Appendix C – Extreme (200-yr) Storm Event Analysis TM

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CITY OF LINCOLN, NE

EVALUATION OF THE SEPTEMBER 30TH TO OCTOBER 1, 2014, STORM

TECHNICAL MEMORANDUM

FINAL
March 2015

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CITY OF LINCOLN, NE

EVALUATION OF THE SEPTEMBER TO OCTOBER 2014 STORM

TECHNICAL MEMORANDUM

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1.0 OVERVIEW

On September 30 and October 1, 2014, (Storm) the City of Lincoln experienced a major storm with storm totals as high 6 inches in localized areas. A graphical representation of the rainfall totals that was provided by the City is located in Appendix A. This storm event was preceded by 8.4 days of dryness. During this storm event there was localized flooding in within the City as shown in Appendix B. Located at Manhole C6-194 is a diversion structure. This diversion structure incorporates two sluice gates that are used to direct the flows entering the diversion structure to either the Theresa Street WWTF or the Northeast WWTF. At the time of the storm event the gates were positioned such that the flows entering the diversion structure were directed to the Theresa Street WWTF, and the gate to the Northeast WWTF was closed. Shown in Figure 1 is the location of the diversion structure.

The influent structure at the Theresa Street WWTF incorporates an overflow weir and 54-inch pipe that flows to the Salt Creek. Located at the end of the 54-inch pipe is a flap gate. During high water situations in the wetwell, if the water rises to the level of the weir, it will flow over the weir, through the 54-inch pipe and flap gate and into Salt Creek. This will only occur if the water level in the creek is lower than the water level in the influent structure.

2.0 PURPOSE

The purpose of this technical memorandum is to evaluate how the diversion structure at manhole C6-194 and the influent structure overflow weir system responded hydraulically to the September 30 through October 1, 2014 storm event.

In order to meet the stated goals, the existing hydraulic model was updated with new I/I parameters, rainfall data from the storm event, flow parameters, and the pump curves for the influent pumps at the two treatment plants. The I/I parameters and rainfall data were extracted from the city's flow monitoring database.

3.0 EVALUATION OF THE RAINFALL DATA

Seven rain gauges listed in Table 1 below were used for the hydraulic modeling effort. The rain gauges provided data in hourly intervals, which were used to estimate the intensity, duration, and volume of storm events that occurred during the study period. The rainfall data were also used to estimate the return periods of the observed storms in the study period.

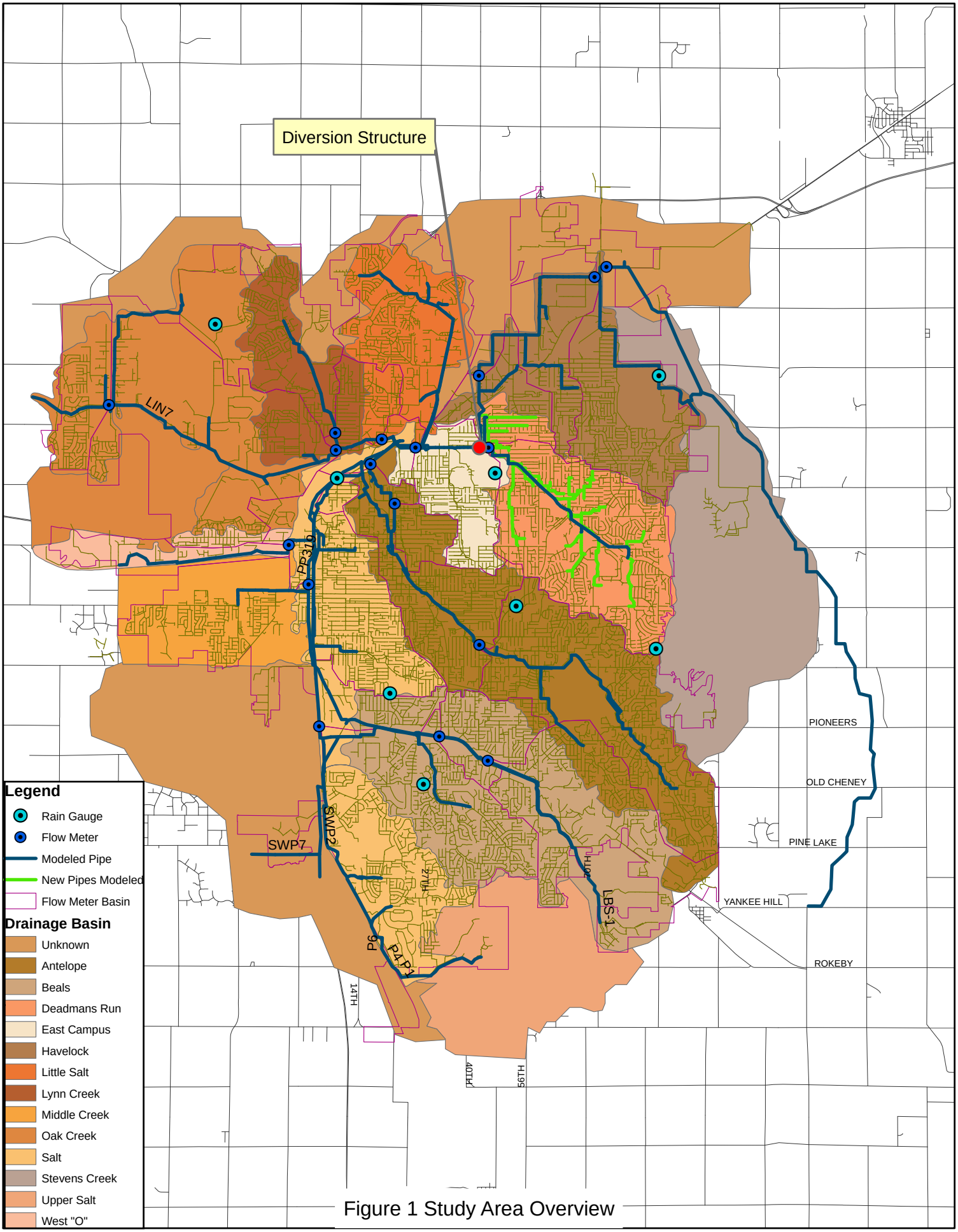


Figure 1 Study Area Overview

Table 1	**Summary of Rain Gauges Evaluation of the September 30 through October 1, 2014 Storm City of Lincoln, NE**				
Gauge ID	Location	Maximum 60 Minutes Rainfall		Total Rainfall (in)	Duration (days)
		Depth (in)	Date		
254739	Highlands Golf Course	0.86	09/30/14	4.09	2.9
254809	IANR (East Campus)	1.40	09/30/14	6.18	2.9
254759	901 N. 6th (GONE NOW)	1.03	09/30/14	6.21	2.9
254699	82nd & Havelock (UNL Bldgs)	1.05	09/30/14	6.02	9.1
254729	82nd & South (Fire Sta.)	1.59	09/30/14	5.73	2.9
254769	27th & Old Cheney (Fire Sta.)	0.87	09/30/14	5.44	2.9
254719	Lincoln Country Club (20th &Calvert)	1.42	09/30/14	6.69	2.9

Five maximum 60 minutes rainfall events occurred between September 30 and October 1. The summary of these storm events are summarized in Table 2. The location of the rain gauges is summarized on Figure 1.

Table 2	**Storm Information Summary (09/30/2014; from the 9th Hour to Midnight) Evaluation of the September 30 through October 1, 2014 Storm City of Lincoln, NE**				
Rain Gauge ID	Total Depth (in)	Storm Duration (hr)	Intensity (in/hr)	Return Period	Storm Period
254739	3.38	17	0.200	5 year	09/30/14; 9th hr to 10/01/14; 1st hr
254809	5.97	17	0.351	100 year	09/30/14; 9th hr to 10/01/14; 1st hr
254759	5.87	17	0.346	> 100 year	09/30/14; 9th hr to 10/01/14; 1st hr
254699	5.85	19	0.308	75 year	09/30/14; 10th hr to 10/01/14; 4th hr
254729	5.52	14	0.395	100 year	09/30/14; 12th hr to 10/01/14; 2nd hr
254769	5.06	14	0.362	100 year	09/30/14; 12th hr to 10/01/14; 1st hr
254719	6.48	16	0.405	> 100 year	09/30/14; 9th hr to midnight

During the storm event which begun on September 30 at the 9th hour and ended on October 1 at the first hour, most of the City received about 6 in of rainfall in about 16 hours; at an average intensity of 0.35 in per hour. The return period estimated at each gauge location is listed in Table 2. Figure 2 shows the variation of rainfall intensity at each gauge location during the storm event.

4.0 FLOW MONITORING

As part of the collection system hydraulic modeling effort, flow data obtained from the City's eighteen flow meters were evaluated in order to correlate real world collection system flows with the estimated flows in the hydraulic model. The flow monitoring and rain gauge data were used to calibrate the collection system hydraulic model for both dry and wet weather flows, as well as perform an inflow and infiltration analysis.

5.0 FLOW MONITORING ANALYSIS

During the flow monitoring period, depth and velocity data were extracted for each meter location at 15-minute intervals. The 15-minute data was then aggregated to hourly data for both the dry and wet weather flow analyses, and model verification effort. All analyses were performed using U.S EPA SSOAP Toolbox. Table 3 summarizes the Average Dry Weather Flow (ADWF), Peak Dry Weather Flow (PDWF) and groundwater infiltration (GWI) determined at each meter location during the storm event. GWI was normalized by drainage basin area in order to rank the basins according GWI severity. Figure 3 shows GWI severity map for the basins. The higher the GWI severity, the greater the influence the GWI has on the collection system.

Individual RDII events were delineated based on the flow monitoring data and rainfall data. An RDII event is defined as the time period during which the flow pattern varies from the dry weather flow (DWF) because of the influence of rainfall.

RDII starts when the rainfall begins and ends when the flow pattern returns to the pre-rainfall level. A flow data analysis was performed to evaluate the information obtained from continuous flow monitoring and other supplemental data in order to categorize the wastewater flow into its various components; sanitary flow, infiltration, and inflow. The flow monitoring was also used to simulate the storm events. This analysis included consideration of whether free flow or restricted flow conditions exist and adjustment of inflow to the designated standard design storm. For all storm events observed during the study period, both the peak inflow rate and the total inflow volume were estimated.

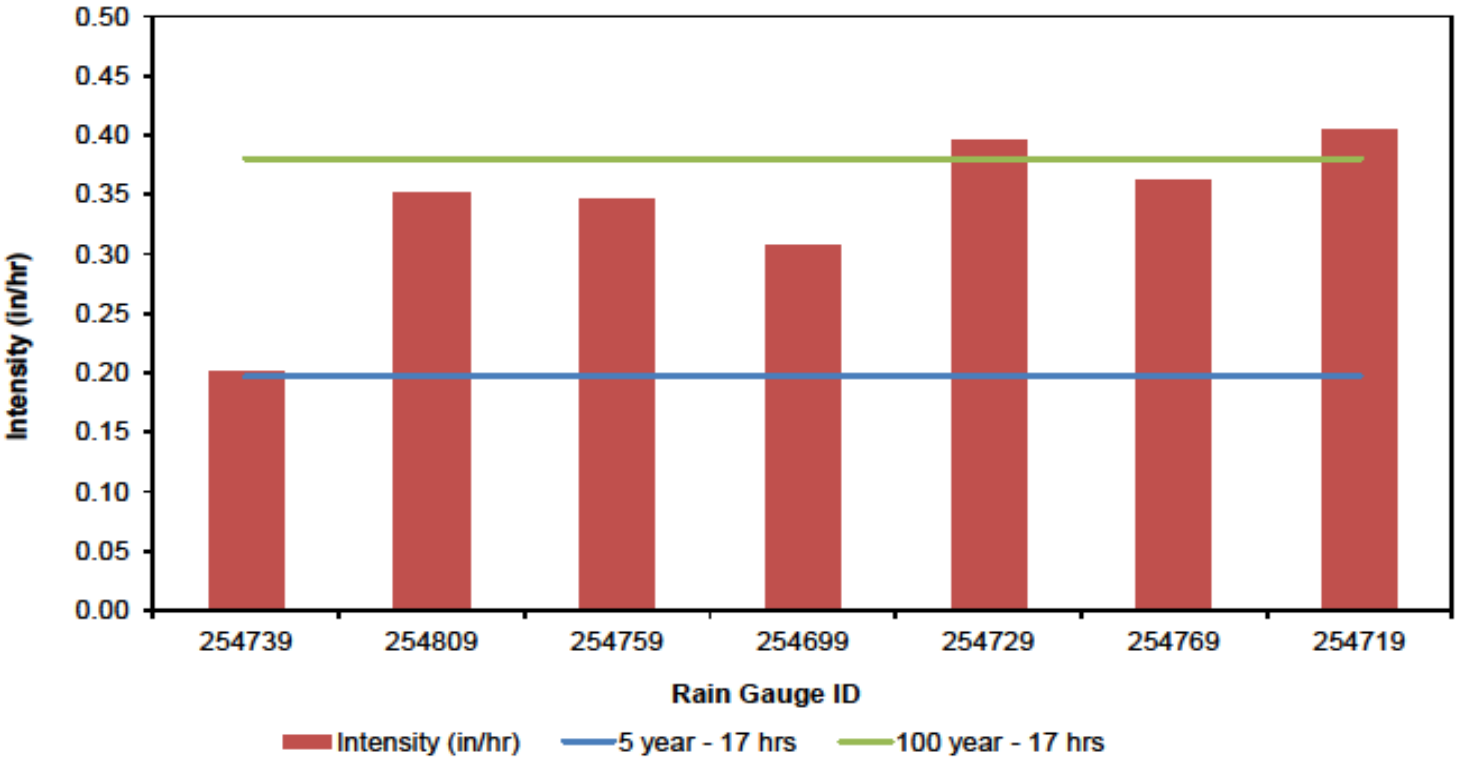


Figure 2 – Storm Event Characterization

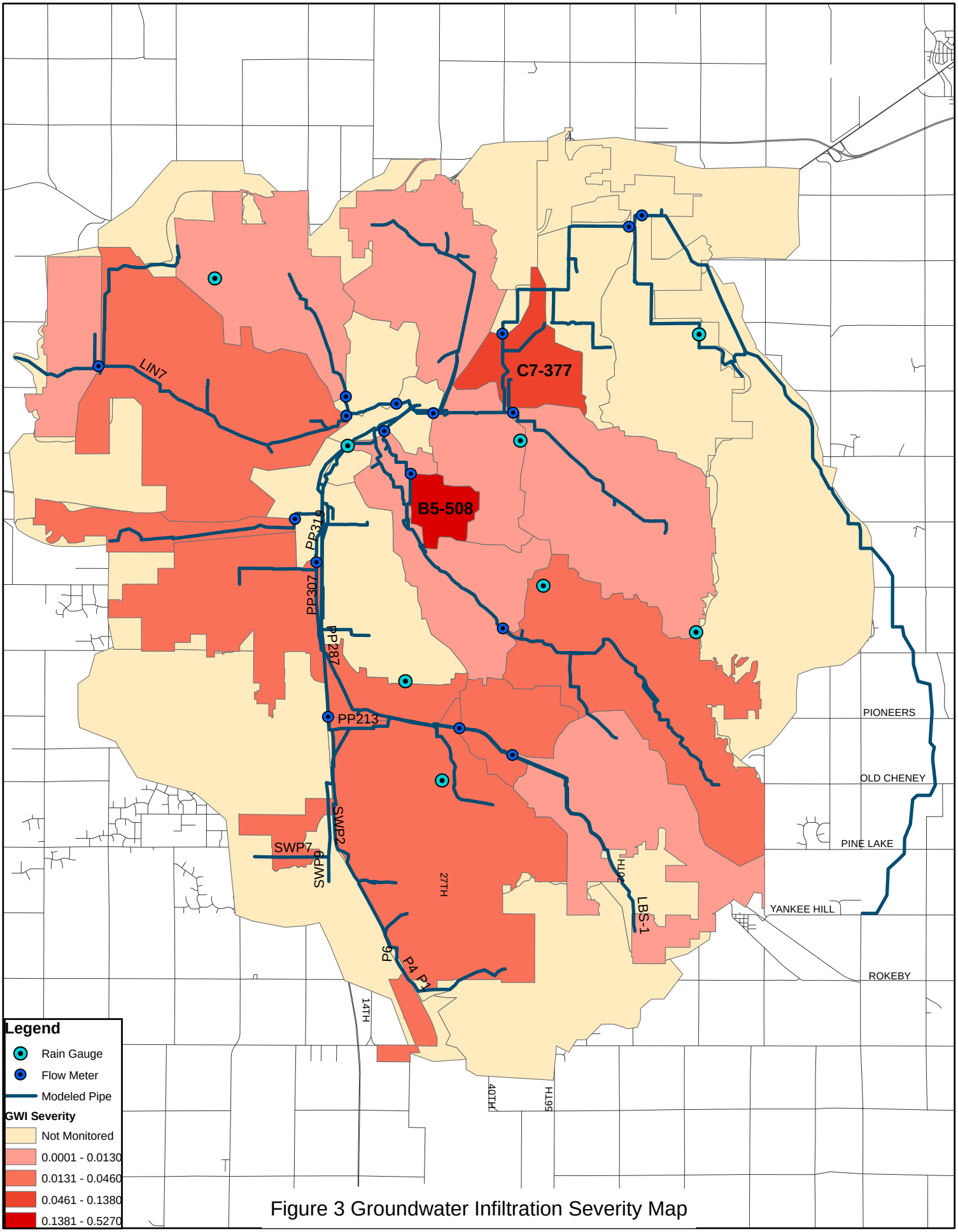


Figure 3 Groundwater Infiltration Severity Map

Table 3	**Dry Weather Flow Summary Evaluation of the September 30 through October 1, 2014 Storm City of Lincoln, NE**				
Basin/Meter ID	Drainage Area (ac)	ADWF (mgd)	PDWF (mgd)	GWI (mgd)	GWI-Area Ratio (100 x mgd/ac)
AA7-25	1,387.3	0.439	0.632	0.114	0.008
C6-388	4,992.0	1.145	1.452	0.446	0.009
C7-377	1,441.8	1.988	2.560	0.628	0.138
B6-115	4,921.0	3.014	3.981	0.491	0.010
B6-269	3,202.9	0.861	1.280	0.318	0.010
A5-129	1,041.6	0.688	0.754	0.482	0.046
B1-290	5,000.0	4.008	5.782	1.430	0.029
C1-39	3,960.6	0.744	1.168	0.184	0.005
C3-561	4,738	2.887	4.092	1.160	0.024
B5-508	551.5	5.313	6.578	2.906	0.527
C1-191	1,217.7	1.054	1.461	0.408	0.033
B4-173	3,024.0	1.908	2.549	0.750	0.025
B6-66	2,697.5	3.014	3.981	0.491	0.013
B6-279	3,648.5	1.764	2.228	0.802	0.022

The total inflow was apportioned into two components: direct inflow and delayed inflow. Direct inflow is the portion of the inflow hydrograph, which rapidly increases soon after the start of the storm and decreases swiftly upon conclusion of the rainfall event. Delayed inflow is the portion of the inflow hydrograph which decreases gradually upon conclusion of the rainfall event and after the peak inflow caused by direct connections. Table 4 depicts the details of the RDII events, which includes:

- Flow data (i.e., peak total flow, peak RDII flow, RDII volume)
- Percentage of rainfall entering sewer system (i.e., R-value)

The table also shows the average peaking factor of all the identified RDII events. The R-value provides a means to compare the relative magnitude and severity of the RDII flow

between different basins and different storms. Systems or basins with an R-value less than 5% are considered as having low RDII. Systems or basins with an R value greater than 5% have a greater RDII influence. This data is shown in Table 4 and graphically in Figure 4. Based on this criterion RDII in the City is generally low with only one basin C7-377 with an R factor greater than 5%.

Table 4 Details of RDII
Evaluation of the September 30 through October 1, 2014 Storm
City of Lincoln, NE

Basin/Meter ID	Drainage Area (ac)	Peak RDII Flow (mgd)	PWWF (mgd)	RDII Volume (MG)	R-Factor (%)	Peaking Factor
AA7-25	1,387.3	1.820	2.054	0.942	0.64	5.24
C6-388	4,992.0	1.323	1.977	1.084	0.14	1.72
C7-377	169.0	9.721	10.580	20.282	8.56	5.76
B6-115	4,921.0	7.127	9.773	1.470	0.55	3.26
B6-269	3,202.9	2.557	3.069	2.000	0.37	3.64
A5-129	1,041.6	1.084	1.759	2.093	1.33	2.50
B1-290	5,000.0	36.070	48.222	11.404	1.37	10.07
C1-39	3,960.6	2.683	3.814	0.645	0.14	4.16
C3-561	4,738	10.565	13.251	6.690	0.85	4.59
B5-508	551.5	9.152	14.738	3.714	4.56	2.78
C1-191	1,217.7	4.383	5.171	2.182	1.01	5.06
B4-173	3,024.0	5.534	8.468	2.546	0.51	3.66
B6-66	2,697.5	7.127	10.795	1.538	0.93	3.26
B6-279	3,648.5	5.742	7.886	3.467	0.63	4.08

Peaking factors are used to determine the relative inflow and infiltration entering the collection system above each of the flow meters. Peaking factors however, do not show which pipes upstream of a meter are contributing the greatest volume of rainfall dependent inflow and infiltration (RDII). Analyzing the peaking factors and the volume of RDII from each basin will yield an overall picture of the performance of the City's collection system during rainfall events.

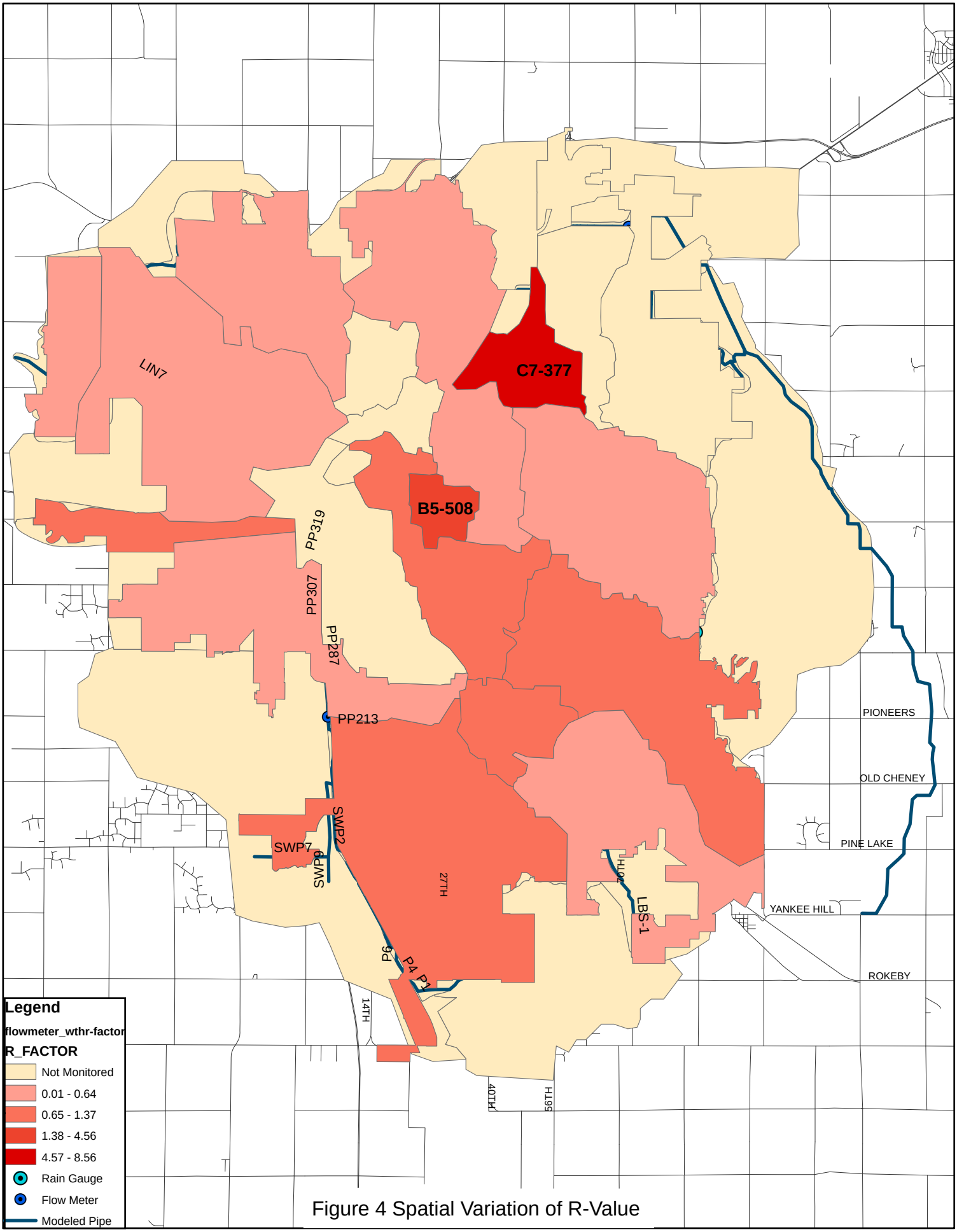


Figure 4 Spatial Variation of R-Value

Figure 5a summarizes total metered flow at B5-508 and Figure 5b summarized the total metered flow at C7-377 from hour 0:00 on September 30 to hour 23:00 on October 4, 2014. These Figures also shows the estimated diurnal dry weather flow (DWF), wet weather flow (WWF), and rainfall dependent inflow and infiltration (RDII) during the same period. In the Figures, hydrograph time 0:00 hours corresponds to 0:00 September 30, 2014. Similar hydrographs for the other monitoring locations are located in Appendix C.

Following inspection of data summarized in the Figures, the period from 9:00 September 30, 2014 through 23:00 October 4, 2014 was selected for additional analysis. That period was preceded by 8.4 days without rainfall. It should be noted, that the surcharged conditions observed during this period can mask the actual I/I potential since the surcharged pipes limit the amount of groundwater that can physically enter the collection system.

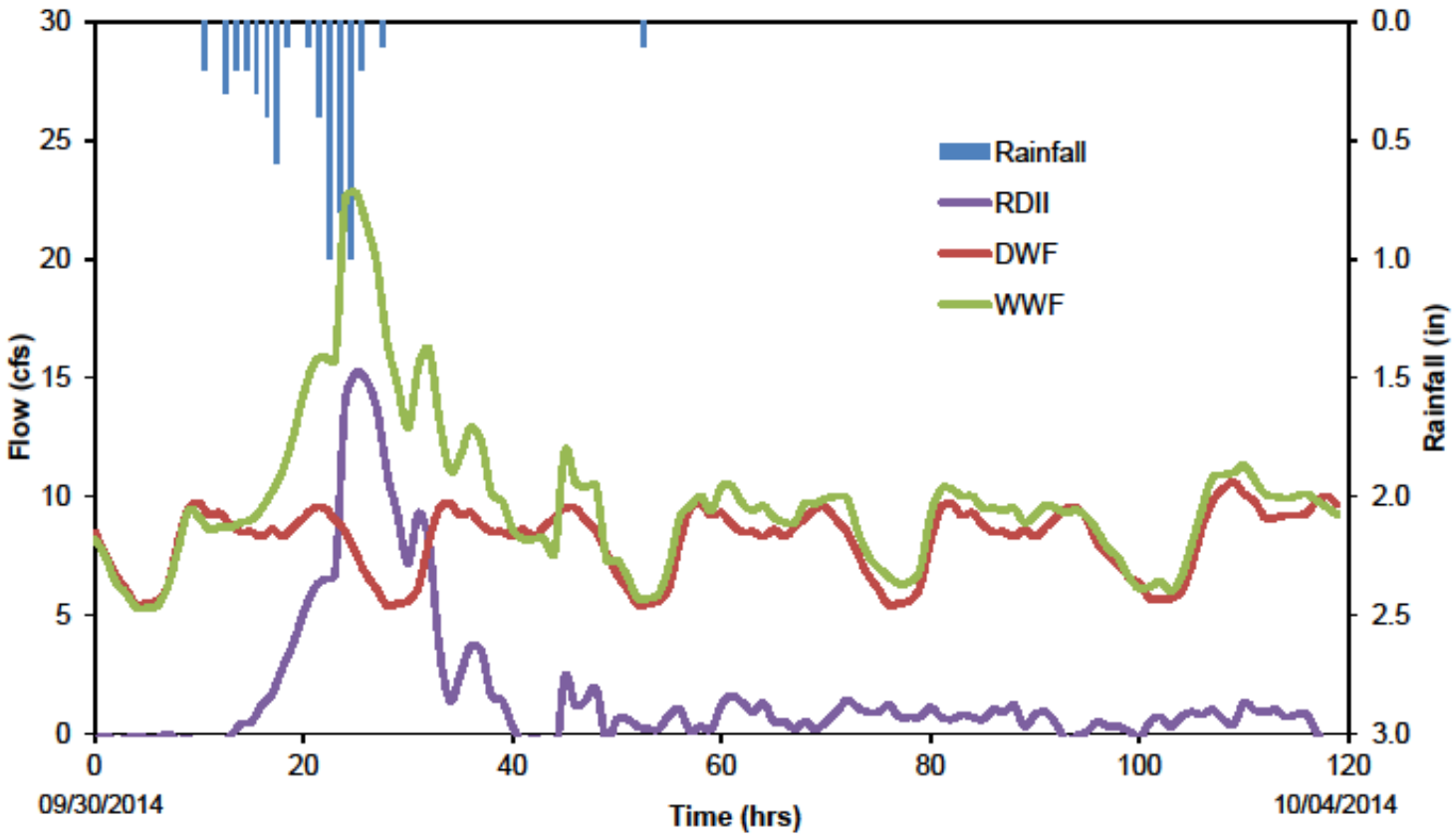


Figure 5a Wastewater Flow Components at Reorded at Meter B5-508

Figure 5a – Wastewater Flow Components Recorded at Meter B5-508

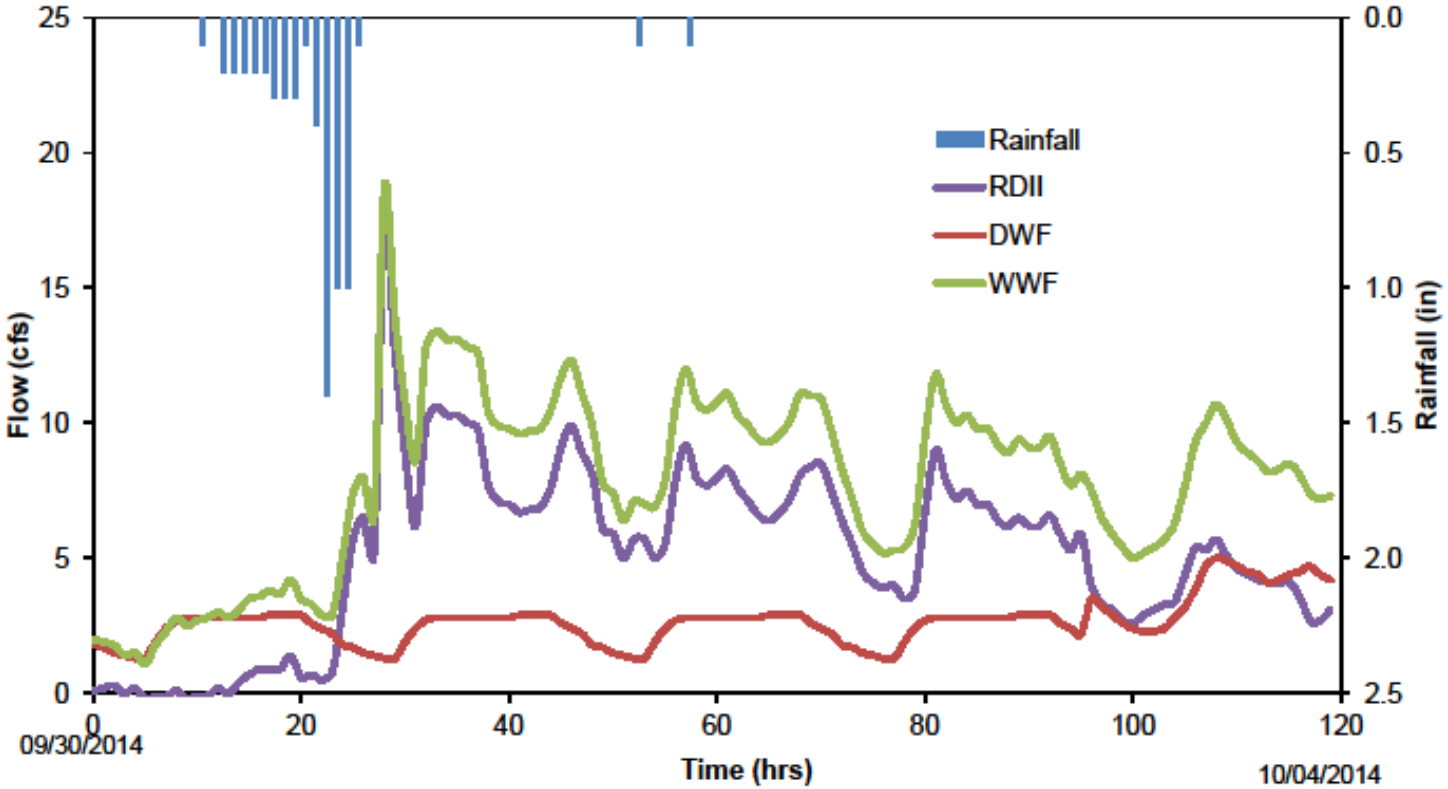


Figure 5b Wastewater Flow Components Recorded at Meter C7-377

Figure 5b – Wastewater Flow Components Recorded at Meter C7-377

6.0 MODEL SCENARIOS

The City's existing collection system model was originally prepared as part of the 2007 Wastewater Facilities Master Plan Update work. At that time only sewers that were equal to or larger than 18-inch in diameter were included in the model. As part of this work, the model was updated to incorporate some of the smaller sewers in the areas of the City where the flooding occurred, primarily in the Deadmans Run, Havelock, Little Salt and East Campus basins. These smaller sewers were included in these areas to allow the model to more closely mimic the actual conditions.

Additionally, the influent pump curves at both wastewater treatment facilities were included as well as the overflow weir and 54-inch pipeline at the Theresa Street Facility.

6.1 Modeled Sewer and Diversion Structure Conditions

The updated model was used to simulate the observed conditions for the September 30 through October 1, 2014 storm event. The model was run in the continuous simulation mode for a modeled period of 420 hours.

Based on the results of the simulation, the observed overflows and flooding are generally in the same locations as the observed overflow locations that were provided by the City (Appendix B). These surcharged conditions in the interceptors caused the observed backups and overflows on smaller lines in the area. The backups and overflows were caused by the surcharged conditions in the trunk sewers, which extended up into the smaller sewers. The model was run in three different configurations as outlined below.

1. The gate to the Northeast WWTF open and the gate to Theresa Street WWTF was in the closed position. (See Figure 6a)
2. Both gates were open. (See Figure 6b)
3. The gate to the Northeast WWTF Closed and the gate to Theresa Street WWTF in the open position. (This is the position that the gates were in during the storm event. (See Figure 6c)

In all three scenarios flooding occurred, with variations of flooding intensity and location based on the gate position.

6.2 Modeled Results of the Influent Wetwell Overflow Weir and Discharge Piping

The operation of the overflow weir, 54-inch overflow piping and flap gate were modeled. The flow over the weir was modeled based on operating data provided by the City with the assumption that the headloss through the bar screen was 2 feet. The water level in the stream was based on USGS information obtained at the 27th street bridge. Two modeling scenarios were run. The first was based on the stream elevation that was reported during

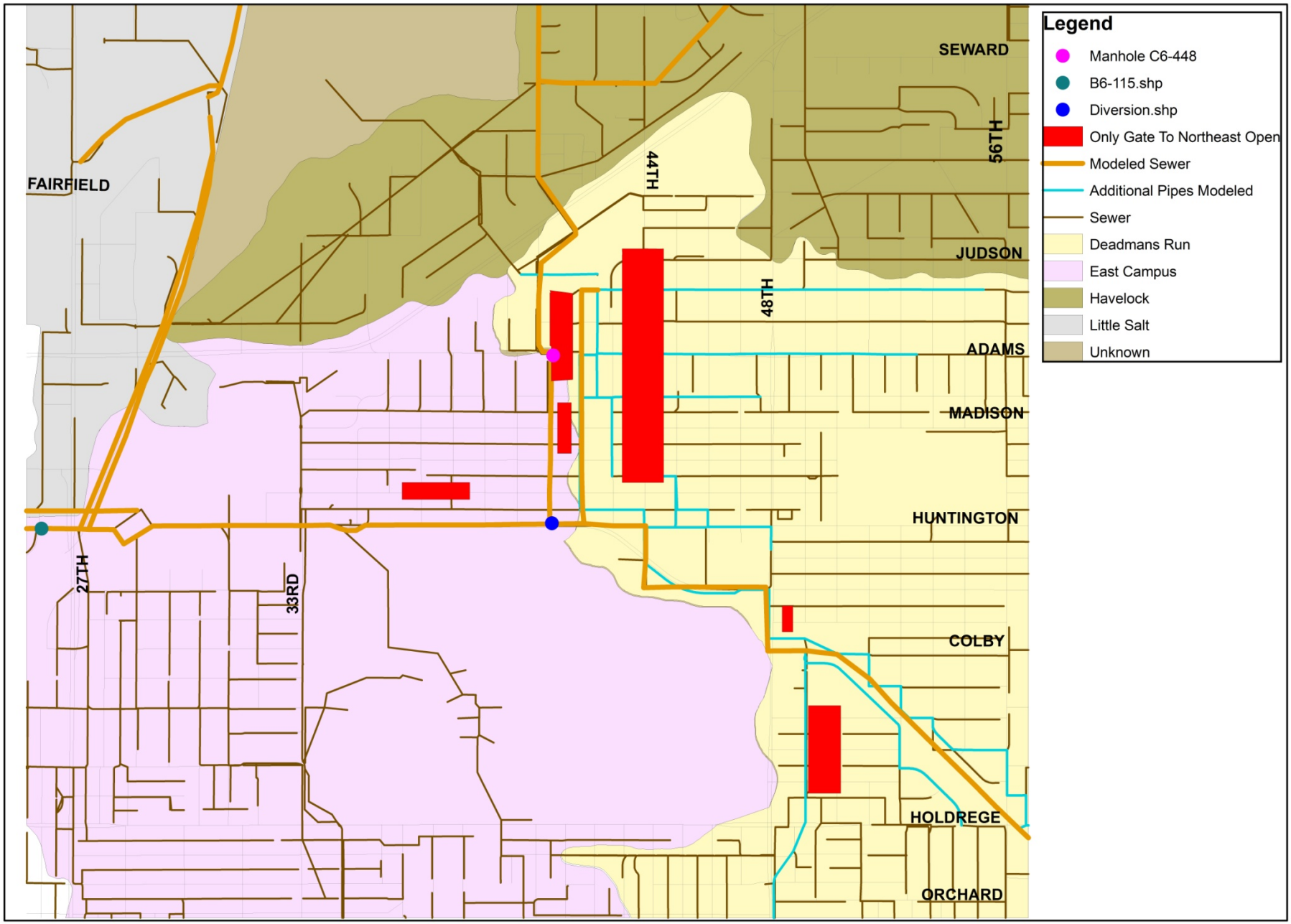


Figure 6a – Gate to Northeast WWTF Open, Gate to Theresa Street WWTF Closed

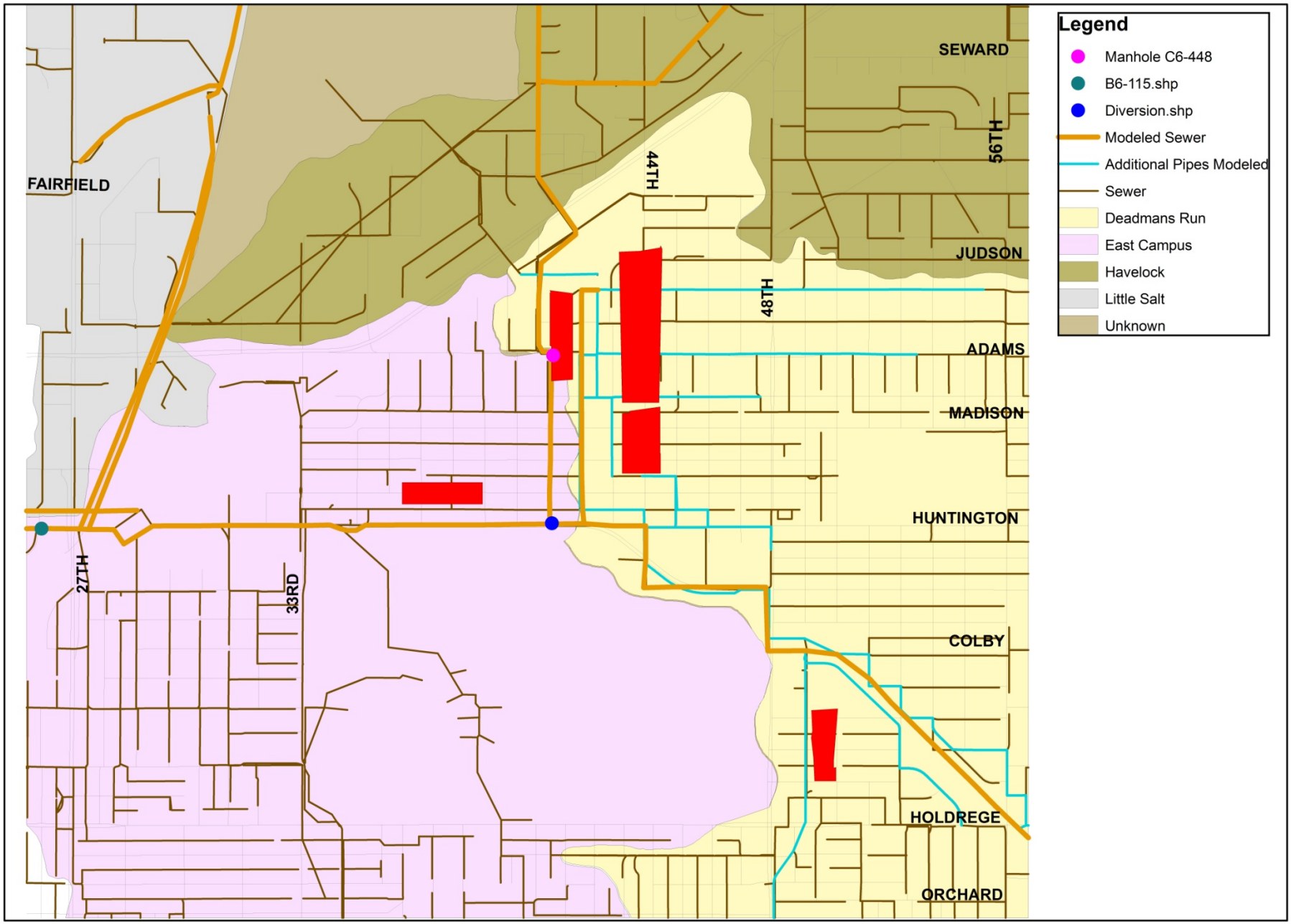


Figure 6b – Gates to Both Northeast WWTF and Theresa Street WWTF Open

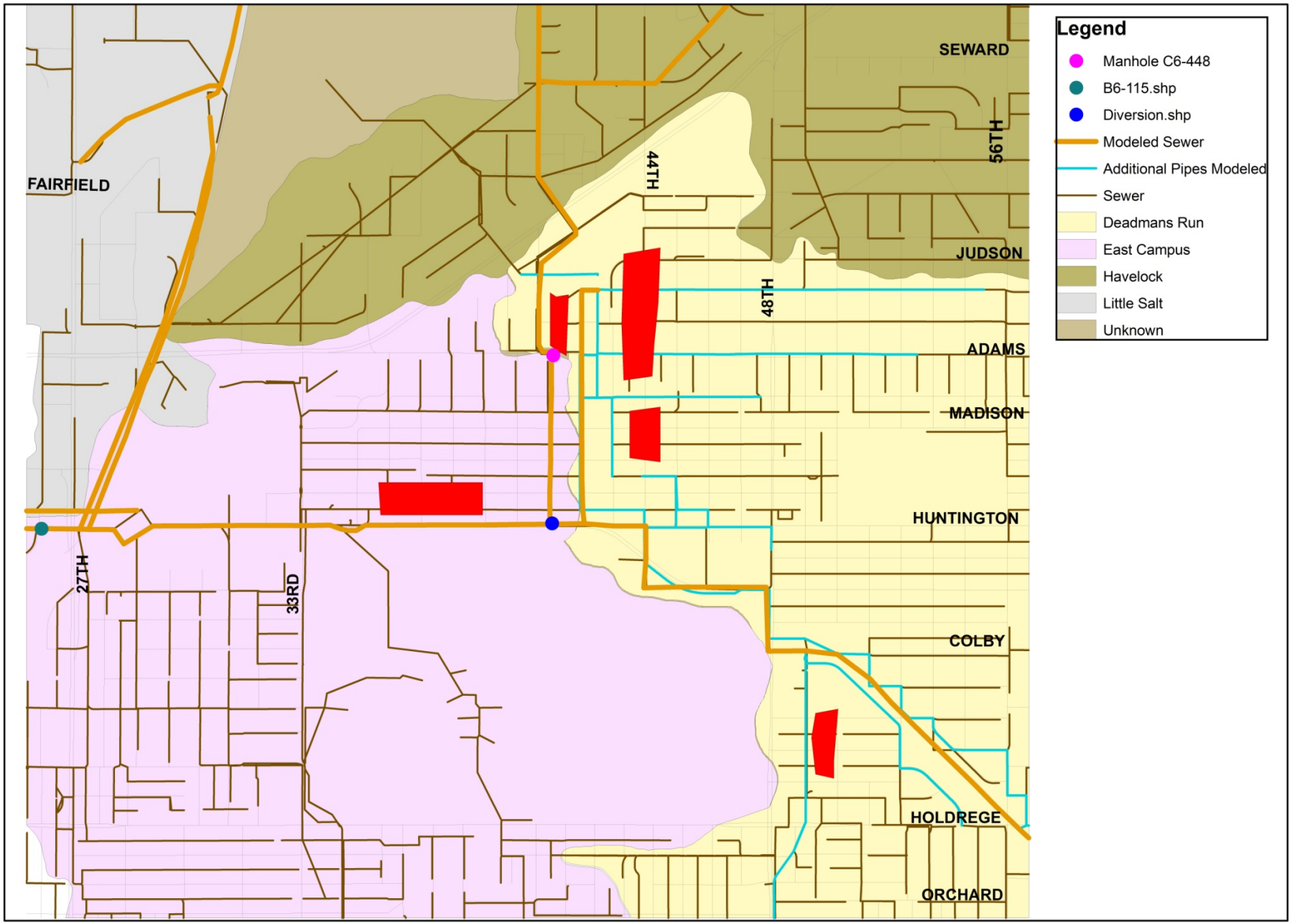


Figure 6c – Gate to Northeast WWTF Closed, Gate to Theresa Street WWTF Open

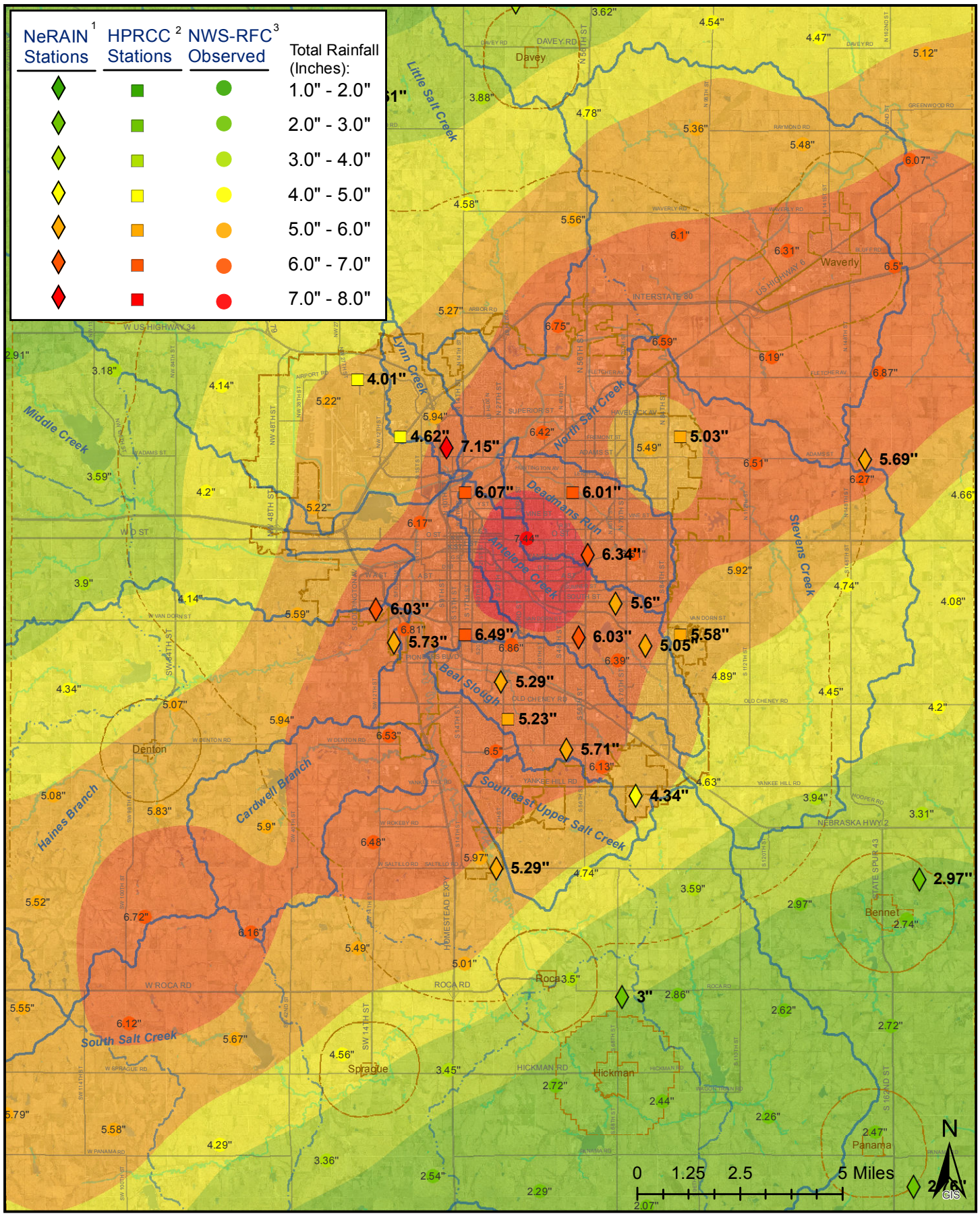
the flooding event of 1134.9 ft. During the model run 12.9 to 14.5 mgd passed over the weir and into the stream. The potential for flooding was observed in the model upstream from the Theresa Street influent structure.

The second model run was based on the stream level being at 1130 ft. which is lower than the weir in the structure, or about 5 feet lower than the previous model run. During the model run 12.5 to 14.0 mgd passed over the weir and into the stream. The potential for flooding was also observed during this model run.

7.0 SUMMARY OF FINDINGS

- The City has a very conservative approach for sizing sanitary sewers using the City's Design equation.
- The storm event was in excess of a 100 year storm. Most sewer systems in the Midwest, are designed for a 10 year storm.
- The modeling did not reveal that the position of the slide gates at Diversion Structure C6-194 caused or increased the flooding conditions.
- The overflow weir system and the Theresa Street WWTF Influent Structure could not have prevented the flooding due to the high water level in the creek.

APPENDIX A – STORM RAINFALL TOTALS



1 - Day Observed Precipitation for October 1st, 2014 - Lincoln, NE

"Heat Map" based on NWS River Prediction Center's Observed Data

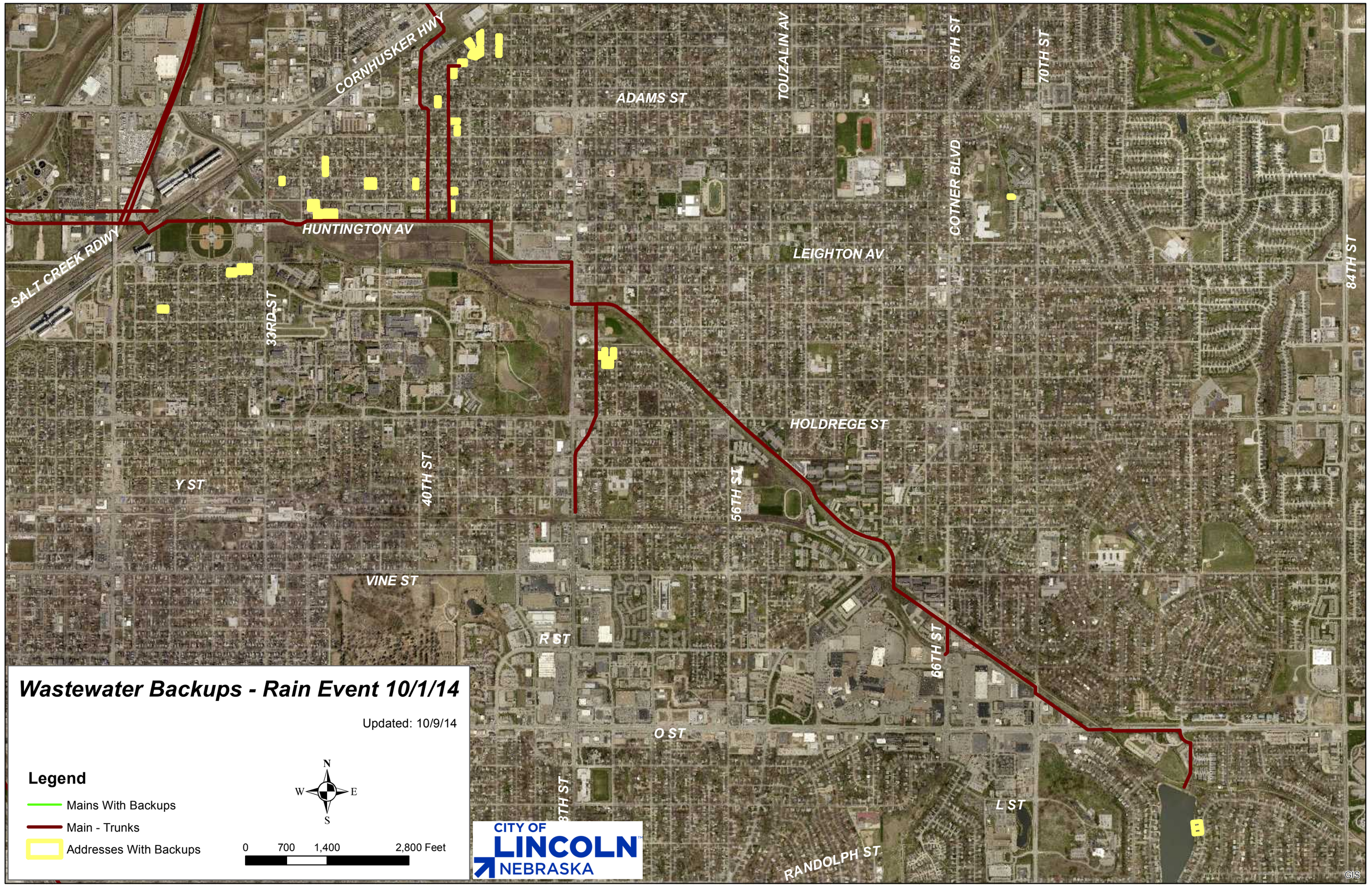
Data Sources:

1) Nebraska Rainfall Assessment and Information Network: Rain Gauge Data [NeRAIN Stations].
2) High Plains Regional Climate Center - Automated Weather Data Network (AWDN) & National Weather Service Cooperative Network (NWS Coop): Rain Gauge Data [HPRCC Stations].
3) National Weather Service (NWS) - River Forcast Center (RFC): "Observed" Grid Data generated from NEXRAD Radar and Rain Gauge Estimates [NWS-RFC Observed].

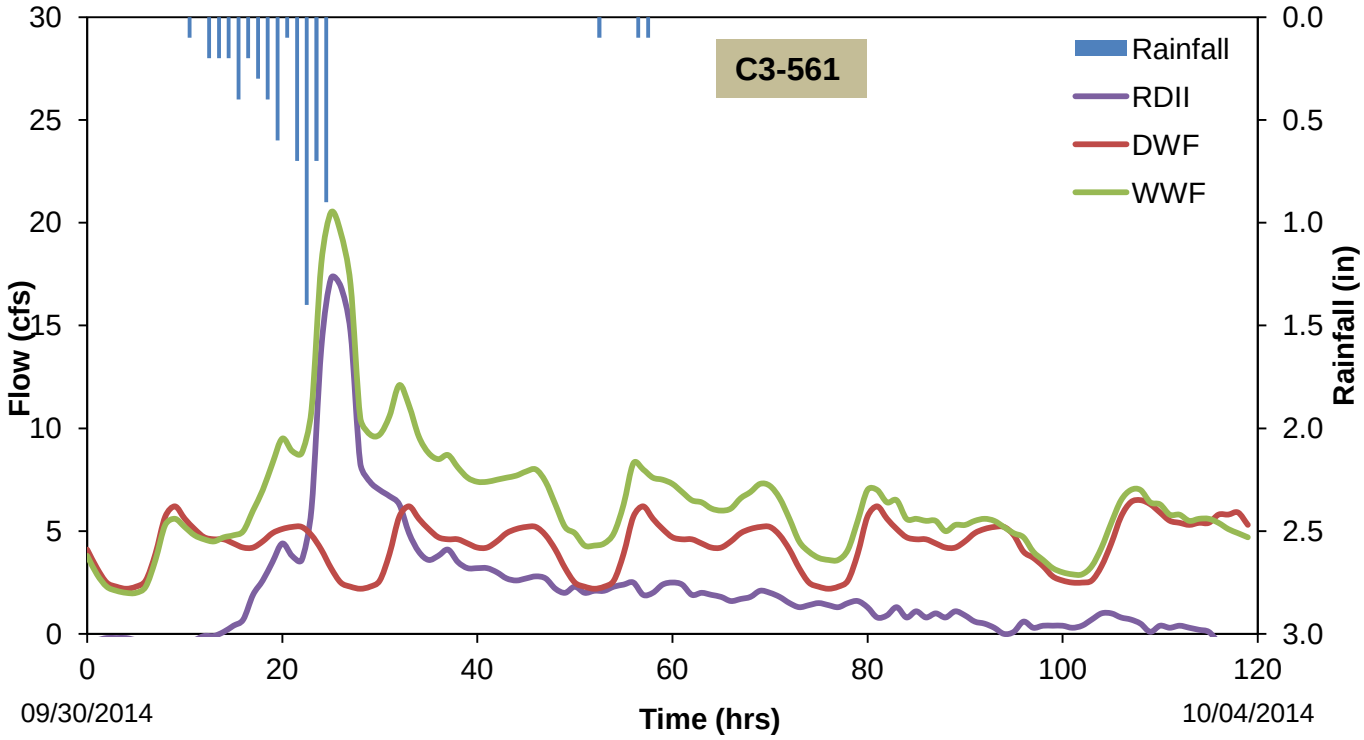
CITY OF LINCOLN Public Works & Utilities WATERSHED MANAGEMENT

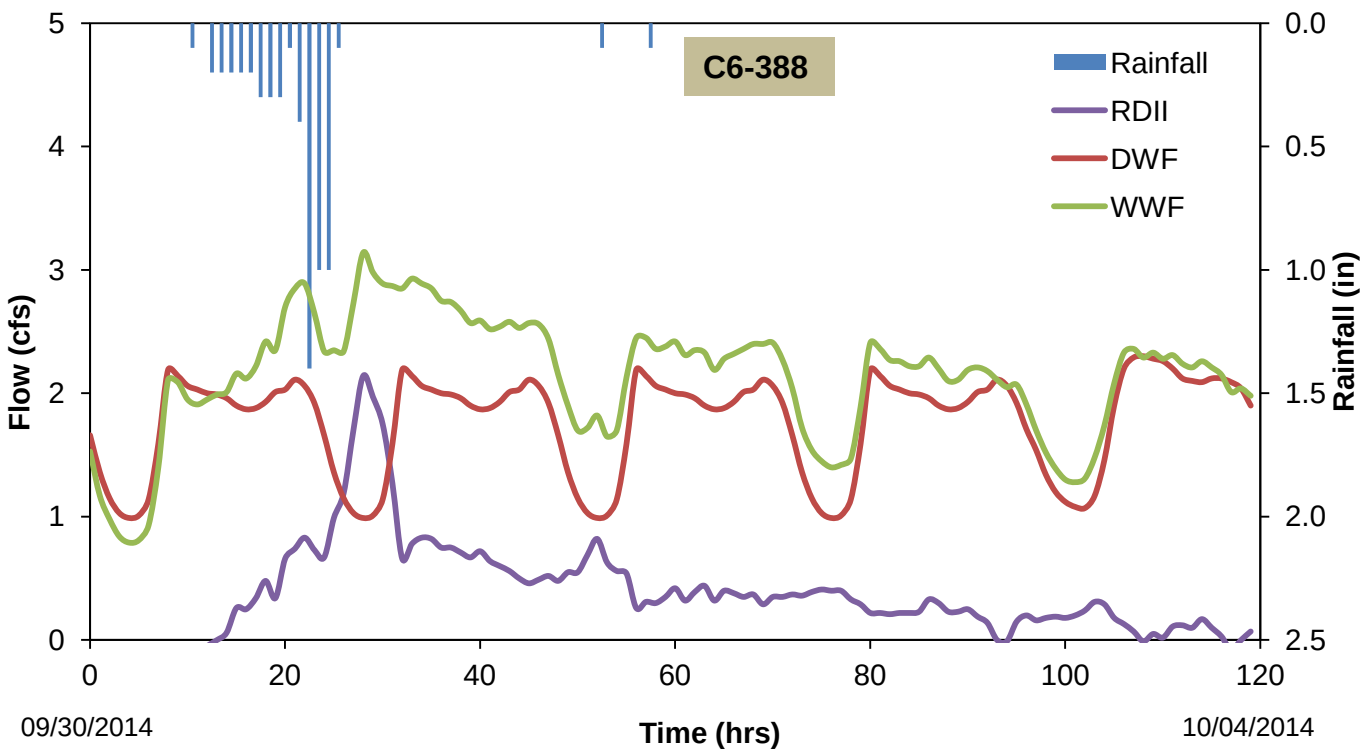
Last Updated: 10/1/2014, WSMJLN, Public Works, City of Lincoln

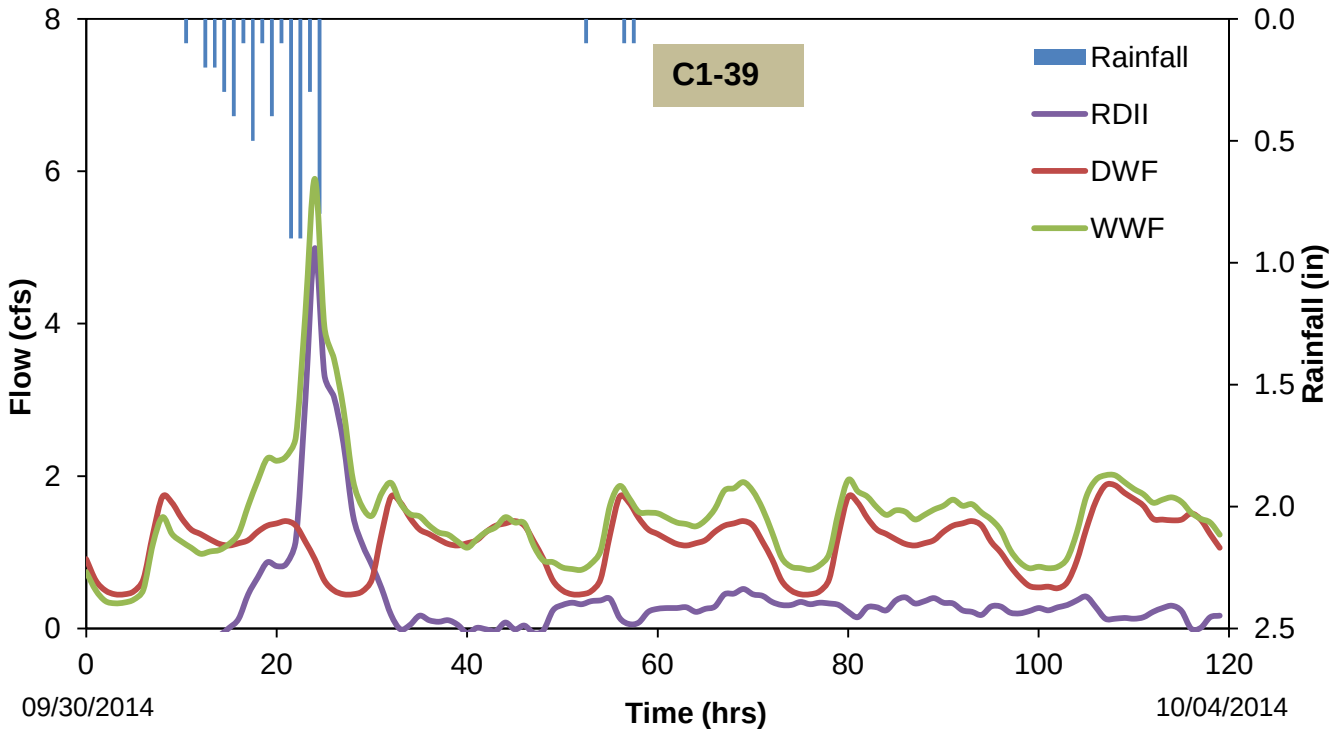
APPENDIX B – WASTEWATER BACKUPS

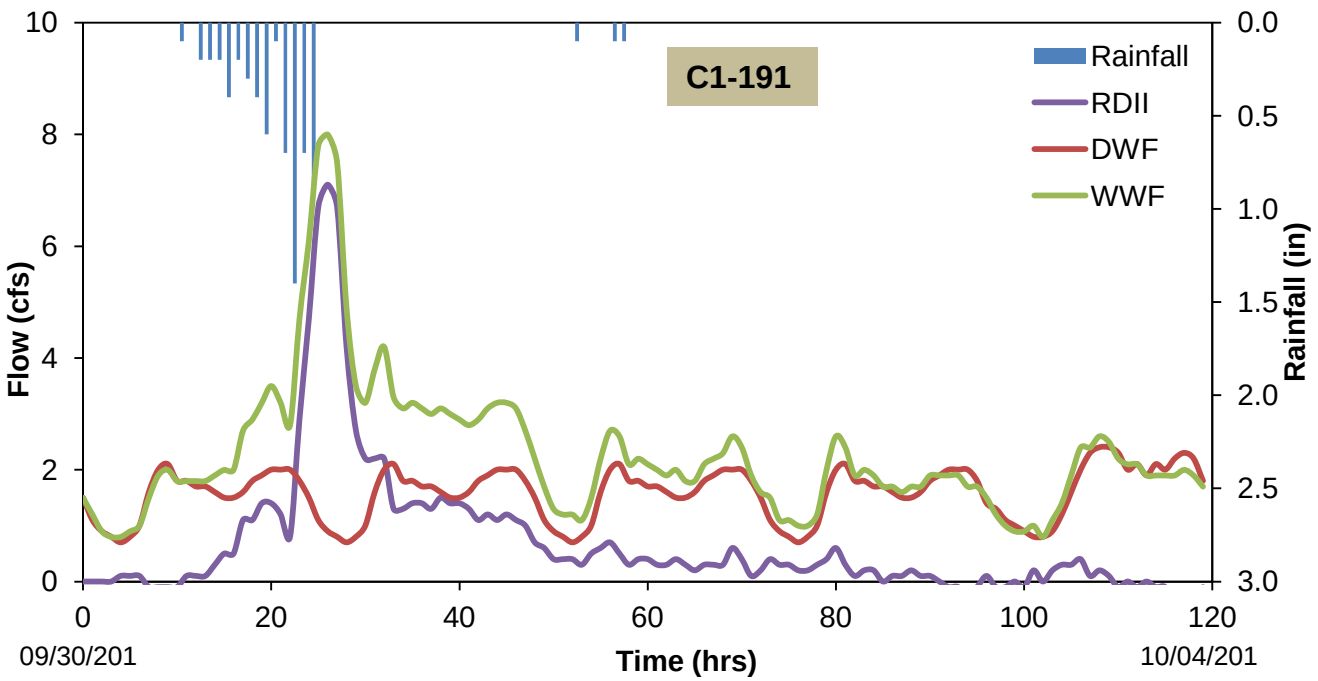

Wastewater Backups - Rain Event 10/1/14
Updated: 10/9/14
Legend
Mains With Backups
Main - Trunks
Addresses With Backups
N
W
E
S
0
700
1,400
2,800 Feet
CITY OF
LINCOLN
NEBRASKA
CORNHUSKER HWY
ADAMS ST
TOUZALIN AV
66TH ST
70TH ST
COTNER BLVD
HUNTINGTON AV
LEIGHTON AV
SALT CREEK RDWY
33RD ST
84TH ST
HOLDREGE ST
40TH ST
56TH ST
Y ST
VINE ST
R ST
66TH ST
O ST
L ST
RANDOLPH ST

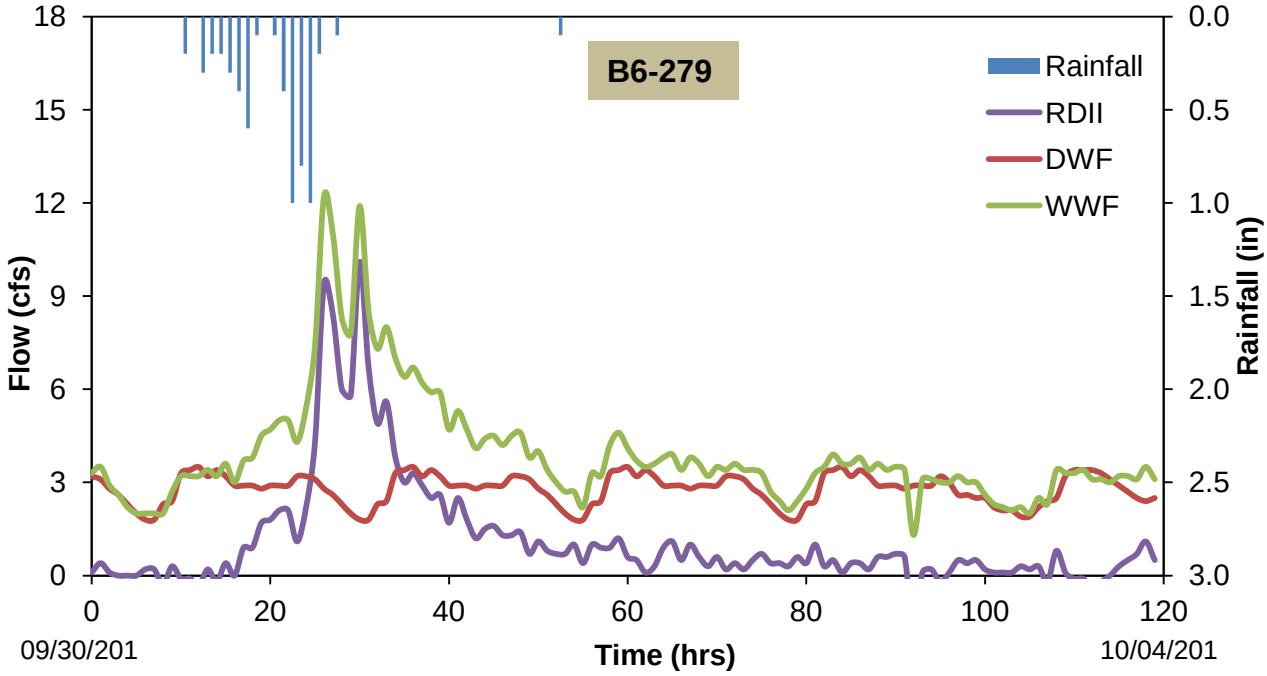
APPENDIX C – WASTEWATER FLOW COMPONENTS BY METER LOCATION

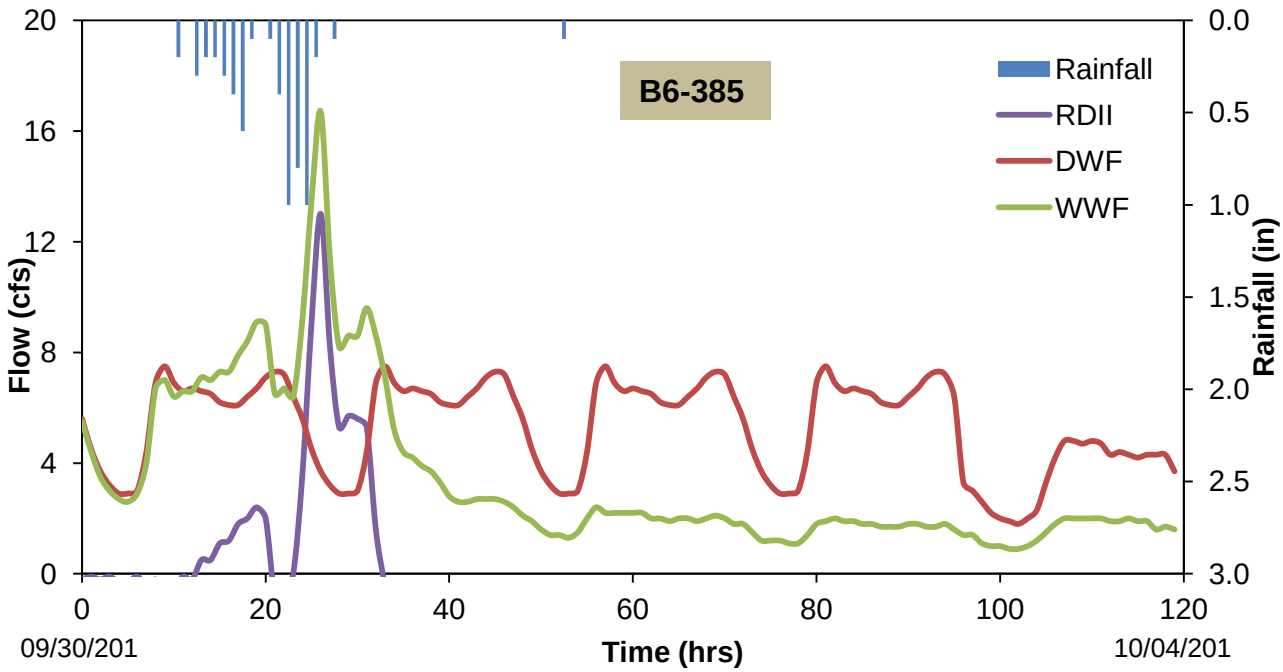

C3-561
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/2014
10/04/2014
0
5
10
15
20
25
30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120

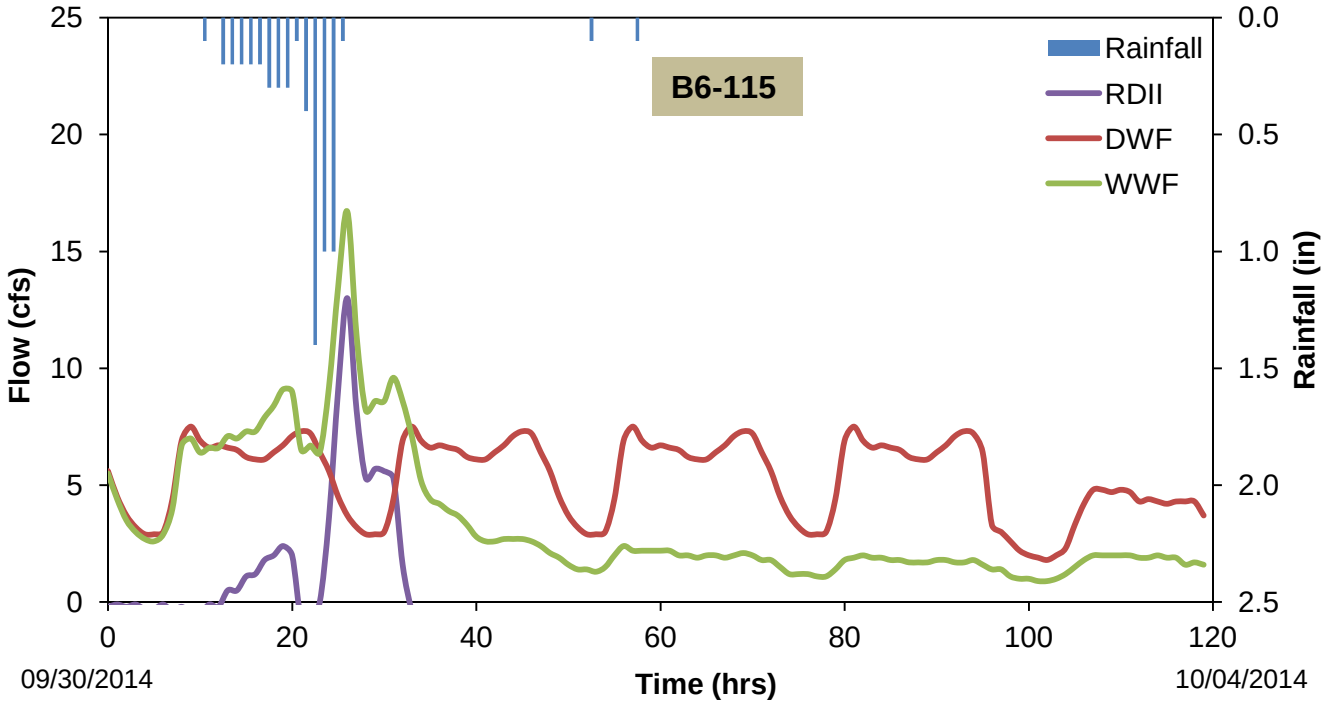

C6-388
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/2014
10/04/2014
0
1
2
3
4
5
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120

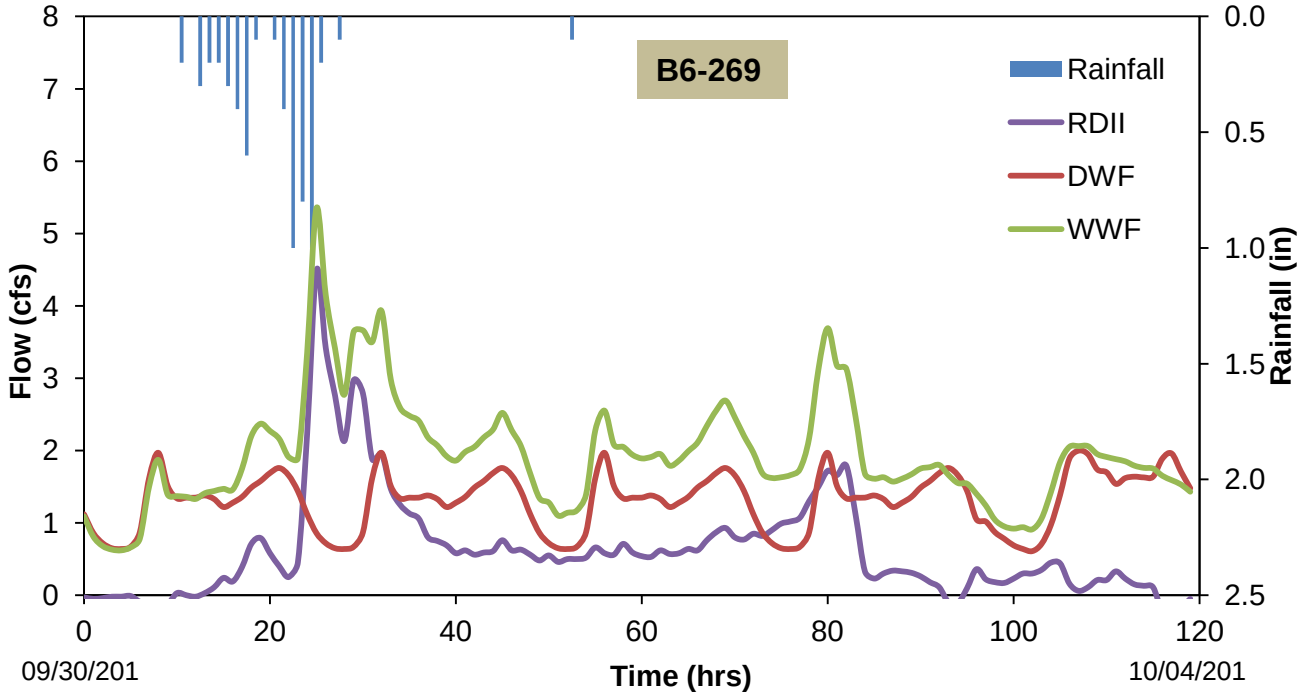

C1-39
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/2014
10/04/2014
0
2
4
6
8
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120

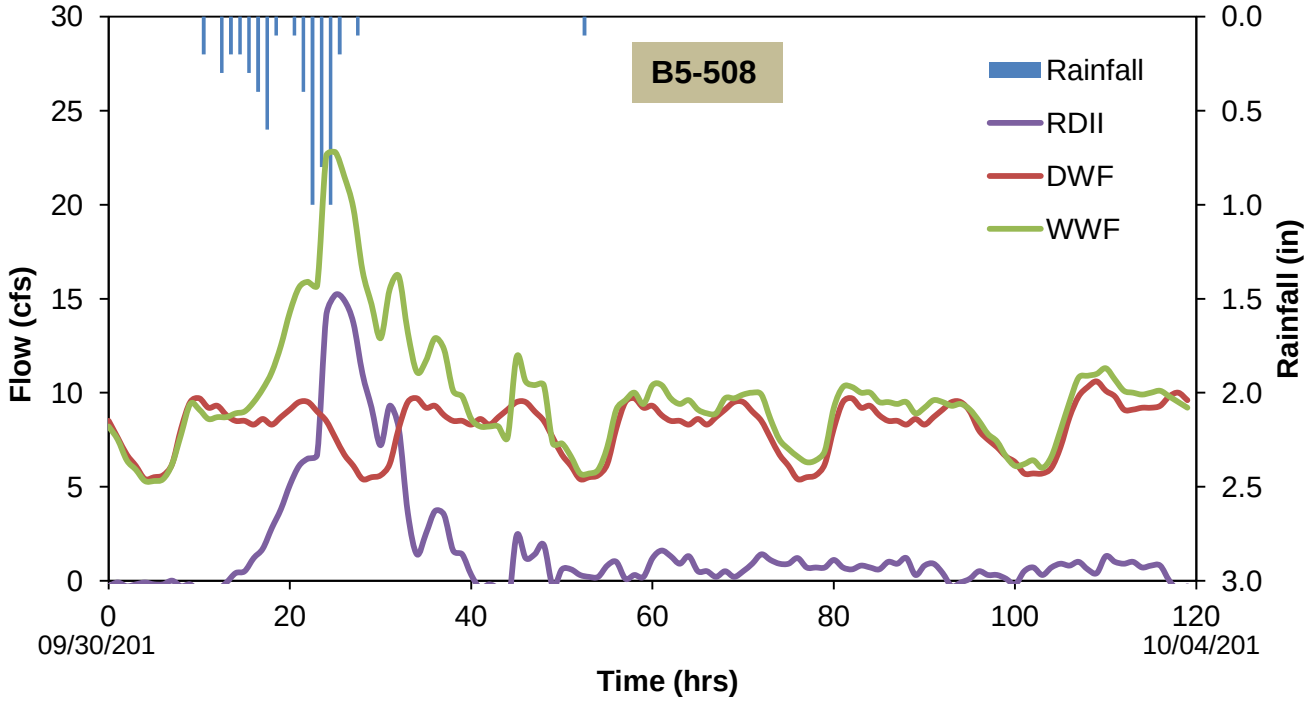

C1-191
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
2
4
6
8
10
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120

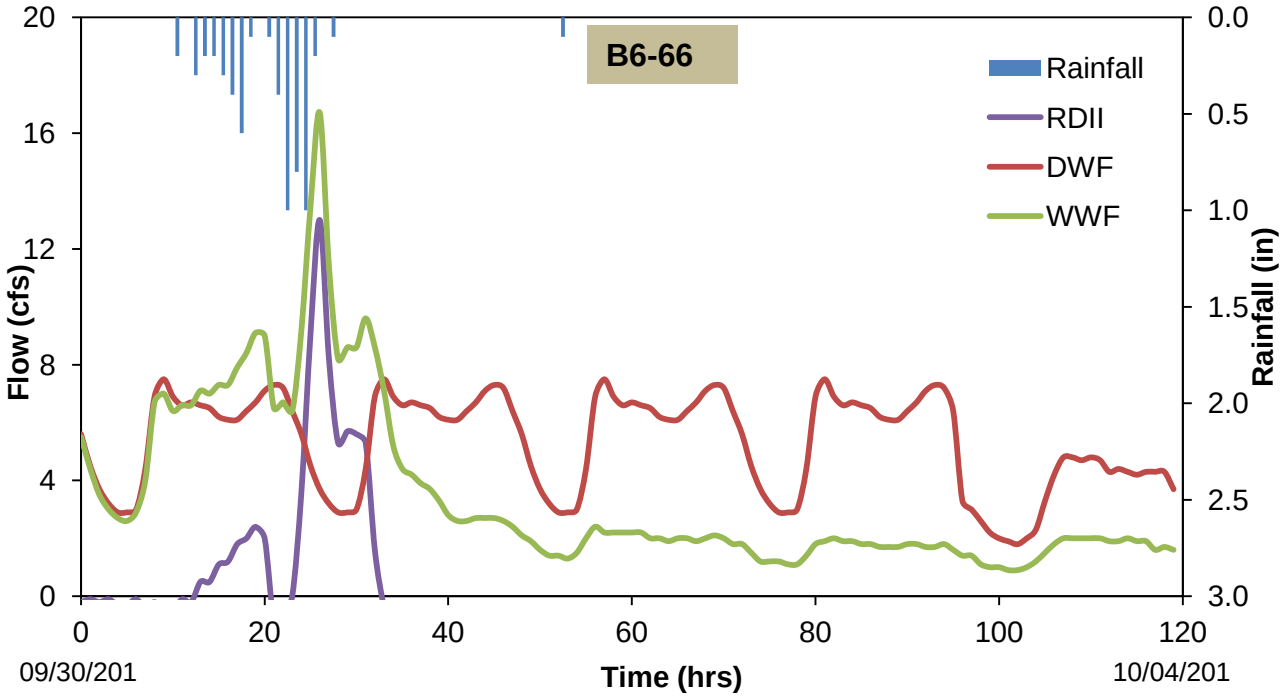

B6-279
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
3
6
9
12
15
18
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120

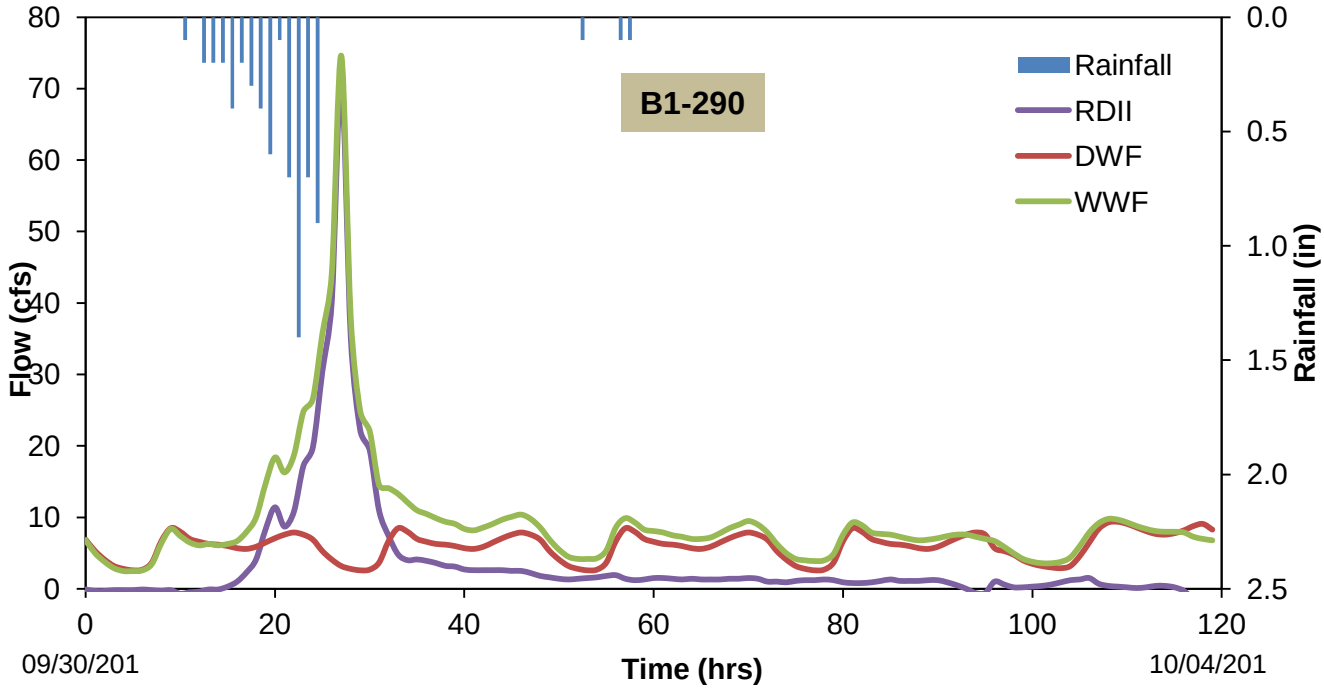

B6-385
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
4
8
12
16
20
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120

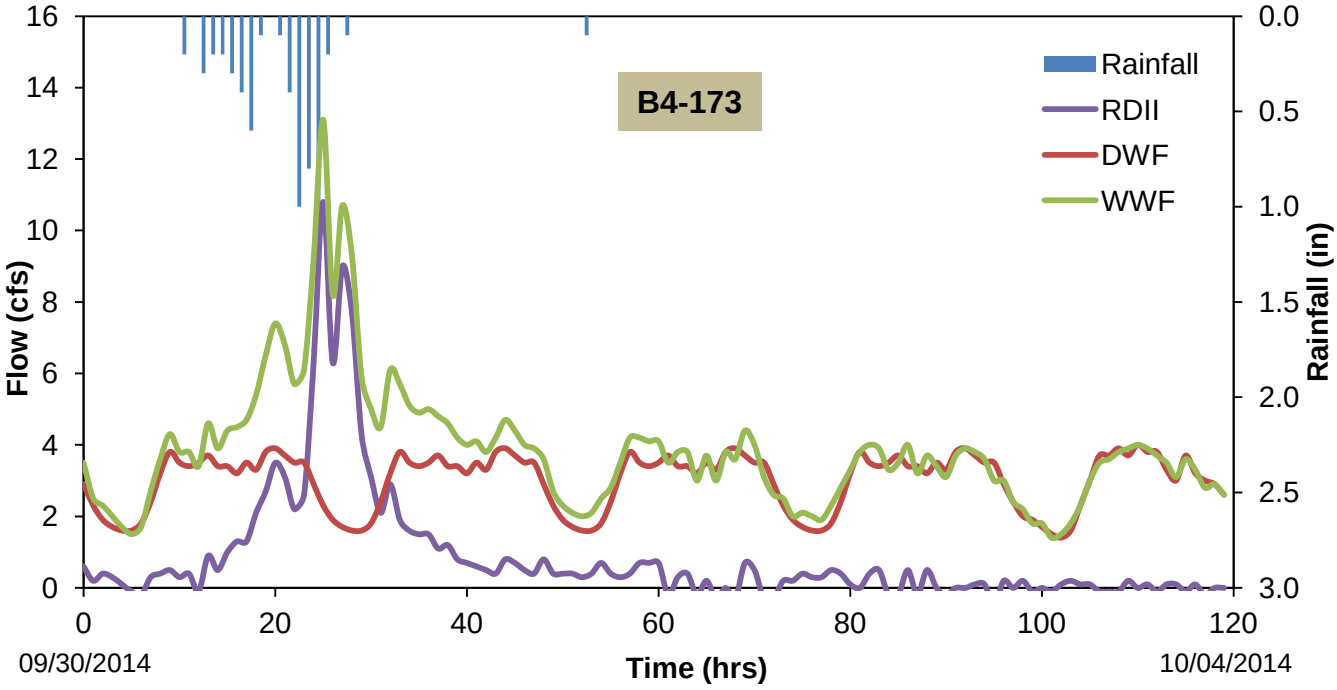

B6-115
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/2014
10/04/2014
0
5
10
15
20
25
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120

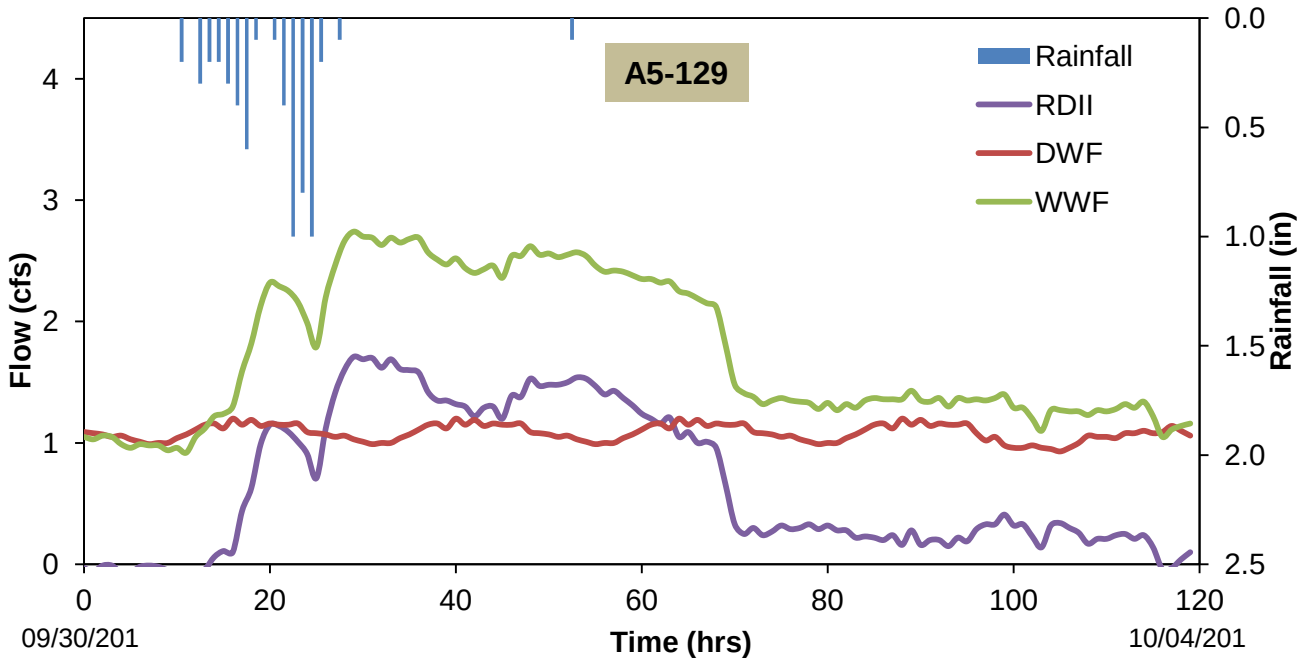

B6-269
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
1
2
3
4
5
6
7
8
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120

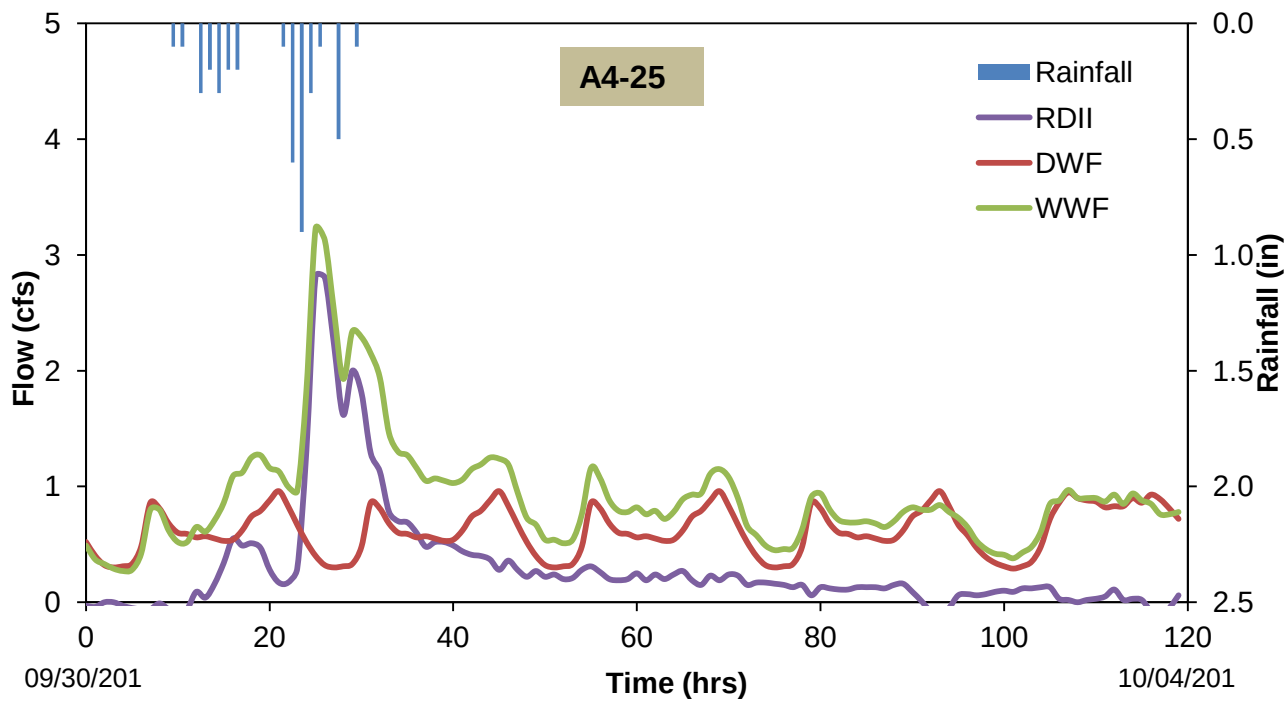

B5-508
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
5
10
15
20
25
30
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120

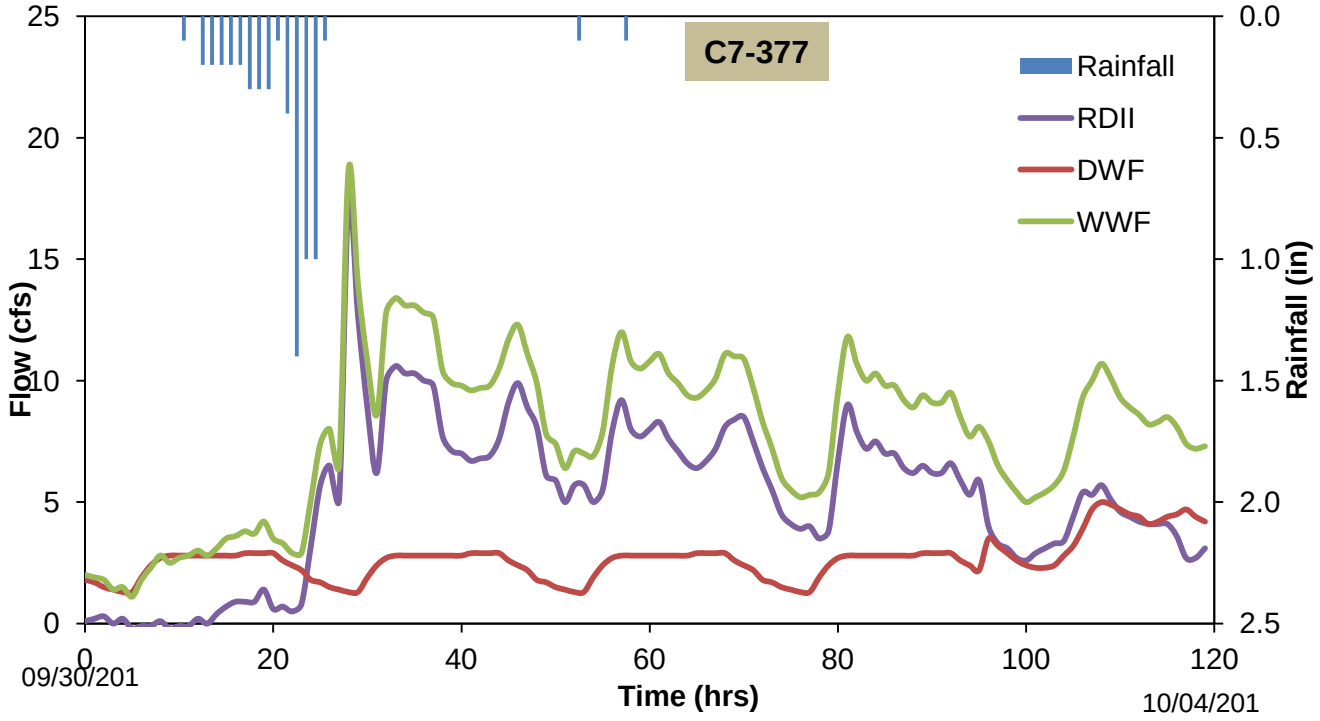

B6-66
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
4
8
12
16
20
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120


B1-290
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
10
20
30
40
50
60
70
80
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120


B4-173
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/2014
10/04/2014
0
2
4
6
8
10
12
14
16
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
20
40
60
80
100
120


A5-129
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
1
2
3
4
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120


A4-25
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
09/30/201
10/04/201
0
1
2
3
4
5
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120


C7-377
Rainfall
RDII
DWF
WWF
Flow (cfs)
Rainfall (in)
Time (hrs)
25
20
15
10
5
0
0.0
0.5
1.0
1.5
2.0
2.5
0
20
40
60
80
100
120
09/30/201
10/04/201