DRAFT

EAST STRAND STREET FLOODING AND STORMWATER MANAGEMENT ANALYSIS

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

April 5, 2013

MMI #4766-02-1

Photo Source: City of Kingston, NY

Prepared for:

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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
GPS ....Global Positioning System
HEC-RAS ....Hydrologic Engineering Center – River Analysis System
HEC-SSP ....Hydrologic Engineering Center – Statistical Software Package
HTL...............................High Tide Line
LWRP ....Local Waterfront Revitalization Program
MHHW ....Mean Higher High Water
MHW ....Mean High Water
MLLW ....Mean Lower Low Water
MLW.............................Mean Low Water
MMI ....Milone & MacBroom, Inc.
MSL ....Mean Sea Level
NAVD88.......................North American Vertical Datum of 1988
NFIP..............................National Flood Insurance Program
NGVD29.......................National Geodetic Vertical Datum of 1929
NOAA ....National Oceanic and Atmospheric Administration
NRCC............................Northeast Regional Climate Center
NYDEC.........................New York Department of Environmental Conservation
NYCDEP ....New York City Department of Environmental Protection
NYDOS.........................New York Department of State
SLR ....Sea Level Rise
USACE ....United States Army Corps of Engineers
USGS ....United States Geological Survey
WWTP ....Wastewater Treatment Plant

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 100-year 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 long-term 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

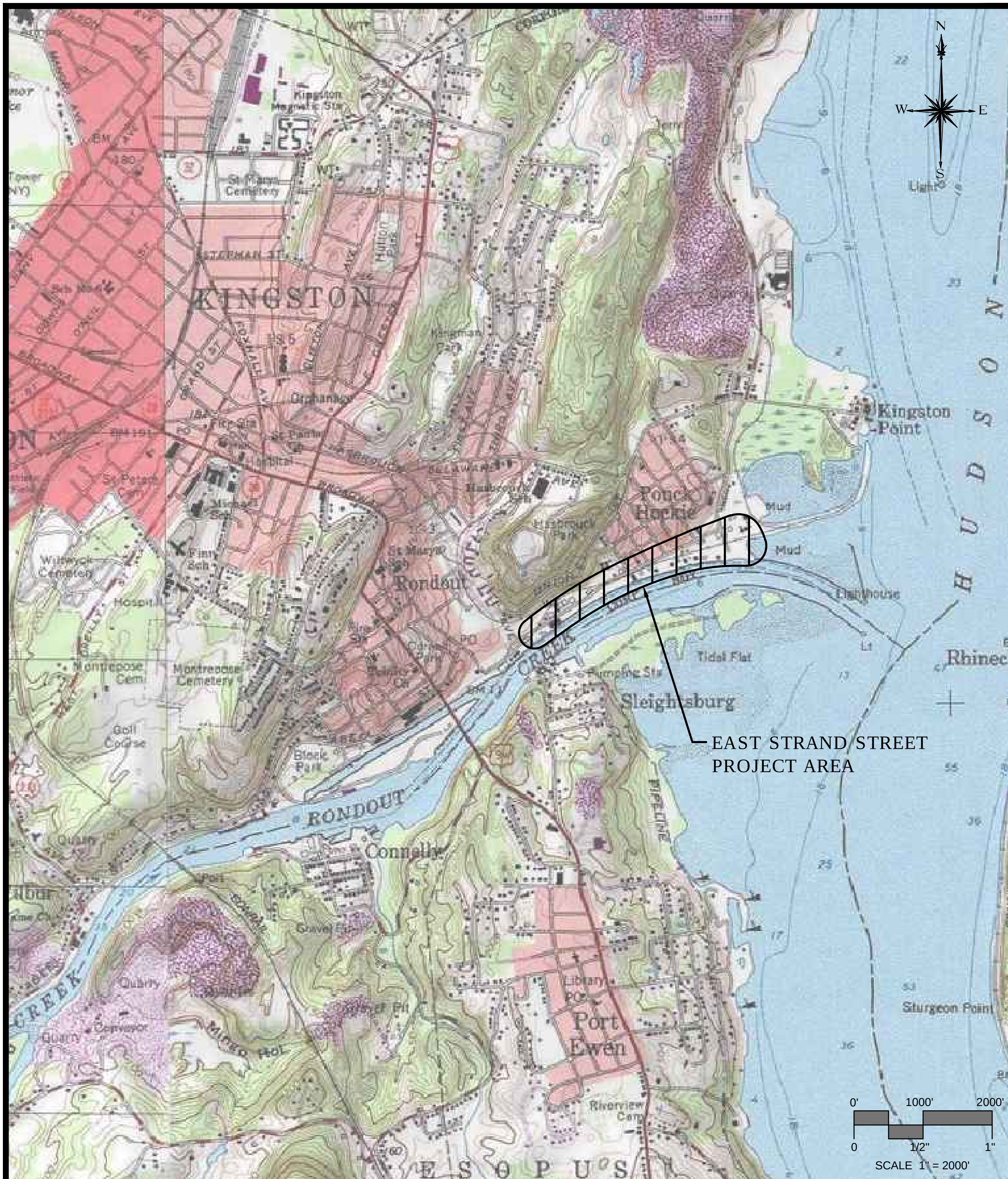
The City of Kingston, New York has retained Milone & MacBroom, Inc. (MMI) to assess the redevelopment potential of the East Strand Street waterfront along the Rondout Creek, near the confluence with the Hudson River. Redevelopment of urban waterfront shorelines represents a growing trend in American 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.



USGS PROJECT LOCATION MAP

EAST STRAND STREET FLOODING ANALYSIS

RONDOUT CREEK AND EAST STRAND STREET
KINGSTON, NEW YORK

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DATE	MARCH 2013
SCALE	1"=2000'
PROJ. NO.	4766-02

DESIGNED	DRAWN	CHECKED
JCM	DRM	NEB

DRAWING NAME:

FIG. 1

Drawing: P:\4766-02\DESIGN\CAD\Z-USGS.DWG Layout Tab:8.5X11V

Plotted by: DANME On this date: Tue, 2013 March 19 - 1:45pm

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 DATA COLLECTION

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 Mapping and Utility Information

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

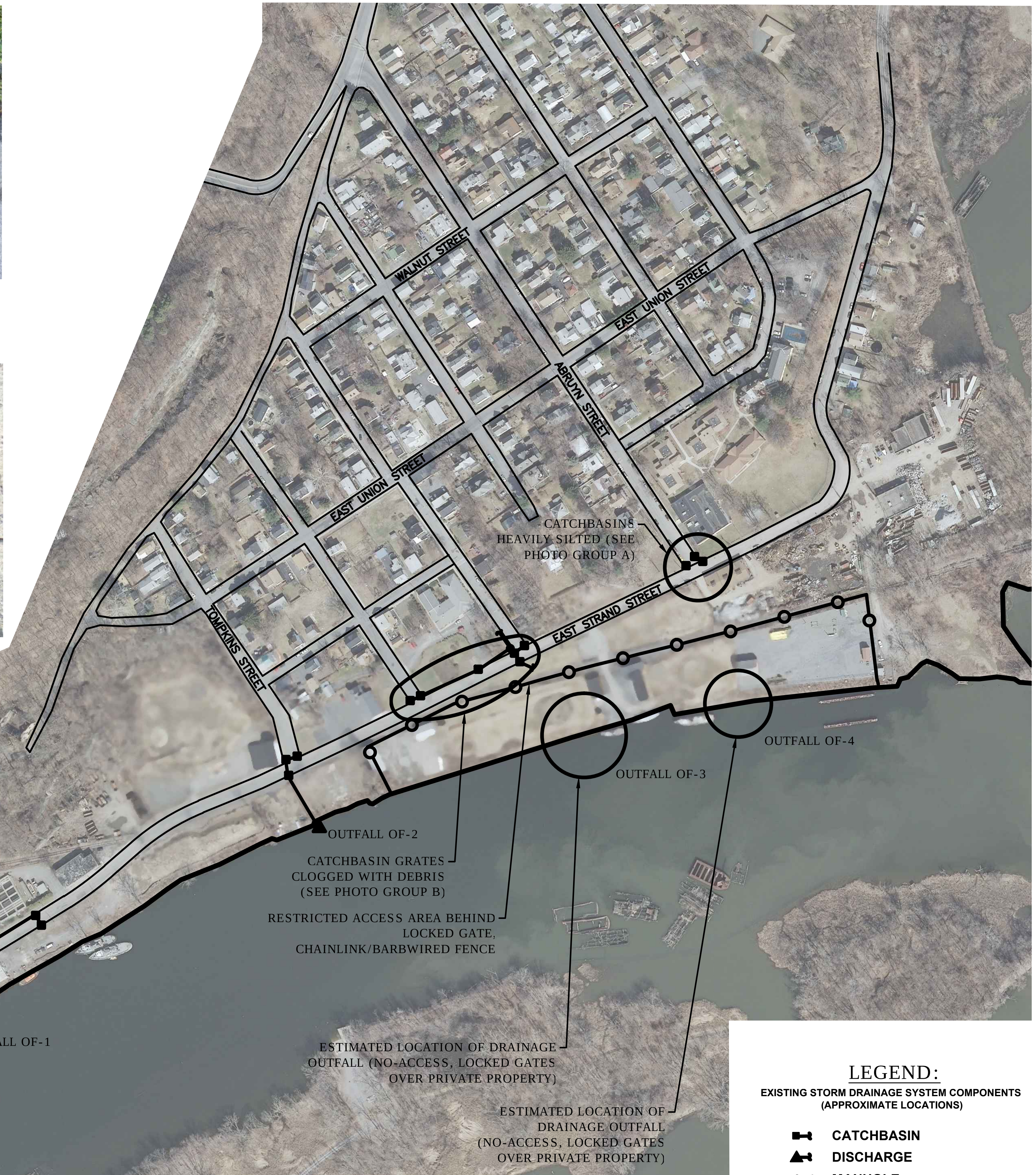
Field survey of key drainage system components identified during the field assessment was performed by MMI in September 2012. This included survey of the elevation of the top of frame and invert elevations, ground and bulkhead elevations, and additional information needed for the drainage analysis. Supplemental 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.

PHOTO GROUP A

PHOTO GROUP B



LEGEND:

EXISTING STORM DRAINAGE SYSTEM COMPONENTS (APPROXIMATE LOCATIONS)

- CATCHBASIN
- DISCHARGE
- MANHOLE

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REVISIONS

EXISTING DRAINAGE MAINTENANCE REQUIREMENTS

EAST STRAND STREET
FLOODING ANALYSIS

RONDOUT CREEK AND EAST STRAND STREET
KINGSTON, NEW YORK

DESIGNED	DRAWN	CHECKED
JCM	DRM	NEB

SCALE: 1"=300'

DATE: MARCH 2013

PROJECT NO.: 4766-02

SHEET NO.: FIG.2

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 Tidal Predictions

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 Elevations[1]

Location		10% (feet)	2% (feet)	1% (feet)	0.2% (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 USGS Hydraulic Gage Data

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.

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.

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 (ft NAVD)	50-Yr (ft NAVD)	100-Yr (ft NAVD)	500-Yr (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

No.	River	Location	Installed	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

Irene 8/28/11

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

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:
1. 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 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	2.9[1]
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.
2. 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	Building Type	First Floor Elevation (feet, NAVD88)
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	6.1[1]
56.43-6-5	Cornell Building	Brick	6.1[1]
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:
1. 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

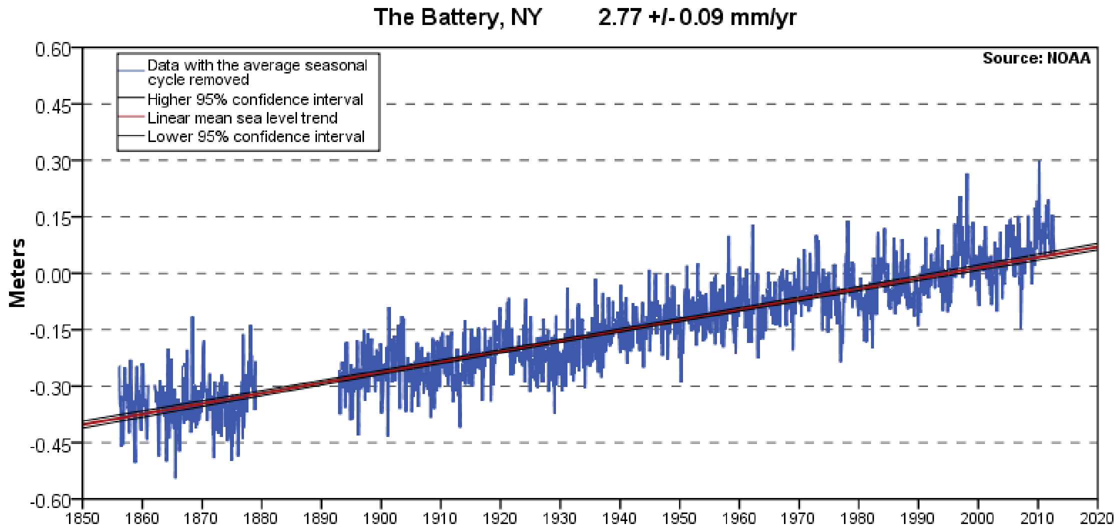
Scientists believe that Mean Sea Level (MSL) has been rising at a variable rate for the past 12,000 years, since the beginning of the current glacial cycle. The rate of SLR has begun to accelerate in recent years according to modern measurements.

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.

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 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). It is sponsored by the city's Conservation Advisory Council and Office of Economic Development and Strategic Partnership and includes representatives from local museums, restaurants, marinas, and the public. The goals of the task force are to understand waterfront flooding, prepare for coastal flooding, and plan for the changing sea levels to help make the East Strand waterfront more flood resilient. The program will help facilities that are at risk of flooding and assess the potential for floods to cause damage at those facilities.

The task force has considered a wide range of potential future SLR scenarios based upon varied forecast methods and analyses. It has chosen 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	2050 Predicted Increase in Sea Level (inches/feet)	2100 Predicted Increase in Sea Level (inches/feet)
Low Prediction	17 / 1.4	36 / 3.0
High Prediction	26 / 2.2	68 / 5.7

The above values are significantly greater than 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

Location	Distance Upstream of Hudson River (miles)	Watershed Size (square miles)	10% (cfs)	2% (cfs)	1% (cfs)	0.2% (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:
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

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 USGS *StreamStats*

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.

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

Location	Watershed Size (square miles)	50% (cfs)	10% (cfs)	2% (cfs)	1% (cfs)	0.2% (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

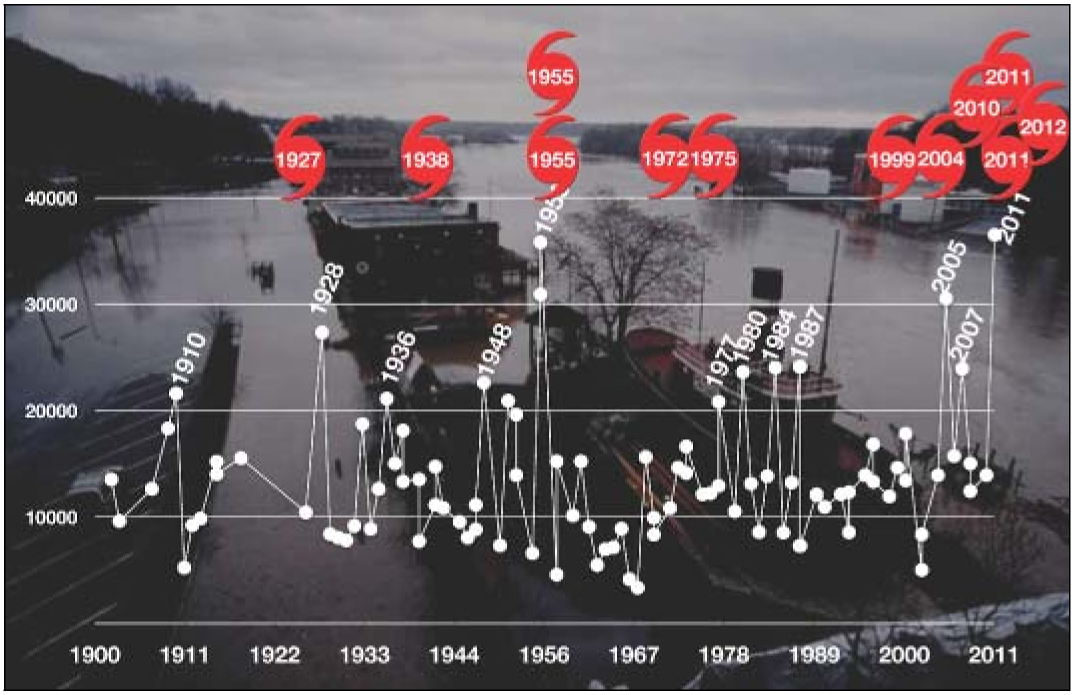
Location	Drainage Area (square miles)	50% (cfs)	10% (cfs)	2% (cfs)	1% (cfs)	0.2% (cfs)
USGS Gage 01367500 (Rosendale, Keator Avenue)	383	12,382	21,935	30,504	34,181	42,860

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.

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.

Drawing: P:\4766-02\DESIGN\DRAINAGE ANALYSIS\CAD\FIGURES - WATERSHEDS.DWG Layout Tab:FIG 6

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EXISTING DRAINAGE SYSTEM DELINEATIONS

EAST STRAND STREET FLOODING ANALYSIS

RONDOUT CREEK AND EAST STRAND STREET
KINGSTON, NEW YORK

DRAWING NAME:

FIG. 6

Plotted by: JAMESM On this date: Thu, 2013 April 4 - 5:17pm

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:
1. Outfall size and elevation are estimated; capacity is approximate.

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 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:
1. 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 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 it should be noted that solutions that effectively eliminate 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 other future development will not be economically sustainable.

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.

Table 14 provides a summary of the alternatives explored 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 Drainage Improvements

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

Figure 7: Photograph of Typical Bulkhead Installation

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.

MAPPING NOTES:

UPLAND TOPOGRAPHIC AND CONTOUR INFORMATION IS BASED UPON AERIAL ORTHOPHOTOGRAMMETRY SUPPLIED BY ULSTER COUNTY INFORMATION SERVICES.

ALL VERTICAL INFORMATION IS REFERENCED TO THE NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).

INFORMATION AND LOCATION OF EXISTING UTILITIES PROVIDED BY UTILITY PROVIDERS, AND SHOULD BE CONSIDERED APPROXIMATE AS SHOWN.

INFORMATION ON STORM SEWER SYSTEM SURVEYED BY MILONE & MACBROOM, INC. IN SEPTEMBER, 2012.

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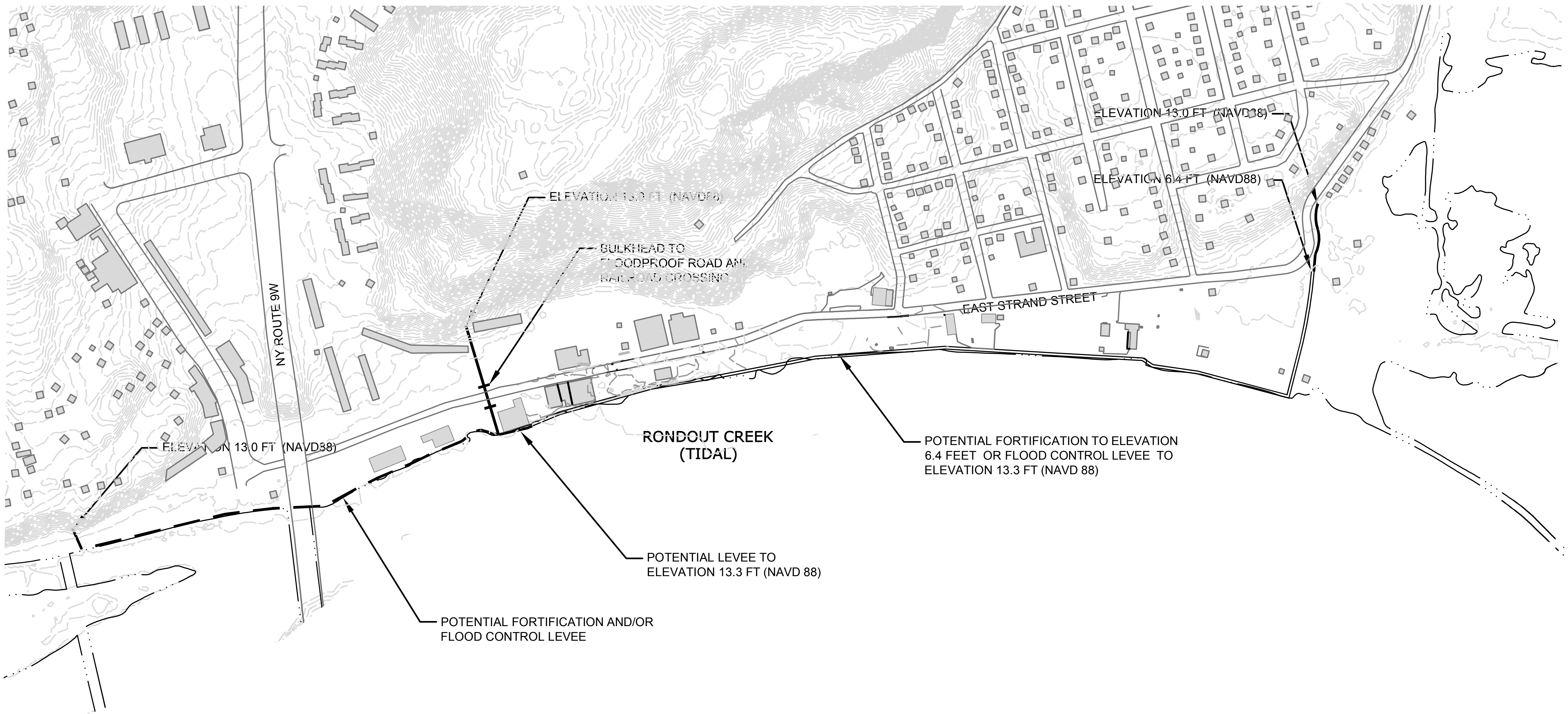

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REVISIONS

SHORELINE MODIFICATION OR FLOOD LEVEE LOCATION

EAST STRAND STREET
FLOODING ANALYSIS

RONDOUT CREEK AND EAST STRAND STREET
KINGSTON, NEW YORK

JCM	JCM	NEB
DESIGNED	DRAWN	CHECKED

SCALE 1"=400'

DATE MARCH 2013

PROJECT NO. 4766-02

SHEET NO. **FIG. 8**

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. More frequent nuisance roadway flooding is caused primarily by rising tides, low roadway elevations, and inadequate drainage systems. Severe flooding (above elevation 6.0 feet NAVD) that occurs less frequently is caused by the storm surge and tidal influences generated in New York Harbor and is transferred upstream to Kingston via the Hudson River.

As SLR continues to worsen the effects and frequency of tidal events, periodic flooding over elevation 6.0 feet NAVD may be unavoidable. These floods may be best prepared for by ensuring that development of the East Strand area is done in a way that can accommodate periodic inundation with minimal damage or through the use of a flood barrier or levee system. Floods that occur much more frequently below elevation 6.0 feet NAVD may be reduced or eliminated altogether through a series of fortification efforts as described below.

The recommended approaches to addressing flooding below elevation 6.0 feet NAVD are:

1. 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.
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.
3. Modify development plans to include the filling of waterfront areas up to elevation 6.0 feet NAVD, ensuring no low points below this elevation occur at the eastern or western ends of the roadway.

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

1. Enact zoning codes to control land use and development of the waterfront area, promoting water-dependent use and public open space creation.
2. Enact 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 retrofitting of existing buildings and infrastructure in the East Strand area of floodprone buildings 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.

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Weather Underground Historical Weather Station Data. http://www.wunderground.com

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