EAST STRAND STREET FLOODING AND STORMWATER MANAGEMENT ANALYSIS

EAST STRAND STREET AT THE RONDOUT WATERFRONT CITY OF KINGSTON, NEW YORK

October 22, 2013

MMI #4766-02-1



Photo Source: City of Kingston, NY

Prepared for:

City of Kingston City Hall, 420 Broadway Kingston, New York 12401

Prepared by:

MILONE & MACBROOM, INC. 99 Realty Drive Cheshire, Connecticut 06410 (203) 271-1773 www.miloneandmacbroom.com



TABLE OF CONTENTS

| | | <u>Page</u> |
|-----|---|-------------|
| 1.0 | INTRODUCTION | |
| | 1.2 Project Setting | |
| | 1.3 Flooding Characteristics | 3 |
| | 1.4 Goals and Objectives | 4 |
| 2.0 | DATA COLLECTION | |
| | 2.1 Mapping and Utility Information | |
| | 2.2 Field Assessment and Maintenance Requirements | |
| | 2.3 Field Survey | |
| | 2.4 Land Use Inventory | |
| | 2.5 Recent Tropical Weather Systems | |
| 3.0 | TIDAL FLOODING ANALYSIS | |
| | 3.1 Tidal Predictions | |
| | 3.1.1 FEMA Tidal Data | |
| | 3.1.3 NOAA Tidal Data | |
| | 3.2 Existing Conditions Tidal Analysis | |
| | 3.3 Future Conditions SLR. | |
| | 3.4 New York State Sea Level Rise Task Force | |
| | 3.5 Kingston Tidal Waterfront Flooding Task Force | |
| 4.0 | RIVERINE FLOODING ANALYSIS | 17 |
| | 4.1 Peak Flow Predictions | |
| | 4.1.1 FEMA Riverine Data | 17 |
| | 4.1.2 USGS StreamStats | |
| | 4.1.3 HEC-SSP Bulletin 17B | |
| | 4.2 Existing Conditions Freshwater Flooding Analysis | |
| | 4.3 Future Conditions Extreme Precipitation Trends | |
| 5.0 | STORMWATER FLOODING ANALYSIS | |
| | 5.1 Stormwater Runoff Analysis | 22 |
| 6.0 | FLOODING SUMMARY AND MITIGATION ALTERNATIVES | 24 |
| | 6.1 Summary of Flooding Behavior at East Strand | |
| | 6.2 Flood Mitigation Criteria | |
| | 6.3 Flooding Mitigation Alternatives | |
| | 6.3.1 Local Protective Measures | |
| | 6.3.2 Drainage Improvements6.3.3 Roadway Elevation | |
| | 6.3.4 Shoreline Modification | |
| | 6.3.5 Flood Barriers and Levees | |
| | 6.4 Coastal Resiliency in Redevelopment | |
| 7.0 | RECOMMENDATIONS AND CONCLUSIONS | |
| 7.0 | 7.1 Nuisance Flooding Mitigation Recommendations | |
| | 7.2 Severe Flooding Mitigation Recommendations | |
| REI | FERENCES | |
| | | |



TABLE OF CONTENTS (continued)

| | | Page |
|------------|---|--------|
| | LIST OF TABLES | |
| Table 1 | Recurrence Interval vs. Annual Chance Exceedance (ACE) | TC-iv |
| Table 2 | Annual Chance Exceedance (ACE) vs. Long-Term Chance of Exceedance | eTC-iv |
| Table 3 | FEMA FIS – Stillwater Tidal Flood Elevations | 9 |
| Table 4 | Tidal Statistics at Kingston Point | 12 |
| Table 5 | Key Elevations of East Strand Street | |
| Table 6 | Key Elevations of Floodprone Buildings Near East Strand Street | |
| Table 7 | New York State Sea Level Rise Task Force Findings | |
| Table 8 | Kingston Tidal Waterfront Flooding Task Force – Selected SLR Values | |
| Table 9 | FEMA FIS – Peak Flow Discharges for Rondout Creek | |
| Table 10 | USGS StreamStats – Peak Flow Discharges for Rondout Creek | |
| Table 11 | HEC-SSP Bulletin 17B – Peak Flow Discharges for Rondout Creek | |
| Table 12 | Existing Conditions Drainage System Analysis | |
| Table 13 | Flooding Summary for Recent Tropical Weather Events | |
| Table 14 | Summary of Potential Flood Mitigation Alternatives | 28 |
| | | |
| | LIST OF FIGURES | |
| Figure 1 | USGS Project Location Map | 2 |
| Figure 2 | Existing Drainage Maintenance Requirements | |
| Figure 3 | Tidal and Storm Data Summary | |
| Figure 4 | Sea Level Rise (SLR) Over Past 160 Years, Manhattan, New York | |
| Figure 5 | Peak Discharge (cfs) in Rondout Creek vs. Tropical Weather Systems | |
| Figure 6 | Existing Drainage System Delineations | |
| Figure 7 | Photograph of Typical Bulkhead Installation | |
| Figure 8 | Shoreline Modification and Flood Barrier Levee Location | |
| Figure 9 | Preliminary Opinion of Probable Construction Costs | 36 |
| | | |
| | LIST OF APPENDICES | |
| Appendix A | USGS Tidal Gage and Recent Storm Data | |
| Appendix B | FEMA Flood Insurance Study Data | |
| Appendix C | Rondout Creek Hydrologic Data | |
| Appendix D | Existing Conditions Storm Drainage System Analysis | |
| Appendix E | Proposed East Strand Street Vertical Realignment | |
| Appendix F | Proposed Conditions Storm Drainage System Analysis | |



TABLE OF CONTENTS (continued)

ABBREVIATIONS/ACRONYMS

| ACE | .Annual Chance of Exceedance |
|---------|--|
| CFS | .Cubic Feet per Second |
| FEMA | .Federal Emergency Management Agency |
| FIRM | .Flood Insurance Rate Map |
| FIS | .Flood Insurance Study |
| GIS | .Geographic Information System |
| | .Global Positioning System |
| HEC-RAS | .Hydrologic Engineering Center – River Analysis System |
| | . Hydrologic Engineering Center – Statistical Software Package |
| HTL | |
| | .Local Waterfront Revitalization Program |
| | .Mean Higher High Water |
| MHW | |
| | .Mean Lower Low Water |
| MLW | .Mean Low Water |
| MMI | .Milone & MacBroom, Inc. |
| MSL | .Mean Sea Level |
| NAVD88 | .North American Vertical Datum of 1988 |
| | .National Flood Insurance Program |
| | .National Geodetic Vertical Datum of 1929 |
| | .National Oceanic and Atmospheric Administration |
| | .Northeast Regional Climate Center |
| | .New York Department of Environmental Conservation |
| | .New York City Department of Environmental Protection |
| | .New York Department of State |
| SLR | * |
| | .United States Army Corps of Engineers |
| | .United States Geological Survey |
| | . Wastewater Treatment Plant |



TABLE OF CONTENTS (continued)

RECURRENCE INTERVAL FLOOD EVENTS EXPLANATION

Statistical floods commonly used in engineering design are delineated by their chances of occurring in a one-year period.

The phrase "'100-Year Flood' is misleading," FEMA says on its website. Many mistakenly believe that it is a flood that occurs every 100 years. Rather, it is the flood elevation that has a one percent chance of being equaled or exceeded in any given year. During a 100-year period, that flood has a 1% chance of occurring each year for 100 years in a row, which makes the actual chance that it will occur in that 100year period approximately 64%. The chance of that same flood event occurring during the life of a standard 30-year mortgage is approximately 26%.

To avoid confusion in this report, flood events will be referred to by their Annual Chance of Exceedance, or ACE, which is the statistical chance that the flow will be exceeded within a one-year period. Table 1 relates these percentages to their equivalent recurrence intervals, and Table 2 relates the ACE to the longterm chance of exceedance.

TABLE 1 **Recurrence Interval vs. Annual Chance Exceedance (ACE)**

| Recurrence Interval | 2-Year | 10-Year | 25-Year | 50-Year | 100-Year | 500-Year |
|--------------------------------------|--------|---------|---------|---------|----------|----------|
| Annual Chance of Exceedance (ACE) | 50% | 10% | 4% | 2% | 1% | 0.2% |

TABLE 2 Annual Chance Exceedance (ACE) vs. Long-Term Chance of Exceedance

| Annual Chance of Exceedance (ACE) | 50% | 10% | 4% | 2% | 1% | 0.2% |
|-----------------------------------|------|------|-----|-----|-----|------|
| 10-Year Chance of Exceedance | 100% | 65% | 34% | 18% | 10% | 2% |
| 20-Year Chance of Exceedance | 100% | 88% | 56% | 33% | 18% | 4% |
| 30-Year Chance of Exceedance | 100% | 96% | 71% | 45% | 26% | 6% |
| 50-Year Chance of Exceedance | 100% | 99% | 87% | 64% | 39% | 10% |
| 100-Year Chance of Exceedance | 100% | 100% | 98% | 87% | 63% | 18% |

1.0 **INTRODUCTION**

1.1 **Project Background**

The City of Kingston, New York has retained Milone & MacBroom, Inc. (MMI) to assess the redevelopment potential of the East Strand Street waterfront along the Rondout Creek, near the confluence with the Hudson River. Redevelopment of urban waterfront shorelines represents a growing trend in American cities. Investment in these downtown areas can stimulate economic growth through commercial development and tourism, revitalize urban settings through park and natural restoration, and increase tourism and community pride.

Recognizing the rich historic appeal of the Rondout waterfront, the City of Kingston has embraced the opportunity to revitalize this area. The combination of a number of efforts since the mid 1980s has already resulted in the redevelopment of the historic West Strand area. The redevelopment created mixed-use commercial shops and residential apartments in rehabilitated 19th century structures, using new buildings that mimic the historic look and feel of the area. The City of Kingston is continuing and expanding its efforts to revitalize its scenic Rondout Creek waterfront, which was initiated with the development of West Strand Street and will continue into the historic East Strand Street area.

In 1992, the Local Waterfront Revitalization Program (LWRP) was approved, and a collaborative study called the "Waterfront Development Implementation Plan" was developed by the city. This plan was focused on the overall vision for the city and what steps were necessary to achieve that vision. The primary goal, as stated in the plan was:

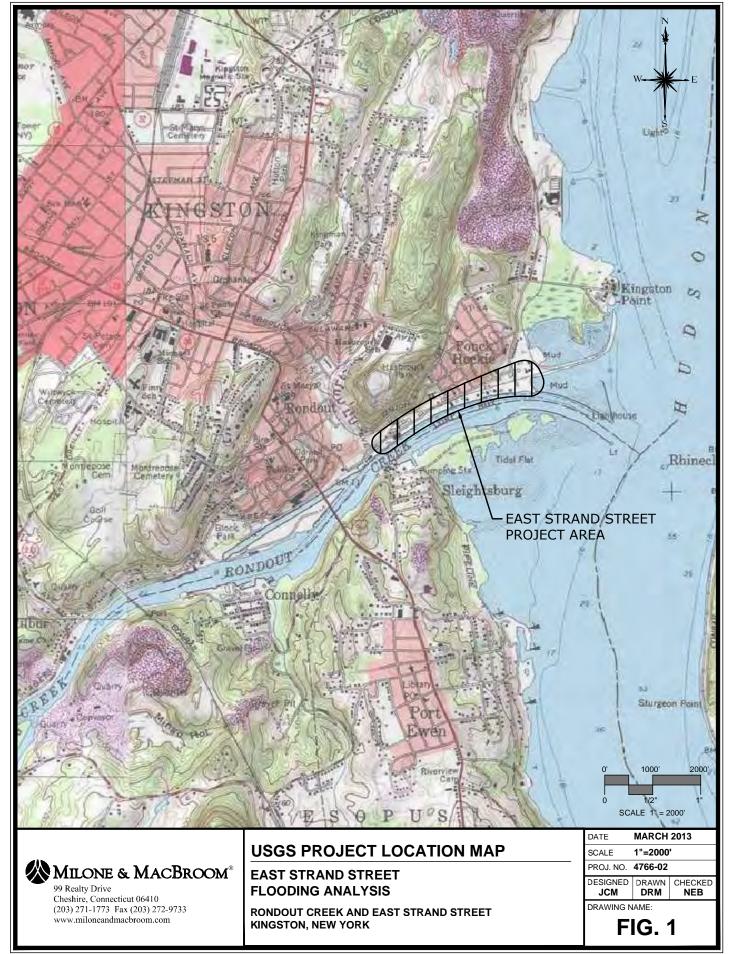
"The Kingston Waterfront will be an attractive, active, walkable, culturally vibrant district with strong linkages to the rest of the City of Kingston..."

In accordance with the goals detailed in this plan and as an extension of the West Strand redevelopment effort, the city intends to lay the groundwork to achieve this vision in the East Strand area through the physical construction of infrastructure, zoning and policy changes, economic development, and tax incentives to potential developers. The city would like to promote the development of shops, restaurants, museums, and parks in the East Strand area. At the same time, it would like to highlight historic and natural resources and connect the public to the riverfront with docks, boat launches, and a riverfront trail that connects West Strand to the lighthouse and park at Kingston Point.

1.2 **Project Setting**

The East Strand waterfront area is uniquely situated in the lowest portion of the Rondout Creek watershed, at its confluence with the Hudson River, in the southeastern corner of the city of Kingston (see Figure 1). The Rondout Creek drains much of the southeastern portion of the Catskill Mountains and the northern side of the Shawangunks Ridge, with a





total watershed area of 1,190 square miles. Many watersheds in the Catskill region have been suffering from increased frequency and intensity of flood events, causing infrastructure and bank stability issues that have been worsening in recent years.

The East Strand area once sustained a thriving industrial shipping base, including the transfer of coal and limestone that would ultimately be shipped to New York City. The infrastructure in place near East Strand included railroad tracks parallel to the road, and deep water docks to support large cargo vessels that came in from the Hudson River.

In the spring of 1615, a party of Dutch traders landed at Ponckhockie, built a fort, and established a trading post there, calling it Rondout. The neighborhood architecture dates back as far as 1777, but most of the modest homes in the neighborhood were built between the 1870s and 1910, in support of the laborers who worked in conjunction with the shipping and freight operations.

The changing economic climate and natural decline in coal and limestone usage caused the shipping from the Rondout port to be reduced, and many of the businesses closed. Many derelict structures remain as a reminder of the bustling past, but many more have been demolished and removed, leaving vacant land and brownfields.

1.3 **Flooding Characteristics**

Successful redevelopment of the Rondout waterfront and East Strand area has been hindered by intermittent floodwater inundation. Anecdotal evidence from residents and community members indicates that certain portions of East Strand Street can be inundated by one foot of water or more when high intensity rainfall events coincide with high tide events in the Hudson River. Nuisance roadway flooding can occur multiple times a year while more damaging floods can occur once every few years.

Flooding on East Strand Street is thought to be caused by three unique but related circumstances:

- 1. Tidal influence from New York Harbor during high tide or storm surge events, transferred to Kingston by the Hudson River (See Section 3)
- 2. Riverine flooding from the Rondout Creek during heavy precipitation events in its watershed (See Section 4)
- 3. Stormwater runoff from the highly developed urban watershed uphill of East Strand Street, with inadequate roadway drainage systems to accommodate the peak runoff flows (See Section 5)

While the tidal influence from the Hudson River plays a large role in roadway flooding, stormwater runoff upland of East Strand contributes to the flooding as well. The upper portion of the drainage area is a very steep limestone bluff that offers little infiltration or detention. Beginning immediately below the bluff at Delaware Avenue and Yeoman



Street, the primary land use becomes densely developed residential. The impervious area and steep slopes near the waterfront cause peak stormwater runoff to reach the East Strand area quickly.

Flooding is complicated by the hydraulic interactions between the Rondout Creek and the Hudson River given the fluctuation of the tidal stage of the Hudson River. The Hudson River as it flows past Kingston is a massive, slow-moving body of water, draining over 11,740 square miles (the contributing watershed area at Poughkeepsie, approximately 15 miles downstream of Kingston). The water surface elevation at the East Strand waterfront is largely controlled by the elevation of the Hudson River and is therefore subject to the influence of Sea Level Rise (SLR). Therefore, it is not practical to assume that flood elevations in the Hudson will ever be lowered. Riverine flooding and stormwater runoff are influenced by the trending increase in frequency and magnitude of heavy precipitation intensities and are also likely to increase over time, which will worsen flooding at the waterfront

1.4 Goals and Objectives

As stated above, the city intends to lay the groundwork for redevelopment of the East Strand waterfront through the physical construction of infrastructure, zoning and policy changes, economic development, and tax incentives to potential developers. However, flooding of the East Strand waterfront area may inhibit any redevelopment efforts the city or others may undertake. The purpose of this study is to understand the causes of the periodic flooding of the roadway and surrounding area and to develop a plan to mitigate it to the extent possible. The specific goals of this study are:

- 1. Identify and quantify the contributions to flooding in the East Strand Street waterfront area that riverine, tidal, and stormwater influences have under current conditions.
- 2. Discuss the potential for flooding to worsen under future conditions based upon the influence of SLR and the trending increase in frequency and magnitude of heavy precipitation events.
- 3. Provide potential solutions and recommendations for the future adaptation of the East Strand area to minimize the frequency and severity of flooding along the waterfront.

2.0 <u>DATA COLLECTION</u>

To obtain an understanding of the contributing factors to the roadway flooding at East Strand Street, a comprehensive data collection effort was undertaken. This involved obtaining data from the following sources:



- Mapping from the City of Kingston, Ulster County, and the relevant utility providers
- Flooding and rainfall records from the City of Kingston Wastewater Treatment Plant (WWTP) and surrounding weather stations
- Historic records from United States Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA) water level gages
- Federal Emergency Management Agency (FEMA) Flood Insurance Rate Study data
- Topographic survey and field reconnaissance

2.1 <u>Mapping and Utility Information</u>

Available mapping of the project area was provided by the City of Kingston, Ulster County, and Central Hudson Gas and Electric Company. This included Geographic Information System (GIS) and paper mapping of topography, utilities, parcels, impervious coverage, soil types, zoning districts, storm drainage systems, and existing utility infrastructure in the roadway. A collection of digital surveys performed by Brinnier & Larios, P.C. covering portions of the project area was provided by the city. The available mapping was compiled into a comprehensive base map and used to delineate preliminary stormwater runoff watersheds, which were modified during field observation.

2.2 Field Assessment and Maintenance Requirements

In June 2012, MMI staff conducted a visual observation of the area to inventory the location and condition of catch basins and storm drainage manholes as presented in the city's mapping. As part of this effort, compiled mapping was verified, the existing drainage system was assessed for its condition and adequacy, and the contributing watersheds and overland flow patterns were confirmed.

Upon field investigation, impervious areas, building locations and shapes, and drainage system information were found to be inaccurate and incomplete in many areas. Drainage structure locations were corrected by using a hand-held Trimble Global Positioning System (GPS) receiver. Data gaps in land use were supplemented with georeferenced aerial photography from Microsoft Bing Maps and Google Maps.

Many drainage structures were found to be in need of routine maintenance to remove silt and debris collection clogging their inlets and sumps (see Figure 2). Structures connected to Outfall 1 appeared to be in reasonable condition. Structures connected to Outfall 2 had some minor siltation and debris blockage while structures connected to Outfall 3 and Outfall 4 were severely impeded by debris and silt.





A request was submitted to the City of Kingston Public Works Department for cleanout of these structures prior to survey, in June 2012, and a formal memorandum documenting the conditions was submitted to the city in December 2012.

2.3 Field Survey

Field survey of key drainage system components identified during the field assessment was performed by MMI in September 2012. This included survey of the elevation of the top of frame and invert elevations, ground and bulkhead elevations, and additional information needed for the drainage analysis. Supplemental survey performed by MMI was limited to the areas of known flooding. The results of the survey were compiled into the base mapping and used to corroborate data found from other sources.

Outfalls 3 and 4 could not be located due to restricted site access. Locked gates and overgrown riverbanks made ground access impossible; therefore, MMI surveyors had to use boats at low tide to attempt to locate these two outfalls but were unsuccessful. These outfalls may be buried or damaged beyond visual recognition. The flooding analysis will recommend the reuse or replacement of these outfalls, but no clear decision can be made until their location, size, and condition can be verified. We would recommend that the city locate these outfalls, uncover them if necessary, and clear access to them such that they can be inventoried appropriately.

Additionally, a more detailed survey of the East Strand roadway was performed by Brinnier & Larios, P.C. for use with the related streetscape design. This information was also compiled into the base mapping to assess the elevation of East Strand in relation to tidal and riverine flooding elevations.

2.4 Land Use Inventory

The Rondout waterfront and East Strand area of Kingston have a complex and varied land use composition with three distinct subareas. The westernmost subarea lies adjacent to Route 9 West and is centered around Hudson Valley Landing and Rondout Drive. This subarea functions as a small extension of downtown Kingston, located on the eastern side of Route 9 West. Properties in this subarea include multifamily apartments operated by the Kingston Housing Authority on Rondout Drive, a collection of attached duplex housing units constructed in 1990, and a vacant parcel of commercial land that has remained as undeveloped open space for the duplex development. To the east of these duplex apartment units on the northern side of East Strand Street are the Trolley Museum of New York and the city's WWTP. Hasbrouck Park, a 45-acre facility opened in 1920, lies to the north of these properties.

East Strand Street forms the connective artery through the Rondout waterfront area and is the second important subarea in this part of Kingston. The actual waterfront properties themselves contain a mix of commercial and water-dependent uses. Beginning at the New York State Route 9W bridge to the west and heading east, the waterfront has three



restaurants interspersed among the Hudson River Maritime Museum, a number of private properties owned by Historic Kingston, LLC, and some vacant commercial property. Additional vacant commercial land and a fuel storage facility are located on the northern side of East Strand Street to the east of the WWTP. Farther east is a dock utilized by the New York State Police for marine units, several bulky waste scrap metal disposal sites. two fuel storage facilities, and some additional vacant industrial land. Land use east of these facilities transitions to parcels of vacant commercial land and an additional waste storage yard as East Strand Street turns north to become North Street. These properties are bisected by a trolley line that crosses East Strand Street and runs east to the city-owned open space known as Kingston Point Park, an 87-acre facility that was restored in the 1980s.

On the northern side of East Strand Street is the Ponckhockie neighborhood. This neighborhood is shaped by a dense grid network of local streets bordered to the northwest and north by Yeoman Street and Delaware Avenue, to the east by North Street, and to the south by East Strand Street. This neighborhood is predominantly single family residential in nature but also includes a mix of two-family structures, three-family structures, multifamily apartments, and row houses. Some vacant residential properties are also present, interspersed among the housing stock. The housing units in the neighborhood were generally developed between 1830 and 1930. The neighborhood is also home to institutional and nonprofit uses such as the Children's Home of Kingston and Ulster County Community Action, as well as the New Central Baptist Church. A few small commercial and industrial uses are also present, particularly as one heads north along North Street approaching Delaware Avenue.

Several of the buildings along East Strand Street are located below the elevation of the 10% ACE frequency tidal flood, as delineated by the FEMA Flood Insurance Study (FIS). The elevation of East Strand Street at the existing railroad crossing near the WWTP is 4.8 feet (NAVD88), which is 1.2 feet below the 10% ACE flood elevation.

2.5 **Recent Tropical Weather Systems**

Two recent tropical weather systems with very different characteristics have caused flooding at the East Strand waterfront. Tropical Storm Irene (August 28, 2011) and Hurricane Sandy (October 30, 2012) both caused water surface elevations greater than the 10% ACE flood; flooding during Irene was driven primarily by heavy rains whereas flooding during Sandy was driven by high winds and storm surge. Hurricane Sandy is listed as the highest water surface elevation recorded by the Poughkeepsie USGS gage, which has a 21-year period of record.

The USGS manually surveyed the wrack line of Hurricane Sandy at elevation 9.3 feet at Kingston Point. Based on the adjusted USGS tide predictions, Hurricane Sandy was equal to a 1% ACE frequency event.



A summary of the meteorological and tidal data is provided in Figure 3, and more detailed raw data is provided in Appendix A. Specific data is discussed in greater detail in the following sections.

3.0 TIDAL FLOODING ANALYSIS

The available tidal gaging and prediction data was compiled and analyzed to gain a better understanding of the influences from the Hudson River, astronomical tides, and storm surges in New York Harbor as they affect the flooding of East Strand Street.

3.1 <u>Tidal Predictions</u>

3.1.1 FEMA Tidal Data

The FEMA FIS (No. 36111CV001A, Effective Date: September 25, 2009, Updated: December 12, 2011) for Ulster County was reviewed to understand the analysis performed on flooding of the area.

The FIS indicates that the flooding elevations in Rondout Creek are controlled by the Hudson River for 2.25 miles upstream of the Hudson River confluence, or just downstream of the Conrail railroad bridge. Data in the FIS includes predicted tidally influenced (stillwater) flooding elevations, which are extrapolated from stage/frequency relationships for the entire Hudson River. This data was originally prepared by the United States Army Corps of Engineers (USACE) in 1975 and, given the acceleration of SLR, is already out of date. Table 3 presents the FIS data in comparison to current tidal elevations.

TABLE 3
FEMA FIS – Stillwater Tidal Flood Elevations¹

| | | 10% | 2% | 1% | 0.2% |
|---------------------------------|------------|--------|--------|--------|--------|
| Location | | (feet) | (feet) | (feet) | (feet) |
| At Kingston Point, Hudson River | 1975 | 6.0 | 7.5 | 8.9 | 10.4 |
| At Kingston Point, Hudson River | 2013^{2} | 6.38 | 7.88 | 9.28 | 10.78 |

Note:

- 1. Elevations are presented in the North American Vertical Datum of 1988 (NAVD88).
- 2. Published elevations from 1975 were adjusted at a rate of one foot per 100 years (according to NOAA data indicating SLR over the past century) to reflect present-day elevations.

3.1.2 <u>USGS Hydraulic Gage Data</u>

The USGS operates and maintains a nationwide grid of stream gages that measure a variety of parameters including stage, velocity, and discharge in the surficial waters of the



United States. Some of these gages have been in continuous operation for up to 100 years and provide the basis for the statistical analyses of peak river flows in their region. They are also used to monitor the instantaneous conditions at watercourses to determine if flooding conditions exist.

Three USGS gages provide data in the area of the East Strand waterfront, a summary of which is presented in Figure 3. The most relevant gage was installed beneath the New York State Route 9W bridge in the Rondout Creek and measures tide and velocity in the Rondout across from the East Strand area. However, this gage was installed in November 2012 and does not have an adequate period of record from which to draw solid conclusions

A second gage located in Rosendale, New York on Rondout Creek has the longest period of record but is far enough upstream to avoid tidal influence. Data recorded from this gage was used by FEMA in its 2011 FIS to generate peak flow rates in Rondout Creek. Data from this gage may give an understanding of riverine influence and severity of flows during past storm events but does not relate directly to water surface elevations at the East Strand waterfront.

A third gage located on the Hudson River south of Poughkeepsie, approximately 17 miles south of Kingston, New York, has just over 20 years of record of the water surface elevation in the Hudson River and is tidally influenced. Although the timing and exact peak elevation that occurs in the East Strand area may be different than what is recorded here, the data obtained gives a relative order of magnitude and approximate timing of the peaking stages of the Hudson River.

A summary of the USGS gage data available is provided in Figure 3, and more detailed raw data is provided in Appendix A.

3.1.3 NOAA Tidal Data

NOAA maintains and operates a series of tidal gages throughout the coastal waters of the United States. These gages are used as the basis for predicting the timing and extent of normal astronomical tides, without the effects of thermal expansion, atmospheric pressure variations, winds and storm surge, or freshwater input. They are also used to monitor instantaneous values of tides and currents at their installed locations.

NOAA has not installed a tidal gage in the vicinity of Kingston, New York. However, NOAA has published tidal estimates at various locations along the Hudson River including Kingston. These estimates have been extrapolated from data acquired at a gage in New York Harbor in New York City and correlated with data found at a second gage on the Hudson River in Albany. Detailed data is provided in Appendix A.



Project No.: 4766-02

Designed By: JCM
Kingston, New York

Checked By: NEB

East Strand Street Flooding Analysis, Kingston NY

Figure 3 - Tidal and Storm Data Summary

Datum Conversion

0 ft NGVD = -0.807 ft NAVD

Watershed Area

Hudson 11,740 sq mi (downstream of Poughkeepsie)

Rondout 1,190 sq mi (at Kingston)

FEMA Elevation in Hudson River

| | 10-Yr | 50-Yr | 100-Yr | 500-Yr | |
|----------------|-----------|-----------|-----------|-----------|----------------------|
| | (ft NAVD) | (ft NAVD) | (ft NAVD) | (ft NAVD) | |
| Kingston Point | 6.0 | 7.5 | 8.9 | 10.4 | (based on 1975 data) |
| Poughkeepsie | 5.9 | 7.1 | 8.0 | 9.7 | (based on 1975 data) |

USGS Gage

| <u>No.</u> | River | Location | <u>Installed</u> | Active? | Data Type | Max Record | Max Date |
|------------|---------|--------------------|------------------|---------|-------------|------------------|------------------|
| 01372007 | Rondout | Kingston | 2012-11-05 | yes | Tidal Stage | 13.5 *(no datum) | 10/30/12 (Sandy) |
| 01367500 | Rondout | Rosendale | 1901-07-08 | yes | Flow | 36,500 cfs | 8/28/11 (Irene) |
| 01372058 | Hudson | S. of Poughkeepsie | 1992-05-12 | yes | Tidal Stage | 8.73 ft NAVD | 10/30/12 (Sandy) |

*Note: *max elev of 13.5 ft was surveyed as 9.3 ft navd, correction factor = -4.2 ft

Hurricane Statistics

| 1 | rene | 8/28/11 | |
|---|-------|---------|--|
| l | Helle | 0/40/11 | |

High Water Mark ± 6.2 ft navd (from photos)

Hudson Stage 7.15 ft navd (South of Poughkeepsie) converted from 7.96 ngvd, from USGS gage

Flow in Rondout 36,500 cfs (flood of record, since 1901 at Rosendale)

Precipitation 6.2 in (knykings13, Kingston, NY)

6.5 in (Kingston WWTP records)

Sandy 10/30/12

High Water Mark 9.3 ft navd (USGS surveyed multiple wrack lines surveyed by USGS near Kingston Point)

Hudson Stage 8.73 ft navd 29-Oct (South of Poughkeepsie) converted from 9.54 ngvd, from USGS gage

4.89 ft navd 28-Oct (South of Poughkeepsie) converted from 4.89 ngvd, from USGS gage

Flow in Rondout 1,500 cfs (at Rosendale)

Precipitation 0.11 in (knykings13, Kingston, NY)

| Sea Level Rise | | Year 2050 | Year 2100 |
|---------------------------------------|---------------|-----------|-----------|
| Data as presented by the City | Low Scenario | 17 in | 36 in |
| of Kingston Sea Level Rise Task Force | High Scenario | 26 in | 68 in |

Data compiled by NOAA measured at The Battery, NYC from 1856-2006 2.77 mm/yr = 0.1091 in/yr

Tidal Statistics at Kingston Point

| | NOAA Elev. (ft, NAVD) | USGS Gage Data (ft, NAVD) |
|------|-----------------------|---------------------------|
| MHHW | 1.32 | 2.8 |
| MHW | 1.07 | 1.8 |
| MTL | -0.78 | 0 |
| MLW | -2.63 | -1.2 |
| MLLW | -2.88 | -2.2 |

3.2 Existing Conditions Tidal Analysis

The Hudson River is a tidal estuary in the study area; therefore, freshwater discharge analysis is not meaningful for determining flood stages. The Hudson River is influenced by tidal elevations from New York Harbor as far as 140 miles upriver, near Albany. These tidal fluctuations have a significant impact on the water surface elevations in Kingston, especially at the low-lying regions near East Strand Street. To determine the extent of this impact, available tidal data was compiled, assessed, and compared with the adjacent ground elevations in East Strand Street.

Two methods were used to obtain mean daily tidal elevations for the Hudson River during normal conditions. NOAA tidal predictions for Kingston are extrapolated based upon data from Albany and New York City and are reported in their published tide charts. This data was compared to results from the USGS gage installed beneath the State of New York Route 9W bridge over the Rondout, directly at the East Strand waterfront. This data is measured at the site and therefore more relevant; however, a 19-year period of water level averaging is used to average daily mean values due to lunar cycles affecting the tides. The USGS gage has been in service for less than a year, and mean daily values so far can only be used as a point of reference. Table 4 presents a comparison of these values.

TABLE 4
Tidal Statistics at Kingston Point

| Statistical Tidal Elevation | NOAA Tidal Prediction (feet, NAVD88) | USGS Gage Data (feet, NAVD88) |
|-------------------------------|--|----------------------------------|
| Mean Higher High Water (MHHW) | 1.32 | 2.8 |
| Mean High Water (MHW) | 1.07 | 1.8 |
| Mean Tide Level (MTL) | -0.78 | 0 |
| Mean Low Water (MLW) | -2.63 | -1.2 |
| Mean Lower Low Water (MLLW) | -2.88 | -2.2 |

Note:

- The USGS gage has an inadequate period of record to determine tidal values definitively. This data is preliminary, includes influences of rainfall, and is only for reference.
- 2. NOAA tidal predictions are based upon astronomical tide only and do not account for precipitation, wind, riverine flooding, storm surge, or other influences.

The Mean Higher High Water (MHHW) of 1.32 feet NAVD as predicted by NOAA estimates only accounts for astronomical tide. The measured values (albeit incomplete due to their short period of record) indicate that the influence of precipitation events can increase this elevation by up to 1.5 feet, to an elevation of 2.8. These values were then compared to important elevations in the East Strand roadway and to elevations of surrounding structures. Tables 5 and 6 present these elevations.



TABLE 5
Key Elevations of East Strand Street

| Object Type | Location | Elevation (feet, NAVD88) |
|---------------------------|-------------------------------------|--------------------------|
| Catch Basin | In front of WWTP | 2.91 |
| Catch Basin | At Tompkins Street | 3.7^{1} |
| Catch Basin | At Sycamore Street | 3.9^{1} |
| Catch Basin | At Gill Street | 5.9^{1} |
| Catch Basin | Between Sycamore and Gill Streets | 3.1^{1} |
| Parking Area | Riverview Missionary Baptist Church | $3.8 (approx)^2$ |
| Adjacent Road | At Railroad Crossing | 4.8^{1} |
| Adjacent Road | Cornell Building / WWTP | $5.5 (approx)^2$ |
| Adjacent Road | Steel House Restaurant | $5.5 (approx)^2$ |
| Bulkhead Elevation | Average Range, East Strand Street | $5.0-6.0 (approx)^2$ |

Note:

- 1. Elevations are based upon ground survey performed by MMI in September 2012 and by Brinnier & Larios, P.C. in January 2013.
- Approximate elevations are based upon topographic mapping provided by the Ulster County GIS Service.

TABLE 6
Key Elevations of Floodprone Buildings Near East Strand Street

| Tax Assessor Map-Block-Lot No. | Current Building Use | Current Building Use Building Type | |
|-----------------------------------|----------------------------|------------------------------------|---------------------------|
| 56.43-6-8 | City of Kingston WWTP | 2-Story Brick | 9.1 ¹ |
| 56.43-6-8.1 | Trolley Museum | Timber | 6.0 (approx) ² |
| 56.43-6-4 | Steel House Restaurant | Brick | 6.11 |
| 56.43-6-5 | Cornell Building | Brick | 6.11 |
| 56.43-6-8 | Garage | Metal | 4.8^{1} |
| 56.36-1-7 | Garage | Brick | 7.0^{1} |
| 56.36-1-6 | 3-Story Building | Timber | 4.6^{1} |
| 56.36-12-7, 8, 9, 10, 11 | New Central Baptist Church | Brick | 5.3^{1} |
| 56.36-12-17.1 | Riverview Baptist Church | Timber | $5.0 (approx)^2$ |
| 56.36-1-12 | Warehouse | Metal | 5.4^{1} |
| 56.36-11-8 | Commercial Structure | Brick | 9.9^{1} |
| 56.36-1-16 | Millens Recycling | Brick | 15.9^{1} |

Note:

- Elevations are based upon ground survey performed by MMI in September 2012 and by Brinnier & Larios, P.C. in January 2013.
- 2. Approximate elevations are based upon topographic mapping provided by the Ulster County GIS Service.



The lowest elevations in East Strand Street are approximately 3.0 feet in elevation NAVD88 at two discrete locations, which relate closely to the MHHW of 2.8 measured in the last few months by the USGS gage. The bulkhead and shoreline elevations along the East Strand waterfront are generally at elevation 5.0 feet to 6.0 feet, meaning normal tidal fluctuation will not overtop the banks of the Rondout.

However, the existing drainage systems beneath the roadway that discharge to the Rondout are hydraulically connected to the tides, meaning that during high tides water from the Rondout can flow "upstream" in the drainage system and at high enough tidal elevations surcharge through the catch basins onto the street on a regular basis.

As intense storms reach the shallow coastal waters in New York Harbor, they frequently generate storm surges and wind-driven swells that increase sea levels further. Like the effects of Hurricane Sandy, this has the effect of raising water surface elevations in the Hudson upriver and exacerbates flooding in Kingston. When these coastal storms occur at the same time as high tides and heavy rainfall, the damage can be substantial.

The FEMA-reported elevations indicate that a 10% ACE tidal flood event can cause water surface elevations to rise up to elevation 6.0 feet NAVD, which was computed in 1975. This was adjusted to account for SLR in Table 3 to an elevation of 6.4 feet NAVD. Based on the values reported in Tables 5 and 6, many areas in East Strand Street are affected by tidal flooding equal to or greater than the 10% ACE frequency event under current conditions.

Of the 3,000 linear feet of East Strand Street assessed and surveyed, less than 1,200 linear feet are above elevation 6.4 feet. The remaining 1,800 feet, or 55% of East Strand Street, would be inundated by floodwaters during a tidal flood event of a 10% ACE flood.

3.3 **Future Conditions SLR**

Scientists believe that Mean Sea Level (MSL) has been rising at a variable rate for the past 12,000 years, since the beginning of the current glacial cycle. The rate of SLR has begun to accelerate in recent years according to modern measurements.

National attention has been given to the topic of SLR as climate change and environmental initiatives have become central political issues at the federal level. A number of studies, computer models, and predictions exist from various data sources and analysis methods. While a significant amount of uncertainty exists with the exact extent and timing of SLR, the consensus is that the water levels are changing, and the rate of that change is increasing with time.

Over the next 100 years, infrastructure and land areas that are not currently subject to inundation during peak water levels may become flood prone, and areas that are subject to periodic inundation may become regularly submerged.



NOAA predicts that SLR over the last 160 years has been occurring at a rate of 2.8 millimeters per year, which is equivalent to a rise in sea level of 0.9 feet over the past 100 years. Figure 4 presents a graph of the data collection efforts that have led to this conclusion. Since 1990, the rate of change has been increasing such that it no longer fits the trend line, as seen in Figure 4.

The Battery, NY 2.77 +1-0.09 mm/yr 0.60 Source: NOAA Data with the average seasonal Higher 95% confidence interval 0.45 Linear mean sea level trend Lower 95% confidence interval 0.30 0.15 Meters 0.00 -0.151890 1900 1920 1940 1950 1960 1970 1980 1880 1910 1930 2000 2010

FIGURE 4 Sea Level Rise (SLR) Over Past 160 Years, Manhattan, New York

Source: National Oceanic and Atmospheric Association

The implications of this change reach farther than simple engineering design and flooding analysis. Policy changes and future land use planning must account for these changes by promoting coastal resiliency as a matter of responsible development in areas that may become floodprone, even if they are not now. It should also consider cost and benefit of attempting to relocate or "floodproof" land uses that may become regularly inundated.

3.4 New York State Sea Level Rise Task Force

The New York State Sea Level Rise Task Force was charged with several assignments including applying the best possible science to SLR and increasing coastal community resilience for increasing flood severity and frequency.

The findings of the New York State Sea Level Rise Task Force were published in a formal report to the State of New York Legislature in December 2010 and included the following:



- Sea levels have risen 15 inches in the past 150 years.
- Future SLR is predicted to be 12 to 23 inches by the year 2100 in the lower Hudson River Valley, with a potential rise of 55 inches. See Table 7.
- SLR has increased the vulnerability of New York to coastal storms.

TABLE 7 **New York State Sea Level Rise Task Force Findings**

| SLR Scenario | 2020s Predicted Increase in Sea Level (inches/feet) | 2050s Predicted Increase in Sea Level (inches/feet) | 2080s Predicted Increase in Sea Level (inches/feet) |
|-----------------|---|---|---|
| Low Prediction | 3.5 / 0.3 | 9.5 / 0.8 | 24 / 2.0 |
| High Prediction | 7.5 / 0.6 | 24 / 2.0 | 48 / 4.0 |

The recommendations include reducing the vulnerability of coastal areas, emphasizing coastal planning, directing new development away from high risk areas, increasing public awareness, and for all relevant agencies to incorporate SLR into their planning.

3.5 Kingston Tidal Waterfront Flooding Task Force

The Kingston Tidal Waterfront Flooding Task Force was formed in October 2012 and sponsored by the city's Mayor, Conservation Advisory Council, and Office of Economic Development and Strategic Partnership. It included representatives from local businesses, museums, restaurants, marinas, and the public and met monthly over the course of eight months. The goals of the task force were to understand waterfront flooding, prepare for coastal flooding, and plan for the changing sea levels to help make the East Strand waterfront more resilient against rising waters.

The task force first met on December 6, 2012 with the guidance of Scenic Hudson, the New York Department of Environmental Conservation (NYDEC) Hudson River Estuary Program, and the New York Department of State (NYDOS). They considered a wide range of potential future SLR scenarios based upon varied forecast methods and analyses and chose to assess the waterfront for the following SLR values, as shown in Table 8.



TABLE 8 Kingston Tidal Waterfront Flooding Task Force - Selected SLR Values

| SLR Scenario | 2060 Predicted Increase in Sea Level (inches/feet) | 2100 Predicted Increase in Sea Level (inches/feet) |
|---|--|--|
| SLR (Low Prediction) | 20" (1.67') | 33" (2.75') |
| SLR – Rapid Ice Melt (High Prediction) | 36" (3.00') | 68" (5.67') |

The above values are significantly greater than those chosen by the New York State Sea Level Rise Task Force and highlight that the various models are based upon uncertain data and assumptions.

4.0 **RIVERINE FLOODING ANALYSIS**

The available gaging and flow prediction data was compiled and analyzed in order to gain a better understanding of the influences from Rondout Creek on the flooding of East Strand Street. The summary of this analysis is presented below.

4.1 **Peak Flow Predictions**

The Rondout Creek is a 63-mile long tributary of the Hudson River, with its headwaters in the Catskill Mountains, including the southeastern portion of the Catskills. It drains an area of over 1,190 square miles extending into northern Sussex County, New Jersey. Flow in the creek was impounded in 1937 by the Merriman Dam near Lackawack, New York, creating the Rondout Reservoir.

The reservoir is owned and operated as a water supply reservoir for the City of New York by the New York City Department of Environmental Protection (NYCDEP), and the water levels in the reservoir may fluctuate based upon current water demand and precipitation. The starting water surface of the reservoir before a flood event occurs can affect how much storage is available and how much the peak discharge is attenuated downstream.

Peak flood flows for the Rondout were assessed from a variety of sources, which are described in the following sections.

4.1.1 FEMA Riverine Data

An analysis of upstream USGS stream gage data to assess the peak flood flows on the Rondout Creek was also presented in the FIS, which was used to generate flows along the creek at various locations. This Log-Pearson Type III statistical analysis was performed



on available gaging data spanning 77 years (1927 to 2004). Table 9 summarizes the results of its analysis.

TABLE 9
FEMA FIS – Peak Flow Discharges for Rondout Creek

| | Distance Upstream of | Watershed Size | 10% | 2% | 1% | 0.2% |
|---|----------------------|----------------|--------|--------|--------|--------|
| Location | Hudson River (miles) | (square miles) | (cfs) | (cfs) | (cfs) | (cfs) |
| At Confluence with Hudson River | 0 | 1,197 | 33,977 | 51,844 | 60,980 | 86,537 |
| Upstream of Twaalfskill Brook Confluence | 2.65 | 1,187 | 33,743 | 51,511 | 60,599 | 86,028 |
| USGS Gage 01367500 (Rosendale, Keator Avenue) | 10.35 | 383 | 22,109 | 33,430 | 38,871 | 53,061 |

Note:

The FIS presents a technical analysis of flooding behavior for the Rondout Creek and Hudson River area; however, it should be noted that this data is largely based upon historic analyses performed in the 1960s. Changing conditions such as climate change, increases in precipitation, and SLR may affect the accuracy of these values.

Relevant excerpts from the FIS have been duplicated and included in this report in Appendix B.

4.1.2 <u>USGS StreamStats</u>

The *StreamStats* web tool provided by the USGS was used to estimate flows for the Rondout Creek at its confluence with the Hudson River. Peak flows were computed based upon regional regression equations (Lumia, 2006 and Mulvihill, 2009), which were derived from upstream gage data. The underlying regression equations used by *StreamStats* only consider data published before September 1999. Table 10 presents the results of this analysis, and the full results are included in Appendix C.



^{1.} The FEMA FIS estimates hydrologic information at the Rosendale gage and extrapolates downstream to the Hudson River confluence based on a ratio of drainage area.

^{2.} cfs = cubic feet per second

TABLE 10 **USGS** StreamStats – Peak Flow Discharges for Rondout Creek

| | Watershed Size | 50% | 10% | 2% | 1% | 0.2% |
|------------------------------|----------------|--------|--------|--------|--------|--------|
| Location | (square miles) | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) |
| Confluence with Hudson River | 1,190 | 12,500 | 21,900 | 31,800 | 36,700 | 49,700 |

Note:

- 1. USGS StreamStats output considers hydrologic data analysis through September 1999.
- 2. cfs = cubic feet per second

4 1 3 HEC-SSP Bulletin 17B

A program from the USACE called the Hydrologic Engineering Center Statistical Software Package (HEC-SSP) was used to perform statistical analyses of the data from the USGS stream gage referenced above. The raw data from the gage was imported into the program, and the software performed a flood flow frequency analysis based on Bulletin 17B, "Guidelines for Determining Flood Flow Frequency" (USGS, 1982).

These results use data from the same USGS gage as *StreamStats* (described below) but take advantage of a more current data set, capturing recent weather events such as Tropical Storm Irene although the location of the gage is 10.3 miles upstream of the Hudson River. As such, the contributing watershed is approximately 32% of the total watershed

Although the drainage area at the Rosendale gage is only 383 square miles, as compared to 1,190 square miles where the Rondout meets the Hudson, the 1% ACE flow reported by this analysis is only 7% smaller. This is because the HEC-SSP analysis includes an additional nine years of data over what was assessed by the FEMA FIS, and 14 years more data than the USGS StreamStats application, which captures recent significant flow events such as Tropical Storm Irene. If these results were transferred downstream using a standard discharge area relationship derived from the USGS regression equations, the predicted flows would increase significantly.

Table 11 presents the results of this analysis, and the full results are included in Appendix C. The flow results at the Rosendale gage match those estimated in the FEMA FIS to within 12%.



TABLE 11 HEC-SSP Bulletin 17B – Peak Flow Discharges for Rondout Creek

| | Drainage Area | 50% | 10% | 2% | 1% | 0.2% |
|--------------------|----------------|--------|--------|--------|--------|--------|
| Location | (square miles) | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) |
| USGS Gage 01367500 | | | | | | |
| (Rosendale, Keator | 383 | 12,382 | 21,935 | 30,504 | 34,181 | 42,860 |
| Avenue) | | | | | | |

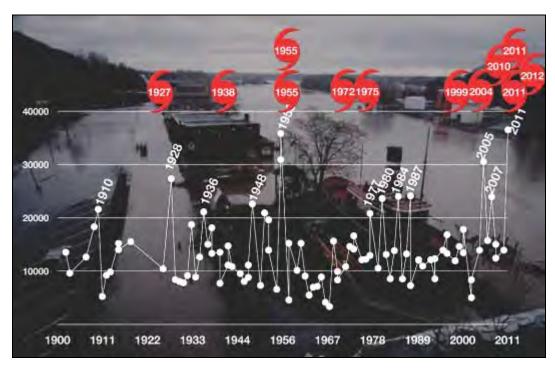
Notes:

- 1. HEC-SSP Bulletin 17B analysis on USGS Gage 01367500 (Rosendale, New York)
- 2. Flows at the Hudson River confluence were extrapolated using the USGS discharge area relationship for Region 4.
- 3. cfs = cubic feet per second

4.2 Existing Conditions Freshwater Flooding Analysis

No detailed record of flooding incidents in the East Strand waterfront area was found as part of this study, so it is difficult to correlate past flood events with tidal or riverine flooding. Figure 5 presents a comparison of tropical weather systems known to have affected the Kingston area and the peak discharges recorded in Rondout Creek over the last 100 years.

FIGURE 5
Peak Discharge (cfs) in Rondout Creek vs. Tropical Weather Systems



Note:

- 1. Source: Scenic Hudson, 2012
- 2. Vertical axis represents discharge in cubic feet per second.
- 3. Horizontal axis represents year.

As seen in Figure 5, many of the highest peak-flow events in the Rondout Creek coincide with tropical weather systems. However, some tropical storm events did not cause excessively high flows in the Rondout such as in 1927, 1938, 1972, 1999, and 2004. Conversely, some high flow events were not a direct result of a tropical weather system, such as in 1928, 1980, 1984, 1987, 2005, and 2007.

It is likely that many of these events correspond with historical flooding of East Strand but, without more detailed records of the water surface elevation, timing, and tidal effects at the time, it is difficult to understand the impact that these flows have.

Hydrologic data for the Rondout Creek was obtained from multiple sources, as described above. The full results from FEMA are located in Appendix B, and data from USGS and HEC-SSP analyses are located in Appendix C. The peak flows predicted in the FEMA FIS represent the highest and therefore most conservative flows.

4.3 **Future Conditions Extreme Precipitation Trends**

Climate change is predicted to increase the frequency of severe storms in the northeastern United States at the same time that SLR magnifies their impact on low-lying coastlines and islands. Rainfall is expected to become more intense, and periods of heavy rainfall are expected to become more frequent. The Northeast Regional Climate Center (NRCC) reports that severe precipitation events that once occurred with a 1% chance in any given year are now likely to occur twice as often.

Until recently, common engineering practice has been to design storm drainage systems for the 10% ACE storm, often using the US Weather Service Technical Paper No. 40 (TP-40). The rainfall data presented in TP-40 is from 1961 and does not include the past 50 years of climatological data in which these trending increases in precipitation have been recorded.

To ensure that the existing drainage system analysis was more relevant to current rainfall patterns, the existing drainage system was analyzed for the 10% ACE storm using data from the NRCC that includes rainfall data through 2008. This provides a more realistic representation of current rainfall trends but does not extrapolate data into the future.

To account for future precipitation trends, communities may choose to increase the rainfall magnitude or intensity for which their storm drainage systems are designed. For the purposes of the conceptual alternatives discussed in Section 4.0 Flooding Mitigation Alternatives, the 10% ACE storm has been chosen to represent a direct comparison to the performance of the existing drainage system. However, because much of the area of East Strand Street is below the FEMA designated 10% ACE water surface elevation of 6.0 feet NAVD88, the cost of designing a larger drainage system may not be justified as the street and surrounding areas may be subject to flooding anyway. This may be something that



the City of Kingston chooses to pursue in future drainage system designs, depending on how the future reuse of the East Strand area is structured.

5.0 STORMWATER FLOODING ANALYSIS

The available survey and land use data was compiled and analyzed in order to gain a better understanding of the influences of stormwater runoff from land uphill of East Strand Street as it affects the flooding of the roadway. The summary of this analysis is presented below

5.1 Stormwater Runoff Analysis

Most of the Ponckhockie neighborhood dates back to the late 1800s and early 1900s. Storm drainage systems were installed on an as-needed basis and were likely not planned for the future expansion of homes in the area. The aging structures and pipes were found to be in need of maintenance and were generally in poor condition.

To assess the capacity of the existing drainage systems if they were to undergo maintenance and minor upgrades, existing conditions hydraulic analysis was performed of the drainage systems found in the 3,000 linear feet of East Strand Street considered in this report. The existing conditions system was analyzed using the *StormCAD V8i* software package from Bentley Systems, Inc. This software determines the capacity of existing pipes and catch basins by estimating flow rates from the contributing watersheds and routing those flows through the network of pipes.

The model uses the Rational Method to determine peak flow rates to each structure, the inlet capacity of each catch basin (i.e., the rate at which water can flow into the inlet grate), hydraulic losses through pipes and junctions, pipe capacities in the network, and the effects of high tailwater elevations at the outfall.

Based upon field survey and visual assessment, four drainage system outfalls are thought to exist along the stretch of East Strand Street in question. The four drainage systems were numbered starting at the western end of the roadway. Watersheds were delineated to each structure within each system based upon available topography, and times of concentration were calculated based on topography and land use. A graphic with delineated watersheds is presented in Figure 6, and full results of the analysis are included in Appendix D.

System 1 discharges through an 18-inch cast iron culvert in a precast concrete endwall, just above two other 21-inch discharges associated with the WWTP, which were located through survey.

The outfall location for System 2 was found near the remnants of a stone endwall, but the pipe itself was not found.





MILONE & MACBROOM®

99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmacbroom.com

| DATE | MARCH 2013 |
|-------------------|------------|
| SCALE | 1"=400' |
| PROJ. NO. | 4766-02 |
| | |
| DESIGNED | JCM |
| DESIGNED DRAWN | JCM |

FLOODING ANALYSIS

RONDOUT CREEK AND EAST STRAND STREET KINGSTON, NEW YORK

DRAWING NAME:

FIG. 6

SCALE 1" = 400'

Although a boat was used to investigate the shoreline at low tide, the outfalls for Systems 3 and 4 were not found. For the purposes of this analysis, their size, shape, location, and elevation were estimated.

Using topographic mapping provided by Ulster County, contributing watersheds to each outfall were delineated, and the land use in each was computed. These were used as inputs to the model. A summary of the drainage analysis results is presented in Table 12.

TABLE 12
Existing Conditions Drainage System Analysis

| Drainage System | Drainage Area (A, ac) | Average Runoff Coef. (C) | Peak 10% ACE Flow (cfs) | Outlet Size (in) | Outlet Capacity (cfs) | Excess Capacity (cfs) |
|--------------------|-----------------------------|--------------------------------|-------------------------------|------------------------|-----------------------------|-----------------------------|
| System 1 | 18.7 | 0.38 | 15.1 | 18-in | 13.8 | -1.3 |
| System 2 | 11.0 | 0.31 | 9.2 | 12-in ¹ | 1.1^{1} | -8.1 ¹ |
| System 3 | 42.9 | 0.41 | 44.6 | 18-in ¹ | 4.8^{1} | -39.8^{1} |
| System 4 | 4.1 | 0.54 | 6.6 | 18-in ¹ | 11.4^{1} | 4.8^{1} |

Note:

The results indicate that three of the four outlets do not have adequate capacity to convey stormwater runoff from the 10% ACE storm event. The analysis was performed without the effects of any tailwater, assuming low tide in Rondout Creek. Adding tidal influence only compounded the level to which these systems failed.

6.0 FLOODING SUMMARY AND MITIGATION ALTERNATIVES

6.1 Summary of Flooding Behavior at East Strand

From the results of the preceding analyses, it is clear that the existing stormwater drainage systems in East Strand are inadequate. They do not have sufficient capacity to convey even the 10% ACE storm. Nuisance flooding develops in the East Strand roadway from this inadequate drainage and from high tide elevations as compared to low roadway elevations.

More extreme flooding may occur less frequently, but these floods are unrelated to the storm drainage system inadequacies. The 10% ACE tidal event will cause inundation on East Strand of up to 6.0 feet in elevation and will only increase as SLR worsens. Approximately 40% of East Strand Street and the surrounding area would be completely under water during this event, and adequate roadway drainage would be irrelevant.

No direct conclusion can be made from correlating high flows in Rondout Creek and flooding on East Strand Street without detailed records of when flooding occurred and how severe it was. Based on the flooding trends seen in recent storms such as Tropical Storm Irene, it is strongly inferred that riverine flooding can cause water surface



^{1.} Outfall size and elevation are estimated; capacity is approximate.

elevations at the East Strand waterfront to increase during heavy flow events in the Rondout

The water surface elevations of the Hudson River and Rondout Creek at the East Strand waterfront are generally the same. The Hudson River has a watershed size of 11,700 square miles whereas the Rondout watershed is only 1,190 square miles. Therefore, the magnitude of peak flows generated by the Rondout would typically be less severe than a flow of equal frequency on the Hudson. The Hudson River basin is capable of passing the peak flows from Rondout Creek with minimal impact to its water surface elevation.

A direct relationship between tidal height and flooding at East Strand can be identified based on recent flood events such as Hurricane Sandy. The storm surge influence from high winds during tropical weather systems has a significant impact on the water surface elevation in the Hudson River and Rondout Creek near the East Strand waterfront.

Table 13 presents statistics of the two most recent tropical storm events as they relate to flooding at the East Strand waterfront. Because a USGS water level gage was installed beneath the New York State Route 9W bridge, it is possible to correlate flooding information at East Strand with measurements of rainfall, tidal influence, and discharge in Rondout Creek. Table 13 includes the precipitation data measured at Kingston, tidal elevations measured in Poughkeepsie, and discharge in the Rondout measured upstream in Rosendale.

TABLE 13 Flooding Summary for Recent Tropical Weather Events

| Storm Event | Date | 24-hr Precip. Kingston (inches) | WSEL Hudson River, Poughkeepsie (feet, NAVD) | Discharge Rondout Creek (cfs) | Water Elevation East Strand, Kingston (feet, NAVD) |
|-------------------------|------------------|---------------------------------------|--|-------------------------------------|--|
| Tropical Storm Irene | Aug. 28, 2011 | 6.5 (38-yr) ¹ | 7.15 (45-yr) ¹ | 36,500 (110-yr) ¹ | $6.2^2 (15-yr)^1$ |
| Hurricane Sandy | Oct. 30, 2012 | $0.1 (n/a)^{1}$ | 8.73 (220-yr) ¹ | 1,500 (n.a.) ¹ | 9.3 (200-yr) ¹ |

Note:

- An estimate of the recurrence interval for each event is included in parentheses after each value. These estimates were based upon published magnitude/frequency relationships from NRCC (precipitation), USGS (water elevation), and USGS StreamtStats (discharge).
- 2. The water elevation at East Strand during Tropical Storm Irene is anecdotal and approximate in nature.
- 3. WSEL = water surface elevation
- 4. cfs = cubic feet per second

As indicated in Table 13, Tropical Storm Irene produced high rainfall in Kingston and the surrounding areas, which generated discharges in Rondout Creek that exceeded the 1% ACE flood event and became the flood of record for the USGS gage in Rosendale.



However, the flooding severity at the East Strand waterfront only peaked at an elevation of 6.2 feet NAVD, which FEMA predicts to be a 15-year recurrence interval.

In contrast, Hurricane Sandy had very low rainfall and generated almost insignificant flow in Rondout Creek. However, the USGS stream gage located at Poughkeepsie underwent the highest tide recorded since its installation 11 years ago, at an elevation of 8.73 feet. This high elevation was due almost entirely to storm surge in New York Harbor from the hurricane. As a result, flooding at the East Strand waterfront reached a recorded elevation of 9.3 feet NAVD.

The implication of this information is that Rondout Creek flooding at East Strand is tidally controlled. While the construction of an adequate roadway drainage system will help with the smaller, nuisance flooding events caused by higher than normal tides, severe flooding events over the 10% ACE will flood East Strand and the surrounding area under existing conditions regardless of drainage improvements performed. This also implies that flooding will be exacerbated by the effects of SLR and can be expected to become more frequent and more severe.

6.2 Flood Mitigation Criteria

Planning for future use of the East Strand waterfront area should consider multiple water resource aspects including the long-term viability and planning of the desired land uses, three sources of flooding, various predictions for SLR, precipitation trends, and the level of acceptable risk.

The long-term viability should be assessed such that the planned infrastructure is designed to withstand the anticipated conditions that may exist at the end of its life expectancy. Suggested dates include conditions in 2050, 2100, 2113 (100 years from today). Based upon the available building materials and assumptions, this study suggests using a planning period of at least until the year 2100.

The three flooding sources are tidal (Hudson River), riverine (Rondout Creek), and stormwater runoff. However, the most damaging floods are from tidal influence and should be considered most carefully. Water levels in the Hudson River are increasing, as influenced by tidal conditions and SLR, and are predicted to rise by 3.0 to 5.7 feet by the year 2100.

The elevation criteria for newly constructed buildings in floodprone areas along the East Strand waterfront should meet or exceed the New York State Task Force findings on SLR, as shown in Table 7 based upon the expected life span of the structure.

The elevation of new bulkheads or levees, if used for flood control, should be at least two feet higher than the New York State Task Force criteria for the year 2100. This will meet the FEMA levee certification criteria of two feet of freeboard over the base flood, or the 1% ACE water surface elevation. Upon completion of their efforts, recommendations as



put forth by the Kingston Tidal Waterfront Flooding Task Force should be considered as well. The estimated levee crest would be at or near elevation 13 to 15, depending on the final criteria selected.

6.3 Flooding Mitigation Alternatives

Effectively mitigating the multiple causes of flooding in East Strand Street may require a combination of types of treatments and strategies.

The primary contributors to frequent, less severe nuisance flooding are the inadequate roadway drainage systems and the low roadway elevations in comparison to normal high tides.

The major contributor to less frequent and more damaging floods is tidal and storm surge influences from the Hudson River. Both causes must be addressed, and solutions that effectively mitigate flooding during the most extreme conditions may not be economically viable.

There are three strategies for mitigating floodwaters from rising sea level, and the alternative likely chosen by the city will involve a combination of these three strategies.

- 1. Fortification of Infrastructure: Fortification of the East Strand waterfront may be viable for protecting against smaller, more frequent nuisance floods. This may involve shoreline treatments; bulkheads; raising the elevation of the roadway, railroad, and adjacent land; and installing backflow prevention devices on drainage systems to prevent frequent flooding from occurring.
- 2. Relocation of Infrastructure: Relocating the development of East Strand is contrary to the goals of this analysis but is an option the city may choose to pursue if flooding of certain infrastructure such as the WWTP or the entire roadway itself such that future development can be explored.
- 3. Accommodation of Floodwaters: Accommodating flood waters in a manner that minimizes damages when they recede is a third strategy that will play an important role in the future development of the East Strand waterfront as rising sea levels will ensure that the frequency and severity of inundation that occurs in the area will only increase with time. Examples of this include elevating new buildings and providing parking or other related uses underneath.

The Relocation of Infrastructure strategy must be assessed on a per-item basis. A more detailed study of each of these individual assets must be performed. Similarly, Accommodation of Floodwaters involves the adoption of revised building codes and methods for the existing structures and infrastructure already in place, which will vary



with each building and infrastructure type. A brief summary of these practices is presented in Section 6.4.

The Fortification of Infrastructure strategy is explored in more detail through a variety of alternatives. Table 14 provides a summary of those alternatives and their applicability to the various sources of flooding. Tidal and riverine effects are combined for this comparison because they both result in rising water elevations in the Rondout, and mitigation alternatives will perform similarly against both types of flooding.

TABLE 14 Summary of Potential Flood Mitigation Alternatives

| Alternative | Tidal/Riverine | Stormwater | Frequent Flood Events | Extreme Flood Events |
|---------------------------|----------------|------------|-----------------------|-------------------------|
| Local Protective Measures | X | | X | X |
| Drainage Improvements | X | X | X | |
| Roadway Elevation | X | X | X | |
| Shoreline Modification | X | | X | |
| Flood Barriers and Levees | X | | X | X |

Note

- 1. Frequent flood events are less than the current 10% ACE frequency, or below elevation 6.0 feet NAVD.
- 2. Extreme flood events are greater than the 10% ACE frequency, or higher than elevation 6.0 feet NAVD.

The proposed alternatives have been described in additional detail in the sections below.

6.3.1 Local Protective Measures

This class of individual flood protection measures can be applied to independent properties or areas to minimize the vulnerability of that property to flood hazards. These measures can include but are not limited to:

- Filling and raising of individual properties
- Raising whole buildings or internal mechanicals
- Floodproofing buildings at grade
- Raising or floodproofing public utilities
- Backflow prevention on drains and sewers

Many of the existing buildings are historic brick structures constructed on slabs that would be difficult to raise. New buildings would be constructed to comply with National Flood Insurance Program (NFIP) regulations that require elevation or enclosure of the buildings.

The primary disadvantage of individualized local measures is that the roadway and public areas will still be flood prone, which would obstruct traffic and emergency services from reaching the buildings in the event of a severe flood. Local protective measures are most



suitable to use for moderate flood frequency but, at an increased cost, most buildings can be raised or sealed from even the most extreme floods.

6.3.2 <u>Drainage Improvements</u>

Roadway reconstruction efforts may only be effective if coupled with the reconstruction of the existing drainage systems. Rebuilding the existing drainage systems to ensure proper inlet and pipe capacity and adding tide gates at the end of them will help prevent smaller, more frequent floods caused by heavy rainfall or higher tides.

Given the low-lying nature of East Strand as compared with the other uphill streets in Ponckhockie, one recommendation for the proposed drainage system involves disconnecting the uphill drainage systems from those that serve East Strand and allowing them to discharge separately. Under existing high tide conditions, these drainage systems exacerbate surcharging of the drainage structures in East Strand. If they are disconnected from the system and discharged separately, their higher elevations may give them the hydraulic head necessary to continue to discharge during high tide events.

After disconnecting the uphill tributary systems, East Strand can be reconstructed with new drainage systems with much smaller, localized contributing drainage areas. This minimizes the amount of water that will accumulate at the low points while tidal influence prevents the drainage systems from discharging.

The second general recommendation for the new drainage systems would be the installation of tidal backflow prevention devices or flap gates to prevent backwater from storm surge and extremely high tides from surcharging the drainage systems and causing the road to become inundated.

As mentioned below in Section 6.3.3, hydraulic modeling indicates the installation of a properly designed storm drainage system combined with the reconstruction of the roadway to a higher elevation (described below) may reduce or eliminate flooding up to a tidal elevation of 6.4 feet, or the 10% ACE frequency event (under current sea level conditions). Schematic plans of the proposed drainage improvements have been included in Appendix F.

6.3.3 Roadway Elevation

Raising the elevation of the roadway and sidewalks provides a simple alternative to lessen the impact of tidal flooding on East Strand Street but also presents a number of complicating factors. The close proximity of historic buildings such as the Cornell Building, the Steel House restaurant, the WWTP, and the adjacent railroad tracks limits the height to which the road can be raised before buildings need to be removed, relocated, or reconstructed.



The lowest regions of East Strand Street are typically the first to flood as the existing drainage system surcharges, and water fills the low points. These areas are as low as elevation 3.0 feet NAVD. To accommodate the existing structures and railroad tracks, which are typically at elevation 5.0 feet NAVD, raising these low areas of the roadway to a maximum elevation of 5.0 feet while maintaining minimum longitudinal slopes of 0.5% slope can reduce the frequency of flooding considerably. Combined with an adequate drainage system and proper backflow prevention devices, the results of hydraulic modeling indicate that roadway flooding may be reduced or eliminated up to a tidal elevation of 6.4 feet, or the 10% ACE frequency event (under current sea level conditions).

Schematic plans of the proposed drainage improvements have been included in Appendix E. These improvements account for the effects of improved roadway drainage as described in Section 6.3.2.

6.3.4 **Shoreline Modification**

Fortification of the existing shoreline may also provide limited benefit to the East Strand area but only for less extreme flooding events. The average elevation of the shoreline from the WWTP to the eastern end of East Strand Street ranges from elevation 5.0 to 6.0 NAVD88, with localized areas that dip below elevation 5.0. In the development plan for these undeveloped parcels, it may be beneficial to raise these isolated low points such that the ground remains continuously at-grade for the length of the street.

Ensuring that the waterfront and bulkheads maintain a minimum elevation of 6.4 feet can provide protection up to and including the existing 10% ACE tidal event and is likely to be feasible given the surrounding topography. Figure 8 presents a schematic of the shoreline fortification that may be required.

It is important to note that raising the grade along the shoreline will only be effective up to the lowest elevation found along its waterward perimeter. From the mapping available through the county, the Rondout waterfront to the west of East Strand and out to Kingston Point Park continues to remain at a low elevation. Therefore, fortifying East Strand may involve fortifying areas along West Strand out to Kingston Point Park as well. This also implies that there will be lower-lying elevations behind the berm that would require the installation of a large area for detention, or a stormwater pumping station to prevent stormwater flooding when the tidal events become too high for drainage to discharge.

6.3.5 Flood Barriers and Levees

Earthen levees and structural floodwalls of concrete, steel sheeting, or timber can form a barrier that separates rising waters in Rondout Creek from the East Strand waterfront. Flood barriers can be located along the riverfront at a sufficient height to provide a high level of protection, but several special considerations must be addressed.



Flood barriers require routine maintenance such that the physical integrity is maintained and that they maintain the eligibility for FEMA Flood Insurance Certification. Earthen levees require a wide area for their construction and maintenance to provide structural stability. A 10-foot high levee with a 12-foot wide crest and 2:1 (horizontal to vertical) side slopes would be a total of 52 feet wide. In areas where open space is restricted, structural floodwalls can be used in a much smaller footprint but at a higher cost.

Accessways through the levees with atgrade sidewalks or driveways can be provided but may require bulkhead closures to seal the openings during floods. Bulkhead closures operate as manually controlled gates that allow access through the levee during dry times and seal against water during flood events but have the disadvantage of being manually opened and closed in preparation for potential flood

events. If levees or floodwalls are



Figure 7: Photograph of Typical Bulkhead Installation

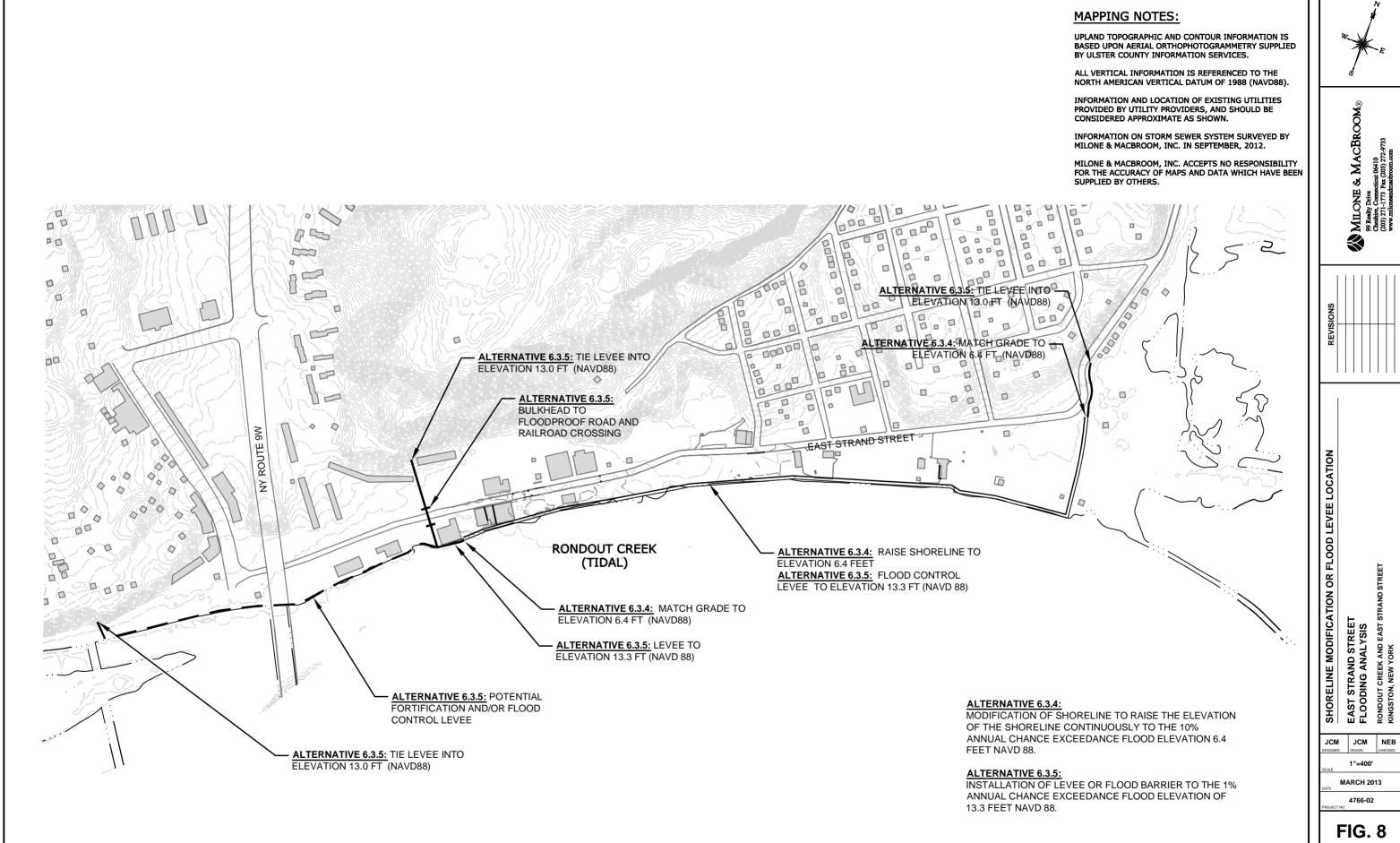
used, their terminal ends must be connected into high ground so floodwaters do not circumvent the walls and the lower lying land behind them.

The installation of levees or floodwalls would isolate the enclosed area from the effects of flooding but in doing so would make access to the waterfront more difficult. This is contrary to the expressed goals of the city to provide a more vibrant, publically accessible waterfront and should be considered carefully before levees or floodwalls are pursued. Access to the waterfront would only be possible through bulkheads through the levees, or pedestrian walkways above the levees with stairs or ramps on the landward and waterward sides of the levee

Stormwater runoff and interior drainage obstructed by the levees or floodwalls must be addressed as well. Commonly, this is achieved through the use of backflow prevention devices at the stormwater discharges that penetrate the levees, and interior detention or pumping stations to accommodate the interior runoff that cannot discharge due to the high water on the discharge side of the levee.

In order to be effective, any barriers or levees would have to protect to at least the anticipated 100-year (1% ACE) water surface elevation. Under current conditions, FEMA lists this elevation as 9.3 feet NAVD88 (9.0 feet NAVD88 before correction for 2013). The New York Sea Level Rise Task Force indicates planning for the next 100 years should include a rise in sea level of 24 – 48 inches. Using the higher value, this would mean a levee to elevation 13.3 feet. Figure 8 presents a graphic of the location of such a levee if it were to be constructed.







Advantages of a levee or floodwall system are the ability of these devices to high levels of flood protection to a broad area and preclude the need to raise roads or floodproof individual buildings. The disadvantages include their maintenance needs, required land area for earthen berms, high costs of installation, the need for regulation of bulkheads and access points prior to the forecast of a flood event, interior drainage management complications (including pump stations, gate valves) that add capitol and operation costs, and the isolation of the community from the waterfront.

6.4 **Coastal Resiliency in Redevelopment**

Accommodation of long-term and severe flooding is likely to be an important part of sustainably developing the East Strand area. Using specialized construction methods that resist erosion, specialized building designs that can allow for periodic inundation, or policy and zoning regulations that prohibit certain types of development types that may be especially vulnerable to inundation are examples of ways that communities can accommodate rising water levels.

Coastal resiliency and adaptation to coastal hazards have traditionally been undertaken using shoreline hardening and engineered defenses, which are often unsuccessful against the rising waters from sea level rise While nuisance flooding may be reduced by the countermeasures and fortification methods described above, it would become increasingly expensive to prevent more severe flooding (over elevation 7.0 feet NAVD), which will become more frequent with the effects of SLR.

Based on zoning changes the city may choose to enact, certain land uses that cannot accommodate periodic flooding may become nonconforming uses. Examples on East Strand may include the WWTP, oil storage, or other areas that could suffer catastrophic failure if inundated. It may be necessary to plan for the longer-term relocation of these land uses away from floodprone areas, especially as SLR causes more frequent and more severe flooding.

In addition to disallowing certain uses of the waterfront, revisions to the zoning regulations could also be used to promote more recreational and open space types of water-dependent land uses. These may become public assets that are naturally more resilient to the periodic inundation that may occur.

The city may also choose to enact provisions in the building codes to account for the increase in flooding of the East Strand area. This may involve retrofitting existing structures to remain in order to ensure they are less vulnerable to floods and planning new construction in such a way as to prevent or minimize damage during floods. This typically involves raising the first floor of buildings, raising the mechanicals and utilities in the buildings, and floodproofing the interiors such that they will not suffer long-term damage if they become wet.



7.0 RECOMMENDATIONS AND CONCLUSIONS

Periodic flooding in the East Strand waterfront area is caused by several contributing factors. For the purposes of this report, the flooding can be characterized into two types. More frequent nuisance roadway flooding below elevation 6.0 feet NAVD is caused by rising tides, low roadway elevations, and inadequate drainage systems. Severe flooding above elevation 6.0 feet NAVD, which is currently specified by FEMA as the 10-year flood or 10% annual chance of recurrence, is caused by the storm surge and tidal influences generated in New York Harbor and transferred upstream to Kingston via the Hudson River.

SLR exacerbates the flooding problems by raising the baseline water elevations in the Hudson River and Rondout Creek, worsening the effects and frequency of tidal events, which may cause periodic flooding over elevation 6.0 feet NAVD to increase in frequency. According to the SLR values adopted by the Kingston Tidal Waterfront Flooding Task Force, the East Strand area can expect up to 36 inches of water level increase by 2060. This would increase the MHHW, the average of the highest daily diurnal tides) from elevation 2.8 feet NAVD to elevation 5.8 feet NAVD, or 0.2 feet lower than the current 10-year (10% annual chance of recurrence) flood.

As described in section 6.3, there are three primary strategies for dealing with floodwaters from rising sea levels: Fortification of Infrastructure, Relocation of Infrastructure, or the Accommodation of Floodwater. While fortification remains the most effective strategy for smaller, more frequent floods, the relocation of important infrastructure elements and changes in the way future development is enacted to accommodate changing flood patterns are more effective for severe floods.

7.1 Nuisance Flooding Mitigation Recommendations

Fortification and proper conveyance of stormwater and lesser floodwaters can mitigate the effects of frequent floods at East Strand Street. The recommended approaches to addressing flooding below elevation 6.0 feet NAVD primarily follow the fortification strategy and are as follows:

- 1. Alternative 6.3.2: Reconstruct the drainage systems and outfalls that drain East Strand and the uphill roadways in Ponckhockie. This includes disconnecting the uphill drainage systems and installing backflow prevention devices at the drainage system outlets.
- 2. Alternative 6.3.3: Raise East Strand Street above the influence of unusually high tidal cycles. This may involve raising the lowest points of the road by up to two feet.
- 3. Alternative 6.3.4: Modify development plans to include the filling of waterfront areas up to elevation 6.0 feet NAVD, ensuring that no low points below this elevation occur at the eastern or western ends of the roadway.



The feasibility of such efforts as described must be further evaluated, and all construction in the FEMA floodplain must be permitted through the applicable local, state, and federal agencies. However, rough costs for the three alternatives are presented in Figure 9.

7.2 Severe Flooding Mitigation Recommendations

In general, it is recommended that as many non-water dependent land uses be relocated from the waterfront area as possible, including the Wastewater Treatment Plant and possible relocation of the East Strand roadway itself. Additionally, building codes and zoning regulations should account for the effects of SLR and should prevent the permitting of water-intolerant development in floodprone areas.

The recommended relocation and accommodation approaches to addressing flooding above elevation 6.0 feet NAVD are:

- 1. Revise zoning regulations to control land use and development of the waterfront area, promoting water-dependent use and public open space creation.
- 2. Revise building codes to require flood-resilient development of any newly constructed buildings or infrastructure in the East Strand waterfront district based upon their elevation and vulnerability to flooding.
- 3. Explore the relocation or retrofitting of existing floodprone buildings and infrastructure in the East Strand area to minimize damage during severe flood events.
- 4. If financially feasible, explore the option of levees or floodwalls to provide protection against the increasing potential for severe floods.



Cheshire, Connecticut 06410

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

11/12/2013 MMI# 4766-02 BY: JCM

FIGURE 9 - PRELIMINARY OPINION OF PROBABLE CONSTRUCTION COSTS

Cost Opinion Based on Conceptual Analysis Report Dated April 5, 2013

| No. Item | Unit | Quantity | Unit Cost | Cost |
|---|----------|----------|--------------------|--------------|
| 1 Alternative (22 Helend Decime - Learness | | | | |
| 1. Alternative 6.3.2 - Upland Drainage Improvements 1.a Design and Permitting | LS | 1 | | |
| <u> </u> | LS | 1 | \$60,000.00 | \$60,000.00 |
| 1.b Drainage System 1 | LS LS | 1 | . , | . , |
| 1.c Drainage System 2 | | 1 | \$50,000.00 | \$50,000.00 |
| 1.d Drainage System 3 | LS | 1 | \$200,000.00 | \$200,000.00 |
| 1.e Drainage System 4 | LS | 1 | \$50,000.00 | \$50,000.00 |
| 1.f Utility Relocation Allowance - not included | | | | - - |
| | | | Subtotal | \$360,000.00 |
| | | | 20% Contingency | \$72,000.00 |
| | | Alten | native 6.3.2 Total | \$432,000.00 |
| 2. Alternative 6.3.3 - Raise East Strand Street | | | | |
| 2.a Design and Permitting | LS | 1 | \$80,000.00 | \$80,000.00 |
| 2.b Roadway Reconstruction | LF | 1,400 | \$275.00 | \$385,000.00 |
| 2.c Drainage Construction | LS | 1 | \$360,000.00 | \$360,000.00 |
| 2.d Utility Relocation Allowance - not included | | | | - |
| 2.e Streetscape (Sidewalks, Lighting, Planting) - not included | | | | - |
| 7 0 0 | | | Subtotal | \$825,000.00 |
| | | +2 | 20% Contingency | \$165,000.00 |
| | | | native 6.3.3 Total | \$990,000.00 |
| 3. Alternative 6.3.4 - Shoreline Modification | | | | |
| | LS | 1 | \$15,000.00 | \$15,000.00 |
| 3.a Design and Permitting | LS LS | I 1 | \$15,000.00 | . , |
| 3.b Import of Fill | LS LS | 1 | | \$80,000.00 |
| 3.c Vegetative Restoration | LS | 1 | \$16,000.00 | \$16,000.00 |
| 3.d Utility Relocation Allowance - not included | | | | ¢111 000 00 |
| | | | Subtotal | \$111,000.00 |
| | | | 20% Contingency | \$22,200.00 |
| | | Alten | native 6.3.4 Total | \$133,200.00 |

Notes:

- 1) Item 2.c includes the same scope of work as Items 1.b-1.e.
- 2) Cost does not account for relocation of existing utilities.
- 3) Costs do not reflect potential need for remediation of environmental contamination.
- 4) Costs do not include temporary or permanent easements required for the proposed work.
- 5) All material quantities and volume estimates are done without formal survey of existing conditions and are approximate.

REFERENCES

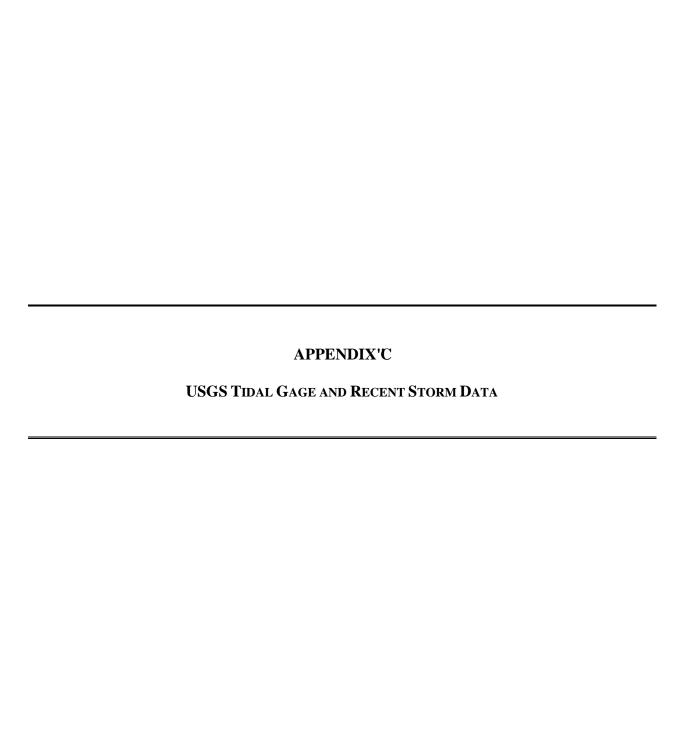
- City of Kingston, NY, October 6, 2003. City of Kingston Local Waterfront Revitalization Program, National Oceanic and Atmospheric Administration, and the New York Department of State.
- Federal Emergency Management Agency, April 5, 1988. Flood Insurance Study, Town of Kingston, New York.
- Federal Emergency Management Agency, September 25, 2009, Updated December 12, 2011. Flood Insurance Study Number 36111CV001A, Ulster County, New York.
- Lumia, R., Freehafer, D., and Smith, M., 2006. Magnitude and Frequency of Floods in New York, Scientific Investigations Report 2006–5112. U.S. Geological Survey, in Cooperation with the New York State Department of Transportation. Troy. NY
- Mulvihill, C., Baldigo, B., Miller, S., and DeKoskie, D., 2009. Bankfull Discharge and Channel Characteristics of Streams in New York State, U.S. Geological Survey, Reston, VA
- New York State Sea Level Rise Task Force, December 31, 2010. Report to the Legislature. New York Department of Environmental Conservation, et al.
- River Street Planning & Development, 2001. Kingston Waterfront Development Implementation Plan, New York Department of State.
- Scenic Hudson, 2010. "Revitalizing Hudson Riverfronts," New York Department of State.
- U.S. Weather Service, May 1961. Technical Paper No. 40 Rainfall Frequency Atlas of the United States.
- U.S. Army Corps of Engineers, 1975. New York District, Stage Frequency Curves, Hudson River Tides, Spuyten Duyvil to Albany, New York.
- U.S. Army Corps of Engineers, 2010. Hydrologic Engineering Center River Analysis System (HEC-RAS) (V. 4.1).U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA
- USGS, 1982. Guidelines for Determining Flood Flow Frequency (Bulletin #17b). Interagency Advisory Committee on Water Data, U.S. Geological Survey, Reston, VA

INTERNET REFERENCES

- Extreme Precipitation in New York and New England, 2013, Northeast Regional Climate Center (NRCC) and Natural Resources Conservation Services (NRCS). http://precip.eas.cornell.edu
- NOAA Center for Operational Oceanographic Products and Services. http://tidesandcurrents.noaa.gov
- NOAA Sea Level Trends. http://tidesandcurrents.noaa.gov/sltrends/
- USGS National Water Information System: Web Interface. http://waterdata.usgs.gov
- USGS StreamStats: A Water Resources Web Application. http://streamstats.usgs.gov
- Weather Underground Historical Weather Station Data. http://www.wunderground.com

4766-02-1-o2213-rpt.doc





Project No.: 4766-02

Designed By: JCM

Kingston, New York

Checked By: NEB

East Strand Street Flooding Analysis, Kingston NY

Figure 3 - Tidal and Storm Data Summary

Datum Conversion

0 ft NGVD = -0.807 ft NAVD

Watershed Area

Hudson 11,740 sq mi (downstream of Poughkeepsie)

Rondout 1,190 sq mi (at Kingston)

FEMA Elevation in Hudson River

| | 10-Yr | 50-Yr | 100-Yr | 500-Yr | |
|----------------|-----------|-----------|-----------|-----------|----------------------|
| | (ft NAVD) | (ft NAVD) | (ft NAVD) | (ft NAVD) | |
| Kingston Point | 6.0 | 7.5 | 8.9 | 10.4 | (based on 1975 data) |
| Poughkeepsie | 5.9 | 7.1 | 8.0 | 9.7 | (based on 1975 data) |

USGS Gage

| <u>No.</u> | River | Location | <u>Installed</u> | Active? | Data Type | Max Record | Max Date |
|------------|---------|--------------------|------------------|---------|-------------|------------------|------------------|
| 01372007 | Rondout | Kingston | 2012-11-05 | yes | Tidal Stage | 13.5 *(no datum) | 10/30/12 (Sandy) |
| 01367500 | Rondout | Rosendale | 1901-07-08 | yes | Flow | 36,500 cfs | 8/28/11 (Irene) |
| 01372058 | Hudson | S. of Poughkeepsie | 1992-05-12 | yes | Tidal Stage | 8.73 ft NAVD | 10/30/12 (Sandy) |

*Note: *max elev of 13.5 ft was surveyed as 9.3 ft navd, correction factor = -4.2 ft

Hurricane Statistics

| 1 | rene | 8/28/11 | |
|---|-------|---------|--|
| l | Helle | 0/40/11 | |

High Water Mark ± 6.2 ft navd (from photos)

Hudson Stage 7.15 ft navd (South of Poughkeepsie) converted from 7.96 ngvd, from USGS gage

Flow in Rondout 36,500 cfs (flood of record, since 1901 at Rosendale)

Precipitation 6.2 in (knykings13, Kingston, NY)

6.5 in (Kingston WWTP records)

Sandy 10/30/12

High Water Mark 9.3 ft navd (USGS surveyed multiple wrack lines surveyed by USGS near Kingston Point)

Hudson Stage 8.73 ft navd 29-Oct (South of Poughkeepsie) converted from 9.54 ngvd, from USGS gage

4.89 ft navd 28-Oct (South of Poughkeepsie) converted from 4.89 ngvd, from USGS gage

Flow in Rondout 1,500 cfs (at Rosendale)

Precipitation 0.11 in (knykings13, Kingston, NY)

| Sea Level Rise | | Year 2050 | Year 2100 |
|---------------------------------------|---------------|-----------|-----------|
| Data as presented by the City | Low Scenario | 17 in | 36 in |
| of Kingston Sea Level Rise Task Force | High Scenario | 26 in | 68 in |

Data compiled by NOAA measured at The Battery, NYC from 1856-2006 2.77 mm/yr = 0.1091 in/yr

Tidal Statistics at Kingston Point

| | NOAA Elev. (ft, NAVD) | USGS Gage Data (ft, NAVD) |
|------|-----------------------|---------------------------|
| MHHW | 1.32 | 2.8 |
| MHW | 1.07 | 1.8 |
| MTL | -0.78 | 0 |
| MLW | -2.63 | -1.2 |
| MLLW | -2.88 | -2.2 |

Engineering, Landscape Architecture and Environmental Science



| JOB E. STRAND KNIGSTON | FLOODING 4766-UZ | |
|------------------------|------------------|---|
| SHEET NO. | OF | |
| CALCULATED BY JCM | DATE 3 6 13 | _ |
| CHECKED BY | DATE | |
| SCALE | | |

| USE NO. | AA 170E | GAGES. GAG | E IN NEW | YORK | CITY CAN | BE WED | 70 |
|--------------|------------|----------------|-----------|----------------|--------------|-------------|---------|
| 30,100 | THE INPLUE | uce in ki | NGTTON. | | | | |
| STATION ID | | | | | | | |
| NAME: THE | BATTERY, 1 | VEW YORK HARI | SOR | | | | |
| NEW | YORK CITY, | | | | | | |
| Actions | | T) MUW | EL | EV. (FT |) NAVD | | |
| | 5.06 | | | 2.28 | | | |
| MHW | | | | 1.95 | | | |
| | | CONVERT | | 0,00 | | | |
| WT | 2 67 | TO NAVO | | -0.21 | | | |
| | 1,68 | Δ=-2. | 10 | - i, 10 | | | |
| MLW | 0.21 | | | -2.57 | | | |
| | 0,00 | | | -2.78 | | | |
| | 3,00 | | | g ., 70 | | | |
| CONJERT TO A | CINGSTON | WHERE M | m = 20' | MEAN T | NE DANGE / | | ? i |
| \$ SPRING | TIDE RAN | CE (MHHW - A | 14.W) = L | .2 FT | DE NOVE (| MIHW MUV) - | 3,7- 41 |
| | | BLEV (FT) MULL | | | ELEV. (FT) N | AVD | |
| MTL= 20 -> | | 4.10 | | | 1,32 | | |
| | MHW | 3.85 | | | 1.07 | | |
| | NAVO 88 | 2.78 | CONVERT | TO | | | |
| | MSL | - | NAVD 88 | | | | |
| | MTL | 200 | △=-2.7 | 8' | -0.78 | | |
| | NGVD 29 | 1.97 | | | -0.81 | | |
| | MLW | 0,15 | | | -2,63 | | |
| | MUW | -0,10 | | | -2.88 | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

| | Motts Basin | 40° 37.0 | ' 73° 45.5 | 5.4 | 6.5 | 2 0 | 2000 41 11 |
|---|--|--|---|--|------------------------------------|------------------------------------|---|
| | Norton Point, Head of Bay | 40° 38.1 | | | 6.5 | 2.9 | Predictions Predictions |
| | J.F.K. International Airport | 40° 37.4 | | | 6.4 | 2.8 | Predictions |
| | North Channel Bridge, Grassy Bay | 40° 39' | 73° 50 | 5.2 | 6.3 | 2.8 | Predictions |
| | Canarsie | 40° 37.8 | 73° 53.1 | 5.2 | 6.3 | 2.8 | Predictions |
| | Mill Basin | 40° 37' | 73° 55' | 5.2 | 6.3 | 2.8 | Predictions |
| | NEW YORK and NEW JERSEY | | | | | | |
| | New York Harbor | | | | | | |
| | | | | Marin | | | ide 41 |
| | | | | Mean Range | Spring Range | Mean T Level | ide EE |
| | Station | Latitude | Longitude | | (ft) . | | Predictions |
| | | | J | () | 1-2/ | (10) | 110010110115 |
| | Coney Island | 40° 34' | 73° 59' | 4.7 | 5.7 | 2.5 | Predictions |
| | Norton Point, Gravesend Bay | 40° 35.4 | | 4.7 | 5.7 | 2.6 | Predictions |
| | Fort Wadsworth, The Narrows | 40° 36.4 | | | 5.4 | 2.5 | <u>Predictions</u> |
| | Fort Hamilton, The Narrows St. George, Staten Island | 40° 36.5 | | | 5.7 | 2.5 | <u>Predictions</u> |
| | Gowanus Bay | 40° 38.6' 40° 39.9' | | | 5.4 | 2.4 | Predictions |
| | NEW YORK (The Battery) | 40° 42 0' | | | 5.7 | 2.6 | Predictions Predictions |
| , | , | 30 12,0 | 7 00.3 | 4.75 | 2,130 | 2, 97 | Frequetions |
| | Hudson River#8 | | | | | | |
| | THE VELLE | | | | | | |
| | | | | Mean | Spring | | ide |
| | Station | | | Range | _ | Level | |
| | Station | Latitude | Longitude | (ft) | (ft) | (ft) | Predictions |
| | Weehawken, Union City, N.J. | 40° 45.9° | 74° 01.1 | 4.37 | 5,29 | 2.41 | Predictions |
| | Edgewater, N.J. | 40° 48.8' | | | 5.13 | 2.33 | Predictions |
| | Spuyten Duyvil Creek ent., N.Y. | 40° 52.7' | | | 4.66 | 2.20 | Predictions |
| | Riverdale, N.Y. | 40° 54.2 | | | 4.67 | 2.13 | Predictions |
| | Alpine, N.J. | 40° 56.7' | 73° 55.1 | 3.78 | 4.57 | 2.09 | Predictions |
| | Tarrytown | 41° 04.7' | | | 3.7 | 1.8 | Predictions |
| | Haverstraw | 41° 13.1' | | | 3.91 | 1.78 | <u>Predictions</u> |
| | Peekskill Newburgh | 41° 17' | 73° 56' | 2.9 | 3.4 | 1.8 | Predictions |
| | New Hamburg | 41° 30.0' 41° 35' | 74° 00.4° 73° 57' | | 3.2 | 1.5 | Predictions |
| | Poughkeepsie | 41 35 42 42 42 42 41 42 41 42 41 42 41 42 41 42 41 42 41 42 41 41 41 41 41 41 41 41 41 41 41 41 41 | 73° 57' | 2.9 3.1 | 3.3 | 1.6 | Predictions |
| | Hyde Park | 41° 47' | 73° 57' | 3.2 | 3.6 | 1.7 | Predictions Predictions |
| | Kingston | 41° 55' | 73° 59' | 3.7 | 4.2 | 2.0 | Predictions |
| | Tivoli | 42° 04' | 73° 56' | 3,9 | 4.4 | 1.9 | Predictions |
| | Hudson | 42° 15' | 73° 48' | 4.0 | 4.4 | 2.2 | Predictions |
| | Castleton | 42° 32' | 73° 46' | 4.3 | 4.7 | 2.2 | Predictions |
| | ALBANY Troy | 42° 39.0° 42° 44' | 73° 44.8' 73° 42' | | 5.0 | 2.5 | Predictions |
| | 2201 | 42 44. | 73 42 | 4.7 | 5.1 | 2.3 | Predictions |
| | The Kills and Newark Bay | 24 | | | | | |
| | The KITTS and Newark Day | | | | | | F 7 |
| | | | | Mean | | Mean T | ide 11 |
| | Station | Tabibuda | 7 | Range | _ | Level | |
| | o cacion | Latitude | Longitude | (ft) | (ft) | (ft) | Predictions |
| | Kill Van Kull | | | | | | |
| | Constable Hook | 40° 39.3' | | 4.63 | 5.60 | 2.54 | Predictions |
| | BAYONNE BRIDGE, STATEN ISLAND | 40° 38.4° | | | 5.52 | 2.70 | Predictions |
| | Port Elizabeth | 40° 40.4' | | | 5.59 | 2.73 | Predictions |
| | Port Newark Terminal Passaic River | 40° 41' | 74° 08' | 5.1 | 6.1 | 2.7 | <u>Predictions</u> |
| | Point No Point | 40° 43 01 | 749 07 01 | F 0.4 | | | |
| | Belleville | 40° 43.9' 40° 47.2' | | 5.24 | 6.34 6.78 | 2.86 | Predictions |
| | | | | | | 3.08 | Predictions |
| | East Rutherford | 40° 50.8° | 74° 07.2' | 5.87 | 7.10 | 3.20 | <u>Predictions</u> |
| | Hackensack River Kearny Point | 409 40 71 | 749 06 01 | F 0.1 | | | |
| | Amtrak RR. swing bridge | 40° 43.7' 40° 45.1' | 74° 06.2' 74° 05.8' | | 6.30 6.40 | 2.85 | Predictions Prodictions |
| | Fish Creek, Berrys Creek | 40° 47.6' | | | 6.45 | 2.89 | Predictions Predictions |
| | Carlstadt, Garretts Reach | 40° 48.4° | | 5.71 | 6.29 | 3.12 | Predictions |
| | North Secaucus, Garretts Reach | 40° 48.4° | 74° 02.6' | 5.61 | 6.79 | 3.06 | Predictions |
| | Ridgefield Park | 40° 51.0' | 74° 01.8' | | 6.93 | | Predictions |
| | _ | | | | _ | 3.29 | Predictions |
| | Hackensack | 40° 52.8' | | 6.01 | 7.27 | | 220020010 |
| | Hackensack New Millford | | | 6.01 4.72 | 5.71 | 2.44 | Predictions |
| | Hackensack New Millford Arthur Kill | 40° 52.8' 40° 56.1' | 74° 01.8' | 4.72 | 5.71 | 2.44 | Predictions |
| | Hackensack New Millford Arthur Kill Port Ivory, Howland Hook, N.Y. | 40° 52.8' 40° 56.1' 40° 38.7' | 74° 01.8' | 4.72 5.10 | 5.71 | 2.44 | Predictions Predictions |
| | Hackensack New Millford Arthur Kill | 40° 52.8' 40° 56.1' 40° 38.7' 40° 35.9' | 74° 01.8' 74° 10.8' 74° 13.9' | 4.72 5.10 5.32 | 5.71 6.12 6.38 | 2.44 2.78 2.89 | Predictions Predictions Predictions |
| | Hackensack New Millford Arthur Kill Port Ivory, Howland Hook, N.Y. Rahway River, RR. Bridge | 40° 52.8' 40° 56.1' 40° 38.7' | 74° 01.8' | 4.72 5.10 5.32 5.0 | 5.71 | 2.44 | Predictions Predictions Predictions Predictions |
| | Hackensack New Millford Arthur Kill Port Ivory, Howland Hook, N.Y. Rahway River, RR. Bridge Chelsea Carteret Rossville, N.Y. | 40° 52.8' 40° 56.1' 40° 38.7' 40° 35.9' 40° 36' 40° 35.2' 40° 33.3' | 74° 01.8' 74° 10.8' 74° 13.9' 74° 12.6' 74° 13.4' | 4.72 5.10 5.32 5.0 5.1 5.22 | 5.71 6.12 6.38 6.0 | 2.44 2.78 2.89 2.7 | Predictions Predictions Predictions |
| | Hackensack New Millford Arthur Kill Port Ivory, Howland Hook, N.Y. Rahway River, RR. Bridge Chelsea Carteret | 40° 52.8' 40° 56.1' 40° 38.7' 40° 35.9' 40° 36' 40° 35.2' | 74° 01.8' 74° 10.8' 74° 13.9' 74° 12' 74° 12.6' | 4.72 5.10 5.32 5.0 5.1 5.22 | 5.71 6.12 6.38 6.0 6.2 | 2.44 2.78 2.89 2.7 2.8 | Predictions Predictions Predictions Predictions Predictions Predictions |

SETTING CLASSIFICATION: Granite sea wall

The bench mark is a disk set in the SW edge of the concrete base of a mooring cleat in a granite seawall at the extreme south corner of Battery Park, next to the west side of the U.S. Coast Guard property, $2.56~\mathrm{m}$ (8.4 ft) NW of the south corner of the seawall, 0.61 m (2.0 ft) NE of the SW edge of the seawall, and 0.09 m (0.3 ft) SW of the edge of the mooring cleat.

U.S. DEPARTMENT OF COMMERCE National Oceanic and Atmospheric Administration National Ocean Service

Page 4 of 5

Station ID: 8518750 PUBLICATION DATE: 11/20/2012

Name: THE BATTERY, NEW YORK HARBOR

NEW YORK

NOAA Chart: 12335 Latitude: 40° 42.0' N USGS Quad: NEW JERSEY CITY Longitude: 74° 0.9' W

TIDAL DATUMS

Tidal datums at THE BATTERY, NEW YORK HARBOR based on:

LENGTH OF SERIES:

19 YEARS

TIME PERIOD:

January 1983 - December 2001

TIDAL EPOCH:

1983-2001

CONTROL TIDE STATION:

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

| HIGHEST OBSERVED WATER LEVEL (10/30/2012) | | = | 4.280 |
|---|--------|----|--------|
| MEAN HIGHER HIGH WATER | WHHM | = | 1.541 |
| MEAN HIGH WATER | MHW | = | 1 443 |
| North American Vertical Datum | NAVD88 | | |
| MEAN SEA LEVEL | MSL | = | 0.783 |
| MEAN TIDE LEVEL | MTL | == | 0.753 |
| MEAN LOW WATER | MLW | = | 0 063 |
| MEAN LOWER LOW WATER | MLLW | | |
| LOWEST OBSERVED WATER LEVEL (02/02/1976) | | | -1.307 |

North American Vertical Datum (NAVD88)

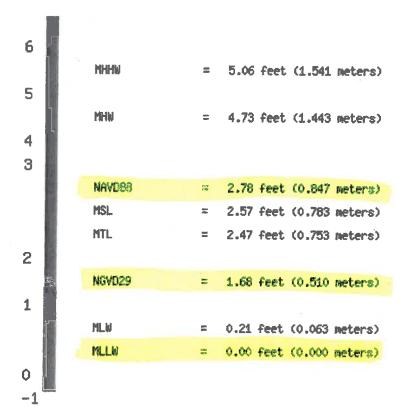
| Bench Mark Elevation Information | In METERS above: |
|----------------------------------|------------------|
|----------------------------------|------------------|

| Stamping or Designation | MLLW | MHW |
|--------------------------|----------------|----------------|
| NO 7 1975 NO 3 | 4.468 | 3.025 |
| NO 6 1975 | 4.277 3.556 | 2.834 |
| BM 851 8750 TIDAL 749 | 5.719 5.689 | 4.276 4.246 |
| R 340 1952 | 2.849 | 1.406 |

Elevation Information

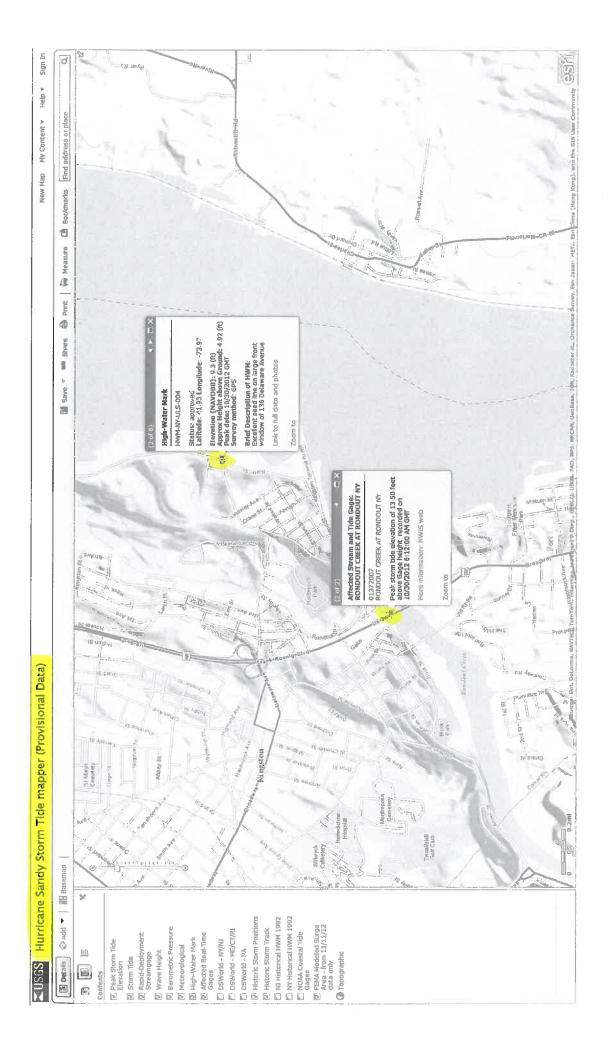
PID: KV0587
VM: 15533
Station ID: 8518750
Epoch: 1983-2001

Date: Wed Mar 6 14:57:28 EST 2013



The NAVD 88 and the NGVD 29 elevations related to MLLW were computed from Bench Mark, R 340, at the station.

Displayed tidal datums are Mean Higher High Water(MHHW), Mean High Water (MHW), Mean Tide Level(MTL), Mean Sea Level (MSL), Mean Low Water(MLW), and Mean Lower Low Water(MLLW) referenced on 1983-2001 Epoch.



History for KNYKINGS13

Keil B Scott WeatherStation, Kingston, NY — Current Conditions

Daily Summary for October 30, 2012

| « Previous Day | | October ▼ 30 ▼ 201 | ber ▼ 30 ▼ 2012 ▼ View | |
|------------------------|-----------------|-----------------------|------------------------|----------------|
| Daily Weekly | Monthly Yearly | Custom | | |
| | Current: | High: | Low: | Average: |
| Temperature: | 46.8 °F | 59.9 °F | 51.4 °F | 54.6 °F |
| Dew Point: | 28.0 °F | 56.0 °F | 48.0 °F | 51.4 °F |
| Humidity: | 49% | 96% | 81% | 89% |
| Wind Speed: | 0.0mph | 3.0mph | ser. | 0.2 mph |
| Wind Gust: | 3.0mph | 10.0mph | o = : | - |
| Wind: | ssw | | - | SSE |
| Pressure: | 30.05 in | 29.50in | 29.09in | ** |
| Precipitation: | 0.11 in | | | |
| Statistics for the res | t of the month | | | |
| | | High: | Low: | Average: |
| Temperature: | | 76.7 °F | 27.9 °F | 54.0 °F |
| Dew Point: | | 70.0 °F | 26.0 °F | 49.4 °F |
| Humidity: | | 100.0% | 34.0% | 85.9% |
| Wind Speed: | | 9.0mph from the NW | ~ | 0.2mph |
| Wind Gust: | | 19.0mph from the West | - | - |
| Wind: | | | | South |
| Pressure: | | 30.55 in | 28.92 in | - |
| Precipitation: | | 3.67 in | | |

Ì USGS 01367500 RONDOUT CREEK AT ROSENDALE HURRICAME SANDY - PEAK FLOWS ON FOMBLY 51 de | 30 | 01 199 2688 21 - 10 2 - 1 2 - 1 3 - 1 Discharge, cubic feet ber second

△ Median daily statistic (60 years) —— Discharge

---- Provisional Data Subject to Revision ----

Nov 81 2812

18:00 Oct 31

12:00 Det 91

06:00 Oct 31

00:00 Oct 31 2012

18:00 Oct 30 2012

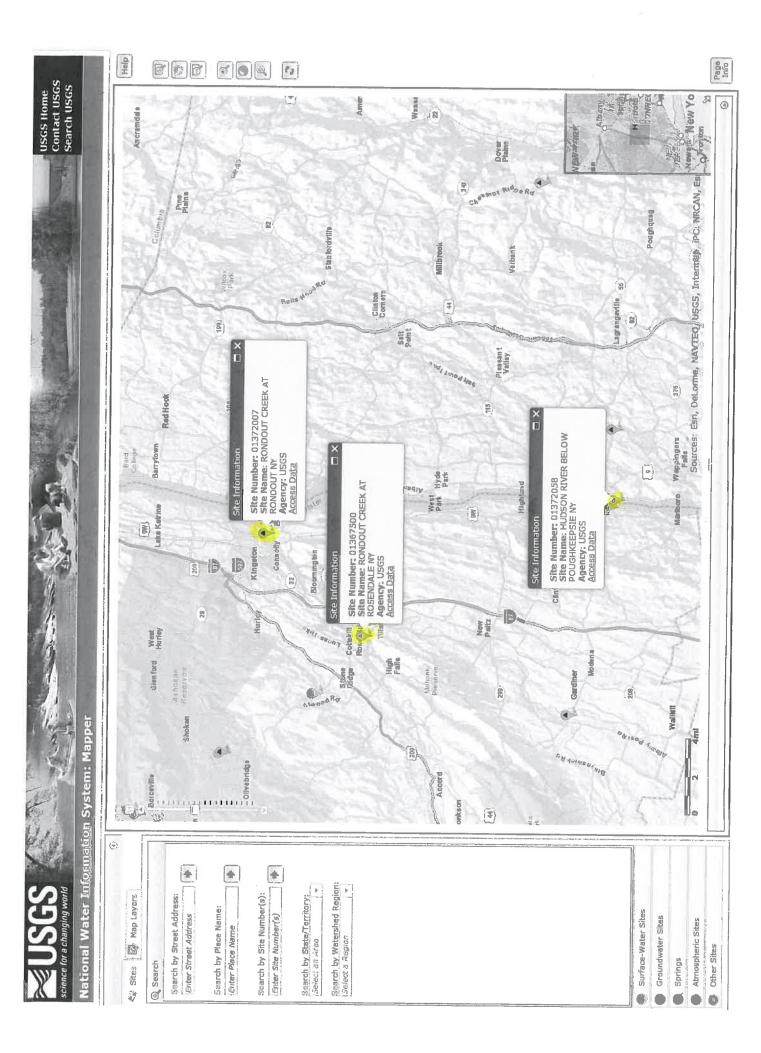
12:86 Oct 38

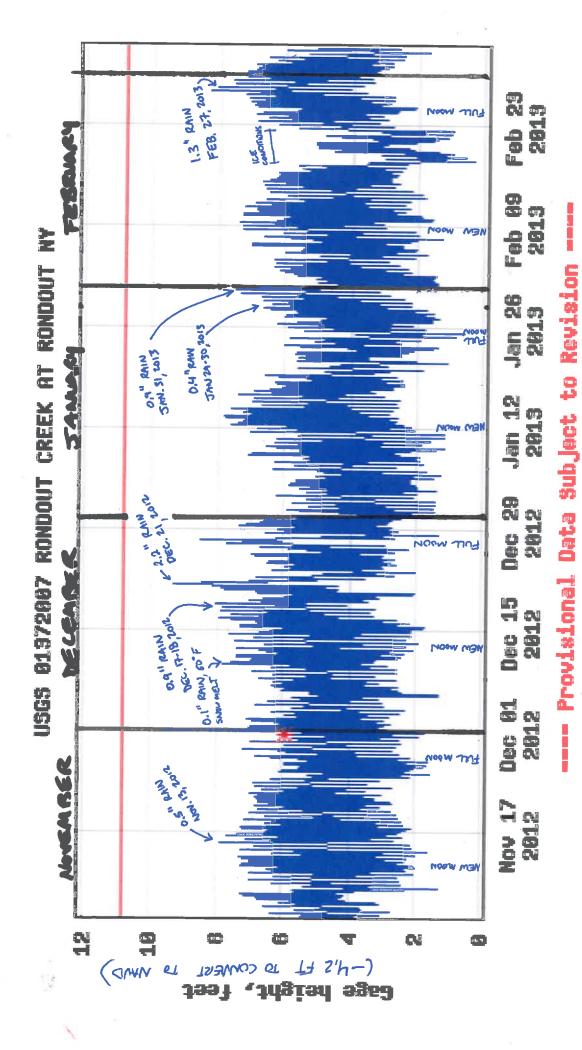
06:68 Oct 38

98:98 Oct 38 2012

2012

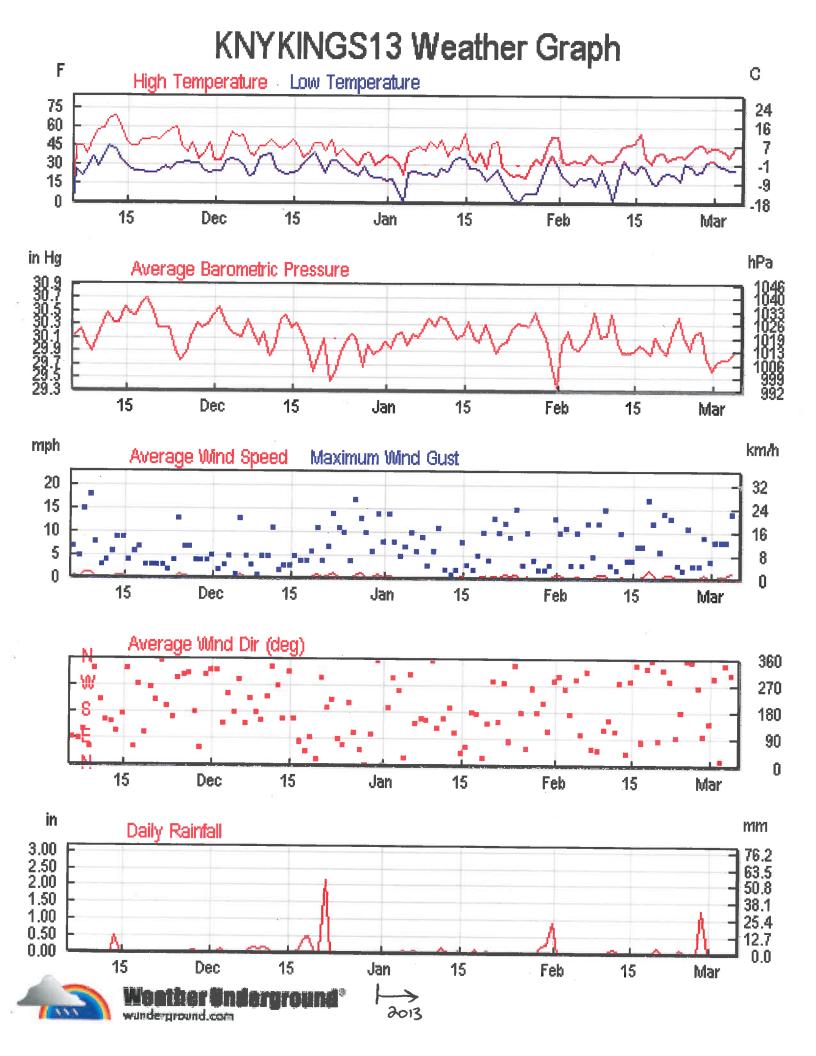
88:88

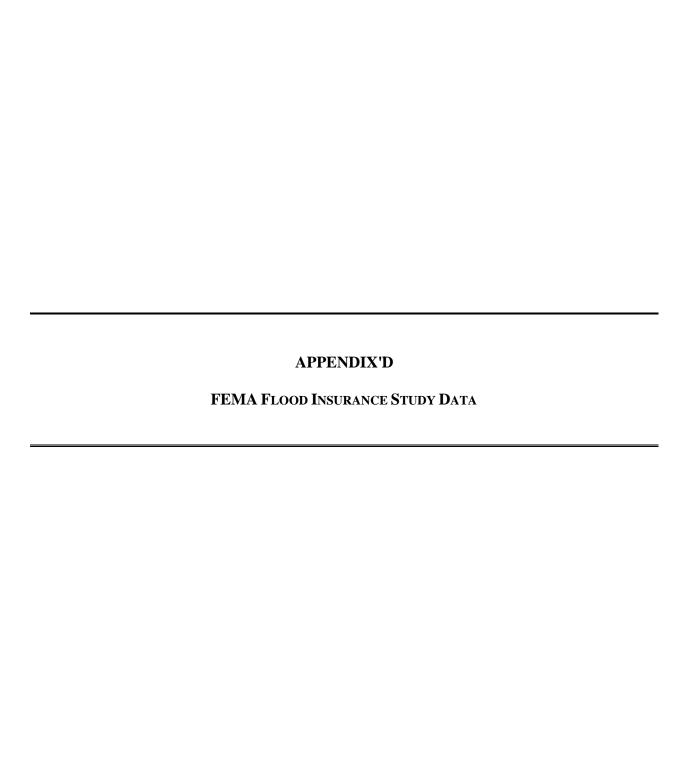




inpact data Streamgage shelter floor - above which flood water may **Heasured gage height**

Gage height







ULSTER COUNTY, NEW YORK

(ALL JURISDICTIONS)

PHASE 1 - AREAS OUTSIDE THE NEW YORK CITY WATERSHED

VOLUME 1 OF 2

| COMMUNITY NAME | COMMUNITY NUMBER |
|------------------------|---------------------|
| ELLENVILLE, VILLAGE OF | 360975 |
| ESOPUS, TOWN OF | 360855 |
| GARDINER, TOWN OF | 360856 |
| KINGSTON, CITY OF | 360858 |
| KINGSTON, TOWN OF | 361218 |
| LLOYD, TOWN OF | 361012 |
| MARBLETOWN, TOWN OF | 361219 |
| MARLBOROUGH, TOWN OF | 361220 |
| NEW PALTZ, TOWN OF | 360859 |
| NEW PALTZ, VILLAGE OF | 361544 |
| PLATTEKILL,TOWN OF | 361221 |
| ROCHESTER, TOWN OF | 360861 |
| ROSENDALE, TOWN OF | 360862 |
| SAUGERTIES, TOWN OF | 360863 |
| SAUGERTIES, VILLAGE OF | 361504 |
| SHAWANGUNK, TOWN OF | 360865 |
| ULSTER. TOWN OF | 360866 |



EFFECTIVE: SEPTEMBER 25, 2009 UPDATED DECEMBER 12, 2011 WITH MINOR CORRECTIONS



Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER 36111CV001A

3.0 ENGINEERING METHODS

For the flooding sources studied by detailed methods in the county, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this FIS. Flood events of a magnitude that are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, or 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term, average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 1-percent-annual-chance flood in any 50-year period is approximately 40 percent (4 in 10); for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this study. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish peak discharge-frequency relationships for each flooding source studied by detailed or limited detailed methods. Detailed revisions were carried out for: 1) Rondout Creek in the Towns of Rosendale, Esopus, Ulster, and in the City of Kingston, and; 2) the Saw Kill in the Towns of Woodstock, Kingston, and Ulster. A new detailed study is provided for Twaalfskill Brook in the City of Kingston, formerly studied by approximate methods. Limited detailed methods were used to study a portion of the Esopus Creek located immediately downstream of Ashokan Reservoir in the Towns of Olive and Marbletown, a reach formerly studied by approximate methods.

Rondout Creek

In the previous effective studies, the hydrologic analysis for Rondout Creek was performed in two parts. These parts consisted of the portions above and below the confluence of the Wallkill River with Rondout Creek.

Above the confluence of the Wallkill River, the previous effective study for Rondout Creek was performed using a log-Pearson Type III analysis (Reference 6) based on USGS gage No. 01367500 on Rondout Creek at Rosendale, New York using the period of record from 1927 to 1981. The previous study also performed a log-Pearson Type III analysis using only the thirty eight years of regulated record (1944 to 1981) to reflect the operation of the Rondout Reservoir, located approximately 35 stream miles upstream of the Rosendale gage. The results of the regulated-only analysis were almost identical to the analysis of the entire record. Therefore, the effects of regulation or diversion were deemed negligible at the gage site.

As described in the previous study for the Town of Rosendale:

"The hydrologic analysis below the confluence of the Wallkill River is complicated by the fact that the Wallkill River basin is approximately twice as large as the Rondout Creek basin at the confluence of the two streams, but the discharges of the Wallkill River are lower due to the geologic conditions in the basin (Reference 1). Therefore, a drainage

area-discharge transfer using the Rosendale gage would not be reliable, and a different method of analysis was required. The methodology in a regional frequency study by the COE was selected for this application (Reference 2). Basin characteristics for each stream were averaged using information from USGS gages Nos. 01367500 on Rondout Creek at Rosendale and 01371500 on the Wallkill River at Gardiner, New York. Discharges for Rondout Creek were then developed and modified to closely relate to the August 1955 and October 1955 floods, which are the floods of record for Rondout Creek and the Wallkill River."

The previous study for the Town of Rosendale also mentions that the discharges on the Wallkill River are influenced by topographic constrictions in the Perrine's Bridge area and large amounts of available storage upstream of Perrine's Bridge. As described in that report:

"Discharges for the Wallkill River were developed using the HEC-1 Modified Puls storage routing model. The flood of October 1955 at the USGS gage in Gardiner, New York, was assigned a recurrence interval of 100 years in the USGS Report No. 78-322 (Reference 3). Discharge ratios used in deriving the discharges for the different frequencies in the HEC-1 analysis were taken from the information provided in the above mentioned report. Surveyed cross-section data and USGS topographic maps were used to determine the storage-elevation relationships for the Wallkill River. A rating curve of elevation-discharge was developed from the COE HEC-2 model. The October 1955 hydrograph, discharge ratios, storage-elevation relationships, and the elevation-discharge rating curve were incorporated into the HEC-1 model. The derived discharges were then used in the HEC-2 model, and the model was adjusted to match the observed elevations of the October 1955 flood."

For the present study, the hydrological analysis of Rondout Creek is divided into two parts, upstream and downstream of the confluence with the Wallkill River, as it was in the previous study.

Rondout Creek upstream of the confluence with the Wallkill River:

A Log-Normal Graphical Analysis was conducted for the USGS Gage 1367500, located at Rosendale on Rondout Creek. This analysis was performed graphically since the record includes the possible effects of regulation by the Rondout Reservoir. The graphical analysis was performed for the period of record after 1943, when the NYC Rondout Reservoir became operational. The contributing area at the Rosendale gage is 383 square miles, and the regulated period of record consists of 61 years (1944 to 2004).

In addition, two Log-Pearson Type III analyses were conducted for the regulated period (1944 to 2004), and for the entire period of record (1927 to 2004). The results of these two new analyses are similar, indicating that the effects of regulation appear to be negligible, as the previous FIS concluded.

The effective discharges are more conservative than the newly computed discharges and the regulated results vary by less than 15%. Therefore, the effective discharges are nominated for new Hydraulic Studies at the Rosendale USGS gage location. Additional nominations were transferred from the Rosendale gage location using a discharge-area

relationship derived from the 1991 USGS regression equations, or by interpolation based on relative drainage areas.

Rondout Creek downstream of the confluence of the Wallkill River:

There is no USGS gage record at or below the confluence of the Wallkill River with Rondout Creek. To obtain a relationship for the combined contribution of the drainage areas (1,173 sq. mi.), a timing analysis was conducted using 15-minute interval hydrographs for two USGS Gages. The gage at Rosendale on Rondout Creek (383 square miles of drainage area at Rosendale), is near the confluence. However, the gage at Gardiner on the Wallkill River (695 square miles of drainage area at Gardiner), is roughly 15 miles upstream of the confluence, and has a difference of approximately 91 square miles of contributing drainage area (695 vs. 786 mi²). The results of the gage analysis at Gardiner were transferred downstream using the discharge-area relationship derived from the USGS Regression Equation for NYS Region 4 (Reference 4).

Peak flows for Rondout Creek below the confluence with the Wallkill River were estimated by combining hydrographs from the two streams. An estimate of the lag time between the arrivals of the two hydrographs at the confluence is required to combine the two hydrographs. Ranges of lag times were estimated from general channel and flood conditions. These estimates were applied to 15-minute interval hydrographs from the Rosendale and Gardiner gages for a November 2005 event. The 15-minute interval hydrograph for Gardiner was transferred downstream, taking into consideration the additional 91 mi² of contributing area. Various lag times were assumed and graphically combined with the 15 minute interval hydrograph for Rosendale. This resulted in the combined peak discharges equal to a fraction (between 0.91 and 0.99) times the sum of the peak discharges of each hydrograph. These relationships were applied to the updated gage analyses for Rosendale and Gardiner to estimate the 10%, 2%, 1%, and 0.2% annual-chance discharges.

The previous effective discharges compare well with the newly estimated discharges for the confluence of the Wallkill River with Rondout Creek, and the previous effective discharges are the more conservative estimates. Therefore, the previous effective discharges are nominated for the reach of Rondout Creek below the confluence with the Wallkill River. The results of the analysis were transferred downstream using the discharge area relationship derived from the USGS regression equations Region 4 (Reference 4).

The nominated discharges for Rondout Creek are presented in Table 4, "Summary of Discharges."

Esopus Creek

This countywide FIS includes a Limited Detailed Study on Esopus Creek of approximately 7.3 miles, proceeding immediately downstream from Ashokan Reservoir. This reach was mapped previously as an approximate study; therefore, discharges were not reported. In the previous FIS, a detailed study was carried out for locations farther downstream on Esopus Creek, and flow nominations were reported at several locations, including the Mount Marion gage site (USGS 01364500), the City of Kingston, and the downstream corporate limits of the Town of Hurley. Peak flow nominations were also reported for the 100 year return period at the downstream corporate limit of the Town of Marbletown. These effective flows were determined using a HEC-1 analysis which was a revision of an earlier HEC-1 analysis used in the original FEMA Flood Insurance Study. The original modeling was based on the assumption that Ashokan Reservoir

TABLE 4 - SUMMARY OF DISCHARGES (continued)

DRAINAGE

| | AREA | PEAK DISCHARGES (c | | | fs) |
|---|----------------|--------------------|---------------|---------|---------|
| FLOODING SOURCE AND LOCATION | (square miles) | 10-Yr. | 50-Yr. | 100-Yr. | 500-Yr. |
| ROCHESTER CREEK | | | | | |
| Mouth | 52.6 | 4,950 | 8,454 | 10,320 | * |
| Upstream of Tributary 1 | 49.1 | 4,700 | 8,030 | 9,820 | * |
| Upstream of Mill Brook | 26.1 | 2,490 | 4,210 | 5,112 | * |
| TRIBUTARY 1 TO ROCHESTER CREEK | | | | | |
| Mouth | 3.3 | 348 | 573 | 686 | * |
| RONDOUT CREEK | | | | | |
| At confluence with Hudson River | 1,197.0 | 33,977 | 51,844 | 60,980 | 86,537 |
| Upstream of confluence with Twaalfskill | | | | | |
| Brook | 1,187.6 | 33,743 | 51,511 | 60,599 | 86,028 |
| Downstream of confluence with Wallkill River | 1,173.0 | 33,377 | 50,990 | 60,002 | 85,233 |
| Upstream of confluence with Wallkill River | 386.0 | 22,260 | 33,651 | 39,126 | 53,404 |
| At Rosendale USGS Gage 01367500 | 383.0 | 22,109 | 33,430 | 38,871 | 53,061 |
| Downstream of confluence with Coxings Kill | 377.1 | 21,813 | 32,996 | 38,371 | 52,388 |
| Approximately 13,900 feet upstream of | 377.1 | 21,013 | 32,990 | 30,371 | 32,300 |
| County Route 29A | 322.0 | 19,850 | 31,870 | 37,940 | * |
| At Accord | 300.0 | 18,700 | 30,500 | 36,400 | 52,300 |
| SANBURG CREEK | | | | | |
| At the confluence with Rondout Creek | 100.0 | 6,900 | 13,800 | 17,900 | 29,500 |
| At Ellenville | 56.7 | 4,050 | 8,200 | 10,700 | 17,200 |
| SAW KILL | | | | | |
| At confluence with Esopus Creek | 41.9 | 4,213 | 8,525 | 11,346 | 20,346 |
| Approximately 100 feet downstream of | | | | | |
| Sawkill Road at Sawkill | 38.6 | 4,123 | 8,403 | 11,223 | 20,086 |
| SHAWANGUNK KILL | | | | | |
| At confluence with Wallkill River | 142.0 | 9,335 | 16,570 | 20,795 | 33,910 |
| Downstream of confluence of Verkeerder Kill | 86.0 | 5,380 | 9,825 | 12,490 | 20,850 |
| TWAALFSKILL BROOK | 00.0 | 3,300 | 7,025 | 12,170 | 20,030 |
| At confluence with Rondout Creek | 2.5 | 420 | 770 | 950 | 1,500 |
| TWAALFSKILL CREEK | 2.3 | 120 | 770 | 750 | 1,500 |
| At Tillison Avenue | 5.9 | 781 | 1,492 | 1,900 | 3,196 |
| VERKEERDER KILL | | , 01 | 1, .> = | 1,500 | 2,130 |
| At confluence with Shawangunk Kill | 14.3 | 1,542 | 2,672 | 3,271 | 5,525 |
| WALLKILL RIVER | | -,- · - | -,~, ~ | -,-,- | - ,- =- |
| At upstream Esopus corporate limits | 764.0 | 18,940 | 28,400 | 33,222 | 46,564 |
| At downstream Gardiner corporate limits | 719.0 | 16,740 | 26,610 | 31,110 | 43,580 |
| 1 10 00 THOUSENING ONIGHNOL COLDOLUG HILLING | , 17.0 | 10,710 | 20,010 | 21,110 | 37,730 |

For the Hudson River, stillwater elevations were taken from the prior FIS's. Stage-frequency relationships for the Hudson River were developed by the U.S. Army Corps of Engineers at Catskill, Spuyten Duyvil and the mouth of Wappinger Creek (Reference 29). The COE basic data covers recurrence periods from one year to 200 years and has been extrapolated to a 500-year frequency on log-probability paper. Tidal stages for points between the mouth of Wappinger Creek and Catskill were obtained by interpolation. Some stillwater elevations were taken from the Flood Insurance Studies for the Town of Catskill (Reference 7).

Elevations for floods of the selected recurrence intervals for the Hudson River are shown in Table 5, "Summary of Stillwater Elevations."

TABLE 5 - SUMMARY OF STILLWATER ELEVATIONS

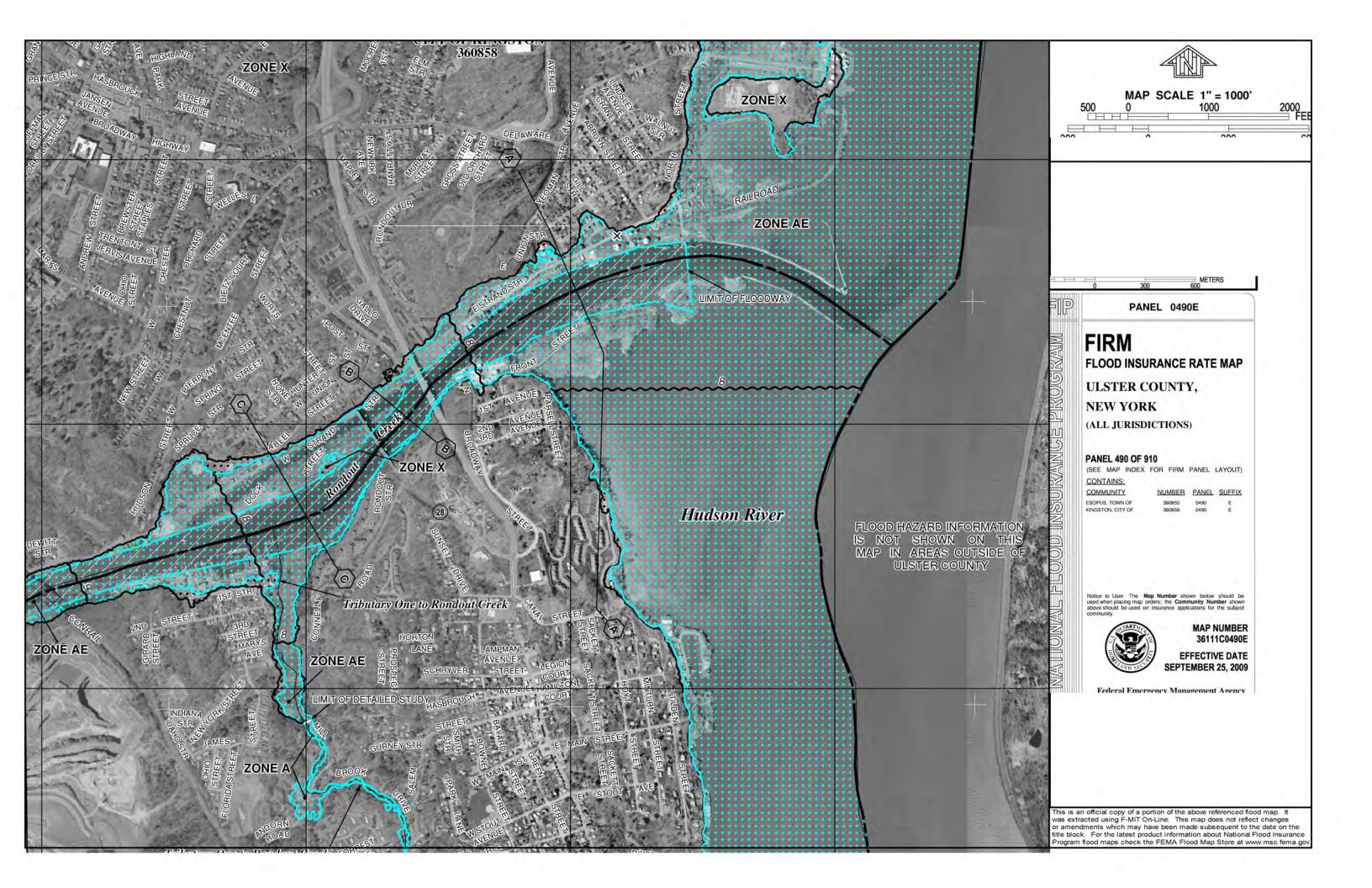
| _ | ELEVATION (FEET NAVD 88) | | | | |
|---|--------------------------|--------|---------|---------|--|
| FLOODING SOURCE AND LOCATION | 10-Yr. | 50-Yr. | 100-Yr. | 500-Yr. | |
| HUDSON RIVER | | | | | |
| At Newburgh, New York | 5.5 | 6.6 | 7.2 | 8.7 | |
| At Poughkeepsie, New York | 5.9 | 7.1 | 7.9 | 9.7 | |
| In the Vicinity of Hyde Park | 5.8 | 7.2 | 7.9 | 9.7 | |
| At Kingston Point | 6.0 | 7.5 | 8.9 | 10.4 | |
| In the Vicinity of Tivoli | 6.1 | 7.8 | 8.5 | 10.6 | |
| At upstream Town of Saugerties corporate limits | 6.2 | 7.9 | 8.5 | 10.8 | |

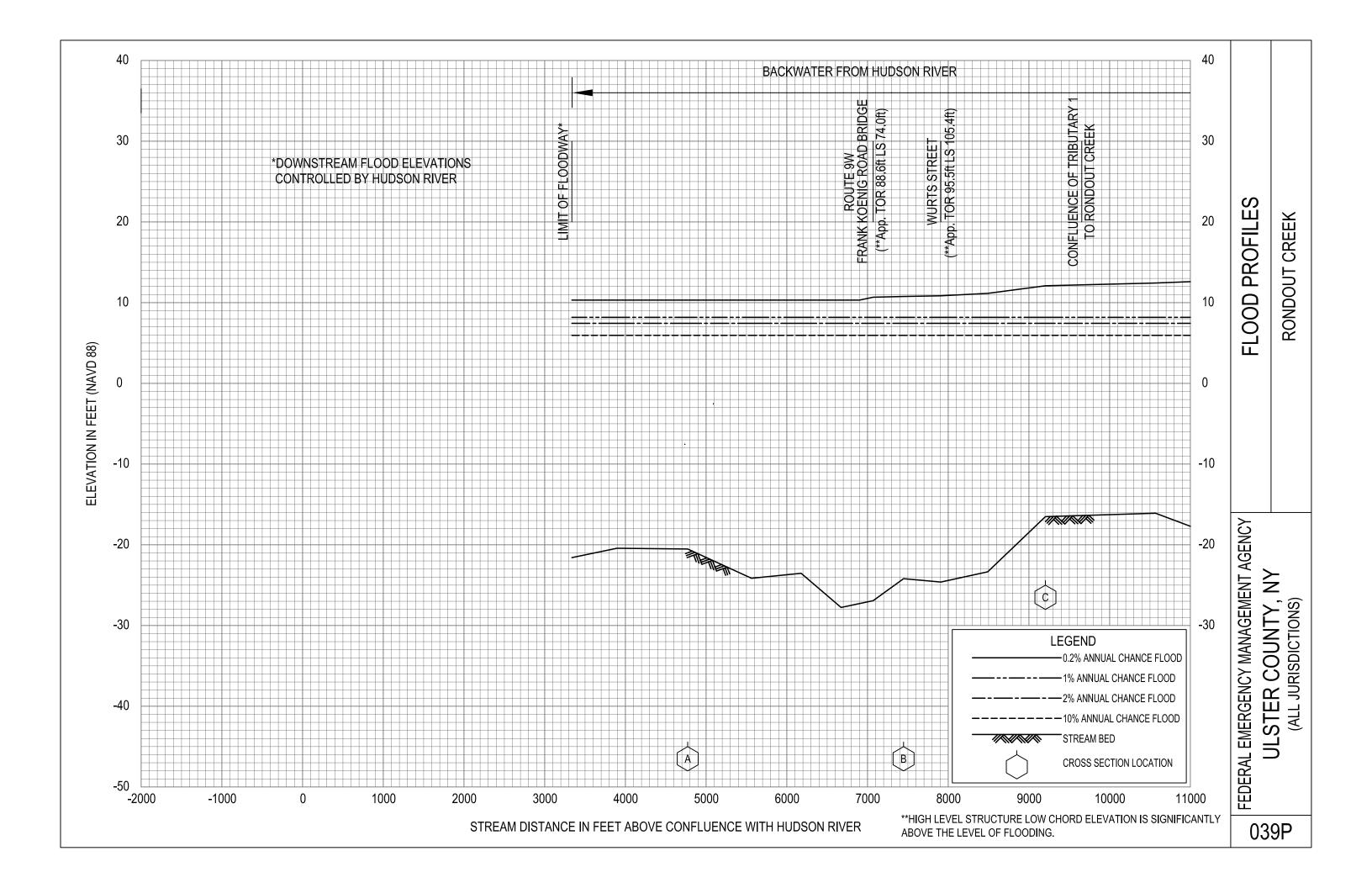
3.2 Hydraulics Analyses

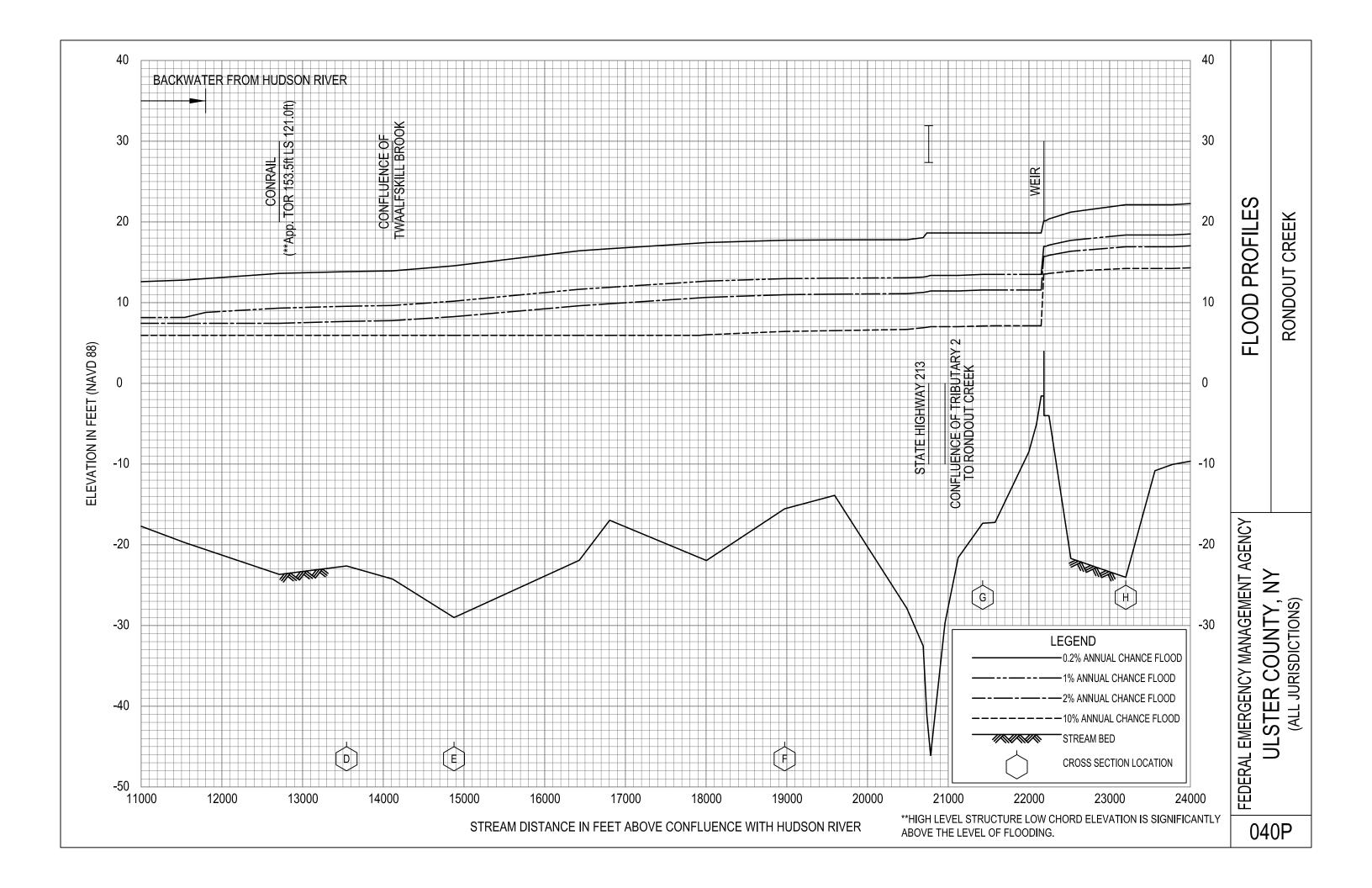
Analyses of the hydraulic characteristics of flooding from the stream sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the Flood Insurance Rate Map (FIRM) represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data Table in this FIS report. Flood elevations shown on the FIRM are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this FIS report in conjunction with the data shown on the FIRM.

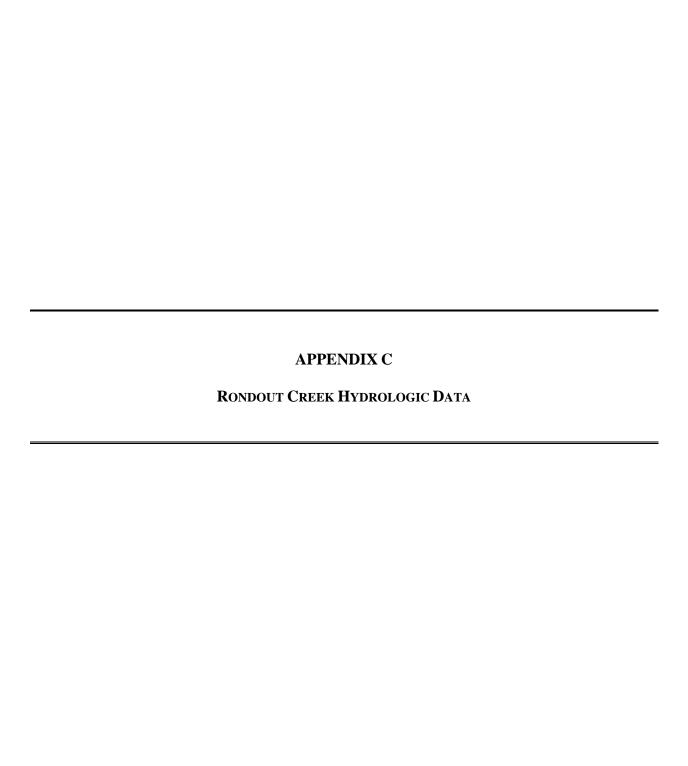
In this countywide analysis, water surface elevations for floods of the selected recurrence intervals for detailed, limited detail, and approximate studies were computed using the USACE Hydrologic Engineering Center River Analysis System (HEC-RAS) river modeling software program (Version 3.1.3). The HEC-RAS model for each flooding source is based on cross section geometry generated using manual and semi-automated methods derived from GIS techniques and data.

Cross section elevations were extracted from a Digital Elevation Model (DEM). The DEM was generated by combining overbank elevation data from an aerial Light Detection and Ranging (LiDAR) survey with data from a traditional field survey of the stream channel and the immediate overbank areas. For detailed studies, cross sections were field surveyed at close intervals just upstream and downstream of bridges, culverts, dams, and other hydraulic obstructions, at natural control sections along the stream length, and at significant changes in ground relief, land use, or land cover. Detailed structural geometry for bridges and culverts was also obtained from NYSDOT as-built drawings where they were available.



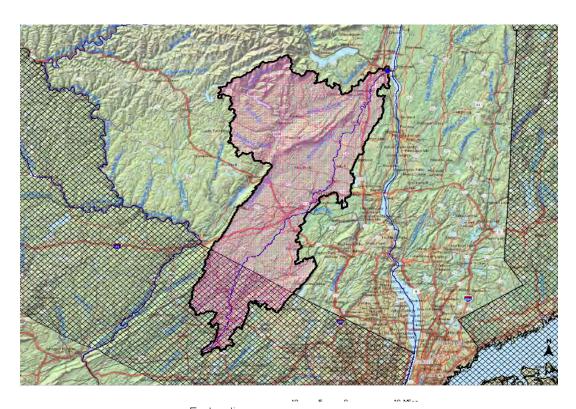






StreamStats Print Page

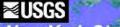
Rondout Creek





- ▶ NHDHGage2
- Gaging Station, Continuous Record
- NHDHDam2
- △ Low Flow, Partial Record
- ★ GlobalWatershedPo.♠ Peak Flow, Partial Record.
- Slp1085Point
- A Peak and Low Flow, Partial Record
- ─MainFlowPath3D
- ▲ Stage Only
- Stream Grid
- ▲ Low Flow, Partial Record, Stage
- ■GlobalWatershed
- A Miscellaneous Record
- ⊠Excludepoly
- ▲ Unknown





New York StreamStats

Streamstats Ungaged Site Report

Date: Thu Mar 21 2013 07:14:32 Mountain Daylight Time

Site Location: New_York
NAD27 Latitude: 41.9201 (41 55 12) NA D27 Longitude: -73.9785 (-73 58 43) NA D83 Latitude: 41.9201 (41 55 13) NA D83 Longitude: -73.9781 (-73 58 41)

ReachCode: 02020007000001

Measure: 14.98

Drainage Area: 1190 mi2 Percent Urban: 2.82 %

| Peak Flows Region Grid Basin Characteristics | | | | | | |
|--|------------------------------------|-------|-------|--|--|--|
| 100% 2006 Full Region 2 (1190 mi | 100% 2006 Full Region 2 (1190 mi2) | | | | | |
| Parameter Value Regression Equation Valid R | | | | | | |
| l'arameter | | Min | Max | | | |
| Drainage Area (square miles) | 1190 (above max value 996) | 1.93 | 996 | | | |
| Lag Factor (dimensionless) | 12.9 (above max value 6.997) | 0.014 | 6.997 | | | |
| Percent Storage (percent) | 4.21 | 0 | 11.88 | | | |
| Mean Annual Runoff in inches (inches) | 22.4 | 16.03 | 33.95 | | | |

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

| Bank Full Region Grid Basin Characteristics | | | | | | |
|--|---------------------------------------|------|-----|--|--|--|
| 47% Bankfull Region 4 SIR2009 5144 (555 mi2) | | | | | | |
| Value Regression Equation Valid Range | | | | | | |
| Min Max | | | | | | |
| Drainage Area (square miles) 1190 (above max value 237) 3.72 237 | | | | | | |
| 53% Bankfull Region 3 SIR | (2009 5144 (635 mi2) | | | | | |
| Parameter | Value Regression Equation Valid Range | | | | | |
| Min Max | | | | | | |
| Drainage Area (square miles) | 1190 (above max value 329) | 0.42 | 329 | | | |

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

| Peak Fl | Peak Flows Region Grid Streamflow Statistics | | | | | | |
|-----------|--|----------------------------|-----------------|--------------------------------|---------|--|--|
| | | 3 | | 90-Percent Prediction Interval | | | |
| Statistic | How (ft ³ /s) | Prediction Error (percent) | years of record | Minimum | Maximum | | |
| PK1_25 | 9050 | | 4.8 | | | | |
| PK1_5 | 10500 | | 4.3 | | | | |
| PK2 | 12500 | | 4.4 | | | | |
| PK5 | 17800 | | 7.3 | | | | |
| PK10 | 21900 | | 10 | | | | |
| PK25 | 27500 | | 14 | | | | |
| PK50 | 31800 | | 16 | | | | |
| PK100 | 36700 | | 18 | | | | |
| PK200 | 42000 | | 19 | | | | |
| PK500 | 49700 | | 20 | | | | |

| Bank Full | Bank Full Region Grid Streamflow Statistics Area-Averaged | | | | | | |
|-----------|---|----------------------------|----------------------------------|--|--|--|--|
| Statistic | Flow (ft ³ /s) | Estimation Error (percent) | Equivalent years of record | | | | |
| BFAREA | 2800 | | | | | | |
| BFDPTH | 8.53 | | | | | | |
| BFFLOW | 19200 | | | | | | |
| BFWDTH | 308 | | | | | | |

| Bank Fu | Bank Full Region Grid Streamflow Statistics Bankfull Region 4 SIR2009 5144 | | | | | | |
|-----------|--|----------------------------|-----------------|--------------------------------|---------|--|--|
| | 2 | | | 90-Percent Prediction Interval | | | |
| Statistic | Flow (ft ³ /s) | Estimation Error (percent) | years of record | Minimum | Maximum | | |
| BFAREA | 4390 | | | | | | |
| BFDPTH | 9.89 | | | | | | |
| BFFLOW | 29400 | | | | | | |
| BFWDTH | 444 | | | | | | |

| Bank Fu | Bank Full Region Grid Streamflow Statistics Bankfull Region 3 SIR2009 5144 | | | | | | |
|-----------|--|----------------------------|-----------------|--------------------------------|---------|--|--|
| | 2 | | | 90-Percent Prediction Interval | | | |
| Statistic | Flow (ft ³ /s) | Estimation Error (percent) | years of record | Minimum | Maximum | | |
| BFAREA | 1400 | | | | | | |
| BFDPTH | 7.34 | | | | | | |
| BFFLOW | 10300 | | | | | | |
| BFWDTH | 190 | | | | | | |

Bulletin 17B Frequency Analysis 05 Mar 2013 12:22 PM

--- Input Data ---

Analysis Name: Bulletin 17B

Description:

Data Set Name: RONDOUT CREEK-ROSENDALE NY-FLOW-ANNUAL PEAK
DSS File Name: P:\4766-02\Design\Data Collection\Flow Data\HEC-SP Rondout_Creek\Rondout_Creek.dss
DSS Pathname: /RONDOUT CREEK/ROSENDALE NY/FLOW-ANNUAL PEAK/01jan1900/IR-CENTURY/USGS/

Report File Name: P:\4766-02\Design\Data Collection\Flow Data\HEC-SP Rondout_Creek\Bulletin17bResults\Bulletin_17B\Bulletin_17B.rpt XML File Name: P:\4766-02\Design\Data Collection\Flow Data\HEC-SP Rondout_Creek\Bulletin17bResults\Bulletin_17B\Bulletin_17B.xml

Start Date: End Date:

Skew Option: Use Station Skew Regional Skew: -Infinity Regional Skew MSE: -Infinity Plotting Position Type: Median Upper Confidence Level: 0.05 Lower Confidence Level: 0.95

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---

<< Low Outlier Test >>

Based on 96 events, 10 percent outlier test deviate K(N) = 3.003Computed low outlier test value = 3,094.46

O low outlier(s) identified below test value of 3,094.46

<< High Outlier Test >>

Based on 96 events, 10 percent outlier test deviate K(N) = 3.003Computed high outlier test value = 48,617.71

O high outlier(s) identified above test value of 48,617.71

--- Final Results ---

<< Plotting Positions >> RONDOUT CREEK-ROSENDALE NY-FLOW-ANNUAL PEAK

| Events Anal | | | | ed Events | |
|----------------------------|--------------------------|----------------|---------------|--------------------------|--------------------|
| Day Mon Year | FLOW CFS | Rank | Water Year | FLOW CFS | Median Plot Pos |
| 01 Mar 1902 | 13, 500. 0 | 1 2 | 2011 | 36, 500. 0 | 0. 73 |
| 29 Aug 1903 | 9, 590. 0 | | 1956 | 35, 800. 0 | 1. 76 |
| 07 Nov 1907 | 12, 600. 0 | 3 | 1955 | 30, 900. 0 | 2. 80 |
| 20 Feb 1909 | 18, 300. 0 | 4 | 2005 | 30, 500. 0 | 3. 84 |
| 26 Apr 1910 | 21, 600. 0 | 5 | 1928 | 27, 300. 0 | 4. 88 |
| 29 Mar 1911 | 5, 200. 0 | 6 | 1987 | 24, 100. 0 | 5. 91 |
| 13 Mar 1912 | 9, 200. 0 | 7 | 1984 | 24, 000. 0 | 6. 95 |
| 27 Mar 1913 | 9, 810. 0 | 8 | 2007 | 23, 900. 0 | 7. 99 |
| 04 Aug 1915 | 15, 180. 0 | 9 | 1980 | 23, 600. 0 | 9. 02 |
| 27 Jul 1916 | 14, 000. 0 | 10 | 1949 | 22, 600. 0 | 10. 06 |
| 20 Feb 1918 17 Nov 1926 | 15, 500. 0 10, 400. 0 | 11 11 12 | 1910 1936 | 21, 600. 0 21, 100. 0 | 11. 10 12. 14 |

Page 1

| 08 Mar 2008 | 15, 000. 0 | 93 | 2002 | 4, 980. 0 | 96. 16 | - 1 |
|-------------|------------|----|------|-----------|--------|-----|
| 12 Dec 2008 | 12, 400. 0 | 94 | 1957 | 4, 530. 0 | 97. 20 | ı |
| 23 Mar 2010 | 13, 900. 0 | 95 | 1966 | 4, 100. 0 | 98. 24 | İ |
| 28 Aug 2011 | 36, 500. 0 | 96 | 1967 | 3, 300. 0 | 99. 27 | İ |
| | | | | | | |

<< Skew Weighting >>

Based on 96 events, mean-square error of station skew = 0.061
Mean-square error of regional skew = -?

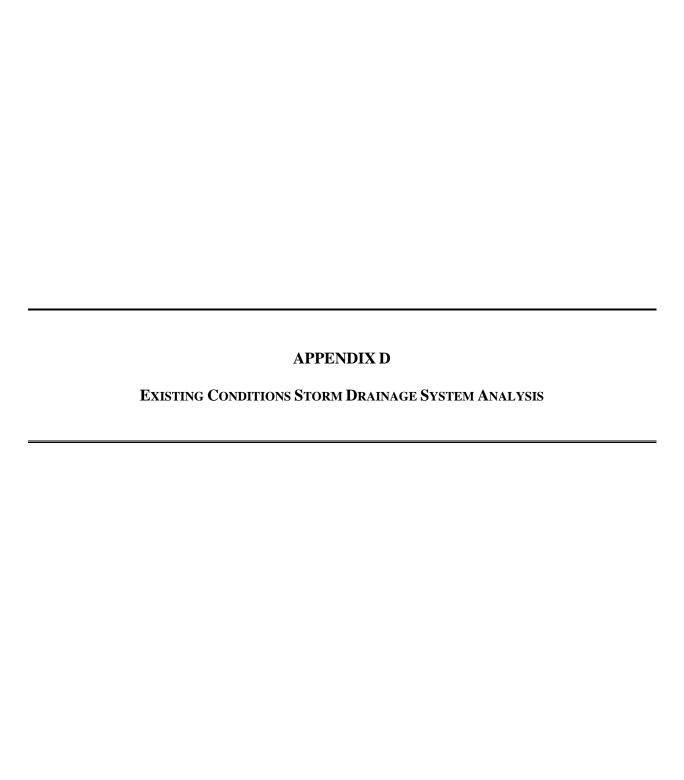
<< Frequency Curve >> RONDOUT CREEK-ROSENDALE NY-FLOW-ANNUAL PEAK

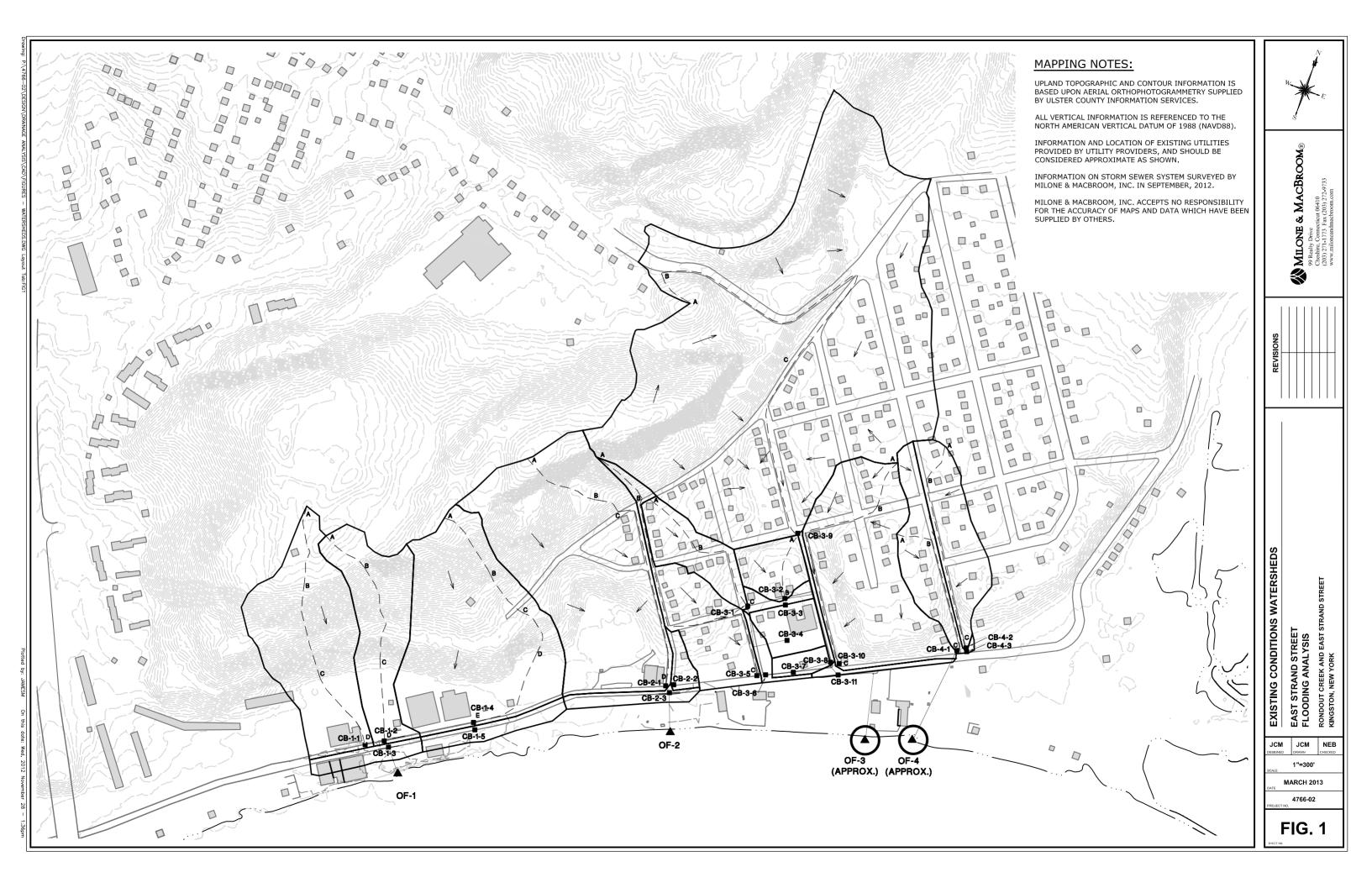
Computed Expected Percent Confidence Limits 0. 95 0.05 FLOW, CFS Curve Probability Chance FLOW, CFS Exceedance 44, 394. 4 38, 928. 2 34, 925. 1 31, 009. 7 25, 924. 1 22, 083. 2 18, 153. 0 12, 382. 2 8, 330. 8 6, 724. 4 5, 609. 7 3, 943. 0 36, 813. 1 32, 914. 7 29, 969. 0 27, 009. 6 23, 033. 9 19, 920. 5 16, 612. 7 11, 459. 8 7, 599. 0 6, 044. 1 4, 974. 4 3, 412. 1 42, 859. 7 37, 888. 3 34, 180. 8 30, 503. 7 25, 651. 1 21, 934. 5 18, 087. 9 12, 382. 2 8, 363. 6 6, 775. 8 5. 678. 5 51, 736. 2 45, 057. 9 40, 156. 0 35, 368. 7 29, 181. 1 0. 5 1.0 2. 0 5. 0 24, 561. 2 19, 916. 4 13, 382. 5 9, 103. 8 7, 467. 0 10.0 20. 0 50. 0 80.0 90.0 6, 339. 6 4, 652. 0 95. 0 5, 678. 5 3, 412. 1 4, 048. 4 99. 0

<< Systematic Statistics >> RONDOUT CREEK-ROSENDALE NY-FLOW-ANNUAL PEAK

| Log Transfo FLOW, CFS | | Number of Events | | |
|--|--|---|-----------------------------|--|
| Mean Standard Dev Station Skew Regional Skew Weighted Skew Adopted Skew | 4. 089 0. 199 -0. 124 -0. 124 | Historic Events High Outliers Low Outliers Zero Events Missing Events Systematic Events | 0 0 0 0 0 96 | |

--- End of Analytical Frequency Curve ---







21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$

25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$

22. Flow Length, L (ft)

Cheshire, Connecticut 06410

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: NEB 11/27/12

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Existing Conditions X
Proposed Condutions Watershed ID: OF-1 Travel Time (Tt) Time of Conc. (Tc) Subwatershed ID: CB-1-1 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **GRASS** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.240 3. Flow Length, L (Max. = 300 ft) 300 4. Two-Year 24-hr rainfall, P₂ (in) 3.2 5a. Change in Elevation, h (ft) 6.0 5b. Land Slope, s (ft/ft) 0.0205b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr) T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} (s^{0.4})}$ 0.577 34.6 **Shallow Concentrated Flow** (Assume Hyd. Radius = Depth of Flow) Segment ID B-C C-D FOREST MIXED 7a. Surface Description **UNPV UNPV** 7b. Paved or Unpaved 7c. Manning's Roughness Coeff., n 0.050 0.050 7d. Depth of Flow, d(ft) (d = 0.4 Unpaved, d = 0.2 Paved) 0.4 0.4 8. Flow Length, L 340 316 9a. Change in Elevation, h (ft) 54.0 2.0 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}})(s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$ 9b. Watercourse slope, s (ft/ft) 0.159 0.006 6.447 1.287 0.015 0.068 0.08 hr. 5.0 min. **Channel Flow** Segment ID 12a. Channel/Conduit Description 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w (ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{\frac{2}{3}}) (s^{\frac{1}{2}})$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ hr. min. Lake or Reservoir Flow Segment ID 20. Mean Depth of Lake or Reservoir, D (ft)

> Total T_c (Sum T_t From Previous Steps) = 40 min.

hr. min. Cheshire, Connecticut 06410

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: NEB 11/27/12

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Segment

Existing Conditions X Travel Time (Tt)

Proposed Condntions Time of Conc. (Tc) Watershed ID: OF-1 Subwatershed ID: CB-1-2

Sheet Flow (Applicable to T_c Only)

- 1. Surface Description (Table 3-1)
- 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1
- 3. Flow Length, L (Max. = 300 ft)
- 4. Two-Year 24-hr rainfall, P₂ (in)
- 5a. Change in Elevation, h (ft)
- 5b. Land Slope, s (ft/ft)
- 5b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr)$ $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$

| Segment ID | A-B | | | | |
|------------|-------|---|----|---|-----|
| | GRASS | | | | |
| 1) | 0.240 | | | | |
| | 186 | | | | |
| | 3.2 | | | | |
| | 6.0 | | | | |
| | 0.032 | | | | _ |
| | 0.325 | = | 19 | 5 | min |

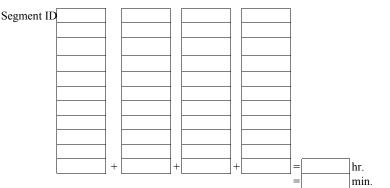
Shallow Concentrated Flow (Assume Hyd. Radius = Depth of Flow)

- 7a. Surface Description
- 7b. Paved or Unpaved
- 7c. Manning's Roughness Coeff., n
- 7d. Depth of Flow, d (ft) (d = 0.4 Unpaved, d = 0.2 Paved)
- 8. Flow Length, L
- 9a. Change in Elevation, h (ft)
- 9b. Watercourse slope, s (ft/ft)
- 9b. Watercourse slope, s (ft/ft) 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}}) (s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$

| ID | В-С | | C-D | | | | | |
|----|--------|----|-------|---|---|---|------|------|
| | FOREST | | MIXED | | | | | |
| | UNPV | | UNPV | | | | | |
| | 0.050 | | 0.050 | | | | | |
| | 0.4 | | 0.4 | | | | | |
| | 377 | | 285 | | | | | |
| | 54.0 | | 2.0 | | | | | |
| | 0.143 | | 0.007 | | | | | |
| | 6.123 | | 1.355 | | | | | |
| | 0.017 | + | 0.058 | + | + | = | 0.08 | hr. |
| | | ji | | | | = | 4.5 | min. |
| | | | | | | | | |

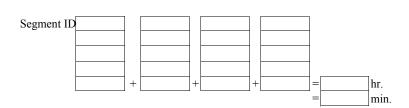
Channel Flow

- 12a. Channel/Conduit Description
- 12b. Cross sectional flow area, A (ft.2)
- 13. Wetted perimeter, $P_{w (ft)}$
- 14. Hydraulic Radius, R (ft)
- 15a. Change in Elevation, H (ft)
- 15b. Channel Slope, S (ft/ft)
- 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{\frac{2}{3}}) (s^{\frac{1}{2}})$
- 18. Flow length, L (ft)
- 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$



Lake or Reservoir Flow

- 20. Mean Depth of Lake or Reservoir, D (ft)
- 21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$
- 22. Flow Length, L (ft)
- 25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$



Total T_c (Sum T_t From Previous Steps) = 24 min.



25. Travel Time, T (hr)

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: <u>JCM 11/27/12</u> Checked By: <u>NEB 11/27/12</u>

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Existing Conditions X Watershed ID: OF-1 Travel Time (Tt) Proposed Condntions Time of Conc. (Tc) Subwatershed ID: CB-1-4 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **FOREST** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.400 3. Flow Length, L (Max. = 300 ft) 281 4. Two-Year 24-hr rainfall, P₂ (in) 3.2 5a. Change in Elevation, h (ft) 33.0 5b. Land Slope, s (ft/ft) 6. Travel Time, T_t (hr) $T_t = \frac{0.007 (nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$ 0.1170.406 24.4 **Shallow Concentrated Flow** (Assume Hyd. Radius = Depth of Flow) Segment ID B-C C-D D-E MIXED FOREST 7a. Surface Description MIXED **UNPV UNPV UNPV** 7b. Paved or Unpaved 7c. Manning's Roughness Coeff., n 0.050 0.050 0.050 7d. Depth of Flow, d(ft) (d = 0.4 Unpaved, d = 0.2 Paved) 0.4 0.4 0.4 8. Flow Length, L 185 182 385 9a. Change in Elevation, h (ft) 13.0 20.0 2.0 9b. Watercourse slope, s (ft/ft) 10. Flow Velocity, V (ft/sec) 11. Travel Time, T_t (hr) $T_t = \frac{U}{3600 * V} = \frac{1.49}{n} (d^{\frac{2}{3}})(s^{\frac{1}{2}})$ 0.005 0.070 0.110 4.289 5.363 1.166 0.012 0.009 0.092 0.11 hr. 6.8 min. **Channel Flow** Segment ID 12a. Channel/Conduit Description 12b. Cross sectional flow area, A (ft 2) $R = \frac{A}{P_{w}}$ 13. Wetted perimeter, $P_{w \text{ (ft)}}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 16. Manning's Roughness Coeff. In $\frac{1.49}{n} (R^{\frac{2}{3}})(s^{\frac{1}{2}})$ 17. Flow Velocity, V (ft/sec)
18. Flow length, L (ft)
19. Travel Time, T (hr) 15b. Channel Slope, S (ft/ft) hr. min. Lake or Reservoir Flow Segment ID 20. Mean Depth of Lake or Reservoi $V_{,u}$ D $\neq f(gD)^{0.5}$ 21. Wave Velocity Ac, V_w 22. Flow Length, L (ft) $T_t = \frac{L}{3600 * V}$

Total T_c (Sum T_t From Previous Steps) = 31 min.

hr. min. Cheshire, Connecticut 06410

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: NEB 11/27/12

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Segment

Existing Conditions X
Proposed Condutions Watershed ID: OF-2 Travel Time (Tt) Time of Conc. (Tc) Subwatershed ID: CB-2-1 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **FOREST** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.400

3. Flow Length, L (Max. = 300 ft) 4. Two-Year 24-hr rainfall, P₂ (in)

5a. Change in Elevation, h (ft)

5b. Land Slope, s (ft/ft)

5b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr)$ $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$

| 300 | | | |
|-------|---|------|------|
| 3.2 | | | |
| 44.0 | | | |
| 0.147 | | | |
| 0.392 | = | 23.5 | min. |

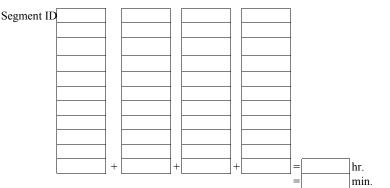
Shallow Concentrated Flow (Assume Hyd. Radius = Depth of Flow)

- 7a. Surface Description
- 7b. Paved or Unpaved
- 7c. Manning's Roughness Coeff., n
- 7d. Depth of Flow, d (ft) (d = 0.4 Unpaved, d = 0.2 Paved)
- 8. Flow Length, L
- 9a. Change in Elevation, h (ft)
- 9b. Watercourse slope, s (ft/ft)
- 9b. Watercourse slope, s (ft/ft) 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}}) (s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$

| t ID | В-С | | C-D | | | | | |
|------|--------|---|-------|---|---|---|------|------|
| | FOREST | | PAVED | | | | | |
| | UNPV | | PAVE | | | | | |
| | 0.050 | | 0.025 | | | | | |
| | 0.4 | | 0.2 | | | | | |
| | 110 | | 722 | | | | | |
| | 10.0 | | 20.0 | | | | | |
| | 0.091 | | 0.028 | | | | | |
| | 4.878 | | 3.392 | | | | | |
| | 0.006 | + | 0.059 | + | + | = | 0.07 | hr. |
| | | , | | | | = | 3.9 | min. |

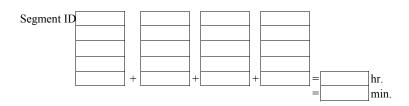
Channel Flow

- 12a. Channel/Conduit Description
- 12b. Cross sectional flow area, A (ft.2)
- 13. Wetted perimeter, $P_{w (ft)}$
- 14. Hydraulic Radius, R (ft)
- 15a. Change in Elevation, H (ft)
- 15b. Channel Slope, S (ft/ft)
- 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{\frac{2}{3}}) (s^{\frac{1}{2}})$
- 18. Flow length, L (ft)
- 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$



Lake or Reservoir Flow

- 20. Mean Depth of Lake or Reservoir, D (ft)
- 21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$
- 22. Flow Length, L (ft)
- 25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$



 $Total T_c (Sum T_t From Previous Steps) =$ 27 min. Cheshire, Connecticut 06410

22. Flow Length, L (ft)

25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: NEB 11/27/12

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Existing Conditions X
Proposed Condutions Watershed ID: OF-3 Travel Time (Tt) Time of Conc. (Tc) Subwatershed ID: CB-3-1 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **GRASS** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.240 3. Flow Length, L (Max. = 300 ft) 260 4. Two-Year 24-hr rainfall, P₂ (in) 3.2 5a. Change in Elevation, h (ft) 8.0 5b. Land Slope, s (ft/ft) 0.0315b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr)$ $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$ 0.433 26.0 **Shallow Concentrated Flow** (Assume Hyd. Radius = Depth of Flow) Segment ID B-C PAVED 7a. Surface Description 7b. Paved or Unpaved **PAVE** 7c. Manning's Roughness Coeff., n 0.025 7d. Depth of Flow, d (ft) (d = 0.4 Unpaved, d = 0.2 Paved) 0.2 8. Flow Length, L 323 9a. Change in Elevation, h (ft) 10.0 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}})(s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$ 9b. Watercourse slope, s (ft/ft) 0.031 3.586 0.025 0.03 hr. 1.5 min. **Channel Flow** Segment ID 12a. Channel/Conduit Description 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w (ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{\frac{2}{3}}) (s^{\frac{1}{2}})$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ hr. min. Lake or Reservoir Flow Segment ID 20. Mean Depth of Lake or Reservoir, D (ft) 21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$

> Total T_c (Sum T_t From Previous Steps) = 28 min.

hr. min.

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: <u>NEB 11/27/12</u>

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

| Watershed ID: OF-3 | Existing Conditions | X | Travel Time (7 | | |
|---|---|-----|------------------|-------|-----|
| watershed ID: CB-3-2 | Proposed Condutions | | Time of Conc. (T | (c) X | |
| Sheet Flow (Applicable to T _c Only) | | | | | |
| (Applicable to 1 _e Gmy) | Segment ID A- | В | | | |
| 1. Surface Description (Table 3-1) | GRA | | | | |
| 2. Manning's Roughness Coeff. for Shee | | | | | |
| 3. Flow Length, L (Max. = 300 ft) | 23 | | | | |
| 4. Two-Year 24-hr rainfall, P ₂ (in) | 3. | | | | |
| 5a. Change in Elevation, h (ft) | 8. | | | | |
| | | | | | |
| 5b. Land Slope, s (ft/ft) 6. Travel Time, T _t (hr) $T_t = \frac{0.007 (nL)}{P_2^{0.5} (s^{0.5})}$ | 0.3 | | 23.4 min. | | |
| $P_2^{0.5}(s^0)$ | 4) | , , | | | |
| Shallow Consentant d Floor (1 | I.D. F. al. CPI | | | | |
| Shallow Concentrated Flow (Assume Hyd | Segment ID | | | | 7 |
| 7a. Surface Description | | | | | |
| 7b. Paved or Unpaved | | | | | |
| 7c. Manning's Roughness Coeff., n | | | | | |
| 7d. Depth of Flow, d (ft) (d = 0.4 Unpaved, d | d = 0.2 Paved) | | | | |
| 8. Flow Length, L | | | | | |
| 9a. Change in Elevation, h (ft) | | | | | |
| 9b. Watercourse slope, s (ft/ft) | 1.492/ 1/. | | | | |
| 10. Flow Velocity, V (ft/sec) $V = -$ | $\frac{d^{3}}{n}(d^{3})(s^{2})$ | | | | |
| 11. Travel Time, T_t (hr) $T_t = \frac{L}{T_t}$ | | + | + | + | |
| 9a. Change in Elevation, h (ft) 9b. Watercourse slope, s (ft/ft) 10. Flow Velocity, V (ft/sec) $V = \frac{L}{3600 *}$ | V | | | | = |
| Channel Flow | | | | | |
| | Segment ID | | | |] |
| 12a. Channel/Conduit Description | | | | _ | |
| 12b. Cross sectional flow area, A (ft. ²⁾ | | | | | |
| 13. Wetted perimeter, P _{w (ft)} | Δ | | | | |
| 14. Hydraulic Radius, R (ft) $R =$ | A | | | | |
| 15a. Change in Elevation, H (ft) | - W | | | | |
| 13a. Change in Elevation, 11 (it) | | | | | |
| 15b. Channel Slope, S (ft/ft) | | | | | |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n | 19 2/ 1/ | | | | |
| 15b. Channel Slope, S (ff/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ff/sec) $V = \frac{1}{2}$ | $\frac{.49}{(R^{2/3})(s^{1/2})}$ | | | | |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{1}$ 18. Flow length, L (ft) | $\frac{.49}{n}(R^{\frac{2}{3}})(s^{\frac{1}{2}})$ | | | |] |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{2}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) T | | + | + | + | |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{4}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600}$ | | + | + | + | = = |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{2}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) T | | + | + | + | = = |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{2}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600}$ | | + | + | + | |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{2}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600}$ | V Segment ID | + | + | + | |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{2}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 *}$ Lake or Reservoir Flow 20. Mean Depth of Lake or Reservoir, D | V Segment ID (ft) | + | + | + | |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{2}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 *}$ Lake or Reservoir Flow 20. Mean Depth of Lake or Reservoir, D 21. Wave Velocity Ac, V_w (ft/sec) V_w 22. Flow Length L (ft) | V Segment ID $= (gD)^{0.5}$ | + | + | + | |
| 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1}{2}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 *}$ Lake or Reservoir Flow 20. Mean Depth of Lake or Reservoir, D | V Segment ID $= (gD)^{0.5}$ | + | + | + | |

25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$

Cheshire, Connecticut 06410

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: <u>JCM 11/27/12</u> Checked By: <u>NEB 11/27/12</u>

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Existing Conditions X
Proposed Condntions Watershed ID: OF-3 Travel Time (Tt) Time of Conc. (Tc) Subwatershed ID: CB-3-5 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **FOREST** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.400 3. Flow Length, L (Max. = 300 ft) 220 4. Two-Year 24-hr rainfall, P₂ (in) 3.2 5a. Change in Elevation, h (ft) 30.0 5b. Land Slope, s (ft/ft) 0.1365b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr)$ $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$ 0.315 18.9 **Shallow Concentrated Flow** (Assume Hyd. Radius = Depth of Flow) Segment ID B-C PAVED 7a. Surface Description 7b. Paved or Unpaved **PAVE** 7c. Manning's Roughness Coeff., n 0.025 7d. Depth of Flow, d(ft) (d = 0.4 Unpaved, d = 0.2 Paved) 0.2 8. Flow Length, L 996 9a. Change in Elevation, h (ft) 20.0 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}})(s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$ 9b. Watercourse slope, s (ft/ft) 0.020 2.888 0.096 0.10 hr. 5.7 min. **Channel Flow** Segment ID 12a. Channel/Conduit Description 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w (ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{2/3}) (s^{1/2})$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ hr. min. Lake or Reservoir Flow Segment ID 20. Mean Depth of Lake or Reservoir, D (ft) 21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$ 22. Flow Length, L (ft)

Total T_c (Sum T_t From Previous Steps) = 25 min.

hr. min. Cheshire, Connecticut 06410

Watershed ID: OF-3

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: NEB 11/27/12

Travel Time (Tt)

MMI# 4766-02

hr. min.

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Existing Conditions X
Proposed Condutions Time of Conc. (Tc) Subwatershed ID: CB-3-9 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **FOREST** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.400 3. Flow Length, L (Max. = 300 ft) 160 4. Two-Year 24-hr rainfall, P₂ (in) 3.2 5a. Change in Elevation, h (ft) 8.0 5b. Land Slope, s (ft/ft) 0.050 5b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr)$ $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$ 0.364 21.8 **Shallow Concentrated Flow** (Assume Hyd. Radius = Depth of Flow) Segment ID B-C C-D PAVED PAVED 7a. Surface Description **PAVE** 7b. Paved or Unpaved **PAVE** 7c. Manning's Roughness Coeff., n 0.025 0.0257d. Depth of Flow, d(ft) (d = 0.4 Unpaved, d = 0.2 Paved) 0.2 0.2 8. Flow Length, L 1273 666 9a. Change in Elevation, h (ft) 26.0 13.0 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}})(s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$ 9b. Watercourse slope, s (ft/ft) 0.020 0.020 2.913 2.848 0.121 0.065 0.19 hr. 11.2 min. **Channel Flow** Segment ID 12a. Channel/Conduit Description 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w (ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{\frac{2}{3}}) (s^{\frac{1}{2}})$

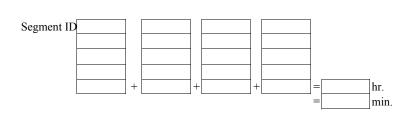
Lake or Reservoir Flow

18. Flow length, L (ft)

20. Mean Depth of Lake or Reservoir, D (ft)

19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$

- 21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$
- 22. Flow Length, L (ft)
- 25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$



Total T_c (Sum T_t From Previous Steps) = 33 min. Cheshire, Connecticut 06410

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: NEB 11/27/12

MMI# 4766-02

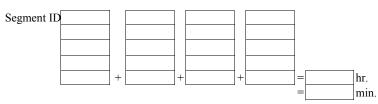
Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Existing Conditions X
Proposed Condutions Watershed ID: OF-3 Travel Time (Tt) Time of Conc. (Tc) Subwatershed ID: CB-3-10 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **GRASS** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.240 3. Flow Length, L (Max. = 300 ft) 180 4. Two-Year 24-hr rainfall, P₂ (in) 3.2 5a. Change in Elevation, h (ft) 3.0 5b. Land Slope, s (ft/ft) 0.017 5b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr)$ $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$ 0.413 24.8 **Shallow Concentrated Flow** (Assume Hyd. Radius = Depth of Flow) Segment ID B-C **GRASS** 7a. Surface Description **UNPV** 7b. Paved or Unpaved 7c. Manning's Roughness Coeff., n 0.050 7d. Depth of Flow, d (ft) (d = 0.4 Unpaved, d = 0.2 Paved) 0.4 8. Flow Length, L 786 9a. Change in Elevation, h (ft) 14.0 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}})(s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$ 9b. Watercourse slope, s (ft/ft) 0.018 2.159 0.101 0.10 hr. 6.1 min. **Channel Flow** Segment ID 12a. Channel/Conduit Description 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w (ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{\frac{2}{3}}) (s^{\frac{1}{2}})$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ hr. min.

Lake or Reservoir Flow

- 20. Mean Depth of Lake or Reservoir, D (ft)
- 21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$
- 22. Flow Length, L (ft)
- 25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$



Total T_c (Sum T_t From Previous Steps) = 31 min.

25. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$

Cheshire, Connecticut 06410

(203 271-1773

East Strand Street Flooding Analysis Kingston, NY

Calculated By: <u>JCM 11/27/12</u> Checked By: <u>NEB 11/27/12</u>

MMI# 4766-02

hr. min.

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

Existing Conditions X
Proposed Condutions Watershed ID: OF-4 Travel Time (Tt) Time of Conc. (Tc) Subwatershed ID: CB-4-1 **Sheet Flow** (Applicable to T_c Only) Segment ID A-B 1. Surface Description (Table 3-1) **GRASS** 2. Manning's Roughness Coeff. for Sheet Flow, n (Table 3-1) 0.240 3. Flow Length, L (Max. = 300 ft) 130 4. Two-Year 24-hr rainfall, P₂ (in) 3.2 5a. Change in Elevation, h (ft) 2.0 5b. Land Slope, s (ft/ft) 0.015 5b. Land Slope, $s(\pi/\pi)$ 6. Travel Time, $T_t(hr)$ $T_t = \frac{0.007(nL)^{0.8}}{P_2^{0.5}(s^{0.4})}$ 0.328 19.7 **Shallow Concentrated Flow** (Assume Hyd. Radius = Depth of Flow) Segment ID B-C PAVED 7a. Surface Description 7b. Paved or Unpaved **PAVE** 7c. Manning's Roughness Coeff., n 0.025 7d. Depth of Flow, d (ft) (d = 0.4 Unpaved, d = 0.2 Paved) 0.2 8. Flow Length, L 427 9a. Change in Elevation, h (ft) 10.0 10. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (d^{\frac{2}{3}})(s^{\frac{1}{2}})$ 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$ 9b. Watercourse slope, s (ft/ft) 0.023 3.119 0.038 0.04 hr. 2.3 min. **Channel Flow** Segment ID 12a. Channel/Conduit Description 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w (ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.49}{n} (R^{\frac{2}{3}}) (s^{\frac{1}{2}})$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ hr. min. Lake or Reservoir Flow Segment ID 20. Mean Depth of Lake or Reservoir, D (ft) 21. Wave Velocity Ac, V_w (ft/sec) $V_w = (gD)^{0.5}$ 22. Flow Length, L (ft)

Total T_c (Sum T_t From Previous Steps) = 22 min.

East Strand Street Flooding Analysis Kingston, NY

Calculated By: JCM 11/27/12 Checked By: NEB 11/27/12

MMI# 4766-02

Time of Concentration (T_c) or Travel Time (T_t) Worksheet

(Derived from Worksheet 3, USDA 210-VI-TR55, Second Ed, June 1986)

| | Existing Conditions X Proposed Condutions | Travel Time (Tt) Time of Conc. (Tc) | X | |
|--|--|-------------------------------------|-----------|----|
| watershed ID: CB-4-2 | | | Λ | |
| Sheet Flow (Applicable to T _c Only) | | | | |
| (FF | Segment ID A-B | | | |
| 1. Surface Description (Table 3-1) | GRASS | | | |
| 2. Manning's Roughness Coeff. for Sheet F | | | | |
| 3. Flow Length, L (Max. = 300 ft) | 145 | | | |
| 4. Two-Year 24-hr rainfall, P ₂ (in) | 3.2 | | | |
| 5a. Change in Elevation, h (ft) | 3.0 | | | |
| 5h. Land Slone's (ft/ft) | 0.021 | | | |
| 6. Travel Time T (hr) $T = \frac{0.007 (nL)^0}{10.007 (nL)^0}$ | 0.318 | = 19.1 min. | | |
| 5b. Land Slope, s (ft/ft) 6. Travel Time, T_t (hr) $T_t = \frac{0.007 (nL)^0}{P_2^{0.5} (s^{0.4})}$ | 0.318 | – <u>19.1</u> mm. | | |
| Shallow Concentrated Flow (Assume Hyd. Ra | adius = Depth of Flow) | | | |
| | Segment ID B-C | | | |
| 7a. Surface Description | PAVED | | | |
| 7b. Paved or Unpaved | PAVE | | | |
| 7c. Manning's Roughness Coeff., n | 0.025 | | | |
| 7d. Depth of Flow, d (ft) (d = 0.4 Unpaved, d = | 0.2 Paved) 0.2 | | | |
| 8. Flow Length, L | 640 | | | |
| 9a. Change in Elevation, h (ft) | 13.0 | | | |
| | 10 2/ 1/ | | | |
| 10. Flow Velocity, V (ft/sec) $V = \frac{1.44}{1.42}$ | $\frac{19}{6}(d^{7/3})(s^{7/2})$ 2.905 | | | |
| 11. Travel Time, $T_t(hr) = L$ | 0.061 | + + | + = 0.0 | 06 |
| 9b. Watercourse slope, s (ft/ft) 10. Flow Velocity, V (ft/sec) 11. Travel Time, T_t (hr) $T_t = \frac{L}{3600 * V}$ | | | = 3. | |
| Channel Flow | | | | |
| | | | | |
| | Segment ID | | | |
| 12a. Channel/Conduit Description | Segment ID | | | |
| 12a. Channel/Conduit Description12b. Cross sectional flow area, A (ft.²⁾ | Segment ID | | | |
| 12b. Cross sectional flow area, A (ft. ²⁾ | | | | |
| 12b. Cross sectional flow area, A (ft. ²⁾ | | | | |
| 12b. Cross sectional flow area, A (${\rm ft}^2$) 13. Wetted perimeter, $P_{\rm w(ft)}$ | | | | |
| 12b. Cross sectional flow area, A (ft. ²⁾ 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Changel Slope, S (ft/ft) | 4 | | | |
| 12b. Cross sectional flow area, A (ft. ²⁾ 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Changel Slope, S (ft/ft) | 4 | | | |
| 12b. Cross sectional flow area, A (ft. ²⁾ 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) 15a. Change in Elevation, H (ft) 15b. Changel Slope, S (ft/ft) | 4 | | | |
| 12b. Cross sectional flow area, A (ft. ²⁾ 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.4}{P}$ | $\frac{4}{2}$ $\frac{9}{2}(R^{\frac{2}{3}})(s^{\frac{1}{2}})$ | | | |
| 12b. Cross sectional flow area, A (ft. ²⁾ 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.4}{P}$ | $\frac{4}{2}$ $\frac{9}{2}(R^{\frac{2}{3}})(s^{\frac{1}{2}})$ | + + | + = | |
| 12b. Cross sectional flow area, A (ft. ²⁾ 13. Wetted perimeter, $P_{w \text{ (ft)}}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.44}{P}$ | $\frac{4}{2}$ $\frac{9}{2}(R^{\frac{2}{3}})(s^{\frac{1}{2}})$ | + + | + = = = = | |
| 12b. Cross sectional flow area, A (ft. ²⁾ 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.4}{P}$ | $\frac{4}{2} = \frac{4}{2} = \frac{4}$ | + + + | + = = = | |
| 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.4}{n}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ Lake or Reservoir Flow | $\frac{4}{2}$ $\frac{9}{2}(R^{\frac{2}{3}})(s^{\frac{1}{2}})$ Segment ID | + + + | + = = = | |
| 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.4}{n}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ Lake or Reservoir Flow 20. Mean Depth of Lake or Reservoir, D (ft | $\frac{4}{9} \left(R^{\frac{2}{3}}\right) \left(s^{\frac{1}{2}}\right)$ Segment ID | + + + | + = = = | |
| 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w \text{ (ft)}}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.4^{\circ}}{n}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ Lake or Reservoir Flow 20. Mean Depth of Lake or Reservoir, D (ft/21). Wave Velocity Ac, V_w (ft/sec) $V_w = 0$ | $\frac{4}{9} \left(R^{\frac{2}{3}}\right) \left(s^{\frac{1}{2}}\right)$ Segment ID | + + + | + = = = = | |
| 12b. Cross sectional flow area, A (ft.2) 13. Wetted perimeter, $P_{w(ft)}$ 14. Hydraulic Radius, R (ft) $R = \frac{A}{P}$ 15a. Change in Elevation, H (ft) 15b. Channel Slope, S (ft/ft) 16. Manning's Roughness Coeff., n 17. Flow Velocity, V (ft/sec) $V = \frac{1.4}{n}$ 18. Flow length, L (ft) 19. Travel Time, T (hr) $T_t = \frac{L}{3600 * V}$ Lake or Reservoir Flow 20. Mean Depth of Lake or Reservoir, D (ft | $\frac{4}{2}$ $\frac{9}{(R^{2/3})(s^{1/2})}$ Segment ID $(gD)^{0.5}$ | + + + | + = = = | |

Total T_c (Sum T_t From Previous Steps) = 23 min.

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing Yes

State New York

Location near Benedictine Hospital Cardiology, Kingston, NY 12401, USA

Longitude 73.997 degrees West **Latitude** 41.927 degrees North

Elevation 196 feet

Date/Time Tue, 27 Nov 2012 14:47:57 -0500

Extreme Precipitation Estimates

| | 5min | 10min | 15min | 30min | 60min | 120min | | 1hr | 2hr | 3hr | 6hr | 12hr | 24hr | 48hr | | 1day | 2day | 4day | 7day | 10day | |
|-------|------|-------|-------|-------|-------|--------|-------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1yr | 0.30 | 0.46 | 0.58 | 0.75 | 0.94 | 1.18 | 1yr | 0.81 | 1.10 | 1.36 | 1.69 | 2.09 | 2.60 | 3.00 | 1yr | 2.30 | 2.88 | 3.36 | 3.97 | 4.56 | 1yr |
| 2yr | 0.36 | 0.56 | 0.70 | 0.92 | 1.16 | 1.45 | 2yr | 1.00 | 1.32 | 1.67 | 2.07 | 2.56 | 3.15 | 3.58 | 2yr | 2.79 | 3.45 | 3.96 | 4.64 | 5.27 | 2yr |
| 5yr | 0.43 | 0.67 | 0.83 | 1.12 | 1.43 | 1.81 | 5yr | 1.23 | 1.64 | 2.09 | 2.60 | 3.21 | 3.95 | 4.54 | 5yr | 3.50 | 4.37 | 4.98 | 5.72 | 6.49 | 5yr |
| 10yr | 0.48 | 0.75 | 0.95 | 1.29 | 1.67 | 2.14 | 10yr | 1.44 | 1.94 | 2.48 | 3.09 | 3.82 | 4.69 | 5.44 | 10yr | 4.15 | 5.23 | 5.92 | 6.71 | 7.61 | 10yr |
| 25yr | 0.56 | 0.89 | 1.13 | 1.56 | 2.07 | 2.66 | 25yr | 1.79 | 2.40 | 3.10 | 3.88 | 4.80 | 5.88 | 6.90 | 25yr | 5.20 | 6.64 | 7.45 | 8.29 | 9.39 | 25yr |
| 50yr | 0.62 | 1.00 | 1.28 | 1.80 | 2.43 | 3.16 | 50yr | 2.10 | 2.83 | 3.70 | 4.63 | 5.71 | 6.98 | 8.27 | 50yr | 6.18 | 7.95 | 8.88 | 9.74 | 11.02 | 50yr |
| 100yr | 0.71 | 1.15 | 1.49 | 2.10 | 2.86 | 3.74 | 100yr | 2.47 | 3.34 | 4.38 | 5.50 | 6.79 | 8.30 | 9.92 | 100yr | 7.34 | 9.54 | 10.60 | 11.44 | 12.93 | 100yr |
| 200yr | 0.81 | 1.31 | 1.70 | 2.44 | 3.37 | 4.44 | 200yr | 2.91 | 3.94 | 5.21 | 6.55 | 8.09 | 9.86 | 11.91 | 200yr | 8.73 | 11.45 | 12.65 | 13.44 | 15.18 | 200yr |
| 500yr | 0.96 | 1.58 | 2.06 | 2.99 | 4.19 | 5.56 | 500yr | 3.61 | 4.89 | 6.55 | 8.25 | 10.19 | 12.41 | 15.17 | 500yr | 10.98 | 14.59 | 16.01 | 16.66 | 18.79 | 500yr |

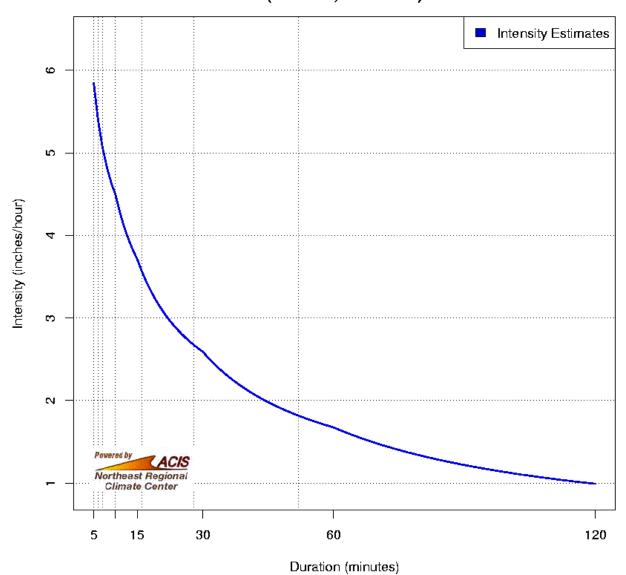
Lower Confidence Limits

| | 5min | 10min | 15min | 30min | 60min | 120min | | 1hr | 2hr | 3hr | 6hr | 12hr | 24hr | 48hr | | 1day | 2day | 4day | 7day | 10day | |
|-------|------|-------|-------|-------|-------|--------|-------|------|------|------|------|------|------|-------|-------|------|-------|-------|-------|-------|-------|
| 1yr | 0.28 | 0.43 | 0.52 | 0.70 | 0.86 | 0.97 | 1yr | 0.74 | 0.94 | 1.16 | 1.45 | 1.81 | 2.28 | 2.61 | 1yr | 2.02 | 2.51 | 2.58 | 3.66 | 3.78 | 1yr |
| 2yr | 0.35 | 0.55 | 0.67 | 0.91 | 1.12 | 1.30 | 2yr | 0.97 | 1.27 | 1.48 | 1.89 | 2.42 | 3.05 | 3.48 | 2yr | 2.70 | 3.34 | 3.86 | 4.53 | 5.13 | 2yr |
| 5yr | 0.39 | 0.60 | 0.74 | 1.02 | 1.29 | 1.51 | 5yr | 1.12 | 1.48 | 1.70 | 2.20 | 2.79 | 3.64 | 4.20 | 5yr | 3.22 | 4.04 | 4.68 | 5.34 | 6.07 | 5yr |
| 10yr | 0.42 | 0.65 | 0.81 | 1.13 | 1.46 | 1.68 | 10yr | 1.26 | 1.65 | 1.88 | 2.45 | 3.08 | 4.12 | 4.84 | 10yr | 3.65 | 4.66 | 5.41 | 6.01 | 6.85 | 10yr |
| 25yr | 0.48 | 0.73 | 0.91 | 1.29 | 1.70 | 1.93 | 25yr | 1.47 | 1.88 | 2.13 | 2.71 | 3.50 | 4.92 | 5.86 | 25yr | 4.35 | 5.64 | 6.59 | 7.04 | 7.93 | 25yr |
| 50yr | 0.52 | 0.80 | 0.99 | 1.43 | 1.92 | 2.11 | 50yr | 1.66 | 2.06 | 2.34 | 2.98 | 3.86 | 5.63 | 6.79 | 50yr | 4.98 | 6.53 | 7.68 | 7.96 | 8.95 | 50yr |
| 100yr | 0.58 | 0.87 | 1.10 | 1.58 | 2.17 | 2.34 | 100yr | 1.87 | 2.29 | 2.58 | 3.29 | 4.27 | 6.47 | 7.87 | 100yr | 5.73 | 7.57 | 8.97 | 9.02 | 9.96 | 100yr |
| 200yr | 0.64 | 0.97 | 1.23 | 1.78 | 2.48 | 2.56 | 200yr | 2.14 | 2.51 | 2.82 | 3.63 | 4.69 | 7.42 | 9.17 | 200yr | 6.57 | 8.82 | 10.54 | 10.26 | 11.21 | 200yr |
| 500yr | 0.75 | 1.12 | 1.44 | 2.09 | 2.97 | 2.93 | 500yr | 2.56 | 2.87 | 3.19 | 4.14 | 5.32 | 8.98 | 11.25 | 500yr | 7.94 | 10.82 | 13.08 | 12.17 | 13.19 | 500yr |

Upper Confidence Limits

| | 5min | 10min | 15min | 30min | 60min | 120min | | 1hr | 2hr | 3hr | 6hr | 12hr | 24hr | 48hr | | 1day | 2day | 4day | 7day | 10day | |
|-------|------|-------|-------|-------|-------|--------|-------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1yr | 0.33 | 0.51 | 0.62 | 0.83 | 1.02 | 1.24 | 1yr | 0.88 | 1.22 | 1.39 | 1.79 | 2.27 | 2.85 | 3.26 | 1yr | 2.52 | 3.13 | 3.61 | 4.29 | 4.91 | 1yr |
| 2yr | 0.38 | 0.59 | 0.73 | 0.99 | 1.22 | 1.45 | 2yr | 1.05 | 1.42 | 1.65 | 2.11 | 2.67 | 3.29 | 3.74 | 2yr | 2.91 | 3.59 | 4.09 | 4.84 | 5.49 | 2yr |
| 5yr | 0.47 | 0.72 | 0.90 | 1.23 | 1.57 | 1.86 | 5yr | 1.35 | 1.82 | 2.14 | 2.76 | 3.47 | 4.28 | 4.91 | 5yr | 3.79 | 4.72 | 5.31 | 6.13 | 6.89 | 5yr |
| 10yr | 0.55 | 0.85 | 1.05 | 1.47 | 1.90 | 2.29 | 10yr | 1.64 | 2.24 | 2.63 | 3.41 | 4.26 | 5.32 | 6.07 | 10yr | 4.71 | 5.84 | 6.46 | 7.35 | 8.29 | 10yr |
| 25yr | 0.69 | 1.05 | 1.30 | 1.86 | 2.45 | 3.02 | 25yr | 2.11 | 2.95 | 3.50 | 4.70 | 5.61 | 6.89 | 8.03 | 25yr | 6.10 | 7.72 | 8.37 | 9.36 | 10.54 | 25yr |
| 50yr | 0.81 | 1.24 | 1.54 | 2.22 | 2.98 | 3.72 | 50yr | 2.57 | 3.63 | 4.35 | 5.87 | 6.88 | 8.46 | 9.91 | 50yr | 7.48 | 9.53 | 10.17 | 11.22 | 12.77 | 50yr |
| 100yr | 0.96 | 1.46 | 1.82 | 2.63 | 3.61 | 4.60 | 100yr | 3.12 | 4.50 | 5.40 | 7.35 | 8.48 | 10.37 | 12.24 | 100yr | 9.18 | 11.77 | 12.37 | 13.49 | 15.20 | 100yr |
| 200yr | 1.14 | 1.71 | 2.17 | 3.15 | 4.39 | 5.66 | 200yr | 3.79 | 5.54 | 6.73 | 9.21 | 10.46 | 12.71 | 15.12 | 200yr | 11.25 | 14.54 | 15.03 | 16.20 | 18.26 | 200yr |
| 500yr | 1.43 | 2.13 | 2.74 | 3.99 | 5.67 | 7.49 | 500yr | 4.89 | 7.32 | 8.98 | 12.40 | 13.82 | 16.60 | 19.96 | 500yr | 14.69 | 19.19 | 19.44 | 20.65 | 23.24 | 500yr |

Intensity Frequency Duration – 10yr (41.927N, –73.997W)

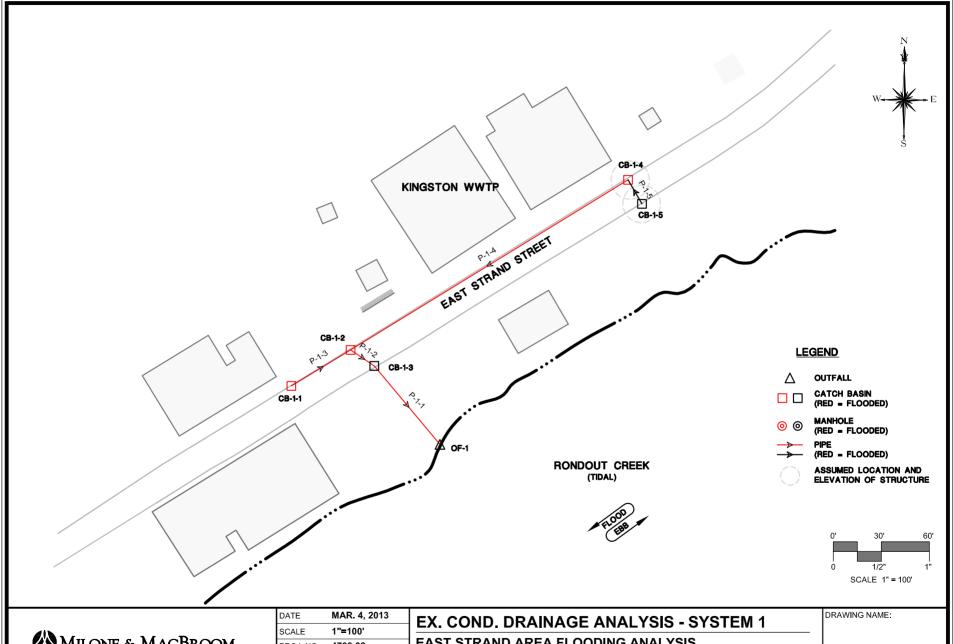


| Time (mins) | <pre>Intensity (in/hr)</pre> | |
|----------------|------------------------------|--------|
| ========= | | :===== |
| 5 | 5.84 | |
| 6* | 5.39 | |
| 7 * | 5.07 | |
| 8* | 4.83 | |
| 9* | 4.64 | |
| 10 | 4.49 | |
| 11* | 4.28 | |
| 12* | 4.10 | |
| 13* | 3.95 | |
| 14* | 3.82 | |
| 15 | 3.71 | |
| 16* | 3.57 | |
| 17* | 3.44 | |
| 18* | 3.34 | |

| | Intensity | Frequency | |
|-----|-----------|-----------|--|
| 19* | | 3.24 | |
| 20* | | 3.15 | |
| 21* | | 3.07 | |
| | | | |
| 22* | | | |
| 23* | | 2.93 | |
| 24* | | 2.87 | |
| 25* | | 2.81 | |
| 26* | | 2.76 | |
| 27* | | 2.71 | |
| 28* | | 2.67 | |
| 29* | | 2.63 | |
| 30 | | 2.59 | |
| 31* | | 2.53 | |
| 32* | | 2.48 | |
| | | | |
| 33* | | | |
| 34* | | 2.37 | |
| 35* | | 2.33 | |
| 36* | | 2.28 | |
| 37* | | 2.24 | |
| 38* | | 2.20 | |
| 39* | | 2.17 | |
| 40* | | 2.13 | |
| 41* | | 2.10 | |
| 42* | | 2.07 | |
| 43* | | 2.04 | |
| | | | |
| 44* | | | |
| 45* | | 1.98 | |
| 46* | | 1.95 | |
| 47* | | 1.93 | |
| 48* | | 1.90 | |
| 49* | | 1.88 | |
| 50* | | 1.86 | |
| 51* | | 1.83 | |
| 52* | | 1.81 | |
| 53* | | 1.79 | |
| 54* | | 1.77 | |
| 55* | | 1.76 | |
| 56* | | 1.74 | |
| 57* | | 1.72 | |
| | | | |
| 58* | | 1.70 | |
| 59* | | 1.69 | |
| 60 | | 1.67 | |
| 61* | | 1.65 | |
| 62* | | 1.63 | |
| 63* | | 1.61 | |
| 64* | | 1.59 | |
| 65* | | 1.57 | |
| 66* | | 1.55 | |
| 67* | | 1.53 | |
| 68* | | 1.51 | |
| 69* | | 1.49 | |
| | | | |
| 70* | | 1.48 | |
| 71* | | 1.46 | |
| 72* | | 1.45 | |
| 73* | | 1.43 | |
| 74* | | 1.41 | |
| 75* | | 1.40 | |
| | | | |

```
76*
                 1.39
 77*
                 1.37
 78*
                 1.36
 79*
                 1.34
 80*
                 1.33
                 1.32
 81*
 82*
                 1.31
 83*
                 1.29
 84*
                 1.28
 85*
                 1.27
 86*
                 1.26
 87*
                 1.25
 88*
                 1.24
 89*
                 1.23
 90*
                 1.22
 91*
                 1.21
 92*
                 1.20
 93*
                 1.19
 94*
                 1.18
 95*
                 1.17
 96*
                 1.16
 97*
                 1.15
 98*
                 1.14
 99*
                 1.13
100*
                 1.13
101*
                 1.12
102*
                 1.11
103*
                 1.10
104*
                 1.09
105*
                 1.09
106*
                 1.08
107*
                 1.07
108*
                 1.07
109*
                 1.06
                 1.05
110*
111*
                 1.04
112*
                 1.04
113*
                 1.03
114*
                 1.03
                 1.02
115*
116*
                 1.01
117*
                 1.01
118*
                 1.00
119*
                 1.00
                 0.99
120
```

*values for noted rows are calculated estimates



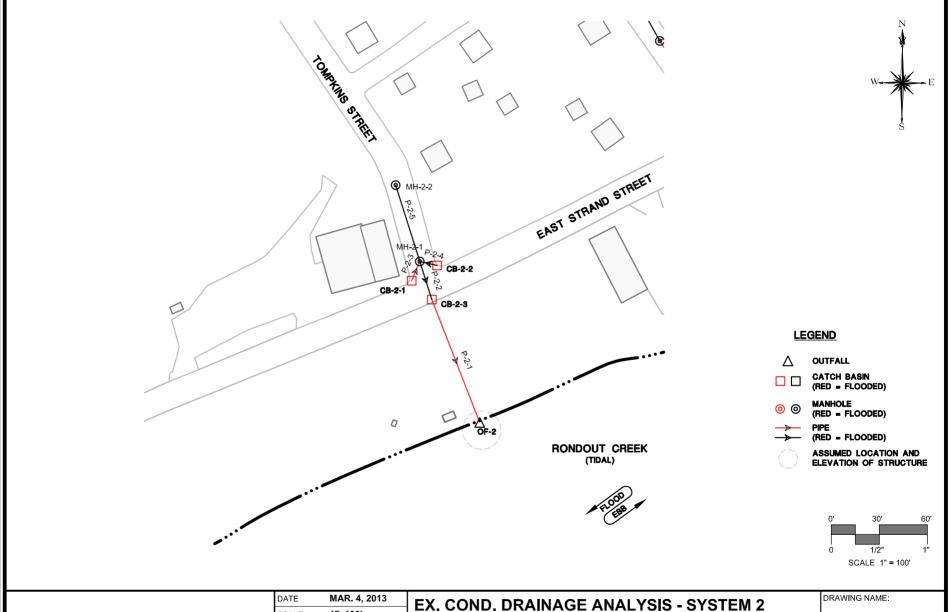


99 Realty Drive Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733 www.miloneandmacbroom.com

| DATE | MAR. 4, 2013 |
|-----------|--------------|
| SCALE | 1"=100' |
| PROJ. NO. | 4766-02 |
| DESIGNED | JCM |
| DRAWN | JCM |
| CHECKED | NFR |

EAST STRAND AREA FLOODING ANALYSIS
RONDOUT CREEK WATERFRONT

EAST STRAND STREET KINGSTON, NEW YORK





Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733 www.miloneandmacbroom.com

| SCALE | 1"=100' |
|-----------|---------|
| PROJ. NO. | 4766-02 |
| DESIGNED | JCM |
| DRAWN | JCM |
| CHECKED | NEB |

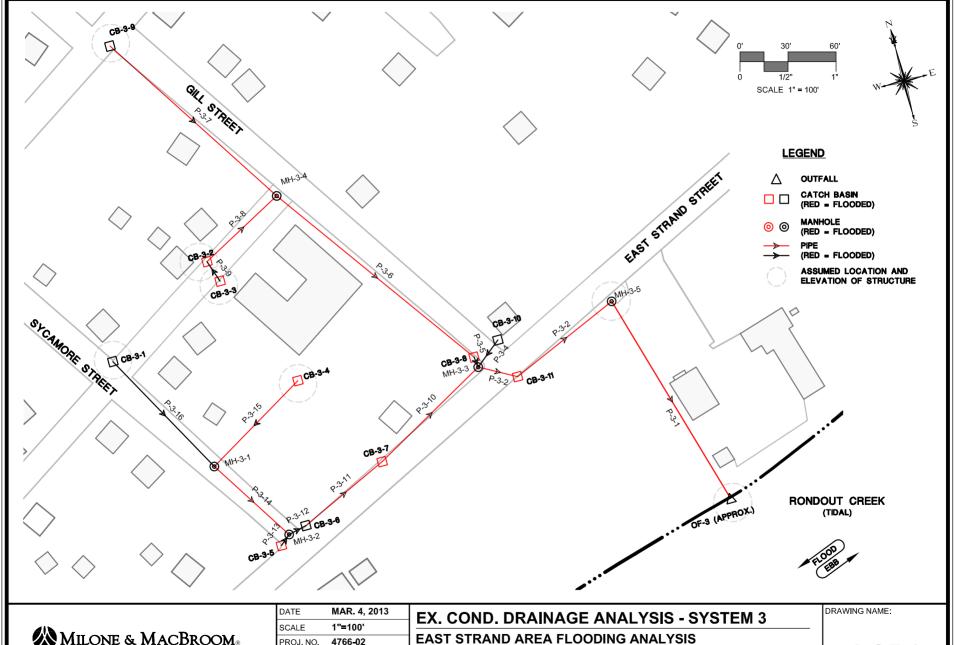
EAST STRAND AREA FLOODING ANALYSIS RONDOUT CREEK WATERFRONT

EAST STRAND STREET KINGSTON, NEW YORK









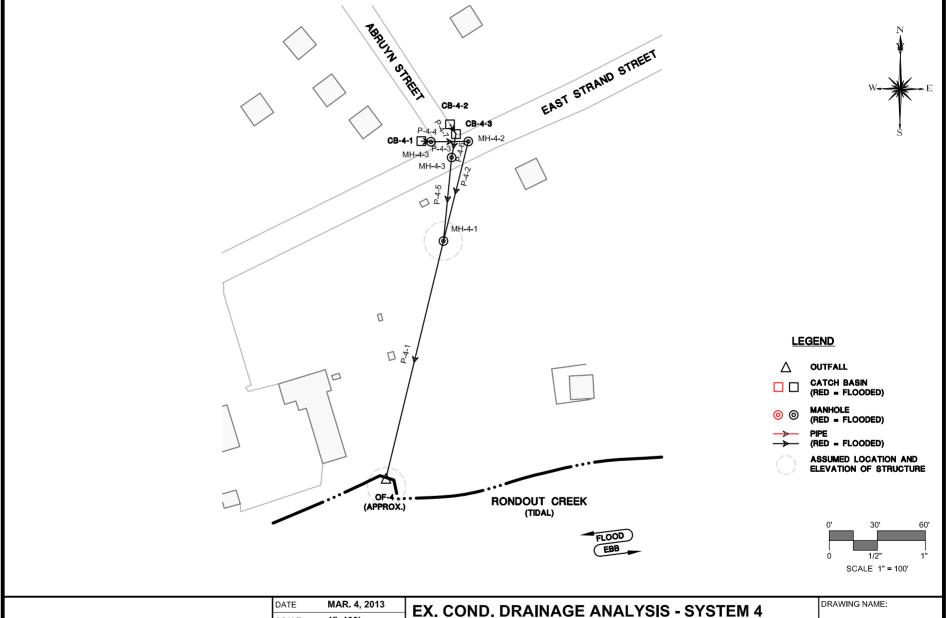
MILONE & MACBROOM®

Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733 www.miloneandmacbroom.com

PROJ. NO. 4766-02 JCM DESIGNED JCM DRAWN CHECKED

RONDOUT CREEK WATERFRONT EAST STRAND STREET

KINGSTON, NEW YORK





Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733 www.miloneandmacbroom.com

| DATE | MAR. 4, 2013 |
|-----------|--------------|
| SCALE | 1"=100' |
| PROJ. NO. | 4766-02 |
| DESIGNED | JCM |
| DRAWN | JCM |
| CHECKED | NEB |

EAST STRAND AREA FLOODING ANALYSIS RONDOUT CREEK WATERFRONT

EAST STRAND STREET KINGSTON, NEW YORK

East Strand Street Flooding Analysis Kingston, NY

Designed By: JCM Checked By: NEB

Watershed Characteristics and Rainfall Runoff Computations, Computed for 10-year Precipitation

| Unimproved and/or Vacant (C=0.25, sf) 16,220 23,128 9,571 26,368 20,205 88,746 | 1/6 Acre Residential Area (C=0.46, sf) 13,634 44,262 28,919 11,032 | Stone Ballast (RR / Util Yard) (C=0.75, sf) 37,316 15,497 20,409 | WWTP Operations (C=0.85, sf) 26,811 20,700 57,774 | Impervious Road or Roof (C=0.9, sf) 6,115 4,332 16,651 16,499 11,620 | Total Drainage Area (A, ac.) 5.59 3.45 0.60 8.25 0.73 | Runoff Coefficient (C) 0.36 0.35 0.66 0.38 0.49 | 10 Time of Conc. (tc, min.) | 2.1 2.9 4.5 2.5 4.5 | Peak Rational Flow (Q, cfs) 4.31 3.42 1.79 7.86 1.60 |
|--|---|---|--|---|--|---|---|---|---|
| 16,220 23,128 9,571 26,368 20,205 | (C=0.46, sf) 13,634 44,262 28,919 | (C=0.75, sf) 37,316 15,497 | (C=0.85, sf) 26,811 20,700 | 6,115 4,332 16,651 16,499 | 5.59 3.45 0.60 8.25 | 0.36 0.35 0.66 0.38 | 40 24 10 31 | 2.1 2.9 4.5 2.5 | 4.31 3.42 1.79 7.86 |
| 16,220 23,128 9,571 26,368 20,205 | 13,634 44,262 28,919 | 37,316 15,497 | 26,811 20,700 | 6,115 4,332 16,651 16,499 | 5.59 3.45 0.60 8.25 | 0.36 0.35 0.66 0.38 | 40 24 10 31 | 2.1 2.9 4.5 2.5 | 4.31 3.42 1.79 7.86 |
| 23,128 9,571 26,368 20,205 | 44,262 28,919 | 15,497 | 20,700 | 4,332 16,651 16,499 | 3.45 0.60 8.25 | 0.35 0.66 0.38 | 24 10 31 | 2.9 4.5 2.5 | 3.42 1.79 7.86 |
| 23,128 9,571 26,368 20,205 | 44,262 28,919 | 15,497 | 20,700 | 4,332 16,651 16,499 | 3.45 0.60 8.25 | 0.35 0.66 0.38 | 24 10 31 | 2.9 4.5 2.5 | 3.42 1.79 7.86 |
| 9,571 26,368 20,205 88,746 | 28,919 | • | · | 16,651 16,499 | 0.60 8.25 | 0.66 0.38 | 10 31 | 4.5 2.5 | 1.79 7.86 |
| 26,368 20,205 88,746 | 28,919 | 20,409 | 57,774 | 16,499 | 8.25 | 0.38 | 31 | 2.5 | 7.86 |
| 20,205 | 28,919 | 20,409 | 57,774 | | | | | | |
| 88,746 | | | | 11,620 | 0.73 | 0.49 | 10 | 4.5 | 1.60 |
| · | | | | | | | | | |
| · | | | | | | | | | |
| 13,169 | 11,032 | | | 54,972 | 10.10 | 0.28 | 27 | 2.7 | 7.78 |
| 13,169 | | | | 4,537 | 0.36 | 0.59 | 10 | 4.5 | 0.94 |
| | | 3,991 | | 6,758 | 0.55 | 0.52 | 15 | 3.7 | 1.05 |
| | | | | | | | | | |
| | 56,123 | | | 14,327 | 1.62 | 0.55 | 28 | 2.7 | 2.37 |
| | 47,020 | | | 410 | 1.09 | 0.46 | 23 | 2.9 | 1.48 |
| | 6,000 | | | 6,407 | 0.28 | 0.69 | 10 | 4.5 | 0.88 |
| 4,187 | 36,883 | | | | 0.94 | 0.44 | 10 | 4.5 | 1.86 |
| | 89,590 | | | 24,202 | 2.80 | 0.53 | 25 | 2.8 | 4.14 |
| 2,665 | 3,907 | | | 6,762 | 0.31 | 0.64 | 5 | 5.8 | 1.15 |
| 8,141 | 6,429 | | | 2,375 | 0.39 | 0.42 | 5 | 5.8 | 0.96 |
| | | | | 7,688 | 0.18 | 0.90 | 5 | 5.8 | 0.93 |
| | 453,802 | | | 168,187 | 28.91 | 0.36 | 38 | 2.2 | 23.02 |
| 77,271 | 150,518 | | | 41,193 | 6.17 | 0.47 | 31 | 2.5 | 7.21 |
| | | | | 10,552 | 0.24 | 0.90 | 10 | 4.5 | 0.98 |
| | | | | | | | | | |
| | 59,134 | | | 14,561 | 1.79 | 0.53 | 22 | 3.0 | 2.85 |
| 4,200 | 79,371 | | | 21,310 | 2.31 | 0.55 | 23 | 2.9 | 3.75 |
| 4,200 | 1,058 | | | · | 0.02 | 0.46 | 5 | 5.8 | 0.06 |
| | 4,200 | 4,200 59,134 79,371 | 4,200 59,134 79,371 | 4,200 59,134 79,371 | 4,200 59,134 14,561 79,371 21,310 | 4,200 59,134 14,561 1.79 79,371 21,310 2.31 | 4,200 59,134 14,561 1.79 0.53 79,371 21,310 2.31 0.55 | 4,200 59,134 14,561 1.79 0.53 22 79,371 21,310 2.31 0.55 23 | 4,200 59,134 14,561 1.79 0.53 22 3.0 79,371 21,310 2.31 0.55 23 2.9 |

^{*} Notes:



^{1.} Time of concentration values that are bolded were estimated.

^{2.} The location of the following catch basins is estimated: CB-3-1, 3-2, 3-3, 3-9

Project No.: 4766-02 Kingston, New York

East Strand Street Flooding Analysis Kingston, NY

Designed By: JCM Checked By: NEB

Existing Drainage System Pipe Capacity Analysis - 10-Year Precipitation

| Pipe ID | U/S Node | D/S Node | U/S Time of Conc. | Pipe Size (Dia.) | Pipe Material | Manning's Coef. "n" | Pipe Length | Invert U/S | Invert D/S | Pipe Slope | Cover U/S | Cover D/S | Average Velocity | Full Capacity | System Flow |
|---------|----------|----------|-------------------|---------------------|---------------|------------------------|----------------|---------------|---------------|---------------|-----------|-----------|---------------------|------------------|----------------|
| | | | (min.) | (in) | | | (ft) | (ft) | (ft) | (ft/ft) | (ft) | (ft) | (ft/s) | (ft³/s) | (ft³/s) |
| P-1-1 | CB-1-3 | OF-1 | 40.3 | 18 | Cast iron | 0.012 | 106 | 1.56 | 0 | 0.015 | 1.15 | -0.87 | 8.56 | 15.13 | 13.8 |
| P-1-2 | CB-1-2 | CB-1-3 | 40.2 | 18 | PVC | 0.01 | 30 | 1.67 | 1.56 | 0.004 | 1.09 | 1.15 | 8.09 | 14.29 | 8.27 |
| P-1-3 | CB1-1 | CB-1-2 | 40.0 | 12 | PVC | 0.01 | 72 | 1.86 | 1.67 | 0.003 | 1.6 | 1.59 | 5.53 | 4.34 | 2.38 |
| P-1-4 | CB-1-4 | CB-1-2 | 31.0 | 12 | PVC | 0.01 | 339 | 1.8 | 1.67 | 0 | 0.1 | 1.59 | 11.28 | 8.86 | 0.91 |
| P-1-5 | CB-1-5 | CB-1-4 | 10.0 | 12 | PVC | 0.01 | 29 | 1.9 | 1.8 | 0.003 | 0.1 | 0.1 | 2.05 | 1.61 | 2.72 |
| P-2-1 | CB-2-3 | OF-2 | 27.1 | 12 | Concrete | 0.013 | 137 | 0.24 | 0.1 | 0.001 | 3.12 | 0.9 | 11.74 | 9.22 | 1.14 |
| P-2-2 | MH-2-1 | CB-2-3 | 27.0 | 12 | PVC | 0.01 | 42 | 1.88 | 0.24 | 0.039 | 2.1 | 3.12 | 10.76 | 8.45 | 9.15 |
| P-2-3 | CB-2-1 | MH-2-1 | 27.0 | 12 | PVC | 0.01 | 22 | 1.44 | 1.78 | -0.015 | 1.31 | 2.2 | 10.03 | 7.88 | -5.76 |
| P-2-4 | CB-2-2 | MH-2-1 | 10.0 | 12 | PVC | 0.01 | 19 | 2.46 | 2.43 | 0.002 | 0.22 | 1.55 | 1.21 | 0.95 | 1.84 |
| P-2-5 | MH-2-2 | MH-2-1 | 5.0 | 12 | PVC | 0.01 | 83 | 11.35 | 1.41 | 0.12 | 2.75 | 2.57 | 0 | 0 | 16.03 |
| P-3-1 | MH-3-5 | OF-3 | 31.2 | 18 | Concrete | 0.013 | 239 | -1.5 | -2 | 0.002 | 6 | 4.5 | 25.33 | 44.77 | 4.8 |
| P-3-10 | CB-3-7 | MH-3-3 | 28.9 | 12 | PVC | 0.01 | 140 | -1.12 | -0.5 | -0.004 | 3.25 | 6.1 | 10.63 | 8.35 | -3.08 |
| P-3-11 | CB-3-6 | CB-3-7 | 28.7 | 12 | Cast iron | 0.012 | 104 | -0.67 | -0.97 | 0.003 | 5.67 | 3.1 | 10.1 | 7.93 | 2.07 |
| P-3-12 | MH-3-2 | CB-3-6 | 28.7 | 12 | PVC | 0.01 | 20 | 0.01 | -0.4 | 0.021 | 4.99 | 5.4 | 9.44 | 7.41 | 6.63 |
| P-3-13 | CB-3-5 | MH-3-2 | 25.0 | 12 | PVC | 0.01 | 14 | 0.54 | 0.05 | 0.035 | 2.4 | 4.95 | 5.32 | 4.18 | 8.66 |
| P-3-14 | MH-3-1 | MH-3-2 | 28.3 | 12 | Concrete | 0.013 | 105 | 0.68 | 0.9 | -0.002 | 4.4 | 4.1 | 4.46 | 3.5 | -1.63 |
| P-3-15 | CB-3-4 | MH-3-1 | 10.0 | 12 | Concrete | 0.013 | 125 | 2 | 1.68 | 0.003 | 2 | 3.4 | 2.39 | 1.87 | 1.8 |
| P-3-16 | CB-3-1 | MH-3-1 | 28.0 | 12 | PVC | 0.01 | 152 | 6 | 0.68 | 0.035 | 3.5 | 4.4 | 9.43 | 2.4 | 8.66 |
| P-3-2 | MH-3-3 | CB-3-11 | 31.1 | 18 | Concrete | 0.013 | 42 | -0.5 | -1 | 0.012 | 5.6 | 5.76 | 25.07 | 44.31 | 11.46 |
| P-3-2 | CB-3-11 | MH-3-5 | 31.1 | 18 | Concrete | 0.013 | 125 | -1 | -1.5 | 0.004 | 5.76 | 6 | 25.37 | 44.84 | 6.64 |
| P-3-4 | CB-3-10 | MH-3-3 | 31.0 | 12 | Cast iron | 0.012 | 35 | 3.39 | 2.1 | 0.037 | 2.65 | 3.5 | 9.39 | 7.38 | 7.41 |
| P-3-5 | CB-3-8 | MH-3-3 | 23.9 | 18 | Concrete | 0.013 | 11 | 3.45 | 2.3 | 0.105 | 0.95 | 2.8 | 18.64 | 32.95 | 33.96 |
| P-3-6 | MH-3-4 | CB-3-8 | 23.6 | 18 | Concrete | 0.013 | 265 | 4.27 | 3.45 | 0.003 | 4.5 | 0.95 | 18.48 | 32.67 | 5.84 |
| P-3-7 | CB-3-9 | MH-3-4 | 10.0 | 18 | Concrete | 0.013 | 233 | 27 | 4.27 | 0.098 | 3.5 | 4.5 | 26.79 | 47.35 | 32.81 |
| P-3-8 | CB-3-2 | MH-3-4 | 23.0 | 12 | Concrete | 0.013 | 100 | 6.6 | 6.37 | 0.002 | 1.4 | 2.9 | 2.65 | 2.08 | 1.71 |
| P-3-9 | CB-3-3 | CB-3-2 | 10.0 | 18 | Concrete | 0.013 | 24 | 6.7 | 6.6 | 0.004 | 0.8 | 0.9 | 0.5 | 0.89 | 6.78 |
| P-4-1 | MH-4-1 | OF-4 | 23.2 | 18 | Concrete | 0.013 | 254 | 1 | -2 | 0.012 | 7.5 | 2.5 | 6.7 | 6.62 | 11.42 |
| P-4-2 | MH-4-2 | MH-4-1 | 22.1 | 18 | Concrete | 0.013 | 107 | 7.72 | 1 | 0.063 | 4.4 | 7.5 | 9.78 | 2.88 | 26.32 |
| P-4-3 | MH-4-3 | MH-4-2 | 22.0 | 12 | Concrete | 0.013 | 39 | 10.62 | 8.92 | 0.044 | 2.8 | 3.7 | 8.87 | 2.88 | 7.44 |
| P-4-4 | CB-4-1 | MH-4-3 | 22.0 | 12 | Concrete | 0.013 | 10 | 11.31 | 10.92 | 0.039 | 1.9 | 2.5 | 8.51 | 2.88 | 7.04 |
| P-4-5 | MH-4-3 | MH-4-1 | 23.0 | 12 | Concrete | 0.013 | 87 | 4.46 | 1 | 0.04 | 8.35 | 8 | 9.21 | 3.82 | 7.1 |
| P-4-6 | CB-4-3 | MH-4-3 | 23.0 | 12 | Concrete | 0.013 | 25 | 9.97 | 4.46 | 0.22 | 2.55 | 8.35 | 17.28 | 3.83 | 16.73 |
| P-4-7 | CB-4-2 | CB-4-3 | 23.0 | 12 | Concrete | 0.013 | 12 | 10.75 | 9.97 | 0.065 | 2.1 | 2.55 | 11.04 | 3.8 | 9.08 |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |



Project No.: 4766-02 Kingston, New York

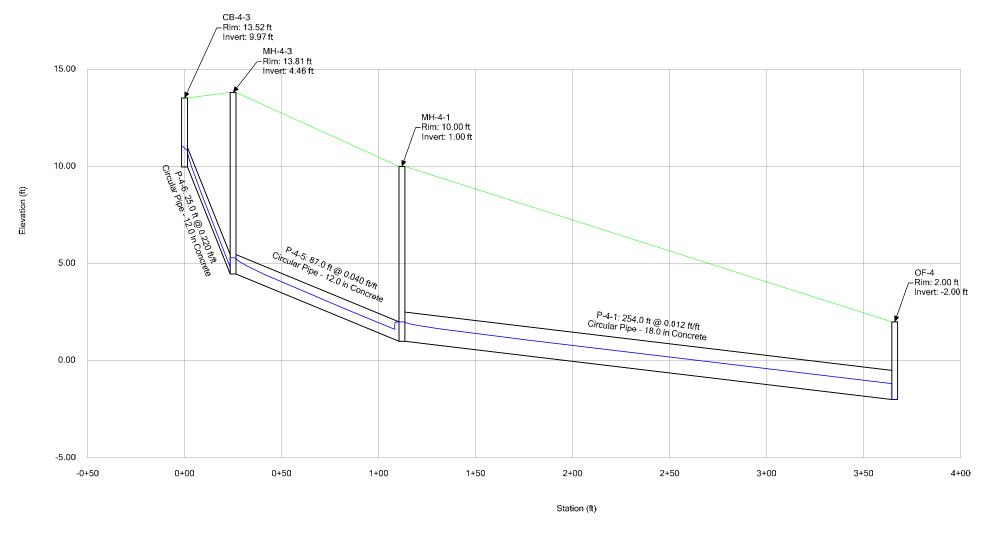
East Strand Street Flooding Analysis Kingston, NY

Designed By: JCM Checked By: NEB

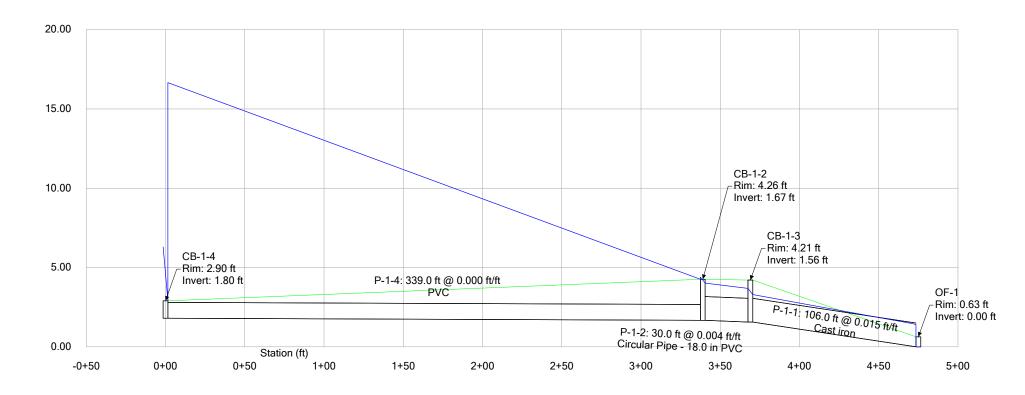
Existing Drainage System Hydraulic Grade Line Analysis - 10-Year Precipitation

| Pipe ID | U/S Node | D/S Node | Pipe Dia. | Flow | Slope | Friction Slope | Headloss | Froude Number | Velocity U/S | Energy Grade Line U/S | Energy Grade Line D/S | Hydraulic Grade Line U/S | Hydraulic Grade Line D/S | Ground Elevation U/S | Ground Elevation D/S |
|---------|----------|----------|-----------|---------|---------|-------------------|----------|------------------|-----------------|-----------------------------|-----------------------------|--------------------------------|--------------------------------|----------------------------|----------------------------|
| | l . | I . | (in) | (ft³/s) | (ft/ft) | (ft/ft) | (ft) | | (ft/s) | (ft) | (ft) | (ft) | (ft) | (ft) | (ft) |
| P-1-1 | CB-1-3 | OF-1 | 18 | 15.13 | 0.015 | 0.017 | 1.89 | 1.232 | 8.56 | 4.43 | 2.61 | 3.29 | 1.41 | 4.21 | 0.63 |
| P-1-2 | CB-1-2 | CB-1-3 | 18 | 14.29 | 0.004 | 0.011 | 0.33 | 1.164 | 8.09 | 5.03 | 4.7 | 4.01 | 3.69 | 4.26 | 4.21 |
| P-1-3 | CB1-1 | CB-1-2 | 12 | 4.34 | 0.003 | 0.009 | 0.63 | 0.974 | 5.53 | 5.37 | 4.73 | 4.89 | 4.26 | 4.46 | 4.26 |
| P-1-4 | CB-1-4 | CB-1-2 | 12 | 8.86 | 0 | 0.037 | 12.4 | 1.988 | 11.28 | 18.63 | 6.24 | 16.66 | 4.26 | 2.9 | 4.26 |
| P-1-5 | CB-1-5 | CB-1-4 | 12 | 1.61 | 0.003 | 0.001 | 0.04 | 0.949 | 2.05 | 3 | 2.97 | 2.94 | 2.9 | 3 | 2.9 |
| P-2-1 | CB-2-3 | OF-2 | 12 | 9.22 | 0.001 | 0.067 | 9.18 | 2.07 | 11.74 | 12.42 | 3.24 | 10.27 | 1.09 | 4.36 | 2 |
| P-2-2 | MH-2-1 | CB-2-3 | 12 | 8.45 | 0.039 | 0.033 | 1.4 | 2.699 | 10.76 | 7.56 | 6.16 | 5.76 | 4.36 | 4.98 | 4.36 |
| P-2-3 | CB-2-1 | MH-2-1 | 12 | 7.88 | -0.015 | 0.029 | 0.64 | 1.769 | 10.03 | 7.18 | 6.54 | 5.62 | 4.98 | 3.75 | 4.98 |
| P-2-4 | CB-2-2 | MH-2-1 | 12 | 0.95 | 0.002 | 0 | 0.01 | 0.657 | 1.21 | 5.01 | 5 | 4.99 | 4.98 | 3.68 | 4.98 |
| P-2-5 | MH-2-2 | MH-2-1 | 12 | 0 | 0.12 | 0.077 | 6.37 | (N/A) | 0 | 11.35 | 4.98 | 11.35 | 4.98 | 15.1 | 4.98 |
| P-3-1 | MH-3-5 | OF-3 | 18 | 44.77 | 0.002 | 0.182 | 43.41 | 3.646 | 25.33 | 52.88 | 9.47 | 42.91 | -0.5 | 6 | 4 |
| P-3-10 | CB-3-7 | MH-3-3 | 12 | 8.35 | -0.004 | 0.032 | 4.55 | 1.874 | 10.63 | 12.9 | 8.36 | 11.15 | 6.6 | 3.13 | 6.6 |
| P-3-11 | CB-3-6 | CB-3-7 | 12 | 7.93 | 0.003 | 0.042 | 4.39 | 1.781 | 10.1 | 9.11 | 4.72 | 7.52 | 3.13 | 6 | 3.13 |
| P-3-12 | MH-3-2 | CB-3-6 | 12 | 7.41 | 0.021 | 0.026 | 0.51 | 1.664 | 9.44 | 7.9 | 7.39 | 6.51 | 6 | 6 | 6 |
| P-3-13 | CB-3-5 | MH-3-2 | 12 | 4.18 | 0.035 | 0.008 | 0.11 | 3.119 | 5.32 | 6.55 | 6.44 | 6.11 | 6 | 3.94 | 6 |
| P-3-14 | MH-3-1 | MH-3-2 | 12 | 3.5 | -0.002 | 0.01 | 1.01 | 0.786 | 4.46 | 7.32 | 6.31 | 7.01 | 6 | 6.08 | 6 |
| P-3-15 | CB-3-4 | MH-3-1 | 12 | 1.87 | 0.003 | 0.003 | 0.35 | 0.451 | 2.39 | 6.51 | 6.17 | 6.43 | 6.08 | 5 | 6.08 |
| P-3-16 | CB-3-1 | MH-3-1 | 12 | 2.4 | 0.035 | 0.005 | 0.58 | 3.23 | 9.43 | 6.96 | 6.23 | 6.66 | 6.08 | 10.5 | 6.08 |
| P-3-2 | MH-3-3 | CB-3-11 | 18 | 44.31 | 0.012 | 0.178 | 7.47 | 3.609 | 25.07 | 23.5 | 16.03 | 13.73 | 6.26 | 6.6 | 6.26 |
| P-3-2 | CB-3-11 | MH-3-5 | 18 | 44.84 | 0.004 | 0.182 | 22.78 | 3.653 | 25.37 | 38.79 | 16.01 | 28.78 | 6 | 6.26 | 6 |
| P-3-4 | CB-3-10 | MH-3-3 | 12 | 7.38 | 0.037 | 0.037 | 1.28 | 2.015 | 9.39 | 9.25 | 7.97 | 7.88 | 6.6 | 7.04 | 6.6 |
| P-3-5 | CB-3-8 | MH-3-3 | 18 | 32.95 | 0.105 | 0.098 | 1.08 | 3.468 | 18.64 | 13.08 | 12 | 7.68 | 6.6 | 5.9 | 6.6 |
| P-3-6 | MH-3-4 | CB-3-8 | 18 | 32.67 | 0.003 | 0.097 | 25.63 | 2.661 | 18.48 | 36.84 | 11.21 | 31.53 | 5.9 | 10.27 | 5.9 |
| P-3-7 | CB-3-9 | MH-3-4 | 18 | 47.35 | 0.098 | 0.203 | 47.34 | 3.857 | 26.79 | 68.76 | 21.43 | 57.61 | 10.27 | 32 | 10.27 |
| P-3-8 | CB-3-2 | MH-3-4 | 12 | 2.08 | 0.002 | 0.003 | 0.34 | 0.467 | 2.65 | 10.72 | 10.38 | 10.61 | 10.27 | 9 | 10.27 |
| P-3-9 | CB-3-3 | CB-3-2 | 18 | 0.89 | 0.004 | 0 | 0 | 0.918 | 0.5 | 9.01 | 9 | 9 | 9 | 9 | 9 |
| P-4-1 | MH-4-1 | OF-4 | 18 | 6.62 | 0.012 | 0.011 | 3.18 | 1.452 | 6.7 | 2.43 | -0.48 | 2 | -1.18 | 10 | 2 |
| P-4-2 | MH-4-2 | MH-4-1 | 18 | 2.88 | 0.063 | 0.061 | 6.37 | 3.551 | 9.78 | 8.61 | 2.08 | 8.36 | 2 | 13.62 | 10 |
| P-4-3 | MH-4-3 | MH-4-2 | 12 | 2.88 | 0.044 | 0.03 | 1.99 | 2.732 | 8.87 | 11.69 | 10.53 | 11.35 | 9.36 | 14.42 | 13.62 |
| P-4-4 | CB-4-1 | MH-4-3 | 12 | 2.88 | 0.039 | 0.018 | 0.6 | 2.569 | 8.51 | 12.38 | 12.21 | 12.04 | 11.44 | 14.21 | 14.42 |
| P-4-5 | MH-4-3 | MH-4-1 | 12 | 3.82 | 0.04 | 0.039 | 3.3 | 2.52 | 9.21 | 5.76 | 2.36 | 5.29 | 2 | 13.81 | 10 |
| P-4-6 | CB-4-3 | MH-4-3 | 12 | 3.83 | 0.22 | 0.102 | 6 | 6.266 | 17.28 | 11.27 | 8.71 | 10.8 | 4.81 | 13.52 | 13.81 |
| P-4-7 | CB-4-2 | CB-4-3 | 12 | 3.8 | 0.065 | 0.051 | 0.51 | 3.311 | 11.04 | 12.04 | 11.43 | 11.58 | 11.07 | 13.85 | 13.52 |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

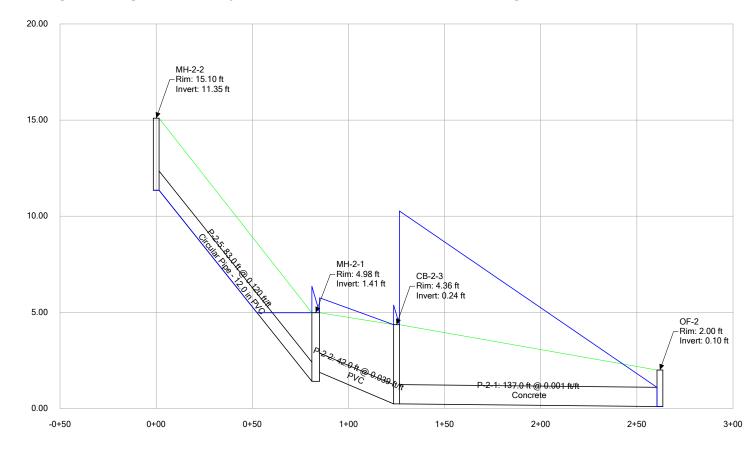
Profile Report Engineering Profile - System 4 - 10-Year Storm (Existing Conditions.stc)



Profile Report Engineering Profile - System 1 - 10-Year Storm (Existing Conditions.stc)

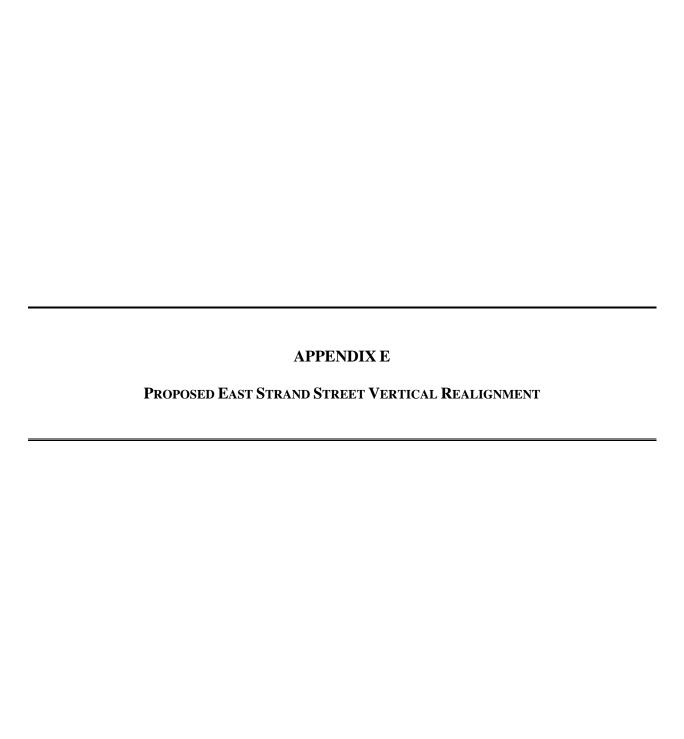


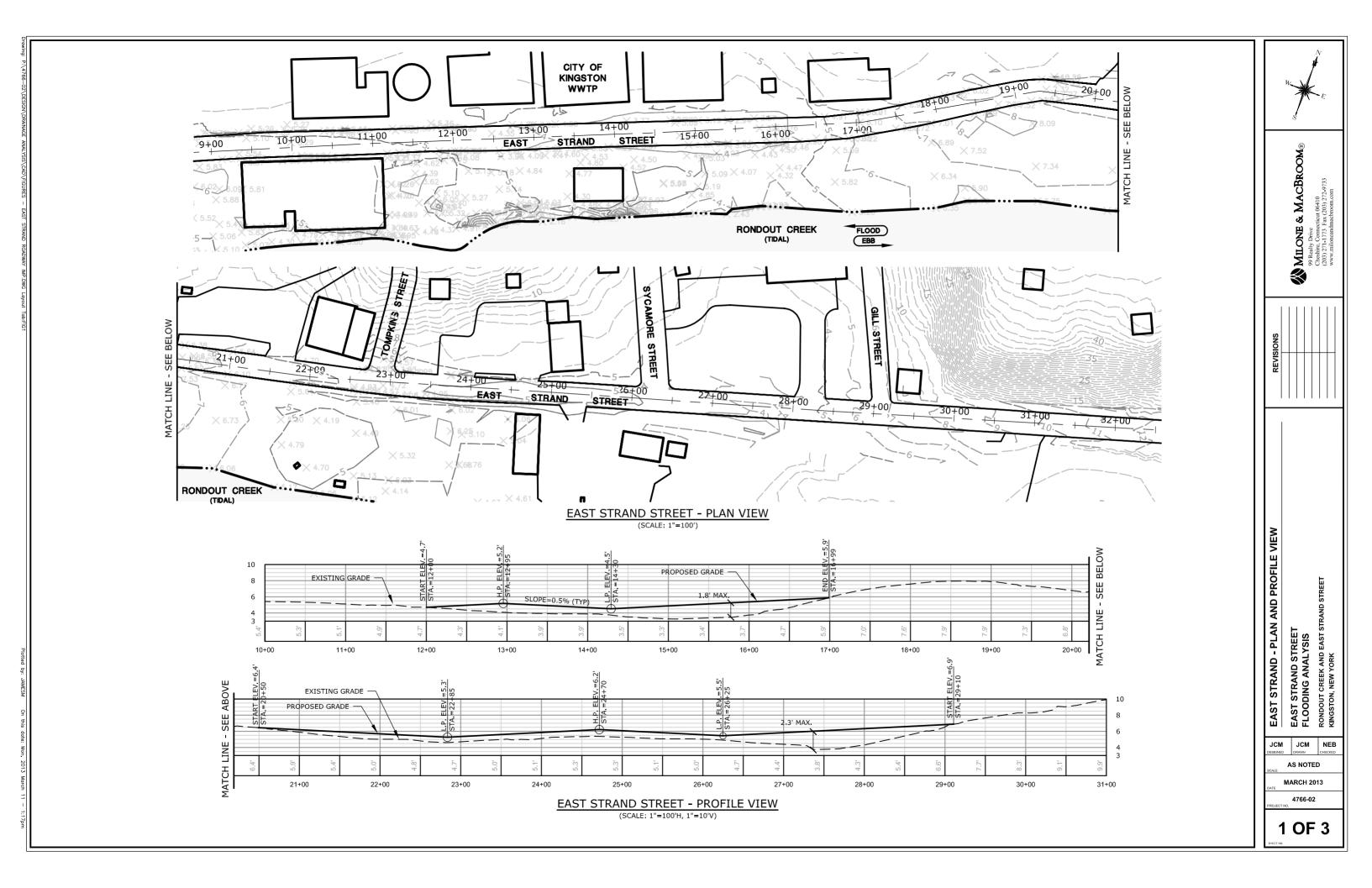
Profile Report Engineering Profile - System 2 - 10-Year Storm (Existing Conditions.stc)

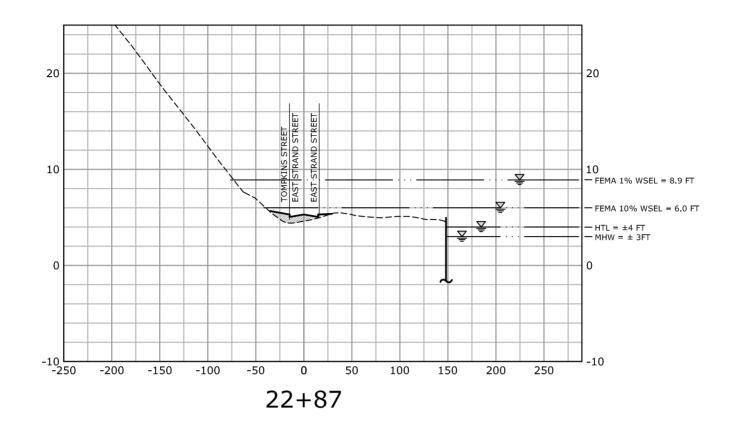


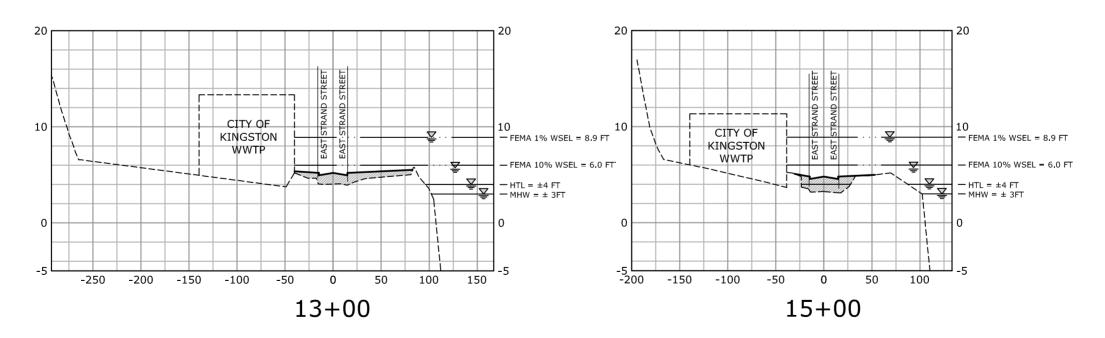
Station (ft)

Elevation (ft)







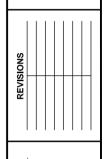


EAST STRAND STREET - SECTION VIEW

(SCALE: 1"=100'H, 1"=10'V)



MILONE & MACBROOM®
99 Realty Drive
Cheshine, Compete 106410
(203) 271-1773 Fax (203) 272-9733
www.miloneandmachroom.com



EAST STRAND - PLAN AND PROFILE VIEW
EAST STRAND STREET

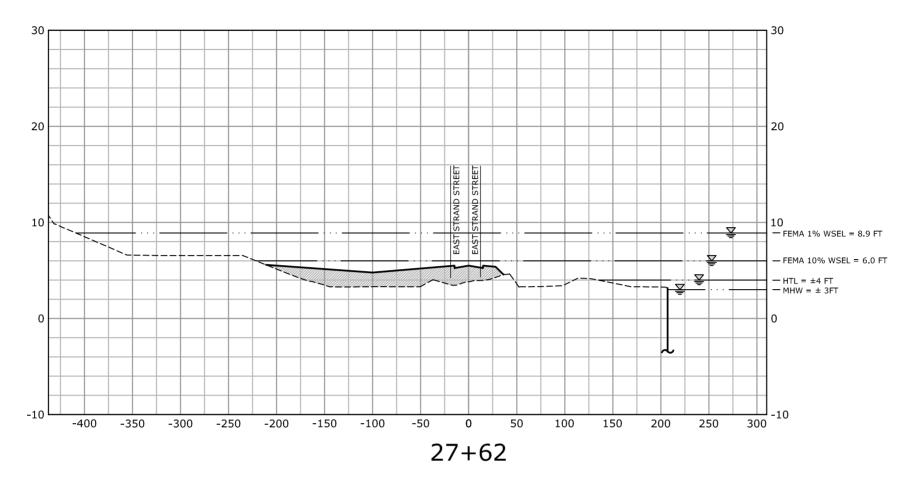
EAST STRAND STREET FLOODING ANALYSIS RONDOUT CREEK AND EAST STRAKINGSTON, NEW YORK

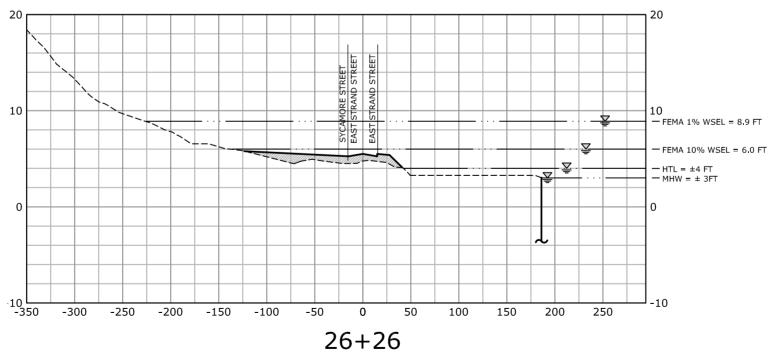
JCM JCM NEB
DESIGNED DRAWN CHECKED

1"=300'

NOV. 2012

4766-02





EAST STRAND STREET - SECTION VIEW (SCALE: 1"=100'H, 1"=10'V)

N. E.

MILONE & MACBROOM®
99 Realty Drive
Cheshire, Connecticut 06410
(203) 271-1773 Fac (203) 272-9733
www.miloneandmachroon.com

REVISIONS

EAST STRAND - PLAN AND PROFILE VIEW
EAST STRAND STREET
FLOODING ANALYSIS

EAST STRAND - PLAN A
EAST STRAND STREET
FLOODING ANALYSIS
RONDOUT CREEK AND EAST STRA
KINGSTON, NEW YORK

AS NOTED

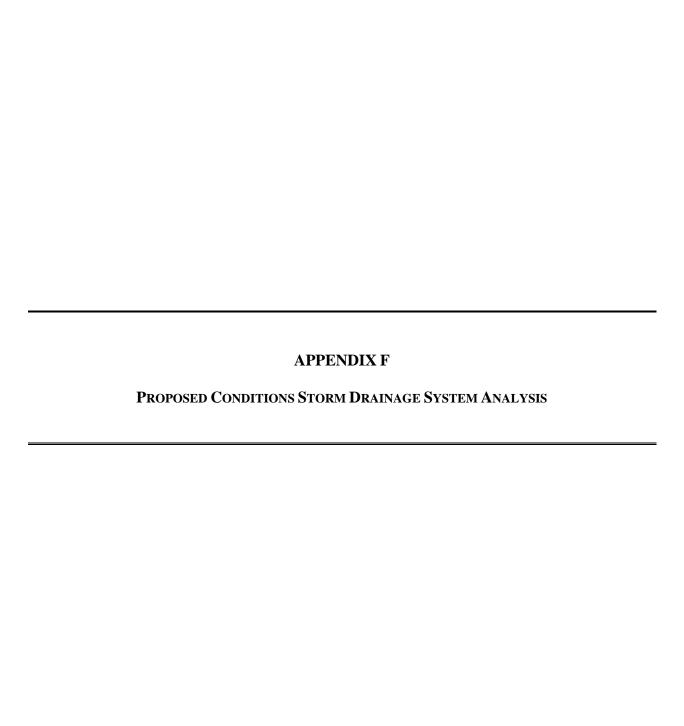
SCALE

MARCH 2013

DATE

4766-02

PROJECT NO.



Project No.: 4766-02 Kingston, New York

East Strand Street Flooding Analysis Kingston, NY

Designed By: JCM Checked By: NEB

Proposed Drainage System Improvements - Pipe Capacity Analysis - 10-Year Precipitation

| Pipe ID | U/S Node | D/S Node | U/S Time of Conc. | Pipe Dia. | Pipe Material | Manning's Coef. "n" | Pipe Length | Invert U/S | Invert D/S | Pipe Slope | Cover U/S | Cover D/S | Average Velocity | Full Capacity | System Flow |
|---------|--------------------|--------------------|-------------------|--------------|------------------|------------------------|----------------|---------------|---------------|---------------|-----------|--------------|---------------------|------------------|----------------|
| | | | (min.) | (in) | | | (ft) | (ft) | (ft) | (ft/ft) | (ft) | (ft) | (ft/s) | (ft³/s) | (ft³/s) |
| *P-1-1 | CB-1-5 | OF-1 | 42.1 | 30 | Concrete | 0.013 | 88 | 1.2 | 1 | 0.002 | 0.65 | 0.5 | 3.04 | 14.94 | 19.55 |
| *P-1-2 | *CB-1-4 | CB-1-5 | 42.0 | 24 | Concrete | 0.013 | 29 | 1.4 | 1.2 | 0.007 | 0.95 | 1.15 | 4.5 | 14.13 | 18.79 |
| *P-1-3 | *CB-1-2 | *CB-1-4 | 41.5 | 24 | Concrete | 0.013 | 79 | 1.6 | 1.4 | 0.003 | 1.1 | 0.95 | 2.43 | 7.62 | 11.38 |
| *P-1-4 | *CB1-1 | *CB-1-2 | 40.0 | 18 | | 0.013 | 219 | 2 | 1.6 | 0.002 | 1.4 | 1.6 | 2.46 | 4.34 | 4.49 |
| *P-1-5 | *CB-1-3 | *CB-1-2 | 10.0 | 12 | PVC | 0.01 | 30 | 2.4 | 1.6 | 0.027 | 1.3 | 2.1 | 2.28 | 1.79 | 7.56 |
| *P-2-1 | *CB-2-3 | OF-2 | 27.2 | 24 | Concrete | 0.013 | 137 | 1.1 | 0.1 | 0.007 | 1.26 | 2.1 | 2.93 | 9.21 | 19.33 |
| *P-2-2 | *MH-2-1 | *CB-2-3 | 27.1 | 18 | Concrete | 0.013 | 42 | 1.41 | 1.1 | 0.007 | 2.49 | 1.76 | 4.78 | 8.45 | 9.02 |
| *P-2-3 | *CB-2-1 | *MH-2-1 | 27.0 | 15 | Concrete | 0.013 | 22 | 1.75 | 1.41 | 0.015 | 2 | 2.74 | 6.42 | 7.88 | 8.03 |
| *P-2-4 | CB-2-2 | *MH-2-1 | 10.0 | 12 | PVC | 0.01 | 19 | 2.46 | 1.41 | 0.055 | 1.54 | 2.99 | 1.21 | 0.95 | 10.89 |
| *P-3-1 | *MH-3-2 | *OF-3 | 28.8 | 12 | | 0.013 | 224 | 0.5 | 0 | 0.002 | 4 | 4 | 3.02 | 2.37 | 1.68 |
| *P-4-1 | *MH-4-1 | *OF-4 | 23.6 | 18 | | 0.013 | 267 | 5.96 | 3 | 0.011 | 3.54 | 1.5 | 6.52 | 6.56 | 11.06 |
| *P-4-2 | *MH-4-2 | *MH-4-1 | 23.1 | 18 | | 0.013 | 184 | 7.5 | 5.96 | 0.008 | 4.81 | 3.54 | 5.87 | 6.64 | 9.61 |
| *P-4-3 | *CB-4-2 (MH-4-2) | *MH-4-2 | 5.0 | 12 | | 0.013 | 28 | 7.72 | 7.5 | 0.008 | 4.9 | 5.31 | 0 | 0 | 3.16 |
| *P-4-4 | *MH-4-3 | *MH-4-2 | 22.0 | 12 | | 0.013 | 24 | 10.62 | 7.5 | 0.13 | 2.8 | 5.31 | 13.18 | 2.88 | 12.85 |
| *P-4-6 | CB-4-3 | *MH-4-2 | 23.0 | 12 | | 0.013 | 28 | 9.97 | 7.5 | 0.088 | 2.55 | 5.31 | 12.39 | 3.83 | 10.58 |
| *P-10-1 | *CB-10-1 | *OF-10 | 39.2 | 36 | | 0.013 | 180 | 1.6 | 1 | 0.003 | 0.7 | 1 | 6.2 | 36.35 | 38.51 |
| *P-10-2 | *CB-10-2 | *CB-10-1 | 38.9 | 36 | | 0.013 | 107 | 2 | 1.6 | 0.004 | 0.8 | 0.7 | 6.42 | 32.87 | 40.78 |
| *P-10-3 | *CB-10-4 (CB-3-4) | *CB-10-3 (CB-3-7) | 10.0 | 15 | | 0.013 | 118 | 2.8 | 2.5 | 0.003 | 0.81 | 2.05 | 1.53 | 1.87 | 3.26 |
| *P-10-4 | *CB-10-5 (CB-3-11) | *CB-10-2 | 38.6 | 30 | | 0.013 | 118 | 2.8 | 2 | 0.007 | 1.2 | 1.3 | 6.48 | 31.78 | 33.77 |
| *P-10-4 | *CB-10-3 (CB-3-7) | *CB-10-2 | 11.3 | 18 | | 0.013 | 26 | 2.5 | 2 | 0.019 | 1.8 | 2.3 | 1.39 | 2.46 | 14.57 |
| *P-10-5 | *CB-11-3 (CB-3-8) | *CB-10-5 (CB-3-11) | 38.5 | 30 | | 0.013 | 51 | 3.45 | 2.8 | 0.013 | 0.75 | 1.2 | 10.13 | 31.35 | 46.3 |
| *P-10-6 | *CB-11-2 (CB-3-10) | *CB-11-3 (CB-3-8) | 31.0 | 15 | | 0.013 | 29 | 3.85 | 3.45 | 0.014 | 1.94 | 2 | 6.01 | 7.38 | 7.59 |
| *P-10-7 | *CB-10-5 (CB-3-6) | *CB-10-1 | 25.1 | 15 | | 0.013 | 29 | 2.1 | 1.6 | 0.017 | 1.95 | 2.45 | 3.85 | 4.72 | 8.48 |
| *P-10-8 | *CB-10-6 (CB-3-5) | *CB-10-5 (CB-3-6) | 25.0 | 15 | | 0.013 | 29 | 2.3 | 2.1 | 0.007 | 1.75 | 1.95 | 3.4 | 4.18 | 5.36 |
| P-2-5 | MH-2-2 | *MH-2-1 | 5.0 | 12 | PVC | 0.01 | 83 | 11.35 | 1.41 | 0.12 | 2.75 | 2.99 | 0 | 0 | 16.03 |
| P-3-14 | MH-3-1 | *MH-3-2 | 28.3 | 12 | Concrete | 0.013 | 96 | 0.68 | 0.5 | 0.002 | 4.4 | 4 | 3.04 | 2.39 | 1.54 |
| P-3-16 | CB-3-1 | MH-3-1 | 28.0 | 12 | PVC | 0.01 | 149 | 6 | 0.68 | 0.036 | 3.5 | 4.4 | 9.5 | 2.4 | 8.75 |
| P-3-6 | MH-3-4 | *CB-11-3 (CB-3-8) | 38.2 | 18 | Concrete | 0.013 | 267 | 4.27 | 3.45 | 0.003 | 4.5 | 1.75 | 14.02 | 24.78 | 5.82 |
| P-3-7 | CB-3-9 | MH-3-4 | 38.0 | 18 | Concrete | 0.013 | 233 | 27 | 4.27 | 0.098 | 3.5 | 4.5 | 20.14 | 23.3 | 32.81 |
| P-3-8 | CB-3-2 | MH-3-4 | 23.0 | 12 | Concrete | 0.013 | 100 | 6.6 | 6.37 | 0.002 | 1.4 | 2.9 | 2.65 | 2.08 | 1.71 |
| P-3-9 | CB-3-3 | CB-3-2 | 10.0 | 18 | Concrete | 0.013 | 24 | 6.7 | 6.6 | 0.004 | 0.8 | 0.9 | 0.5 | 0.89 | 6.78 |
| P-4-5 | CB-4-1 | *MH-4-3 | 22.0 | 12 | Concrete | 0.013 | 10 | 11.31 | 10.92 | 0.039 | 1.9 | 2.5 | 8.51 | 2.88 | 7.04 |
| P-4-7 | CB-4-4 | CB-4-3 | 23.0 | 12 | Concrete | 0.013 | 12 | 10.75 | 9.97 | 0.065 | 2.1 | 2.55 | 11.04 | 3.8 | 9.08 |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |



Project No.: 4766-02 Kingston, New York

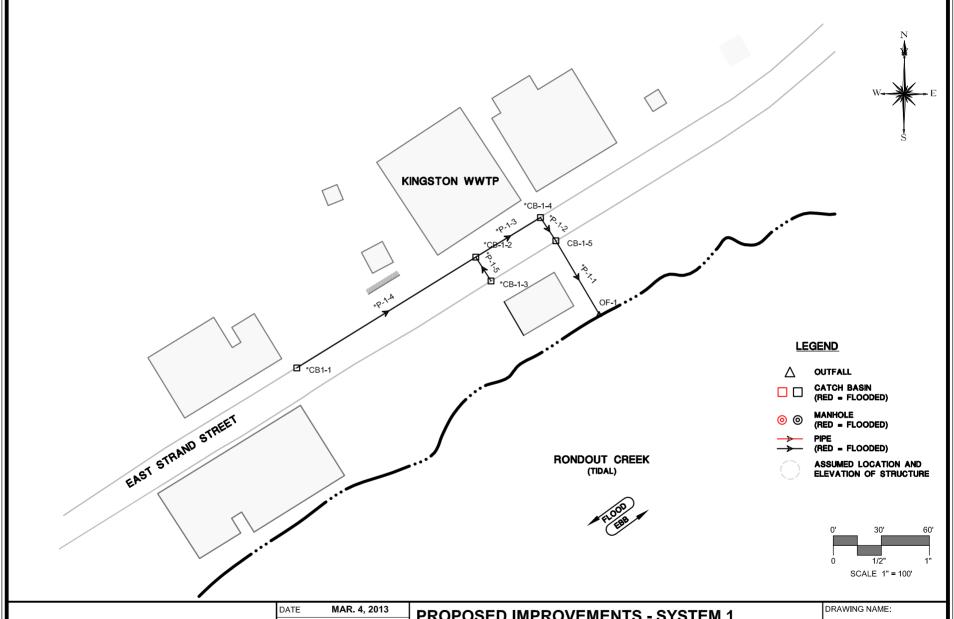
East Strand Street Flooding Analysis Kingston, NY

Designed By: JCM Checked By: NEB

Proposed Drainage System Improvements - Hydraulic Grade Line Analysis - 10-Year Precipitation

| Pipe ID | U/S Node | D/S Node | Pipe Dia. | Flow | Slope | Friction Slope | Headloss | Froude Number | Velocity U/S | Energy Grade Line U/S | Energy Grade Line D/S | Hydraulic Grade Line U/S | Hydraulic Grade Line D/S | Ground Elevation U/S | Ground Elevation D/S |
|---------|--------------------|--------------------|--------------|---------|---------|-------------------|----------|------------------|-----------------|-----------------------------|-----------------------------|--------------------------------|--------------------------------|----------------------------|----------------------------|
| | | | (in) | (ft³/s) | (ft/ft) | (ft/ft) | (ft) | l . | (ft/s) | (ft) | (ft) | (ft) | (ft) | (ft) | (ft) |
| *P-1-1 | CB-1-5 | OF-1 | 30 | 14.94 | 0.002 | 0.001 | 0.12 | 0.646 | 3.04 | 4.26 | 4.14 | 4.12 | 4 | 4.35 | 4 |
| *P-1-2 | *CB-1-4 | CB-1-5 | 24 | 14.13 | 0.007 | 0.004 | 0.11 | 1.091 | 4.5 | 4.55 | 4.43 | 4.23 | 4.12 | 4.35 | 4.35 |
| *P-1-3 | *CB-1-2 | *CB-1-4 | 24 | 7.62 | 0.003 | 0.001 | 0.09 | 0.684 | 2.43 | 4.51 | 4.42 | 4.41 | 4.32 | 4.7 | 4.35 |
| *P-1-4 | *CB1-1 | *CB-1-2 | 18 | 4.34 | 0.002 | 0.002 | 0.37 | 0.46 | 2.46 | 4.9 | 4.53 | 4.81 | 4.43 | 4.9 | 4.7 |
| *P-1-5 | *CB-1-3 | *CB-1-2 | 12 | 1.79 | 0.027 | 0.001 | 0.04 | 2.832 | 2.28 | 4.56 | 4.51 | 4.47 | 4.43 | 4.7 | 4.7 |
| *P-2-1 | *CB-2-3 | OF-2 | 24 | 9.21 | 0.007 | 0.002 | 0.23 | 1.23 | 2.93 | 4.36 | 4.13 | 4.23 | 4 | 4.36 | 4.2 |
| *P-2-2 | *MH-2-1 | *CB-2-3 | 18 | 8.45 | 0.007 | 0.006 | 0.27 | 0.955 | 4.78 | 4.86 | 4.59 | 4.51 | 4.24 | 5.4 | 4.36 |
| *P-2-3 | *CB-2-1 | *MH-2-1 | 15 | 7.88 | 0.015 | 0.015 | 0.33 | 1.275 | 6.42 | 5.64 | 5.31 | 5 | 4.67 | 5 | 5.4 |
| *P-2-4 | CB-2-2 | *MH-2-1 | 12 | 0.95 | 0.055 | 0 | 0.01 | 4.02 | 1.21 | 4.61 | 4.6 | 4.59 | 4.58 | 5 | 5.4 |
| *P-3-1 | *MH-3-2 | *OF-3 | 12 | 2.37 | 0.002 | 0.004 | 0.99 | 0.532 | 3.02 | 5.13 | 4.14 | 4.99 | 4 | 5.5 | 5 |
| *P-4-1 | *MH-4-1 | *OF-4 | 18 | 6.56 | 0.011 | 0.011 | 2.95 | 1.401 | 6.52 | 7.39 | 4.43 | 6.95 | 4 | 11 | 6 |
| *P-4-2 | *MH-4-2 | *MH-4-1 | 18 | 6.64 | 0.008 | 0.008 | 1.62 | 1.176 | 5.87 | 8.94 | 7.41 | 8.5 | 6.88 | 13.81 | 11 |
| *P-4-3 | *CB-4-2 (MH-4-2) | *MH-4-2 | 12 | 0 | 0.008 | 0 | 0 | (N/A) | 0 | 8.5 | 8.5 | 8.5 | 8.5 | 13.62 | 13.81 |
| *P-4-4 | *MH-4-3 | *MH-4-2 | 12 | 2.88 | 0.13 | 0.124 | 2.85 | 4.804 | 13.18 | 11.69 | 8.71 | 11.35 | 8.5 | 14.42 | 13.81 |
| *P-4-6 | CB-4-3 | *MH-4-2 | 12 | 3.83 | 0.088 | 0.086 | 2.3 | 3.904 | 12.39 | 11.27 | 8.87 | 10.8 | 8.5 | 13.52 | 13.81 |
| *P-10-1 | *CB-10-1 | *OF-10 | 36 | 36.35 | 0.003 | 0.003 | 0.49 | 0.715 | 6.2 | 4.91 | 4.41 | 4.49 | 4 | 5.3 | 5 |
| *P-10-2 | *CB-10-2 | *CB-10-1 | 36 | 32.87 | 0.004 | 0.002 | 0.2 | 0.836 | 6.42 | 5.1 | 4.87 | 4.73 | 4.53 | 5.8 | 5.3 |
| *P-10-3 | *CB-10-4 (CB-3-4) | *CB-10-3 (CB-3-7) | 15 | 1.87 | 0.003 | 0.001 | 0.1 | 0.654 | 1.53 | 4.89 | 4.79 | 4.85 | 4.75 | 4.86 | 5.8 |
| *P-10-4 | *CB-10-5 (CB-3-11) | *CB-10-2 | 30 | 31.78 | 0.007 | 0.006 | 0.71 | 0.991 | 6.48 | 6.09 | 5.38 | 5.44 | 4.73 | 6.5 | 5.8 |
| *P-10-4 | *CB-10-3 (CB-3-7) | *CB-10-2 | 18 | 2.46 | 0.019 | 0.001 | 0.01 | 1.978 | 1.39 | 4.77 | 4.76 | 4.74 | 4.73 | 5.8 | 5.8 |
| *P-10-5 | *CB-11-3 (CB-3-8) | *CB-10-5 (CB-3-11) | 30 | 31.35 | 0.013 | 0.006 | 0.24 | 1.588 | 10.13 | 6.44 | 6.15 | 5.75 | 5.51 | 6.7 | 6.5 |
| *P-10-6 | *CB-11-2 (CB-3-10) | *CB-11-3 (CB-3-8) | 15 | 7.38 | 0.014 | 0.013 | 0.38 | 1.218 | 6.01 | 6.72 | 6.34 | 6.15 | 5.78 | 7.04 | 6.7 |
| *P-10-7 | *CB-10-5 (CB-3-6) | *CB-10-1 | 15 | 4.72 | 0.017 | 0.005 | 0.15 | 1.713 | 3.85 | 4.89 | 4.73 | 4.66 | 4.5 | 5.3 | 5.3 |
| *P-10-8 | , | *CB-10-5 (CB-3-6) | 15 | 4.18 | 0.007 | 0.004 | 0.12 | 0.996 | 3.4 | 5.25 | 5.13 | 5.07 | 4.95 | 5.3 | 5.3 |
| P-2-5 | MH-2-2 | *MH-2-1 | 12 | 0 | 0.12 | 0.081 | 6.76 | (N/A) | 0 | 11.35 | 4.59 | 11.35 | 4.59 | 15.1 | 5.4 |
| P-3-14 | MH-3-1 | *MH-3-2 | 12 | 2.39 | 0.002 | 0.004 | 0.43 | 0.536 | 3.04 | 5.64 | 5.21 | 5.5 | 5.07 | 6.08 | 5.5 |
| P-3-16 | CB-3-1 | MH-3-1 | 12 | 2.4 | 0.036 | 0.008 | 1.11 | 3.264 | 9.5 | 6.96 | 5.7 | 6.66 | 5.56 | 10.5 | 6.08 |
| P-3-6 | MH-3-4 | *CB-11-3 (CB-3-8) | 18 | 24.78 | 0.003 | 0.056 | 14.86 | 2.018 | 14.02 | 23.71 | 8.85 | 20.66 | 5.8 | 10.27 | 6.7 |
| P-3-7 | CB-3-9 | MH-3-4 | 18 | 23.3 | 0.098 | 0.078 | 18.21 | 3.981 | 20.14 | 31.2 | 12.97 | 28.48 | 10.27 | 32 | 10.27 |
| P-3-8 | CB-3-2 | MH-3-4 | 12 | 2.08 | 0.002 | 0.003 | 0.34 | 0.467 | 2.65 | 10.72 | 10.38 | 10.61 | 10.27 | 9 | 10.27 |
| P-3-9 | CB-3-3 | CB-3-2 | 18 | 0.89 | 0.004 | 0 | 0 | 0.918 | 0.5 | 9.01 | 9 | 9 | 9 | 9 | 9 |
| P-4-5 | CB-4-1 | *MH-4-3 | 12 | 2.88 | 0.039 | 0.018 | 0.6 | 2.569 | 8.51 | 12.38 | 12.21 | 12.04 | 11.44 | 14.21 | 14.42 |
| P-4-7 | CB-4-4 | CB-4-3 | 12 | 3.8 | 0.065 | 0.048 | 0.47 | 3.311 | 11.04 | 12.04 | 11.47 | 11.58 | 11.1 | 13.85 | 13.52 |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |







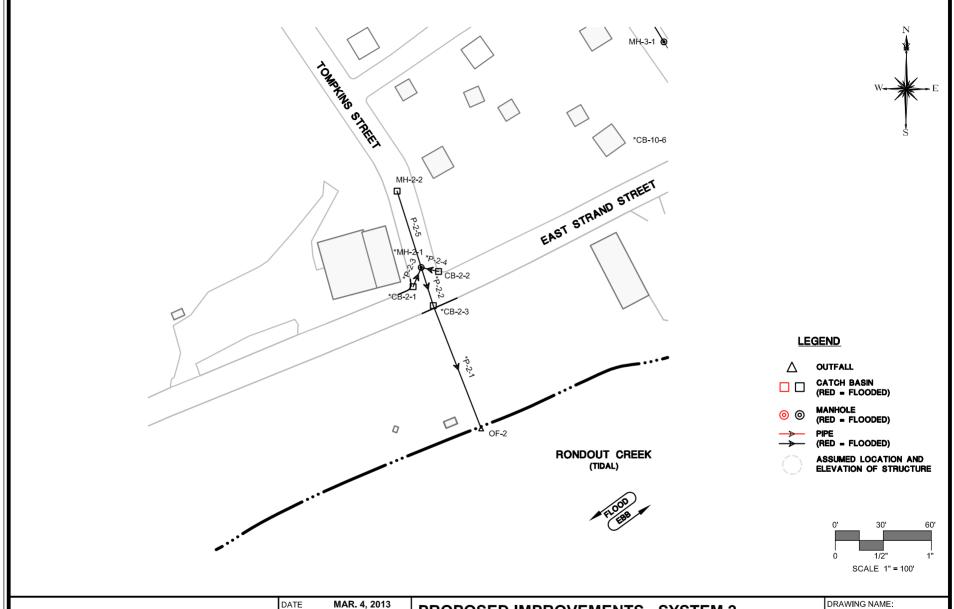
Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733 www.miloneandmacbroom.com

| DATE | MAR. 4, 2013 |
|-----------|--------------|
| SCALE | 1"=100' |
| PROJ. NO. | 4766-02 |
| DESIGNED | JCM |
| DRAWN | JCM |
| CHECKED | NEB |

PROPOSED IMPROVEMENTS - SYSTEM 1

EAST STRAND AREA FLOODING ANALYSIS RONDOUT CREEK WATERFRONT

EAST STRAND STREET KINGSTON, NEW YORK





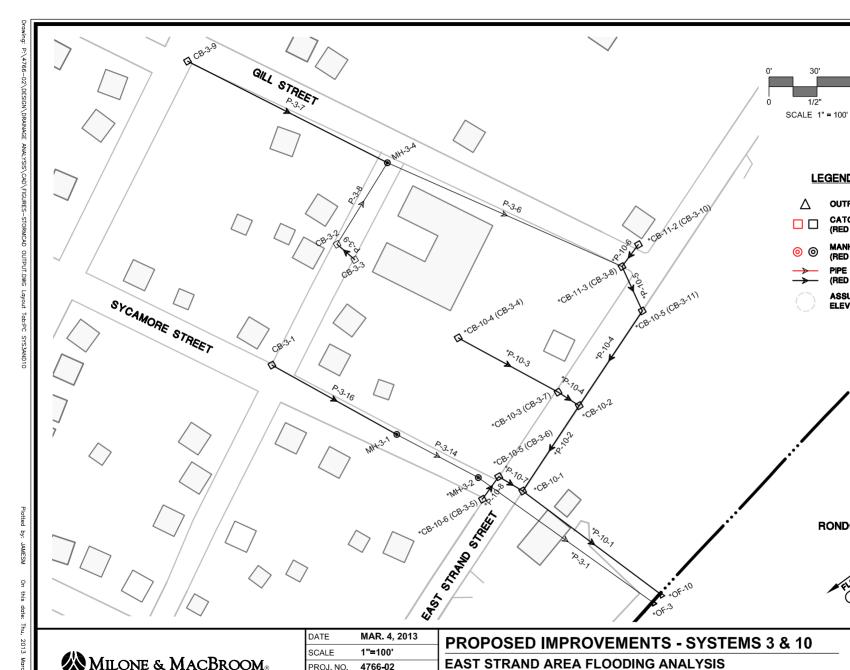
99 Realty Drive Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733 www.miloneandmacbroom.com

| DATE | MAR. 4, 2013 |
|-----------|--------------|
| SCALE | 1"=100' |
| PROJ. NO. | 4766-02 |
| DESIGNED | JCM |
| DRAWN | JCM |
| CHECKED | NEB |

PROPOSED IMPROVEMENTS - SYSTEM 2

EAST STRAND AREA FLOODING ANALYSIS RONDOUT CREEK WATERFRONT

EAST STRAND STREET KINGSTON, NEW YORK



DRAWING NAME:

RONDOUT CREEK (TIDAL)

60'

LEGEND

OUTFALL

CATCH BASIN (RED = FLOODED)

MANHOLE (RED = FLOODED)

(RED = FLOODED)

ASSUMED LOCATION AND ELEVATION OF STRUCTURE

3 OF 4

MILONE & MACBROOM®

Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733 www.miloneandmacbroom.com

| MAR. 4, 2013 |
|--------------|
| 1"=100' |
| 4766-02 |
| |
| JCM |
| JCM |
| |

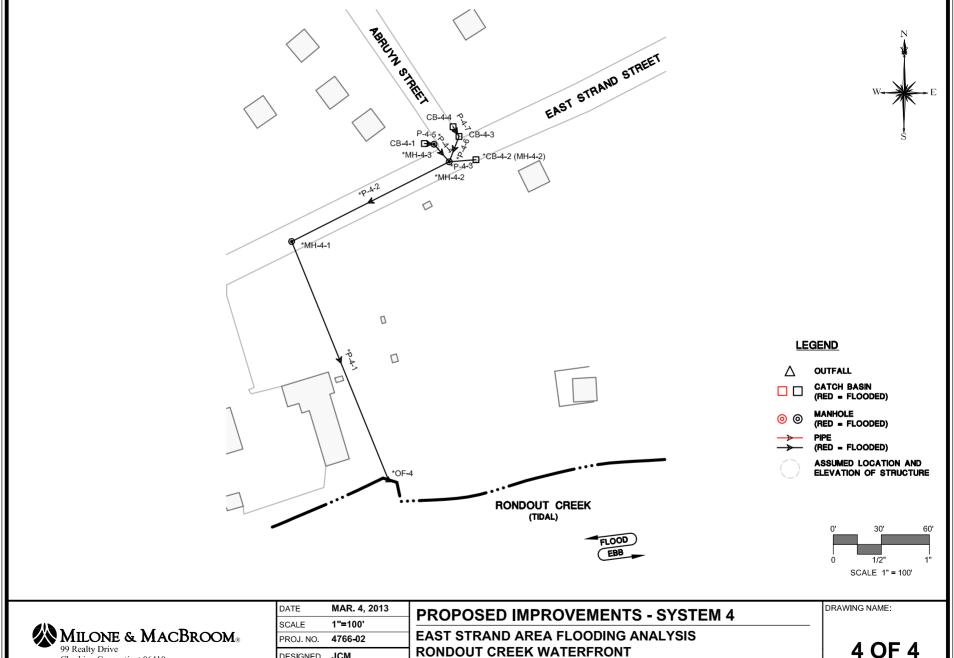
RONDOUT CREEK WATERFRONT

EAST STRAND STREET KINGSTON, NEW YORK



Cheshire, Connecticut 06410 (203) 271-1773 Fax (203) 272-9733

www.miloneandmacbroom.com



PROJ. NO.

DESIGNED

CHECKED

DRAWN

4766-02

JCM

JCM

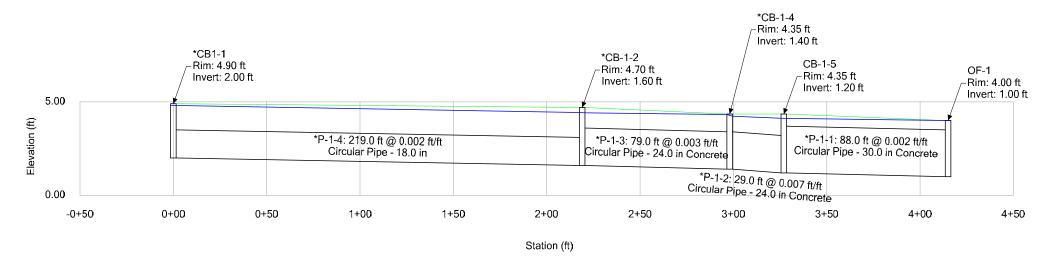
EAST STRAND AREA FLOODING ANALYSIS

RONDOUT CREEK WATERFRONT

EAST STRAND STREET

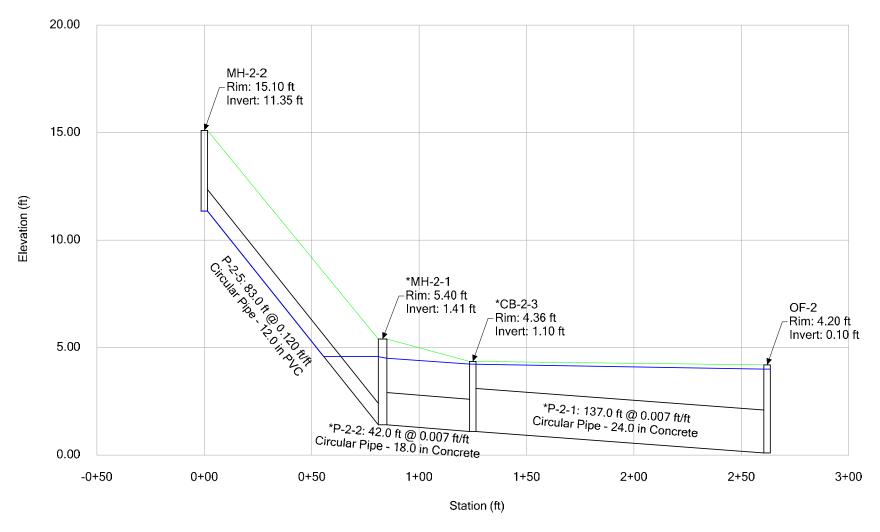
KINGSTON, NEW YORK

Profile Report Engineering Profile - System 1 - 10-Year Storm (Proposed - Concept Design.stc)

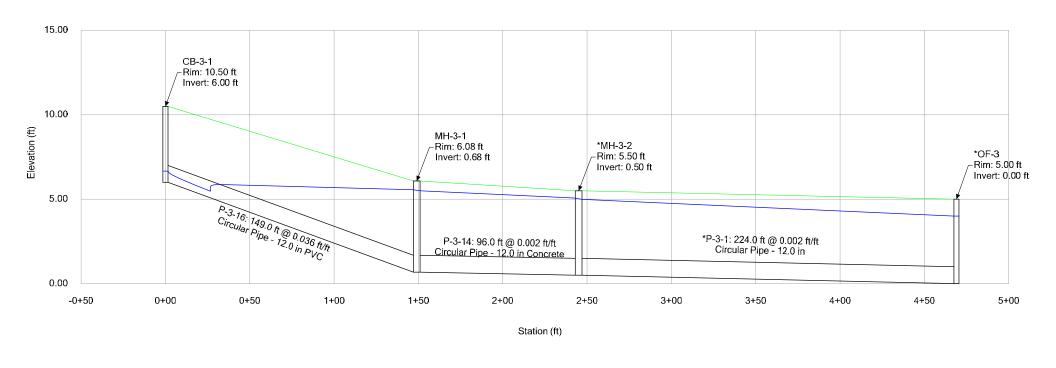


Profile Report

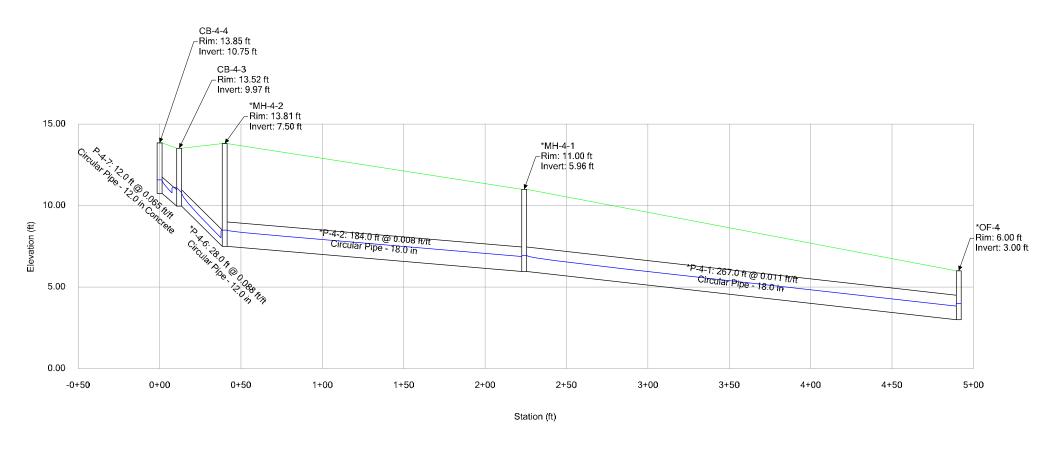
Engineering Profile - System 2 - 10-Year Storm (Proposed - Concept Design.stc)



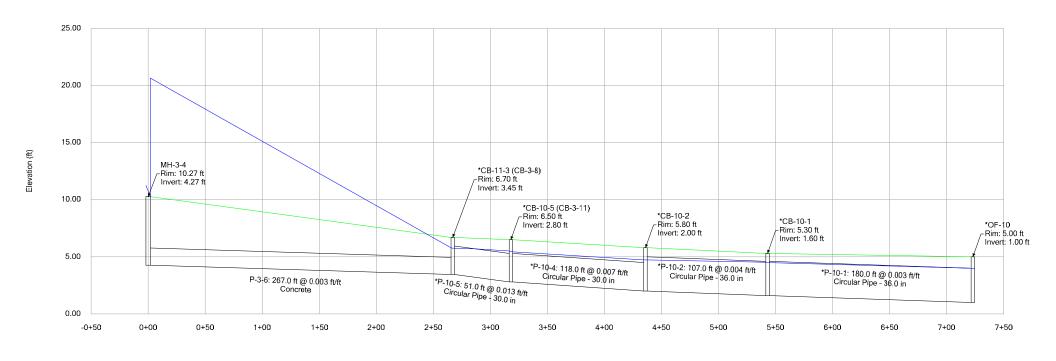
Profile Report Engineering Profile - System 3 - 10-Year Storm (Proposed - Concept Design.stc)



Profile Report Engineering Profile - System 4 - 10-Year Storm (Proposed - Concept Design.stc)



Profile Report Engineering Profile - System 10 - 10-Year Storm (Proposed - Concept Design.stc)



Station (ft)