# Technical Memorandum

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| **To:** | Uki Dele, PE, City of Shoreline |
| **From:** | Ryan Hawkins, PE<br>Shailee Jain, EIT |
| **Copies:** | Tyson Hounsel, PE<br>File |
| **Date:** | January 26, 2018 |
| **Subject:** | Flooding at NE 175th Street and 10th Ave NE (Task 16, WO #16516) |
| **Project No.:** | 32713.B16 |

This technical memorandum documents the modeling, analysis and results of a study performed to identify the causes of flooding occurring near the intersection of NE 175th Street and 10th Avenue NE in the City of Shoreline (City), WA. The flooding complaint(s) are documented in the Cityworks database as work order #16516. The City has also requested additional background on the operation of an offline detention pond and flow diversion options available in the study area that were installed as part of previous projects.

The study area, shown in Figure 1, is in the headwaters of the Littles Creek basin in the North City neighborhood of the City. Littles Creek is a tributary to Thornton Creek, which ultimately drains to Lake Washington in the City of Seattle. A low point in NE 175th Street exists between 10th and 11th Avenues NE and water is known to pond across the street during periods of heavy rainfall. Residents on the south side of NE 175th Street have also reported that street runoff flows onto their property and has caused damage to private infrastructure (flooded furnace at 1017 NE 175th Street). The flooding is thought to be occurring due to a combination of several factors including a complex pipe network that includes several flow splits and valves, little elevation relief, and a high effective imperviousness in the drainage basin.

On Wednesday, December 13, 2017, Otak staff performed a site visit to the project location and met with City staff to review the existing conditions at the site. Baseline information about the drainage system was obtained from a review of the City's Geographic Information System (GIS) database along with Cityworks data. Cityworks is an infrastructure management program that tracks maintenance, inspections and asset performance. During the site visit, several catchbasins were inspected to confirm the accuracy of the data available. Additional detailed survey information of the stormwater system in the intersection was provided by the City from a recent project along 10th Avenue NE.

To begin to analyze the existing conditions, the drainage area was studied to determine the land uses and soil types present in order to calculate the stormwater runoff to the study area during high flow events. This was performed in GIS (ArcMap Version 10.4.1) and the output (areas of pavement, grass, etc.) was used in the Western Washington Hydrologic Model (WWHM, 2012) to estimate the runoff from the drainage basin to the project site. WWHM is a continuous simulation hydrology modeling software recommended by the Washington Department of Ecology and uses the industry standard Hydrologic Simulation Program – Fortran (HSPF) for computation. The model uses a continuous record of precipitation data from 1949 through 2009.



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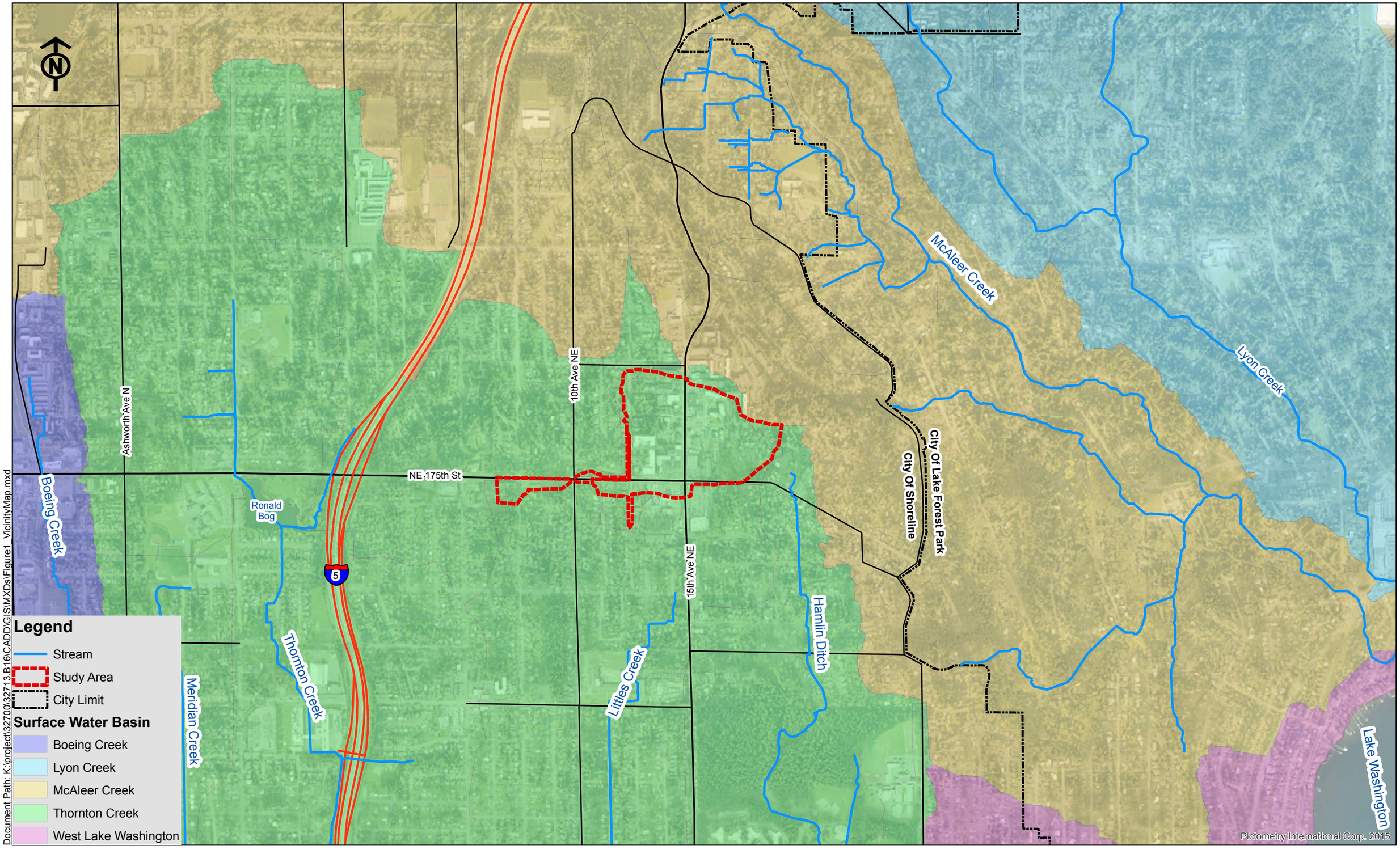


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Figure 1: Vicinity Map
Task 16, WO #16516, Flooding at NE 175th Street and 10th Ave NE

1 inch = 1,500 feet

1,500 750 0 1,500 Feet

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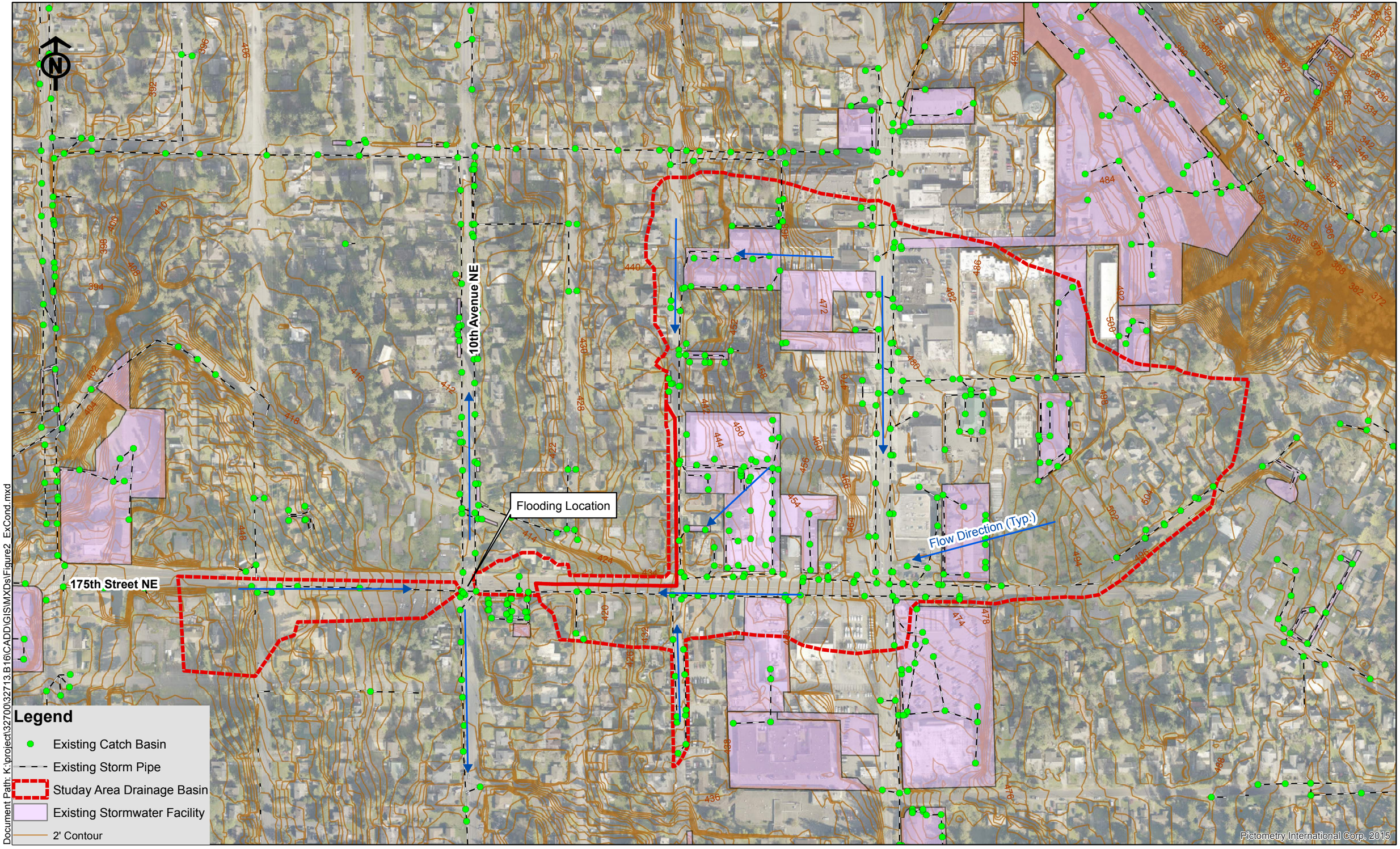


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Figure 2: Existing Conditions
Task 16, WO #16516, Flooding at NE 175th Street and 10th Ave NE

1 inch = 400 feet

400 200 0 400 Feet

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A total of 51.6 acres of land ultimately flows to the intersection of NE 175th Street and 10th Avenue NE from three distinct subbasins within the project area. The land use analysis showed that 63% of the drainage basin (32.5 of 51.6 acres) is impervious surface. The remaining areas are mostly lawns with a small amount of forested area. Three basins were created in WWHM to provide flow rates for the hydraulic model (one basin for each input to the hydraulic model). Figure 2 shows the areas that drain to the study area. Figure 3 shows a screenshot from WWHM of one of the subbasins (eastern section of project area).

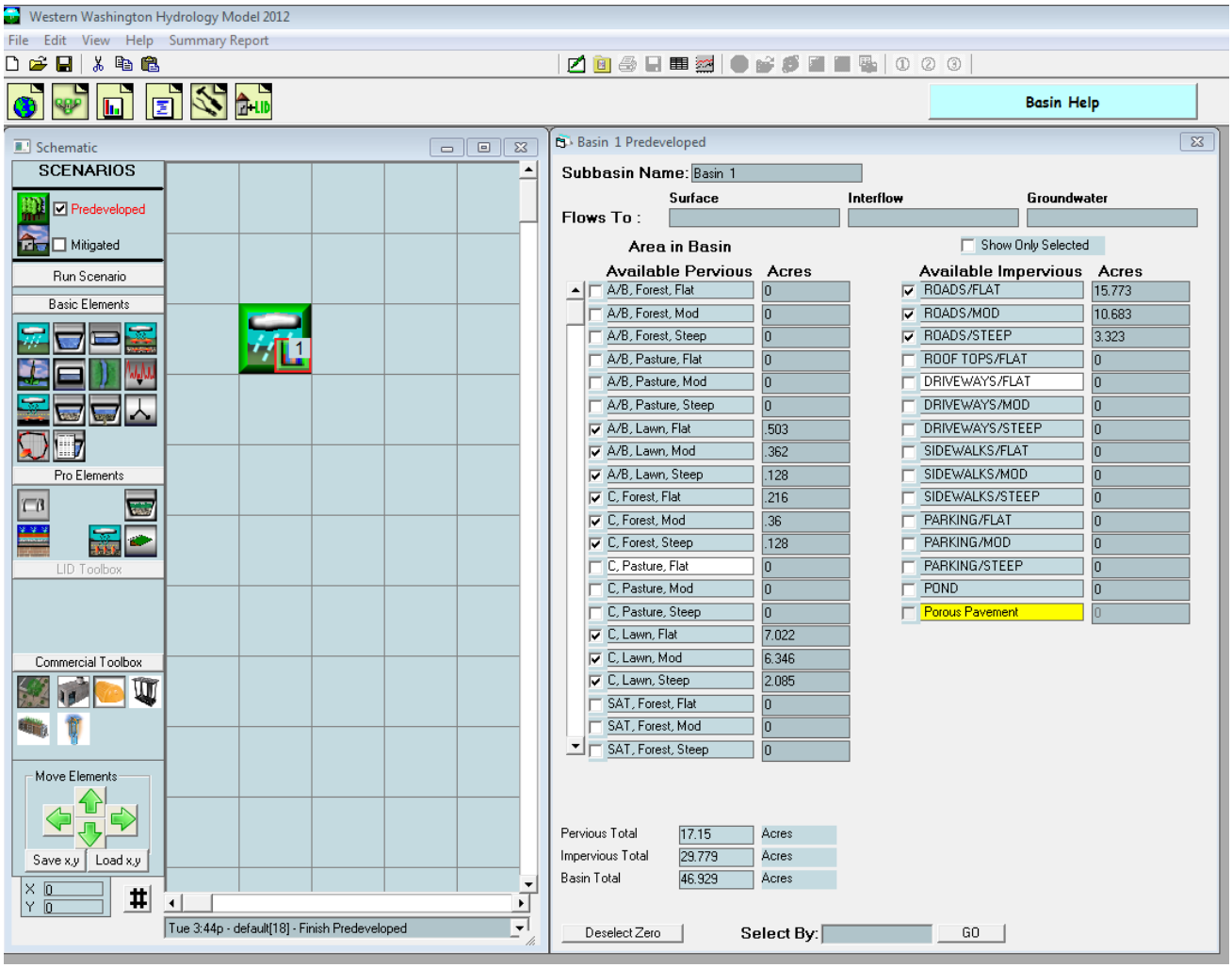


*Figure 3: WWHM Screenshot*

At this point in the study, the hydrologic model built for this study is somewhat conservative as it does not take into consideration the numerous stormwater detention facilities located in the eastern subbasin, which are also shown in Figure 2. These facilities will dampen the peak flows during large storms and were not included in the model as it is beyond the scope of this study. The WWHM Model performs a Flood Frequency Analysis (Log Pearson Type 3) to provide flow rates from each subbasin. Table 1 below shows the total flow to the project area from all three subbasins.

Table 1: Flood Frequency Analysis Results

| Recurrence Interval (years) | Flow to Study Area ($ft^3/s$) |
|---|---|
| 2 | 11.4 |
| 5 | 14.7 |
| 10 | 17.0 |
| 25 | 20.0 |
| 50 | 22.3 |

The flow rates generated from the WWHM model were used in a hydraulic simulation developed in a stormwater management model (PC-SWMM) to analyze the conveyance capacity of the various stormwater system components, as seen in Figure 4, and to identify probable flooding location(s) in the system. Existing pipes (links) and catchbasins (nodes) were entered into the model based on locations and invert elevations interpreted from survey maps and Cityworks. Figure 5 shows the arrangement of the PC-SWMM model. The existing stormwater system at the intersection of NE 175$^{th}$ Street and 10$^{th}$ Avenue NE has two potential flow paths. The primary course is through an 18″ diameter pipe north from the intersection along 10$^{th}$ Avenue NE. This flow eventually turns west and drains to Ronald Bog and Thornton Creek. A secondary flow path goes south along 10$^{th}$ Avenue NE in a 12″ pipe and outfalls to Littles Creek near Ridgecrest Elementary School at NE 165$^{th}$ Street. Littles Creek is tributary to Thornton Creek; their confluence is in the City of Seattle at the Jackson Park Golf Couse. The secondary flowpath is likely only engaged during the highest flows as the inlet to the 12″ pipe going south is approximately 3.4 feet higher than the 18″ pipe going north. Each of these flow paths has a gate valve to control the amount of flow going in each direction.

The first modeling runs were focused on the basic components of the stormwater system and did not include the flow split valves and small detention pond located in the study area, which are discussed later. The model results (Table 2) showed that, with the valve to the stormwater pond closed and all other diversion valves fully open, the system starts to flood 175$^{th}$ Street NE at a flow rate between the 2 and 5 year recurrence interval. The modeling also showed that with these conditions, during all storms, no flow is directed to the south (through CB-12420). The main cause of flooding is the 18″ pipe (SP-8465) that goes north from the flow split catchbasin in the southern side of the intersection. The pipe has a slope of 0.18% (0.2′ drop over 112′ of length) and is the main flow constriction in the system.

VALVE ON NORTH SIDE CB- 4096


CB- 4096

SP-2622
18" CMP

CB- 8175

SP-6088
18" CMP

SP-8465
18" CPP

CB- 7705
IE IN= 407.5(18" E)
IE IN= 407.17(18" W)
IE OUT= 407.37(18" N)
IE OUT= 410.17(12" SW)

NE 175TH ST

10TH AVE NE

CB- 10550

SP-8459
12" CMP

NE SERPENTINE PL

SP-6089
12" CONC

SP-8463
18" CPP

CB- 8176

SP- 1930
12" CMP

CB- 8622

CB- 4095

SP- 8664
12" CMP

CB- 8622

SP- 8464
12" CMP

SP-8660
12" CMP

SP-8461
18" CPP

SP-8460
18" CPP

CB- 12546

SP-8607
18" CPP

CB- 4823

VALVE ON SOUTH SIDE CB- 12420


CB- 12420

Private Infiltration System

SP-8884
24" CMP

Valve Box

SP-8682
18" CMP

PD- 15

Detention Pond

Pictometry International Corp. 2015

**Legend**

- Flow Split
- Gate Valve
- Existing Catch Basin
- Existing Storm Pipe
- Street
- Tax Parcel

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Figure 3: Stormwater Network
Task 16, WO #16516, Flooding at NE 175th Street and 10th Ave NE

1 inch = 50 feet

50 25 0 50 Feet

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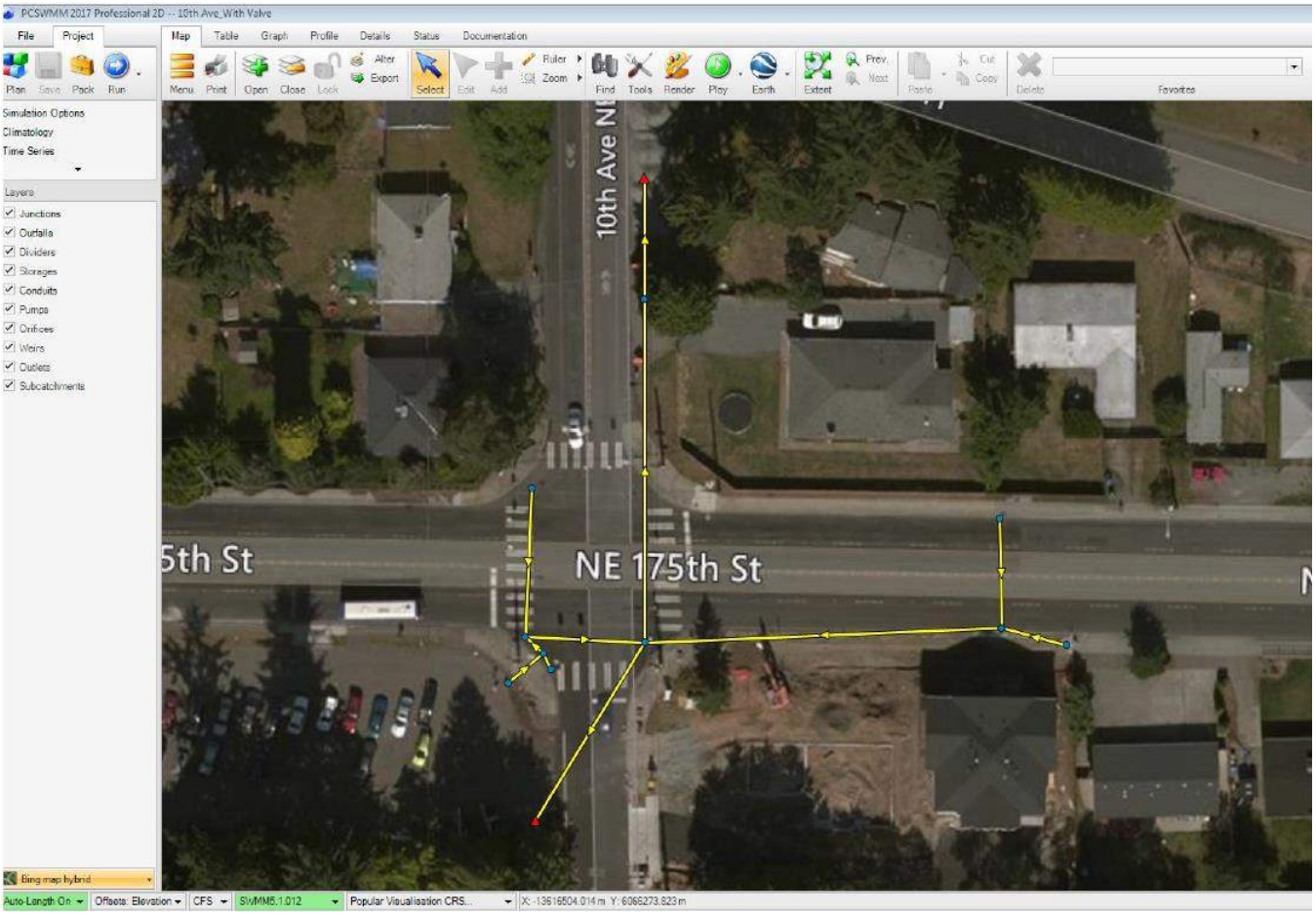


*Figure 5: Hydraulic Model Screenshot*

Table 2: Hydraulic Model Results

| Flood Recur. Interval | Flow Rate | Flooding Occurs? | Flood Duration | Flood Volume | Flow to South | Flow to North |
|---|---|---|---|---|---|---|
| (years) | (cfs) | | (hours) | (gallons) | cfs | cfs |
| 2 | 11.45 | No | 0 | 0 | 0 | 11.45 |
| 5 | 14.75 | Yes | 0.22 | 3,000 | 0 | 12.82 |
| 10 | 17.03 | Yes | 0.33 | 20,000 | 0 | 13.33 |
| 25 | 20.02 | Yes | 0.82 | 71,000 | 0 | 12.89 |
| 50 | 22.34 | Yes | 0.62 | 81,000 | 0 | 13.58 |

During the site visit we found that both valves in the storm system were partially closed as shown in Figure 6 below. It is not known why or when these valves were last operated. Otak and City staff did not have proper confined space entry training and were not able to quantify how much the valves had been closed. Later in December, City staff returned with videotaping equipment and were able to accurately measure this (see Figure 7). They reported that the valves were approximately 6.5″ closed. Since this will have an impact on the conveyance capacity in the system, another hydraulic model scenario was created

to reflect the valve closures. City measurements showed that the valve in CB-4096 was closed approximately 6.4″ which will reduce the capacity of the 18″ pipe by about 24%. So instead of using an 18″ diameter pipe flowing to the north from CB-4096, the model uses a 13.67″ diameter pipe. The results of this scenario, seen in Table 3, showed that with the valve partially closed flooding can occur at the project site as often as the 2-year recurrence interval flow. In this condition the southern flow path begins to see flow around the 25 year recurrence interval.

Table 3: Hydraulic Model Results with Valves Partially Closed

| Flood Recur. Interval | Flow Rate | Flooding Occurs? | Flood Duration | Flood Volume | Flow to South | Flow to North |
|---|---|---|---|---|---|---|
| (years) | (cfs) | | (hours) | (gallons) | cfs | cfs |
| 2 | 11.45 | Yes | 0.23 | 4,000 | 0 | 10.07 |
| 5 | 14.75 | Yes | 0.46 | 3,100 | 0 | 9.93 |
| 10 | 17.03 | Yes | 1.04 | 80,000 | 0 | 10.21 |
| 25 | 20.02 | Yes | 2.09 | 176,000 | 0.06 | 9.98 |
| 50 | 22.34 | Yes | 0.8 | 141,000 | 0.14 | 10.29 |

*Figure 6: CB-12420 and Partially Closed Valve*


*Figure 7: Results from Videotape*

In all modeling scenarios, the flooding at the project site occurs for a relatively brief period. Table 4 shows the flooding durations at the project site. In most conditions, flooding is occurring for less than an hour when the system cannot convey the peak storm flows. As seen in the table, the flood duration for the 50-year is less than the 25-year flow. As the flow in the system begins to exceed 20 $ft^3/s$, the overflow pipe to the south is engaged and provides some relief. The valve in CB-12420 controlling flow to the south is currently closed roughly 47%, but this does not seem to impact the relatively small amount of flow going that direction. At flow rates exceeding the 50-year flow rate, the valve closure may limit the amount of flood relief being provided to the south. At this time maintenance records have not been found by the City that document any actual flood durations.

Table 4: Flooding Duration

| Recurrence Interval (years) | Flooding Duration (hours) | |
|---|---|---|
| | Valves Open | Valves Closed |
| 2 | 0 | 0.23 |
| 5 | 0.22 | 0.46 |
| 10 | 0.33 | 1.04 |
| 25 | 0.82 | 2.09 |
| 50 | 0.62 | 0.80 |

The study area also contains a small stormwater detention pond (PD- 15) in the area southeast of the 175th and 10th intersection that appears to have been constructed to provide flood storage for peak flows that exceed the capacity of the roadway conveyance system. A valve must be manually opened to allow flow to the pond through a 4″ diameter pipe. Records of the pond design have not been found and usage of the pond is not a regular procedure for the City. The volume of this pond was calculated using field measurements and elevation data from GIS. The pond is estimated to have a storage volume of

approximately 5,500 $ft^3$. This pond, shown in Figure 8, is a closed detention basin as it does not have an outlet. There will be some amount of infiltration through the bottom of the pond but currently there is no available data about the infiltration rate of the underlying soils which is mapped by the United States Geologic Survey as the Vashon Advance Outwash (Qva). These soils are deposits of compacted sand, well-round gravel, and silt that were laid down during the Vashon glacial advance. These proglacial soils were overridden by the advancing ice, and are typically dense to very dense.

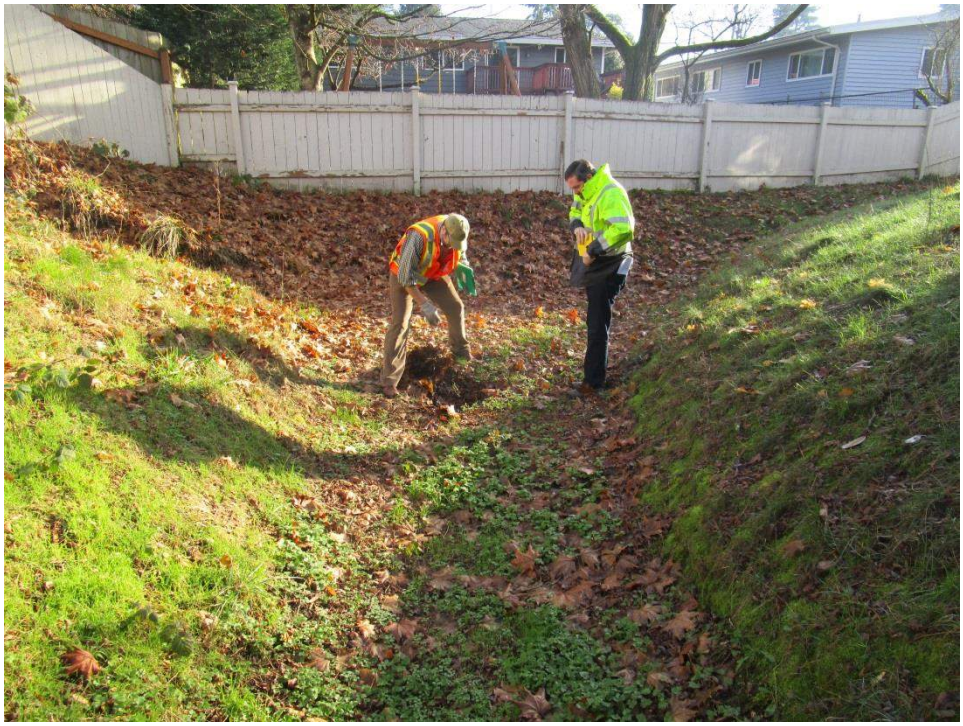

Figure 8: Stormwater Pond

Currently the valve allowing flow to the pond is shut and the City has questioned how much flooding relief could be provided if the flow was allowed to the pond. Assuming a slope of 1%, the maximum capacity of the 4-inch diameter pipe leading to the pond is approximately 0.2 $ft^3/s$ (see Appendix for calculations). This is a small amount of flow compared to the total flow in the system. At 0.2 $ft^3/s$, the pond would take over 7 hours to fill. Flooding, however, only lasts about an hour in most situations.

As the hydraulic modeling showed, the stormwater system has the capacity for approximately 12 $ft^3/s$ with the valves fully open and around 10 $ft^3/s$ as it currently exists with the valves partially closed. The flow in the system during the 50-year storm peak is roughly 22 $ft^3/s$ leaving a difference of 10 $ft^3/s$ that overflows the system and floods the street. By increasing the size of the pipe flowing to the pond, additional flooding relief could be provided. For example, a 12″ diameter pipe could be installed and could draw up to 3.9 $ft^3/s$ from the system but would fill the pond in 0.4 hours or 24 minutes. To eliminate the flooding, it is estimated that an 18″ diameter pipe would need to lead to the pond, which could provide over 11 $ft^3/s$ of flow and relieve the flooding in the street. This would fill the pond in less than 8 minutes and flooding would resume after shutting the valve to the pond. Table 5 below shows the estimated flow rates and filling time for the pond based on several different pipe sizes.

Table 5: Detention Pond Flows

| Pipe Diameter | Maximum Flow Rate ($ft^3/s$) | Time to Fill Pond (Hours) (Pond Volume = 5,500 $ft^3$) |
|---|---|---|
| 4″ (existing) | 0.21 | 7.28 |
| 6″ | 0.61 | 2.50 |
| 8″ | 1.31 | 1.17 |
| 12″ | 3.86 | 0.40 |
| 15″ | 7.00 | 0.22 |
| 18″ | 11.38 | 0.13 |

After studying the system, it was found that even with all valves fully open, the system does not have capacity for flow rates exceeding the 2-year recurrence interval (around 12 $ft^3/s$). The current conditions in the field (valves partially closed) restrict the capacity of the system below the 2-year flow. There are existing management options that could be used to reduce the amount of flooding but not to eliminate it entirely. A portion of the flooding could be diverted to the stormwater pond, but with the current 4″ diameter pipe in place, the amount of flow that could be diverted (0.2 $ft^3/s$) is quite small. The stormwater system to the south has additional capacity but the inlet pipe has been installed too high to engage most flows.

This study has several limitations; most importantly, the need to include the flow dampening effects of several stormwater detention/retention facilities in the basin. At the time of this report, it is beyond the scope of the study. Including these facilities will reduce the estimated runoff contributing to this system. This may reveal that flooding is occurring less frequently than shown in this study.

Next Steps for Engineering Analysis

We understand that the City is planning for a pavement overlay of NE 175th Street in 2019 and would like to implement any necessary stormwater improvements related to this study area prior to the paving work. Based on the results presented in this memo, we recommend that solution concept drawings and cost estimates be developed for the following solution elements:

- Lowering pipe (SP- 8660) and diverting a larger portion of storm flows to the south along 10th Ave NE
- Constructing detention storage and infiltration capacity along 10th Ave NE south of NE 175th to dampen the increased flow due to diversion of storm flows from NE 175th. This could include underground facilities, bioretention, or a combination.
- Lowering pipe (SP- 8465) to the north to increase the slope and capacity – this may not be feasible since the downstream conveyance system to the north is rather flat (The City recently constructed a project to add bioretention along 10th Ave NE north of 175th and to correct some problematic pipes and ditches that were reverse grade and poorly draining and to provide infiltration)
- Increasing the inlet pipe size for the existing detention facility and constructing an outlet pipe or overflow swale to direct pond overflows into the existing conveyance system along 10th Ave NE.

As part of concept development, we recommend that the hydraulic model be expanded to include the existing upstream detention systems and approximately 1,300 LF of additional storm sewer pipe/ditches

to the north and 1,300 LF' additional storm sewer pipe/ditches to the south. This will allow the existing baseline flooding conditions to be estimated more accurately and then proposed flood relief solutions could be modeled to compare alternatives. It will also allow for more detailed assessment of impacts to the downstream systems if the flooding is relieved at the study area location.