# Lauderdale Drive Drainage Study
# Final Report

## University of Wisconsin – Whitewater
## City of Whitewater, Wisconsin

**Department of State Facilities Project Number: 08G3J**

**Date Submitted: March 16, 2010**

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## EXECUTIVE SUMMARY

This report summarizes the methodology and results for the evaluation of improvement alternatives to the Lauderdale Drive storm sewer system and drainage areas on the University of Wisconsin – Whitewater campus. Flooding has occurred every year or two on Lauderdale Drive since the construction of the parking lots north of Tutt Hall and Wellers Hall in 1996. The goal of this project is to determine the cause of the flooding and present alternatives to mitigate flooding.

The hydraulic analysis of the Lauderdale Drive storm sewer system indicates that the system does not have sufficient capacity to convey a 10-year rainfall event. The analysis shows that water backs up from the inlets at a low point along Lauderdale Drive, east of Prairie Street, in front of Tutt Hall.

This report presents an evaluation of six improvement alternatives to reduce surcharging in the storm sewer system and to mitigate the flooding on Lauderdale Drive. The alternatives could be considered as stand-alone projects or combined with other alternatives to achieve a greater reduction of flooding of the street.

- Alternative 1 - Replace the existing 42-inch storm sewer pipe that discharges to Whitewater Creek with a 60-inch pipe.
- Alternative 2 - Divert the runoff from Drainage Subareas 4 and 8 away from the Lauderdale Drive storm sewer system and to the Starin Road storm sewer system.
- Alternative 3 - Divert the runoff from Drainage Subareas 13 and 14 away from the Lauderdale Drive storm sewer system and to the wetland complex north of Schwager Road and west of Fremont Street.
- Alternative 4 – Replace the existing 60-inch storm sewer in Lauderdale Drive, from Whitewater Creek to North Prairie Street, with a 72-inch storm sewer.
- Alternative 5 – Add storm inlets at the low point in Lauderdale Drive.
- Alternative 6 – Raise a portion of Lauderdale Drive in the low area and create an overland flow path to the north.

The six alternatives were evaluated for effectiveness at reducing flooding, potential impacts on other areas of the campus, and cost. Combinations of some of the alternatives were also evaluated.

The most cost effective combination was Alternative 1, upsizing of the 42-inch sewer to 60-inch sewer, and Alternative 6, creating an overland flow path from the low point. Alternative 1 increased the capacity of the Lauderdale Drive storm sewer system, while Alternative 6 reduced the maximum flooding depth in Lauderdale Drive from 1.5 feet to 0.5 feet. The estimated construction cost for the combination of Alternatives 1 and 6 is $132,000.

Alternative 2, Diversion to the Starin Road storm sewer system, was more costly, and could result in negative impacts to the Starin Road storm sewer system. Alternative 3, Diversion to the north wetland area was more costly, and only reduced the frequency, not the severity of flooding on Lauderdale Drive. Alternative 4, Replace 2,314 feet of 60-inch storm sewer, was effective at eliminating flooding, but was cost prohibitive. Alternative 5, Additional inlet capacity, did not reduce the frequency or severity of flooding on Lauderdale Drive.

It is recommended that a design of the combination of Alternatives 1 and 6 be prepared and constructed, as the most cost effective solution to flooding on Lauderdale Drive.

Flooding at Tutt Hall and Wellers Hall does not appear to be directly related to surcharging of the Lauderdale Drive storm sewer system, or flooding on Lauderdale Drive. The buildings are 50 feet south of the roadway flooding area, with first floor elevations that are 2.48 and 12.38 feet respectively above the high water elevation on Lauderdale Drive. It is possible that the surcharging of the Lauderdale Drive storm sewer system is causing a backup in the roof drainage or sump pump

systems of the building.

An additional investigation at Tutt Hall was conducted in September 2009. Discussions with University maintenance staff, and a visual inspection of the sump pump room and the area around the west building entry provided additional information regarding the flooding problems. Two issues were identified: excess flow to the sump pumps during rainfall events, leading to flooding in the building; and surface flooding around the west entrance, due to inadequate storm sewers and changes to the surface grading. The sump pump problem was also attributed to Wellers Hall.

Disconnection of several roof drain connections, and creation of two rain garden areas, at an estimated construction cost of $67,400 is recommended to address the sump pump issue at Tutt Hall and Wellers Hall. Modification to the storm sewer system and installation of a new overland flow path, at an estimated construction cost of $14,100 is recommended to address the flooding problems at the west entrance to Tutt Hall.

## INTRODUCTION

The University of Wisconsin – Whitewater has experienced flooding in the northeast section of the campus, adjacent to Lauderdale Drive. The lower level of Tutt Hall was flooded three times and Wellers Hall flooded once in the summer of 2008. The water level on Lauderdale Drive and the adjacent parking lot (Lot 19) was high enough to damage cars parked at metered stalls along Lauderdale Drive, reaching depths up to about 19 inches. The purpose of this report is to present alternatives for mitigation of the flooding that occurs in the Lauderdale Drive drainage basin.

## SCOPE OF STUDY

The scope of this project is to examine the existing conditions of the Lauderdale Drive storm sewer system drainage area and determine how to effectively mitigate the storm sewer surcharging, and flooding on Lauderdale Drive. A hydrologic model was prepared using TR-55 methodology to determine peak flow rates. A hydraulic model was prepared using StormCAD by Haestad Methods to identify deficiencies in the storm sewer system. The StormCAD model was used to test potential storm sewer system improvements. Inlet capacity of the six existing structures at the location of the flooding along Lauderdale Drive was analyzed using the Neenah Foundry Weir and Orifice equation to determine if inlet capacity was a contributing factor to the flooding occurrences.

Six improvement alternatives were evaluated for effectiveness, feasibility and construction cost. The improvement alternatives are as follows:

- Alternative 1 - Replace the existing 42-inch storm sewer pipe that discharges to Whitewater Creek with a 60-inch pipe.
- Alternative 2 - Divert the runoff from Drainage Subareas 4 and 8 away from the Lauderdale Drive storm sewer system and to the Starin Road storm sewer system.
- Alternative 3 - Divert the runoff from Drainage Subareas 13 and 14 away from the Lauderdale Drive storm sewer system, to the wetland complex north of Schwager Road and west of Fremont Street.
- Alternative 4 – Replace 60-inch storm sewer in Lauderdale Drive from Whitewater Creek to North Prairie Street with a 72-inch sewer.
- Alternative 5 – Add storm inlets at the low point in Lauderdale Drive.
- Alternative 6 – Raise a portion of Lauderdale Drive in the low area and create an overland flow path to the north.

The six alternatives were evaluated for effectiveness at reducing flooding, potential impacts on other areas of the campus, and cost. Combinations of some of the alternatives were also evaluated.

An investigation of the flooding issues at Tutt Hall and Weller Hall was also conducted after it was concluded that surface flooding in Lauderdale Drive was not causing the flooding problems reported for these buildings.

## LOCATION OF STUDY AREA

The Lauderdale Drive storm sewer is located on the University of Wisconsin - Whitewater campus in the City of Whitewater in south central Jefferson and northwest Walworth Counties. The drainage basin extends roughly from the intersection of CTH N and West Starin Road northerly to Perkins Stadium and easterly to North Fremont Street. The drainage subareas are roughly enclosed by CTH N, West Starin Road, Schwager Drive, and North Fremont Street. Figure 1 shows the site location.

## GENERAL DRAINAGE BASIN CHARACTERISTICS

The drainage basin for the Lauderdale Drive storm sewer system is 149.5 acres, of which approximately 30 percent is impervious. It contains buildings, roadways, sidewalks, and parking lots along with several athletic fields and landscaped areas. Relatively steep slopes on the pervious areas

of the basin rapidly convey storm water runoff to the basin low point on Lauderdale Drive, just north of Tutt Hall and Wellers Hall. A 60-inch storm sewer pipe begins by the athletic fields and runs down the hill to Lauderdale Drive to North Fremont Street. This 60-inch pipe continues east of North Fremont Street where it changes to a 42-inch pipe before discharging into Whitewater Creek. The discharge point is ½-mile east of the flooding location. Figure 2 shows the drainage basin and subareas, and the site topography.

## LOCATION OF EXISTING FLOODING

Flooding in the Lauderdale Drive drainage basin occurs just north of Tutt Hall and Wellers Hall, along Lauderdale Drive. This flooding has occurred every year since 1996, when the parking lots north of Lauderdale Drive were built. Figure 3 shows an outline of where the flooding occurs along Lauderdale Drive and north into Lot 19. The maximum depth of this flooding is about 19 inches based on the lowest elevation of the ridge line in parking lot 19 (815.52) and the inlet low point in Lauderdale Drive (814.00). The first floor elevations of Tutt Hall and Wellers Hall are 818.00 and 827.90, respectively. The lowest elevation along the northwest side of Tutt Hall is at an inlet with an elevation of 817.36 and along the building at an elevation of 817.96 which are 1.74 and 2.34 feet, respectively, above the high water elevation in Lauderdale Drive. The lowest elevation along the north side of Wellers Hall is 817.87, which is 2.27 feet above the high water elevation in Lauderdale Drive. The building floors are above the estimated high water elevation, so it appears the flooding at the buildings is not directly due to the flooding in Lauderdale Drive.

## INLET CAPACITY

The flooding location in Subarea 18 is the low point of the subarea and a low point in the drainage basin. This location has six inlets that primarily drain the overland flow from the south end of Lot 19 and from the north sides of Tutt Hall and Wellers Hall. The inlets consist of four curb inlets and two area inlets. The area that is tributary to these inlets produces approximately 24 cfs of runoff during the 10-year storm event. An inlet capacity analysis was performed for the inlets using the Neenah Foundry Weir and Orifice equation spreadsheet. It was calculated that each inlet grate could handle 5.4 cfs, using a 0.5 foot depth of water along the curb and ponding depth at the area inlets. It appears that the inlets in this area provide enough capacity to accommodate the runoff from a 10-year storm event without spilling over the curb.

## HYDROLOGIC ANALYSIS

Peak runoff rates for use in the drainage analysis were computed using NRCS's TR-55 and TR-20 methodologies, as implemented by PondPack Version 10 software by Haestad Methods. Runoff rates were determined for the following rainfall recurrence interval and distribution:

- 10-year storm recurrence interval with a 24-hour SCS Type II rainfall distribution.

Rainfall depths for the hydrologic analysis were taken from the Field Office Technical Guide (FOTG) published by the USDA Natural Resources Conservation for the SCS Type II distribution. A 24-hour rainfall depth of 4.1 inches was used for this analysis.

The drainage basin was divided into 21 subareas based on topography and the configuration of the storm sewer system to determine peak runoff rates. Ground cover was determined for each subarea using a combination of topographic survey data provided by Jefferson County and Walworth County and aerial photography provided by the 2005 National Agricultural Imagery Program (NAIP). Soil types for the site were determined from the NRCS soil survey for Jefferson and Walworth Counties. Soils at the site are predominantly Hydrologic Soil Group B with some C soils present at lower elevations. See Appendix A for the NRCS Soil Survey data. See Appendix B for inputs to the hydrologic model including area, curve number, and time of concentration.

Table 1 shows the peak flow rates from the hydraulic analysis used for the hydraulic modeling.

| Table 1 - Hydrologic Analysis Results<br>10 Year Storm, 24-hour SCS Type II Rainfall Distribution | |
|---|---|
| **Subarea** | **Peak Flow Rate** |
| 1 | 31.56 cfs |
| 2 | 4.94 cfs |
| 3 | 4.13 cfs |
| 4 | 37.20 cfs |
| 5 | 6.04 cfs |
| 6 | 3.76 cfs |
| 7 | 2.70 cfs |
| 8 | 6.94 cfs |
| 9 | 1.87 cfs |
| 10 | 0.68 cfs |
| 11 | 16.84 cfs |
| 12 | 1.82 cfs |
| 13 | 17.68 cfs |
| 14 | 12.63 cfs |
| 15 | 11.95 cfs |
| 16 | 2.75 cfs |
| 17 | 11.51 cfs |
| 18 | 42.36 cfs |
| 19 | 1.33 cfs |
| 20 | 10.88 cfs |
| 21 | 21.00 cfs |

## HYDRAULIC ANALYSIS

Storm sewer characteristics such as pipe sizes, invert elevations, and inlet tributary areas were taken from topographic survey data provided by Jefferson County and Walworth County and a field survey performed by GRAEF on January 7, 2009. Flows calculated from the hydrologic analysis were used to evaluate the hydraulic performance of the storm sewer system and determine system capacity. Runoff generated from the 10-year 24-hour storm events was used to determine the capacity of the system.

The performance of the storm sewer was analyzed using Bentley StormCAD V5.6. The model calculates the hydraulic grade line (HGL) for the system that is used to determine the water surface elevation. The profiles, included in Appendix C, show the ground surface, the hydraulic grade line, the water surface, and the energy grade line.

## BASE CONDITIONS

The hydraulic model for the base conditions showed the storm sewer system to be surcharged from just upstream of the outfall to the low point, just east of Lauderdale Drive and North Prairie Street. The storm sewer becomes much steeper west of this intersection, as does the grade, resulting in increased storm sewer capacity, and a return of the hydraulic grade line to within the pipe. Water would be backing up out of the inlets in the low area in front of Tutt Hall and Wellers Hall, flooding the roadway and parking lot area to a maximum depth of about 1.6 feet, at the inlets, and then overflowing northward across parking lot 19. Table 2 shows a summary of the storm sewer model for the base condition. Appendix C includes the water surface profiles and summary of the Storm CAD calculations for the base conditions.

**Table 2 – Hydraulic Analysis – Base Condition**

| LOCATION | FLOW | SIZE | INVERT ELEVATIONS | RIM ELEVATIONS | HYDRAULIC GRADE LINE |
|---|---|---|---|---|---|
| 99-Outlet | 240 CFS | 42-inch | 793.61 | 814.00 | 800.00 |
| MH5-Fremont St. | 219 CFS | 42-inch | 801.40 | 814.46 | 814.46+ |
| JNTN 20-Bend in Lauderdale Drive | 219 CFS | 60-inch | 804.60 | 830.11 | 824.38 |
| JNTN 19-Bend in Lauderdale Drive | 208 CFS | 60-inch | 806.50 | 825.12 | 825.12+ |
| JNTN 18-Between Tutt and Wellers | 206 CFS | 60-inch | 807.70 | 817.38 | 817.38+ |
| Low Point – in front of Tutt Hall | 165 CFS | 60-inch | 807.87 | 814.00 | 814.00+ |
| JNTN 17 – N. Prairie Street | 165 CFS | 60-inch | 808.60 | 817.77 | 815.40 |

+ Means that water is backing up from inlet or manhole.

## ALTERNATIVE ANALYSIS

Peak runoff rates from the 10-year storm were used to analyze the effectiveness of proposed improvement alternatives. Peak flow rates from the hydrological analysis were input to the storm sewer model to determine the peak hydraulic grade line in the sewer, and locations where the water level was higher than the manhole or inlet rim. The base conditions storm sewer model was modified for Alternatives 1, 2, 3, and 4 and various combinations of those alternatives, to determine the impact on the hydraulic grade line and manhole/inlet overflows. The model was not modified for Alternatives 5 and 6 because the actions called for in these alternatives do not impact the performance of the storm sewer system. Following is a description of the results of the modeling.

**Alternative 1 – Upsize 42-inch Sewer**

Alternative 1 involves removing approximately 234 feet of existing 42-inch pipe at the discharge to Whitewater Creek and replacing it with 60-inch pipe. Figure 4 shows this alternative. The new 60-inch pipe was modeled to remain at the existing 3.3 percent slope. Approximately 234 feet of 60-inch pipe would be installed from Manhole 5 to the discharge point in Whitewater Creek. A 60-inch apron end wall and grate would also be required.

Alternative 1 reduces the hydraulic grade line to within the pipe for the upsized section, but surcharging begins by the next manhole upstream, although it is less than under base conditions. Water would still be backing up out of the inlets in the low area in front of Tutt Hall and Wellers Hall, flooding the roadway to a maximum depth of about 1.6 feet. System performance upstream of the low area would not be changed by this alternative. The estimated construction cost for this alternative is approximately $55,000. Table 3 summarizes the hydraulic performance for this alternative. Appendix C includes the water surface profiles and a summary of the StormCAD calculations for Alternative 1.

**Table 3 – Hydraulic Analysis – Alternative 1**

| LOCATION | FLOW | SIZE | INVERT ELEVATIONS | RIM ELEVATIONS | HYDRAULIC GRADE LINE |
|---|---|---|---|---|---|
| 99-Outlet | 240 CFS | 60-inch | 793.61 | 814.00 | 800.00 |
| MH5-Fremont St. | 219 CFS | 60-inch | 801.40 | 814.46 | 806.20 |
| JNTN 20-Bend in Lauderdale Drive | 219 CFS | 60-inch | 804.60 | 830.11 | 814.88 |
| JNTN 19-Bend in Lauderdale Drive | 208 CFS | 60-inch | 806.50 | 825.12 | 820.77 |
| JNTN 18-Between Tutt and Wellers | 206 CFS | 60-inch | 807.70 | 817.38 | 817.38+ |
| Low Point – in front of Tutt Hall | 165 CFS | 60-inch | 807.87 | 814.00 | 814.00+ |
| JNTN 17 – N. Prairie Street | 165 CFS | 60-inch | 808.60 | 817.77 | 815.40 |

+ Means that water is backing up from inlet or manhole.

**Alternative 2 – Diversion to Starin Road Sewer**

Alternative 2 involves the diversion of Subarea 4 and Subarea 8 from the Lauderdale Drive drainage basin to the Starin Road storm sewer system. The discharge pipe to Whitewater Creek would remain a 42-inch pipe. Figure 5 shows this alternative. These diverted subareas will be piped from the intersection of Stadium Drive and Koshkonong Drive south to the existing storm sewer system at the intersection of Koshkonong Drive and West Starin Road. The storm sewer along West Starin Road from Koshkonong Drive to Prince Street would have to be upsized to a minimum of a 30-inch pipe and possibly a 36-inch pipe.

Alternative 2 reduces the hydraulic grade line in the entire Lauderdale Drive storm sewer system, but not enough to stop the back-up of water from the inlets at the low area, during a 10-year storm event. The impacts on the Starin Road storm sewer system would need to be evaluated to determine if this alternative was feasible. The estimated construction cost for this alternative is approximately $135,000. Table 4 summarizes the hydraulic performance for this alternative. Appendix C includes the water surface profiles and a summary of the StormCAD calculations for Alternative 2.

**Table 4 – Hydraulic Analysis – Alternative 2**

| LOCATION | FLOW | SIZE | INVERT ELEVATIONS | RIM ELEVATIONS | HYDRAULIC GRADE LINE |
|---|---|---|---|---|---|
| 99-Outlet | 197 CFS | 42-inch | 793.61 | 814.00 | 800.00 |
| MH5-Fremont St. | 176 CFS | 42-inch | 801.40 | 814.46 | 813.33 |
| JNTN 20-Bend in Lauderdale Drive | 176 CFS | 60-inch | 804.60 | 830.11 | 819.50 |
| JNTN 19-Bend in Lauderdale Drive | 165 CFS | 60-inch | 806.50 | 825.12 | 823.51 |
| JNTN 18-Between Tutt and Wellers | 163 CFS | 60-inch | 807.70 | 817.38 | 817.38+ |
| Low Point – in front of Tutt Hall | 121 CFS | 60-inch | 807.87 | 814.00 | 814.00+ |
| JNTN 17 – N. Prairie Street | 121 CFS | 60-inch | 808.60 | 817.77 | 814.75 |

+ Means that water is backing up from inlet or manhole.

**Alternative 3 – Diversion to Schwager Road Wetland**

Alternative 3 involves the diversion of Subarea 13 and Subarea 14 from the Lauderdale Drive drainage basin to the wetland complex north of Schwager Road and west of Fremont Street. Figure 6 shows this alternative. These subareas will be diverted into a new storm sewer in Schwager Road that will discharge into a new bioretention basin or wet detention basin constructed north of Schwager Road. The bioretention basin or new wet detention basin would discharge clean water into the wetland complex north of Schwager Road.

Alternative 3 reduces the hydraulic grade line in a portion of the Lauderdale Drive storm sewer system, but not as much as Alternatives 1 or 2. There would still be water backing up from the inlets at the low area during a 10-year storm event. The impacts of additional water to the wetland would need to be evaluated to determine if this alternative was feasible. The estimated construction cost for this alternative is approximately $193,000. Table 5 summarizes the hydraulic performance for this alternative. Appendix C includes the water surface profiles and a summary of the StormCAD calculations for Alternative 3.

**Table 5 – Hydraulic Analysis – Alternative 3**

| LOCATION | FLOW | SIZE | INVERT ELEVATIONS | RIM ELEVATIONS | HYDRAULIC GRADE LINE |
|---|---|---|---|---|---|
| 99-Outlet | 211 CFS | 42-inch | 793.61 | 814.00 | 800.00 |
| MH5-Fremont St. | 190 CFS | 42-inch | 801.40 | 814.46 | 814.46+ |
| JNTN 20-Bend in Lauderdale Drive | 190 CFS | 60-inch | 804.60 | 830.11 | 821.88 |
| JNTN 19-Bend in Lauderdale Drive | 179 CFS | 60-inch | 806.50 | 825.12 | 825.12+ |
| JNTN 18-Between Tutt and Wellers | 178 CFS | 60-inch | 807.70 | 817.38 | 817.38+ |
| Low Point – in front of Tutt Hall | 136 CFS | 60-inch | 807.87 | 814.00 | 814.00+ |
| JNTN 17 – N. Prairie Street | 136 CFS | 60-inch | 808.60 | 817.77 | 814.94 |

+ Means that water is backing up from inlet or manhole.

**Alternative 4 – Upsize 60-inch Sewer**
Alternative 4 involves the replacement of 2,314 feet of 60-inch storm sewer in Lauderdale Drive, from Whitewater Creek, to North Prairie Street, with a 72-inch storm sewer. This alternative would include the replacement of the 42-inch storm sewer at the outfall to Whitewater Creek. Flooding at the low area in front of Tutt Hall would be eliminated. A new overland flow path to the north, as described is Alternative 6, would also be included in this alternative, as the roadway in front of Tutt Hall and Wellers Hall would be reconstructed as part of the sewer replacement. The estimated construction cost of this alternative is approximately $1,120,000. Table 6 summarizes the hydraulic performance of this alternative. Figure 7 shows this alternative. Appendix C includes the water surface profiles and a summary of the StormCAD calculations for Alternative 4.

**Table 6 – Hydraulic Analysis – Alternative 4**

| LOCATION | FLOW | SIZE | INVERT ELEVATIONS | RIM ELEVATIONS | HYDRAULIC GRADE LINE |
|---|---|---|---|---|---|
| 99-Outlet | 240 CFS | 72-inch | 793.61 | 814.00 | 800.00 |
| MH5-Fremont St. | 219 CFS | 72-inch | 801.40 | 814.46 | 805.82 |
| JNTN 20-Bend in Lauderdale Drive | 219 CFS | 72-inch | 804.60 | 830.11 | 810.22 |
| JNTN 19-Bend in Lauderdale Drive | 200 CFS | 72-inch | 806.50 | 825.12 | 811.78 |
| JNTN 18-Between Tutt and Wellers | 206 CFS | 72-inch | 807.70 | 817.38 | 813.01 |
| Low Point – in front of Tutt Hall | 165 CFS | 72-inch | 807.87 | 814.00 | 813.05 |
| JNTN 17 – N. Prairie Street | 165 CFS | 72-inch | 808.60 | 817.77 | 813.52 |

**Alternative 5 – Add Inlets**
Alternative 5 involves the addition of inlets on the 60-inch storm sewer, in the low area north of Tutt Hall and Wellers Hall. An evaluation of the capacity of the six existing inlets indicated that the inlets can handle the anticipated peak flow with a maximum flooding depth of 6 inches. The hydraulic analysis indicates that water is backing up from the inlets in the low area. Adding new inlets would not improve the performance of the storm sewer system or reduce the depth or frequency of flooding in the low area. This alternative is removed from further consideration.

**Alternative 6 – Create an Overland Flow Path**
Alternative 6 involves providing an overland flow path away from the low area north of the Tutt Hall, along Lauderdale Drive. The objective of this alternative is to reduce the flooding to 6 inches or less for all rainfall events that produce runoff in excess of the capacity of the Lauderdale Drive storm sewer system. Components of this alternative include:

- Slightly raise the elevation of the Lauderdale Drive drop off lane north of Tutt Hall.

- Regrade the northeast corner of the intersection of Lauderdale Drive and Prairie Street to provide a flow path to the northwest.
- Regrade the parking lot island located along the western edge of Parking Lot 19 to create a swale that drains to the north.
- Install two culverts beneath the entrance to the parking lot from Prairie Street.
- Regrade the swale north of the Prairie Street entrance to provide drainage to the existing culvert which conveys storm water north beneath Schwager Drive.

This alternative will create a lower overland flow path to the north than the existing path, which is over a high point in Parking Lot 19. The overflow elevation will be reduced from 815.52 to 814.95. The lowest inlet rim elevations will be raised from 814.00 to 814.45, resulting in a maximum ponding depth of about 6-inches. Water will no longer back up into Parking Lot 19. The estimated construction cost for this alternative is $77,000. Figure 8 shows the conceptual plan for this alternative.

**Combinations of Alternatives**

Combinations of Alternatives 1, 2, 3, and 6 were also evaluated for hydraulic performance, feasibility, and cost. Hydraulic modeling was performed for the four possible combinations of Alternatives 1, 2, and 3. Following are the findings of those evaluations:

*ALTERNATIVES 1 and 2*
The combination of Alternatives 1 and 2, upsizing the 42-inch storm sewer and diverting to the Starin Road system, would result in a further reduction in the hydraulic grade line. There would still be water backed up in the low area north of Tutt Hall for a 10-year storm event. An evaluation of the impacts to the Starin Road storm sewer system would be required to determine if this combination alternative is feasible. The estimated construction cost of this combination of alternatives is approximately $190,000.

*ALTERNATIVES 1 and 3*
The combination of Alternatives 1 and 3, upsizing the 42-inch storm sewer and diverting to the Schwager Road wetland, would result in a further reduction in the hydraulic grade line, but not as much as the combination of Alternatives 1 and 2. There would still be water backing up from the inlets in the low area north of Tutt Hall for a 10-year storm event. An evaluation of the impacts to the Schwager Road wetland would be required to determine the feasibility of this combination of alternatives. The estimated construction cost of this combination of alternatives is approximately $248,000.

*ALTERNATIVES 2 and 3*
The combination of Alternatives 2 and 3, diverting flow to the Starin Road system and the Schwater Road wetland would result in a further reduction in the hydraulic grade line about the same as the combination of Alternatives 1 and 2, but there would still be water backing up from the inlets in the low area north of Tutt Hall for a 10-year storm event. An evaluation of the previously discussed impacts of these alternatives would be required. The estimated construction cost of this combination of alternatives is approximately $328,000.

*ALTERNATIVES 1, 2 and 3*
The combination of Alternatives 1, 2 and 3, upsize the 42-inch sewer and divert flow to the Starin Road system and the Schwager Road wetland, would result in the maximum, reduction in the hydraulic grade line. There would be surcharging in the 60-inch storm sewer at the low point north of Tutt Hall, but there would be no back-up of water from the inlets during a 10-year

storm event. An evaluation of the previously described impacts for Alternatives 2 and 3 would be required to determine if this combination of alternatives is feasible. Back-ups of water from the inlets at the low point would still occur during storm events greater than the 10-year, and the maximum flooding depth would still be about 1.6 feet. The construction cost of this combination of alternatives is approximately $383,000.

*ALTERNATIVES 1 and 6*
The combination of Alternatives 1 and 6, upsizing the 42-inch sewer and creating a lower overland flowpath, was also considered. The replacement of the 42-inch storm sewer with 60-inch storm sewer would result in a lower hydraulic grade line, improving the performance of the storm sewer system. An evaluation of the permitting and construction impacts for this alternative would be required to confirm feasibility. Alternative 6 would mitigate flooding impacts at the low area north of Tutt Hall. The result would be a reduction in the frequency and severity of flooding events on Lauderdale Drive. The estimated cost of this combination of alternatives is approximately $132,000.

Appendix D contains details on the cost estimates prepared for each alternative.

## FLOODING AT TUTT HALL AND WELLERS HALL

The scope of this study and report focused on improving the performance of the storm sewer system to mitigate the occurrence of flooding on Lauderdale Drive. The flooding of existing Lauderdale Drive reaches an elevation of approximately 815.52 and a depth of approximately 1.6 feet before the water flows overland to the outlet north of Schwager Road. The first floor elevation of Tutt Hall is 818.00. The first floor elevation of Wellers Hall is 827.90. This would suggest that storm sewer surcharging is not a direct cause of flooding at Tutt Hall and Wellers Hall. It is possible that direct connection of roof drains to the storm sewer could be impacted by the surcharging, causing water to back up in the roof drain conductors and either leak from the conductions or spill off the roof. Reduction of the hydraulic grade line in the storm sewer, during frequent rainfall events, and the reduction of high water elevations during severe events may reduce the incidences of building flooding.

A detailed investigation of the drainage conditions for Tutt Hall and Wellers Hall was conducted to try to determine the cause of building flooding.

A field visit to investigate reports of flooding problems at Tutt Hall and Wellers Hall was conducted by John McCarthy, Civil Engineer, and Tim Kehoe, plumbing designer, on September 16, 2009. John and Tim met with Dave Dorgan, UWW Facilities Manager, and toured Tutt Hall, with the assistance of building maintenance personnel.

### Roof and Foundation Drainage

A basement mechanical room in Tutt Hall, with a sump crock and dual sump pumps, was observed. It was reported that the sump pumps occasionally have difficulty keeping up with the incoming water during rainfall events. A raised curb on the floor around the crock was installed to contain any overflows. Jeff Eysnogle, UWW plumbing maintenance, indicated that roof drains were not connected to the piping to the sump crock, but may have been in the past. He indicated that they have not had as much of a problem with the crock overflowing recently. Our expectation is that rainwater within the underground roof leaders may be leaking into the foundation drains during severe rainfall events, putting excess water into the sump crock. The underground piping for the roof leaders may be surcharged as a result of backed up water in the 60-inch storm sewer in Lauderdale Drive.

The roof drains from Tutt Hall, Weller Hall, and Knilans Hall all connect underground to a 12-inch storm sewer that runs north in the courtyard between the three residence halls, and connects to a manhole on the 60-inch storm sewer in Lauderdale Drive. The connection is near the top of the manhole so that there is normally a free discharge from the connecting pipe. The water level in the 60-inch storm sewer has surcharged above the level of the manhole rim and the nearby inlets,

impeding the discharge from the building roof drain sewer, and surcharging the underground roof leader piping where it crosses the foundation drains that connect to the sump pumps. The sump pumps in Tutt Hall discharge to grade in the courtyard area northeast of the building.

A solution to this problem would be to replumb the roof drains from Tutt Hall and Wellers Hall to discharge to grade. Rain gardens, designed and sized to handle the roof runoff could be created in the lawn areas northeast of Tutt Hall and northwest of Wellers Hall. The rain gardens would have an overflow system that would convey any excess flow to the 60-inch storm sewer in Lauderdale Drive. The advantages of this approach is that the roof leaders can discharge freely to the rain gardens, instead of being surcharged by the 60-inch storm sewer.

There could be problems with this approach during the winter, due to freezing. This could be addressed by retaining the ability to switch back to the original system configuration during winter, when the potential for the type of rainfall event that surcharges the 60-inch storm sewer is minimized.

The details associated with replumbing the roof leaders would need to be evaluated. It may not be possible to cost-effectively re-route all the roof leaders, but even a partial re-route would be beneficial. A conceptual cost estimate was developed to accomplish this work. The estimate assumed that two roof leaders on the courtyard side of each of the two buildings could be intercepted and re-routed to discharge by gravity to a rain garden in the courtyard area. The rain garden would have a gravity overflow sewer to the 60-inch storm sewer, and an overland flow path to Lauderdale Drive. The estimated cost for this work is $33,700 for each building, for a total of $67,400. Figure 9 shows the proposed concepts.

### Sanitary Sewer Back-ups

It was reported during the sump pump investigation that the buildings had also experienced sanitary sewer back-ups from basement floor drains during heavy rainfall events. It is not anticipated that there are direct connections between the sanitary and storm sewer systems. Infiltration and inflow (I/I) into the sanitary sewer lateral and mainlines is the likely cause of these back-ups. The storm laterals from the buildings run parallel and in close proximity to the storm laterals, which could be contributing to sanitary sewer infiltration. The mainline sanitary sewer also runs parallel and in close proximity to the Lauderdale Drive storm sewer system, which could contribute to the problem. An internal inspection of the sanitary sewer and service laterals may identify locations of infiltration to the system. A smoke test and manhole inspection of the sanitary sewers may also reveal other sources of I/I.

### Surface Flooding at Tutt Hall

The west entrance to Tutt Hall has experienced problems with surface water flooding. This area was also inspected on September 16, 2009. Water is trapped in the area near the door, due to changes in the surface drainage path, and ineffective inlets and storm sewer.

A trash enclosure was constructed just west and north of the west entrance to Tutt Hall, which is at the basement level. The original paving and grading in this area allowed water to flow away from the doorway, although the area that receives the flow is a low point that can only be drained by the 60-inch storm sewer in Lauderdale Drive.

The trash enclosure is blocking the overland flow path. Apparently, when the trash enclosure was constructed, changes were also made to the storm sewer that conveys flow from an inlet in the doorway area, also reducing the drainage system performance. Possible solutions include replacing the piping from the inlet, to improve performance, and modifying the pavement at the trash enclosure to create an overland flow path.

The piping from the inlet could be replaced with a larger pipe that would connect to the storm sewer Prairie Street, instead of under the trash enclosure to another inlet. This system would still be subject to surcharging from the Lauderdale Drive storm sewer system, but will perform better when the recommended improvements are made to that system.

The overland flow path is hindered by grades needed to access the trash enclosure. It would be possible to provide an overland flow path while maintaining the required access elevations by constructing a grated or plated trench parallel to the west face of the building, through the trash enclosure access area. A sketch of these concepts is included as Figure 9. The estimated cost for these measures is $14,100.

## FINDINGS AND RECOMMENDATIONS

The purpose of this report was to determine ways to mitigate the flooding along Lauderdale Drive just north of Tutt Hall and Wellers Hall. The hydraulic analysis indicates that the system has insufficient capacity to convey the 10-year SCS Type II 24-hour event. Stormwater is backed up out of the inlets in the low area during this storm event. Several alternatives were analyzed for hydraulic performance, feasibility, and construction cost.

Six different alternatives were analyzed. Alternative 1 upsized the outlet pipe of the storm sewer system from a 42-inch pipe to a 60-inch pipe, Alternative 2 diverted drainage from Subarea 4 and Subarea 8 to a different storm sewer system, and Alternative 3 diverted drainage from Subarea 13 and Subarea 14 to a wetland. All three of these alternatives reduce the hydraulic grade line at Junction 18, but do not eliminate the surface flooding that occurs at this location. Alternative 1 is the most effective and least expensive improvement alternative, but still does not solve the flooding problem. Alternative 2 and Alternative 3 are more expensive and less effective, and also do not solve the flooding problem.

Combinations of Alternatives 1, 2, and 3 were also evaluated, but were not found to be effective at reducing flooding at the low areas on Lauderdale Drive. The combination of Alternatives 1, 2, and 3 would eliminate the flooding during at 10-year storm, but would not be sufficient to prevent flooding during less frequent events. Impacts of the flow diversions proposed for Alternatives 2 and 3 would also need to be evaluated.

Alternative 4 involved replacement of 2,314 feet of 60-inch storm sewer in Lauderdale Drive with 72-inch sewer. This alternative is effective at reducing the frequency and depth of flooding in the low area, but appears to be cost prohibitive with an estimated construction cost of $1,120,000.

Alternative 5, the addition of more inlet capacity at the low area was determined to be ineffective at reducing surface flooding, since water is backing through the existing inlets from the storm sewer.

Alternative 6, lowering the overland flow path to the north, was found to be a feasible and cost effective method to reduce surface flooding in the low area of Lauderdale Drive.

It is recommended that a combination of Alternatives 1, upsize the 42-inch storm sewer; and Alternative 6, lower the overland flow path; be advanced for final design. The estimated construction cost of these two alternatives is $132,000.

It is also recommended that disconnection of roof drains and construction of rain gardens at Tutt Hall and Wellers Hall; and modification of the storm sewer and installation of an overland flow path at the west entrance to Tutt Hall be advanced to final design. The estimated construction cost of these measures to mitigate flooding at Tutt Hall and Wellers Hall is $81,500.