguamish River flows at

Arlington, and a time-series of hourly NOAA tides at Everett for the model simulation period. This simulation period was shorter than that used in Areas 1 through 4 because the HEC-RAS model runs are very computationally intense; however, it was considered to be of adequate length for a statistical analysis of flows in this system. The 1960 through 1961 period was only included to see if the same October 1960 storm event, identified for Areas 1 through 4 could, also be used for Area 5.

5. A table defining the relationship between water level and discharge in the 92nd Avenue NW ditch at Lover's Lane Road, the location where the Area 5 SWMM model interfaces with the Douglas Creek HEC-RAS model, was developed using the SWMM model of the 92nd Avenue NW stormwater system. The resulting rating table was assigned to the HEC-RAS model to define the relationship between depth and flow at that location in the system.

6. The Douglas Creek HEC-RAS model was run for the periods 1960 through 1961, and 1980 through 2012, to calculate a time-series of inflows to the 92nd Avenue NW stormwater system from Lover's Lane Road for that period. The model run utilized the HSPF simulated runoff from Step #3 and the time-series of tides at the Douglas Creek outfall simulated from Step #4 for the model simulation period. The model run calculated 2 cfs of inflow on average, with a peak inflow of 11 cfs occurring less frequently than the 5-year flood. Flow reversals to the north were not allowed.

7. The Area 5 SWMM model was run for the periods 1960 through 1961, and 1980 through 2012, to calculate a time-series of flows through the 92nd Avenue NW stormwater system. The model run utilized HSPF simulated runoff from Step #3, and the time-series of simulated inflows from Lover's Lane Road into the 92nd Avenue NW stormwater system, simulated in Step #6, for the model simulation period.

8. A flood frequency analysis was performed to identify the 25-year flows at the 92nd Avenue NW stormwater system outfall.

9. The October 1960 historic storm event was identified as having a similar peak discharge as that of the statistical 25-year storm. (Note: This is the same event used in Areas 1 through 4.)

10. The Lover's Lane Road inflow rates calculated with HEC-RAS in Step #6, and the land surface runoff rates calculated with HSPF in Step #3 for the October 1960 event, were scaled by a factor of 0.895 to match the statistical 25-year storm discharge.

11. This scaled October 1960 storm event was applied to the Area 5 SWMM model for simulation of water levels throughout the system. These water level simulations were used to identify which locations in the stormwater system experience flooding with the ISSSP constructed, but without any other CIP projects in place.

12. The SWMM model was run iteratively to identify CIP projects needed to eliminate street flooding within the modeled portions of the stormwater system. These runs were made for both a free outfall condition at the ISSSP and fixed outfall water level of 4 feet NAVD 1988.

5.3.4 Pipe Network Geometry and Sub-Basin Delineations

The model was defined using the City's GIS stormwater inventory, as-built drawings, LiDAR elevation data, field reconnaissance, and consultation with City staff. The model is generally limited to pipes in the City's stormwater system that exceed 12 inches in diameter, though some key smaller pipes were added to capture full network connectivity. The resulting geometry of the City's stormwater system used in this modeling analysis, as shown in Figure 5-1, includes 83 modeled pipes or ditches and 70 catch basins or manholes. Individual subbasins were delineated to define the contributing area draining to 24 of the 70 inlets in the modeled stormwater system. Each of the sub-basins averaged about 6.2 acres in total area. (Note: Those pipes that were modeled are shown in yellow, and the other supporting drainage pipes are shown in white, within each of the five model areas.)

There are a relatively large number of stormwater system features that are missing, missing attributes, or are not spatially correct in the City's GIS inventory. Most features are off by about 30 feet spatially, as well. (Note: This was also documented in compiling the data for the GIS geodatabase of the City's stormwater system.) To address these data gaps, NHC staff filled in data gaps in those portions of the stormwater system that were targeted for modeling. These gaps were filled in by collecting the missing data using RTK GPS equipment to record the location and elevations of catch basins and manholes, measurements of the depth to pipe inverts below the ground surface, review of as-built drawings, the Snohomish County drainage inventory, and discussions with City staff.

5.3.5 Model Representation of Land Cover and Soil

The HSPF model calculates hydrologic runoff by calculating the hydrologic response of different combinations of land cover and soil to rainfall that falls on the land surface. The model used here utilized an existing land cover condition that was characterized by Snohomish County for the study area basin (NHC, 2014) and soils data from the NRCS, as described previously in Chapter 2. It is worth noting that an existing land cover condition, rather than a future build-out land cover condition, was used because the amount of land-surface runoff is proportional to the area of pervious land cover that has been converted to impervious land cover as a result of development in the basin. (Note: The rate water reaches the stormwater system can be mitigated with engineered flow controls such as infiltration or detention ponds). It was decided that an existing land cover condition was appropriate for sizing new CIP projects because it is expected that the future land cover within the study area basins will have a similar impervious area to that of the City's existing pattern of land use. According to the 2012 Ecology Manual amended in 2014, any increase in impervious area associated with any new or redevelopment will be mitigated with onsite flow controls. Thus, future land uses will be generating an amount of runoff similar to that currently being generated under existing land use conditions. In addition to land cover, the amount of runoff is also a function of rainfall intensity, rainfall duration, soil type, and tidal fluctuations, but these factors do not generally change significantly within the planning horizon of 30 years. (Note: That if there is a large area within the study area that increases in density under future development, but is exempt from onsite flow control requirements due to their ability to provide direct discharge to the Stillaguamish River, then the capacity of the stormwater system should be re-evaluated to ensure that adequate capacity exists.)

5.3.6 Flood Frequency Analysis Results

The modeling approach used for this evaluation of drainage system capacity utilized a flood frequency analysis to identify the rate of flow within each basin that corresponds to the 25-year flood event, based on the simulated flows within the stormwater system. That analysis was done using 65 and 34 years' worth of accumulated flow data from simulated discharges of the system that flows into the ISSSP for Areas 1-4 and 5, respectively. Table 5-1 summarizes the resulting 25-year return interval peak flow statistics for the two model geometries of each system, one with restrictions remaining in the system and the other without. The "without restrictions" condition represents a system in which all of the drainage CIP projects that are sized and discussed in Chapter 6 have been constructed. In the "with restrictions" condition, all of those existing restrictions within the City's drainage system are still in place. The un-routed surface runoff and inflows to the 92nd Street NW system from outside the basin (i.e., Lover's Lane Road) are also presented in the table. Most notable is that discharges at the outfall for Areas 1-3 nearly doubles when CIP projects are added to remove the restrictions within the system. This doubling occurs because there is a substantial amount of surface ponding within the system providing internal detention (and flooding within the City) that is slowly released back into the system under existing conditions and freely discharges to the outfall when restrictions are removed from the system. This limitation in the capacity of the system is not related to Irvine Slough or the ISSSP because the model is assuming no restrictions to the outfall from the downstream collection system. These types of delays in flow are characteristic of the nature and function of the City's drainage system itself, including the network and size of pipes and ditches that currently make up the City's drainage system.

Table 5-1: Flood Frequency Statistics: For Modeled Areas of City's Stormwater System				
Model Area	25-year Flood Peak Discharge (cfs)			
	Flow @ ISSSP Outfall		Un-Routed Surface Runoff Flow	Inflow from Outside Basin
	With restrictions in system (Without CIP improvements)	Without restrictions in system (With CIP improvements)		
Areas 1 – 3, 103rd Drive to Augusta Street	13	25	34	–
Area 4, 94th Avenue NW	7.5	–	7.6	–
Area 5, 92nd Avenue NW	23	26	32	5

As stated earlier, the historical storm used to characterize the 25-year flood in the system was the October 23, 1960, event. There are other events with a similar peak discharge, but the selected event had multiple advantages, particularly that the inflows to the Area 5, the 92nd Avenue NW modeling area, were dominated by local runoff rather than inflows from Lover's Lane Road. Some other historical storms with comparable total flows at the system outfall had simulated inflows from Lover's Lane Road, on the order of 10 cfs, but lower local inflows. It was decided that the selected event was the best suited for sizing of the conveyance elements within the stormwater pipe network, which was the focus of this current stormwater planning effort. The resulting 25-year flood hydrographs and hyetographs of flow and precipitation, reflecting the October 23, 1960, flood pattern, are shown in Figures 5-2 and 5-3. Figure 5-2 shows flow restrictions before proposed CIP project construction, and Figure 5-3 shows flows with the constructed CIP outfall project in place, thus, without any flow restrictions.

Figure 5-2: Simulated Runoff and System Outfall Discharges: With Flow Restrictions (Without CIPs constructed)

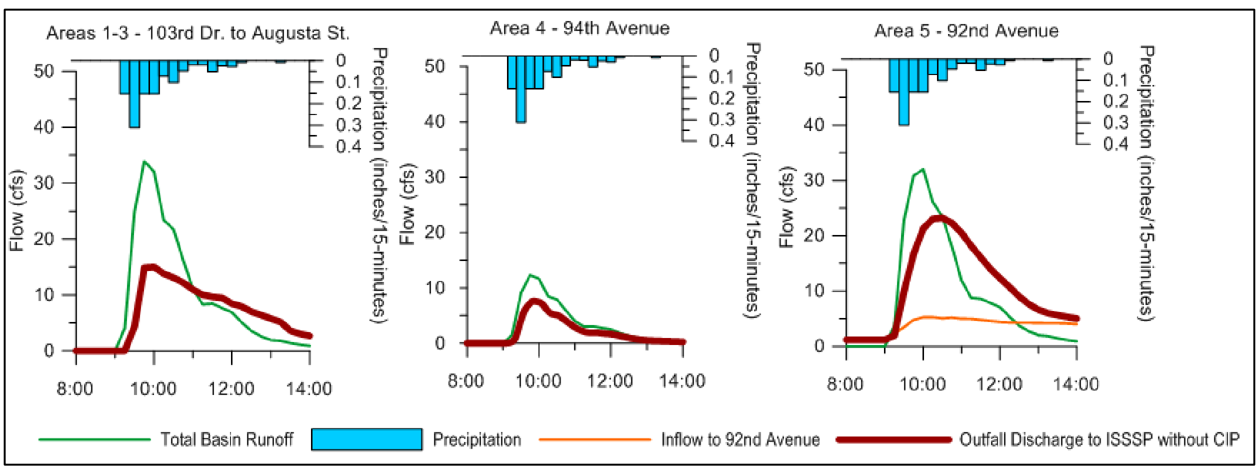
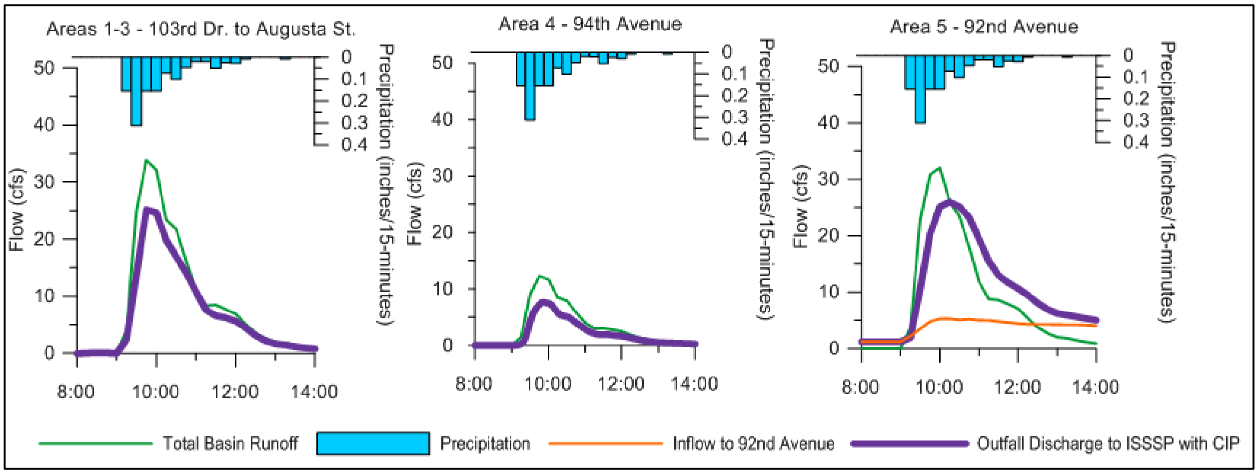


Figure 5-3: Simulated Runoff and System Outfall Discharges: Without Flow Restrictions (With CIPs constructed)



5.3.7 Flooding Locations within City's Existing/Future Drainage System

The stormwater model was applied to identify two sets of existing flooding locations within the stormwater system. The first set corresponded to the free outfall condition in which there is no backwater restriction imposed on the outfall of the stormwater system, and a second in which the ISSSP was limited to a water elevation of 4 feet. (See previous discussion of ISSSP for background on the use of two outfall water level conditions in Section 5.3.2.) A total of 17 catch basins or manholes had water levels classified as street flooding from the free outfall condition simulation results; these are identified as orange squares in Figure 5-4. An additional five locations were classified as street flooding from the high 4-foot water elevation run, as shown as purple squares in Figure 5-4.

Most of the flooding locations are located within Areas 1 – 3, 103rd Drive NW to Augusta Street subbasins. There was no flooding in Area 4, the 94th Avenue NW subbasin, and there were only two flooding locations in Area 5 (within the 92nd Avenue NW basin). The CIP projects sized to address these flooding problems are presented in Chapter 6.

5.4 SUMMARY OF STANWOOD MODELING ANALYSIS

The modeling of the City's stormwater drainage system was used as a tool to investigate the most complicated problem areas within the City's drainage system. The modeling was used to both better describe the nature and frequency of the problem, as well as to identify the appropriate sized pipe or ditch to reduce flooding to the desired level of service. The modeling analysis again used the 25-year flow/rainfall event as the desired level of service. This level of flood control is typical within most urban areas and is largely dictated by the amount of money a community has available to build and annually maintain its drainage system.

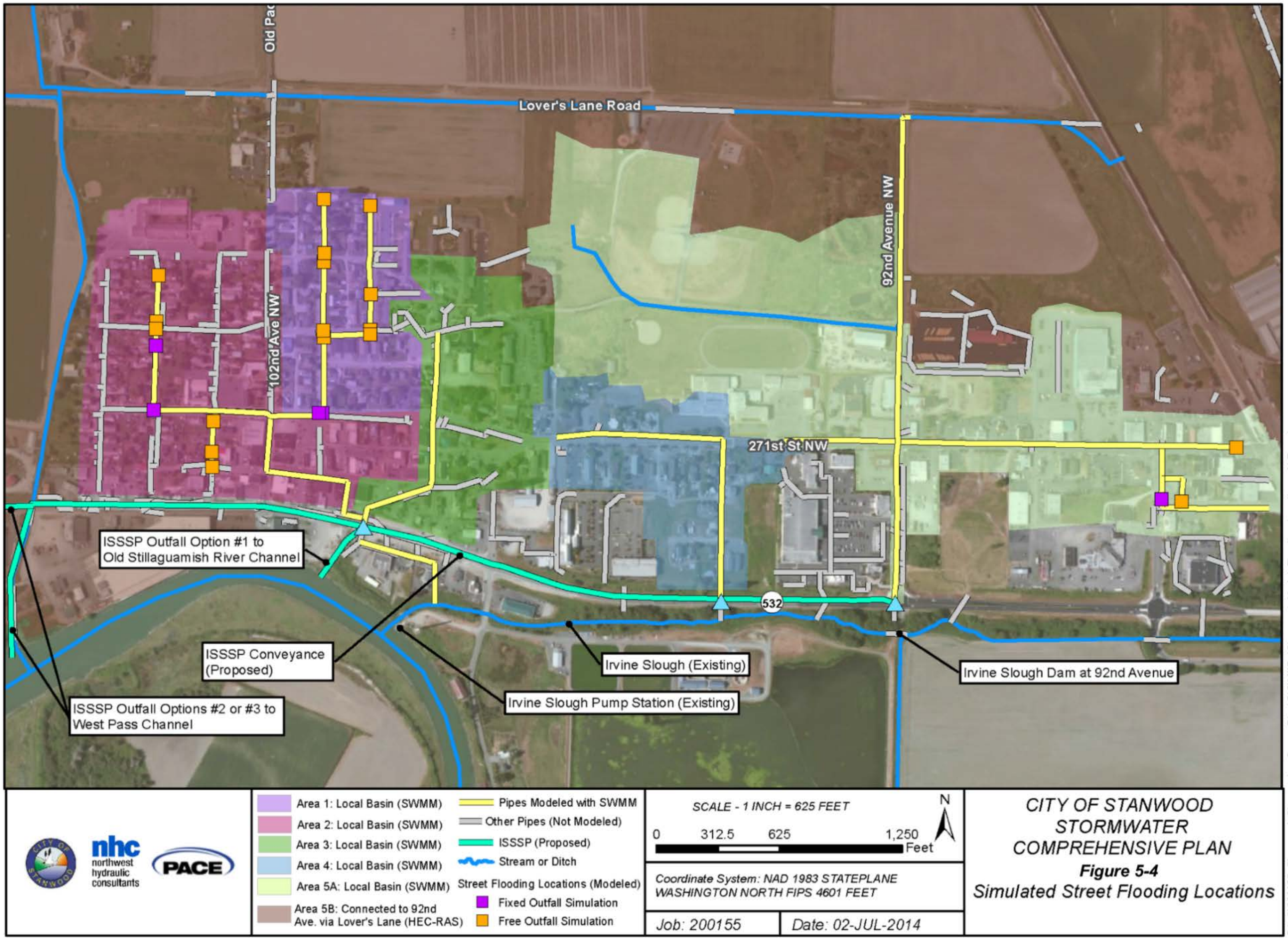


Figure 5-4
Simulated Street Flooding Locations

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In all, a total of 39 drainage problems were identified through this modeling analysis. The most significant and unique problems not already identified by City staff or the public were placed in the master list of drainage problems. These problems were rated and ranked, and are shown in the master list of drainage problems presented in the following chapter. Those that are of an adequately high ranking and priority/severity were developed into new capital improvement projects that will allow the City to reduce the frequency and severity of flooding. The 39 drainage problems are listed below by each of the five modeling areas.

Summary of Results by Model Area:

- **Model Areas #1 – 3: Augusta Street – SWMM Model Outfall to ISSSP**
  - *Under Existing Conditions with No Restriction:*
    - ✓ 15 drainage problem areas identified, these include:
      - 103rd Drive NW (3)
      - 102nd Drive NW (3)
      - 101st Avenue NW (5)
      - 100th Avenue NW (4)
  - *Under Existing Conditions with 4 Feet of Backwater:*
    - ✓ 19 drainage problem areas identified, these include:
      - 103rd Drive NW (5)
      - 102nd Drive NW (3)
      - 101st Avenue NW (7)
      - 100th Avenue NW (4)
- **Model Area #4: 94th Drive NW – SWMM Model Outfall to ISSSP**
  - *Under Existing Conditions with No Restriction:*
    - ✓ No drainage problem areas identified,
  - *Under Existing Conditions with 4 Feet of Backwater,*
    - ✓ No drainage problem areas identified, however,
      - Water levels at the library site are at an elevation of 5.85' NAVD 1988, only 0.5 feet below the rim of the catch basin at that site.
- **Model Area #5: 92nd Avenue NW – SWMM Model Outfall to ISSSP**
  - *Under Existing Conditions with No Restriction:*
    - ✓ 2 drainage problem areas identified, these include:
      - 271st Street NW (1)
      - 270th Street NW (1)
  - *Under Existing Conditions with 4 Feet of Backwater:*
    - ✓ 3 drainage problem areas identified, these include,
      - 271st Street NW (1)
      - 270th Street NW (1)
      - 88th Avenue NW (1)

5.5 BIBLIOGRAPHY AND REFERENCES FOR CHAPTER 5

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