Flood Risk Reduction Program
Review of Prior Investigations
Action Plan

February 2013

Denville Township, Morris County, New Jersey
HMM 315057

Hatch Mott MacDonald

Table of Contents

Letter of Transmittal

Executive Summary

Detailed Report

Section 1
Introduction and Scope

Section 2
Document Review and Comments

Section 3
Evaluation of Potential Projects

Section 4
Recommended Action Plan

Appendix
Reference Maps

Portions of the Township of Denville have experienced significant losses due to flooding events over a period of several decades. Several investigations proposing various flood mitigation measures have been undertaken to address this problem. The Township authorized Hatch Mott MacDonald (HMM) to undertake a review of prior investigations of flooding conditions in the Township and propose recommended actions to reduce flood risk.

The following documents were reviewed under this investigation:

1. NJDEP flood delineation maps – Feb 1986 (regulatory with respect to work near streams)
2. FEMA flood mapping (1985) and Flood Insurance Study (October 17, 1984)
3. *Morris County, New Jersey, Multi-Jurisdictional Hazard Mitigation Plan*, prepared by Morris County Office of Emergency Management, Third Final Draft – July 23, 2010.
4. Map entitled: *Severe Repetitive & Repetitive Properties, CRS Program, Township of Denville, Morris County, New Jersey*, prepared by William Denzler and Associates, Community Planning Consultants, dated April 2012
5. *Master Drainage Plan*, Elson T. Killam Associates, revised December 1980 (includes a list of prioritized projects.)
6. *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report*, USACE, dated June 2008 (documents include Main Report and 2 additional volumes with Appendices.)

The flood maps provided by the NJDEP and by FEMA serve as useful tools for flood mitigation planning. FEMA is expected to release updated digital mapping for all of Morris County in mid-2013. The digital mapping will be available through the internet and can be viewed on Google Earth ™ through use of an application freely available from FEMA. A link to the FEMA web page with instructions and applications is included in Section 2.3 of this Report. Copies of the current NJDEP maps are included in the Appendix of this Report.

Item 4 above, the map of repetitive loss properties, serves as a useful planning tool for prioritizing property acquisitions in the Township. Denville has acquired several of these properties. The remaining repetitive loss properties should be evaluated for appropriate action, whether flood proofing, elevation or acquisition. For acquired properties, a comprehensive plan should be established for preservation and appropriate use of the floodplain area.

Projects described in Items 3, 5 and 6 above have been reviewed for current applicability, in some cases with suggested modification. Descriptions and comments are provided in Section 3 and a list of recommended actions is included in Section 4. Further concepts for evaluation for Denville Center are presented in Section 4.5 of this Report.

Item 3, the *Morris County, New Jersey, Multi-Jurisdictional Hazard Mitigation Plan,* includes a list of 14 mitigation actions in Section 9 of that document, which are listed in Section 3.4 of this Report. Most of the actions are relevant to flood mitigation. Four actions pertain to acquisition or elevation of repetitive loss properties and should be updated. Comments and follow up recommendations are included in this Report for the pertinent flood mitigation actions.

Item 5, the 1980 *Master Drainage Plan* for Denville, focused on several local flooding problems. The projects addressing local storm sewer issues ("Small Scale Projects") are not evaluated in this Report, but should be considered as road improvements are undertaken in the respective areas. The "Large Scale Projects" are reviewed in detail, with some recommended modifications.

The document review reveals that Item 6, the USACE 2008 Report, does not contain any final recommended project as the investigations and evaluations were halted in 2006 due to direction of the non-Federal sponsor, the NJDEP, based upon local objections to the plan selected by the USACE. That plan would have provided only a 2-year level of protection to the Township of Denville.

No single project which will provide a great degree of flood risk reduction has been identified in any of the prior investigations. The slope of the Rockaway River from the Town of Boonton to and through Denville is relatively flat with significant adjacent floodplain areas. The channel can carry only part of the peak flow of major floods. The channel capacity has been estimated to be only one-fourth of the total 100-year flood peak flow.

The bridges between Boonton Township and through Denville do not introduce highly significant hydraulic losses as water passes through or over the structures. Replacement of the bridges is reviewed in this Report and is found to have only minor benefits. However, improvement of the hydraulic capacity at the Pocono Road Bridge and the Diamond Springs Road Bridge should be considered if these bridges are replaced for other reasons in the future. Similarly, modification of the Powerville Dam has minor benefits to Denville, but should be considered if major modifications of the dam are required for other reasons. These concepts should be included in long range planning for the Rockaway River, in coordination with Morris County and the owners of the Powerville Dam.

Flood mitigation for the Township of Denville should include a combination of measures to provide local flood protection where economically justified and practical. These measures will include:

Non-structural measures –

- Acquisition, elevation, or flood proofing of repetitive loss structures
- Improved flood warning and public education for preparedness
- Updating of the Flood Hazard Area Ordinance

Structural measures –

- Channel and bridge maintenance – debris removal, sediment removal from critical areas
- Local mitigation measures – culverts, pump stations, tide gates on storm sewer outlets, levees

Long range planning –

- Master plan for improved hydraulic capacity at key bridges when replaced in the future
- Plan for hydraulic improvements at Powerville Dam when modified for other reasons

- Planning for regional stormwater detention, in cooperation with Morris County

Section 4 of this Report presents several projects for consideration with suggested action items for Project advancement. Projects and other actions listed for further consideration include:

1. Peck Meadow Brook – modified plan
2. Hinchman & Corey Road Area – modified plan
3. Woodland Avenue Area – berm near Den Brook
4. Sunset Bay Area – modified plan
5. NJ Foundation for Blind – berm near Rockaway River
6. First Avenue and Bloomfield Avenue area – modified plan
7. Bridges – long range planning
8. Powerville Dam – long range planning
9. Stormwater detention – long range planning and address prior objections
10. Continuation of acquisition, elevation or flood proofing of repetitive loss properties
11. Evaluate and update the flood warning system and public education for preparedness
12. Request Morris County to update the *Multi-Jurisdictional Hazard Plan*, particularly with respect to actions along the Upper Rockaway River
13. Review and update the Denville Flood Hazard Area Ordinance
14. Continue with stream and bridge maintenance – remove obstructions to flow and select areas of sediment accumulation. Periodically survey the river to locate debris points and sediment areas.
15. Promote regional stormwater management for the watershed. Enlist the cooperation of other municipalities in the Upper rockaway River Basin.
16. Communicate with the USACE regarding potential assistance with long range planning for bridges, Powerville Dam modifications and regional detention.

Following review of the above, the Township should establish priorities for further review and development of the suggested action items. The first area selected by the Township for further review of flood mitigation concepts is the Denville Center area, as described in Section 4.5 of this Report.

1.1 Introduction

The Township of Denville has authorized Hatch Mott MacDonald (HMM) to undertake a review of prior investigations of flooding conditions in the Township and propose recommended actions to reduce flood risk, particularly in the hard-hit central portion of the Township near the Rockaway River and Den Brook. While it is generally not possible or economically practical to eliminate all risk of flooding, certain actions can be implemented to reduce the frequency of flooding and associated damages and losses.

1.2 Background

The Township of Denville has endured numerous severe flooding events, the latest and perhaps most severe occurring during Hurricane Irene on August 27 – 28, 2012. The primary source of this flooding is the Rockaway River and its tributaries.

The Rockaway River receives flow from Beaver Brook just before entering Denville Township from Rockaway Borough to the west. The River then flows to the east under I-80 (where the reported tributary drainage area is 87.1 square miles) and through the central portion of the Township where it receives flow from Den Brook just prior to turning to the northeast. The River continues flowing to the northeast through Denville Township and into Boonton Township, where it eventually turns to the east and flows through the Town of Boonton and into the Boonton Reservoir. Downstream of the reservoir, the Rockaway River flows into the Passaic River at the Morris County boundary near the Pine Brook area, east of the split between Routes I-80 and I-280.

Township residents and businesses have suffered extensive losses and damage from several severe flooding events in recent decades. The central business district has been hard hit and numerous residential properties have been affected.

The Federal Emergency Management Agency (FEMA) has published maps (effective date April 17, 1985) delineating the flood plain along the Rockaway River and major tributaries, and the State of New Jersey has adopted Flood Delineation maps showing the floodway and flood hazard

areas. Both of these mapping documents are intended for flood plain management purposes, with the FEMA maps also intended for flood insurance purposes, and the NJDEP maps intended for flood plain regulatory purposes. These maps provide valuable information for planning and for those seeking to purchase or modify property or structures in the flood plain areas. The NJDEP maps also serve as a basis for regulatory enforcement of the New Jersey Flood Hazard Area Act Regulations, which prohibit certain activities and regulate others in the delineated areas. These mapping documents serve to guide efforts to avoid an increase in flood risk and damage. While neither serves directly to implement flood mitigation to reduce the current flood risk to existing development, both sets of maps can help in the identification of critical flood prone areas and guide decisions regarding mitigation actions.

Efforts to develop flood mitigation measures were undertaken by the Township through engaging Elson T. Killam Associates, Inc. in 1979 to investigate flooding conditions and develop a Master Drainage Plan. The Killam report, final version dated December 1980, presented maps showing drainage area boundaries, the 100-year flood plain, the locations of analyzed drainage facilities and locations of recommended improvements. Identified flooding problems are documented and the report evaluated 9 “large scale” projects and 8 “small scale” projects, with priorities recommended based upon the number of residents and businesses affected, essential services affected, estimated cost, and the flooding frequency of the project area. The report also contained recommendations for dealing with existing flooding that would not be soon corrected and for avoiding further problems as undeveloped land is utilized.

The Killam 1980 report addressed both local flooding problems beyond the impact of the Rockaway River and mitigation in some areas in the river flood plain. The report did not contain recommendations for improvements to the Rockaway River channel. However, Killam did undertake hydraulic analyses, including detailed modeling of existing conditions and flood mitigation alternatives, of the Rockaway River for the US Army Corps of Engineers (USACE) in the 1980s. The considered alternatives included channel improvements, floodwalls and levees along the river. The hydraulic models and results were provided to the USACE for evaluation in its study.

The USACE proceeded further with evaluation of flood mitigation alternatives for the Rockaway River, as described in a report dated June 2008 and titled: *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report*. As stated in that Report, the prior studies of the Rockaway River did not result in any comprehensive plan that was in the "Federal interest." "Plans were either rejected due to high cost, lack of economic justification, major environmental impacts, or lack of public acceptability." (Op. cit., p. i). The Report did identify a potentially feasible solution to flooding problems (the Plan), consisting of the following principal elements:

1. A 3-mile long diversion culvert from Dover to Rockaway Borough (discharging to Lake Estling.)
2. Channel improvements consisting of approximately 6.7 miles of bioengineered channel reconstruction (25-foot channel cut within the river banks, from Rockaway Borough through Denville and ending in Boonton Town below the Powerville Dam.)
3. Removal and replacement of Powerville Dam with a crest gate structure.

Although the Plan was estimated to have a benefit/cost ratio of 1.3, further development and environmental assessment of the Plan was halted in 2006 due to significant public concern regarding key aspects of the Plan and the subsequent withdrawal of non-Federal partnership support by the NJDEP. The Report states (p. vi) that the primary public concerns included:

- Project cost,
- Level of protection provided by the project, and
- Potential adverse environmental impacts to Lake Estling.

1.3 Scope of Current Investigations

1.3.1 Purpose

The purpose of the current investigations described in this Report is to review the prior studies, primarily the Killam 1980 *Master Drainage Plan* and the USACE 2008 *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation*

Report, evaluate the applicability and potential modifications of prior recommendations to suite current conditions, and develop a recommended plan of action for Denville Township to address flood mitigation. While protection from a 100-year flood event would be highly desirable, it may not be economically achievable. Therefore, lesser levels of protection, such as from a 25 or 50-year flood event, will also be considered.

1.3.2 Document Review

In association with the current investigations, the following documents were reviewed:

1. NJDEP flood delineation maps – Feb 1986 (regulatory with respect to work near streams)
2. FEMA flood mapping (1985) and Flood Insurance Study (October 17, 1984)
3. *Morris County, New Jersey, Multi-Jurisdictional Hazard Mitigation Plan*, prepared by Morris County Office of Emergency Management, Third Final Draft – July 23, 2010.
4. Map entitled: *Severe Repetitive & Repetitive Properties, CRS Program, Township of Denville, Morris County, New Jersey*, prepared by William Denzler and Associates, Community Planning Consultants, dated April 2012
5. *Master Drainage Plan*, Elson T. Killam Associates, revised December 1980 (includes a list of prioritized projects.)
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1.3.3 Evaluation of Potential Projects

Following review of the documents listed above, a list of potential projects for further consideration is presented.

1.3.4 Recommended Action Plan

The recommended actions are summarized in a suggested Action Plan for further consideration and implementation as means and opportunity provide.

1.3.5 Exhibits

The appendix to this Report includes several maps illustrating the limits of flooding for a range of storms, including the 10, 25, 50 and 100-year floods, based upon flood levels in the Rockaway

River and in Den Brook. Other maps illustrate the estimated peak flood depths based upon the 100-year flood conditions. These exhibits provide a visual representation of the extent of overland flooding and the number and types of structures and roads affected. They also serve to indicate where it may be practical to construct barriers (e.g. levees or flood walls) to limit overflow from the streams.

1.3.6 Order of This Report

The following sections of this Report include:

- Pertinent information from the document review,
- Evaluation of potential projects with respect to providing mitigation for significant flooding, and
- A suggested Action Plan for further consideration by the Township.

Following review of the Report and suggested Action Plan by Township officials, HMM would be pleased to meet with Township representatives to review the findings and recommendations and refine the Action Plan as appropriate.

2.1 Key Documents

Comments regarding review of key documents pertaining to flooding in Denville are presented in the following order below:

1. NJDEP flood delineation maps -1986 (regulatory with respect to work near streams)
2. FEMA flood mapping and Flood Insurance Study (dated 1985 and 1984, respectively)
3. *Morris County, New Jersey, Multi-Jurisdictional Hazard Mitigation Plan,* prepared by Morris County Office of Emergency Management, Third Final Draft – July 23, 2010.
4. Map entitled: *Severe Repetitive & Repetitive Properties, CRS Program, Township of Denville, Morris County, New Jersey,* prepared by William Denzler and Associates, Community Planning Consultants, dated April 2012
5. *Master Drainage Plan,* Elson T. Killam Associates, revised December 1980 (includes a list of prioritized projects.)
6. *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report,* USACE, dated June 2008 (documents include Main Report and 2 additional volumes with Appendices.)

2.2 NJDEP Flood Delineation Maps

The New Jersey Department of Environmental Protection (NJDEP) adopts maps illustrating the floodway and flood hazard areas (100-year flood limits and NJ Flood Hazard Area limits) for waterways of interest, generally the larger waterways in a region. The floodway is essentially the corridor required to convey the peak flow of the 100-year flood. Areas outside of the floodway also may be inundated by the 100-year peak flow, but are not considered essential for conveyance of the 100-year peak. The NJ Flood Hazard Area is the area inundated by a flood peak 25% greater than the 100-year peak. No recurrence frequency is assigned to the NJ Flood Hazard Area flood.

Where these NJDEP maps have been adopted, they become the regulatory maps for purposes of administering and enforcing the New Jersey Flood Hazard Area Control Act rules (N.J.A.C. 7:13) and related permits issued by the NJDEP. The floodway and 100-year flood limits delineations on the NJDEP maps generally agree with the delineations presented on the FEMA flood maps (discussed below), particularly where the two sets of maps were prepared in a coordinated program. However there may be differences between the NJDEP and FEMA maps, particularly when one agency updates its maps and the other agency has not done so. Also, the

FEMA maps are issued based upon civil boundaries (municipality and county) while the NJDEP maps are issued based upon a waterway alignment and cross civil boundaries.

The NJDEP flood delineation maps pertaining to the Township are dated February 1986 and include maps prepared for the Rockaway River, for Den Brook and for a tributary identified as Tributary #1. These maps illustrate the Floodway Limit and the Flood Hazard Area Limit. A set of stream profiles accompany the maps and illustrate the water surface elevations for the 100-year flood and for the NJ Flood Hazard Area flow. The delineations for the Township are illustrated on topographic maps with 2-foot contour intervals, at a scale of 1-inch equals 200 feet. Pertinent information (100-year floodplain and floodway) presented on these maps is incorporated on maps accompanying this Report.

2.3 FEMA Flood Mapping and Flood Insurance Study

The Township of Denville is one of the 500 municipalities in the State of New Jersey which participate in the National Flood Program under the guidance of the Federal Emergency Management Agency (FEMA). Initial flood hazard boundary maps (FHBM) and flood insurance rate maps (FIRM) were prepared for the Township in June 1971. The current effective maps are dated April 17, 1985, and consist of a Map Index and five printed panels. The panels for the Township are each at a scale of 1 inch equals 400 feet and show the delineated boundaries for the 500-year and 100-year floods as well as the floodway limits. These maps are intended for flood insurance purposes and for use by the municipality in identifying areas subject to flood hazards and in regulating activities in the delineated flood areas under the municipal Land Use Ordinance.

The 1985 maps are associated with a Flood Insurance Study report dated October 17, 1984. The report contains additional information including a set of stream profiles for the water courses studied in detail. The profiles show road and railroad crossings, the stream bed elevation profile, and water surface profiles for the 10, 50, 100 and 500 year floods. Key cross section locations are shown to assist in coordinating the profiles with the maps.

Through coordinated use of the maps and profiles, it is possible to determine the estimated peak water surface elevation for a specific location in the Township. Based upon the water surface elevation derived from the FIS and a known ground elevation based upon local topographic mapping, the depth of flooding associated with the respective storm can be estimated.

Significant developed portions of the Township are subject to flooding. In some areas the 100-year flood depth can exceed 6 feet and several homes and other structures are in the floodway. Maps included in the Appendix of this report illustrate this type of information as pertinent to evaluation of flood mitigation alternatives. The current FEMA maps are available for review in municipal offices.

Since late 2009, FEMA has been in the process of converting all distribution of maps and FIS reports for digital delivery. This process has been completed for many of the New Jersey municipalities in the program, but is still in progress for some communities in Morris County, the last being the revision of the Pequannock study. Under the current FEMA practice, the digital maps for the entire county will be released at one time, with an anticipated availability in mid-2013 (according to information from the NJDEP). No changes are expected for Denville Township other than conversion of elevations to the NAVD 88 datum. However, the Township will need to modify its ordinance to reference the new maps.

Once converted, the digital mapping is conveniently accessible via a commonly available internet browser through the use of Google Earth™ enhanced with an application freely available from the FEMA web site (see box at right). With this tool, the delineated floodway and flood boundaries and other information can be selected for viewing as overlays to an aerial photographic background. The user can select areas of interest for preparing and locally printing a map. This can be a very useful tool for a range of users, from a prospective home-buyer to flood mitigation planners and regulatory officials.

Use the National Flood Hazard Layer Web Map Service (WMS) in Google Earth™

For instructions see:

https://hazards.fema.gov/femaportal/wps/portal/NFHLWMSkmzdownload

2.4 Multi-Jurisdictional Hazard Mitigation Plan

The *Morris County, New Jersey, Multi-Jurisdictional Hazard Mitigation Plan,* prepared by Morris County Office of Emergency Management, Third Final Draft – July 23, 2010, addresses several types of hazards, including flood hazards. Section 6.3.6 "Flood" provides background information on flood events in the area, Section 7 "Risk Assessment" provides information regarding present risks, and Section 9.4 "Flood Mitigation Projects" provides some flood risk reduction concepts for consideration. Selected information from this document pertinent to flood conditions in the Township is presented below. See the referenced document sections for further details and comments regarding methods of deriving the data.

Section 6.3.6 "Flood" provides some historical data regarding flooding in Morris County. Table 6.3.6-1, page 6-30, lists severe flood events in the Passaic River Basin in recent decades including the storms of April 7, 1984; September 16, 1999; April 2, 2005; April 15, 2007. In addition, the county experienced the worst storm of record in many areas on August 27-28, 2012 during Hurricane Irene. Figure 6.3.6-3 "USGS Rain Gage Totals for Northern New Jersey After the August 11-14, 2000 Flood Event" (Source: USGS) indicates that, while the central portion of the Rockaway River Watershed experienced a total of about 4 inches of rainfall, the upper reaches of the watershed near Jefferson experienced 8 to 16 inches of rainfall during the 2000 storm. On page 6-35, Table 6.3.6-3 "Summary of Flood Peaks for Select USGS Gage Stations in Morris County During the August 11-14, 2000 Flood" (Source: USGS) provides the following information for two gages on the Rockaway River (note – gage numbers corrected):

Table 2.4-1 Summary of Flood Peaks for Select Rockaway River Gage Stations During the August 11-14, 2000 Flood

Gage #	Station Name	Drainage Area (sq. mi.)	Peak Discharge (CFS)	Peak Gage Height (Feet)	Date of Peak Discharge	Recurrence Interval (Years)
01379700	Rockaway River at Berkshire Valley, NJ (Roxbury Twp.)	24.4	2,500	10.86	8/13/2000	40
01380500	Rockaway River above reservoir at Boonton, NJ	116	2,750	5.04	8/13/2000	3

The above data shows similar peak flows at gage stations upstream and downstream of Denville Township during the August 2000 flood, even though the drainage areas are substantially different (24.4 sq. mi. versus 116 sq. mi.). It should be remembered that the rainfall was not evenly distributed over the watershed. The greatest amount of rainfall (8 to 16 inches) was in the headwaters, with significantly less rainfall (about 4 inches) in the central area of the watershed. Therefore, the bulk of the flow traveled down through the river valley, but apparently with little change in the peak as it moved through, picking up additional drainage area and going through a number of lakes and large flood plains. This data is very pertinent to understanding the hydrologic characteristics of the Rockaway River, and timing of these peaks should be considered along with data from other significant storms before drawing any conclusions.

Gage 01379700 for the Rockaway River at Berkshire Valley, NJ was located at a bridge on Berkshire Valley Road. It was discontinued in 1996 (except for a few miscellaneous measurements) and was replaced in August 2010 with Gage 01379699 located on the downstream side of the NJ Route 15 Bridge, a short distance upstream of the prior gage site.

Comparison of the August 28, 2011, Hurricane Irene peak flows for this new gage and for the gage located upstream of the Reservoir at Boonton, NJ, reveals that the peak flows were 1,840 cfs and 8,210 cfs, respectively. Unlike the August 2000 storm, where the rainfall was heavily concentrated in the headwaters, the August 2011 storm was spread over the entire watershed. Thus the Rockaway River gathered much additional flow as the flood peak proceeded down the river. The August 2011 pattern, rather than that of the August 2000 storm, is expected to be characteristic of conditions with most severe storms – namely that peak flows will increase in a downstream direction if the rainfall is spread relatively uniformly over most of the watershed.

Links to the USGS web sites for each of these three gaging stations are presented below. From these links, other dates of interest can be selected. Also, real-time flood stage and flow data can be obtained during a storm event, providing information for emergency management purposes.

Table 2.4-2 Links to USGS Stream Gage Web Pages of Interest
USGS 01379700 - Rockaway River at Berkshire Valley NJ http://nwis.waterdata.usgs.gov/nwis/peak?site_no=01379700&agency_cd=USGS&format=gif
USGS 01379699 - Rockaway River at NJ Rt 15 at Berkshire Valley NJ http://nwis.waterdata.usgs.gov/nwis/peak/?site_no=01379699&agency_cd=USGS Historical – August 27 to September 10, 2011: http://nwis.waterdata.usgs.gov/nwis/uv?cb_00065=on&cb_00060=on&format=gif_default&period=&begin_date=2011-08-27&end_date=2011-09-10&site_no=01379699
USGS 01380500 - Rockaway River above Reservoir at Boonton http://nwis.waterdata.usgs.gov/nwis/peak/?site_no=01380500&agency_cd=USGS Historical – August 25 to September 11, 2011: http://nwis.waterdata.usgs.gov/nwis/uv?cb_00060=on&cb_00065=on&format=gif_default&period=&begin_date=2011-08-25&end_date=2011-09-11&site_no=01380500

From Section 7.3.1 "Flood Risk in Morris County", page 7-7, Table 7.3.1-4 "Summary of Residential NFIP Repetitive Loss Statistics, Morris County, Ordered by Number of Properties in Each Municipality" (Source: FEMA NFIP Query March, 2008). Also page 7-8, Table 7.3.1-5 similar for non-residential. Denville Township is listed as having the third highest number of residential properties and fourth highest non-residential properties in the category. Information for the Township is as follows:

Table 2.4-3 - NFIP Repetitive Loss Statistics (March 2008)		
Denville Twp.	**Residential**	**Non-Residential**
Properties	61	4
Building	$1,574,193	$87,398
Contents	$518,870	$21,606
Total	$2,093,063	$109,004
# Claims	225	13
Average in Denville	$9,303	$8,385
County Wide		
For comparison: Average	$13,950	$29,005

Review of the above data reveals that while the dollar value of the average NFIP flood loss claim to a property in the Township may be lower than the Morris County average, none-the-less the Township has a high number of properties affected, exceeded by only 2 (for residential) or 3 (for non-residential) other municipalities in the county. The Township also has the third highest value of total residential loss in the county.

It should be noted that this data only reflects NFIP repetitive loss claims. It does not include damages and other losses for which no NFIP claim was submitted, nor does it include losses from Hurricane Irene (August 2011), which affected not only the repetitive loss properties but also caused first-time damages at some properties. It is also noted that Table 7.3.1-6 "Summary of Residential NFIP RL Statistics, Morris County, Ordered by Number of Properties on Each Street" does not include any listings for Denville Township. This table includes data only for streets that include two or more properties with NFIP claims, and therefore includes only 417 of the 493 residential RL properties in the county. For some reason the 61 RL residential properties in Denville Township were not identified as including multiple properties on several streets, at least according to the reported data based upon the March 2008 data query. This information does not agree with the map of RL properties prepared in 2012, as reviewed in Section 2.5 of this Report below. An update of the FEMA data can be requested when there is a need for current information (i.e. to include Hurricane Irene losses). For current flood mitigation planning purposes, the information presented in Section 2.5 below should be considered.

2.5 Repetitive Loss Properties

The map entitled: *Severe Repetitive & Repetitive Properties, CRS Program, Township of Denville, Morris County, New Jersey,* prepared by William Denzler and Associates, Community Planning Consultants, dated April 2012, shows a total of 64 affected properties, including 46 Repetitive Loss Properties and 18 Severe Repetitive Loss Properties. All but 8 of these RL properties are located between route I-80 and the Rockaway River. Most of these RL properties are located along a few streets, with 29 of the RL (including 13 Severe RL) properties on Riverside Drive East, 5 on Snyder Avenue, and 6 on Hinchman Avenue.

Thus 40 of the 64 RL properties are clustered in the area along Riverside Drive East, Snyder Avenue and Hinchman Avenue. While this data varies from the NFIP data from 2008, it is likely more current since it would include the August 2011 Hurricane Irene damages. This current data also is more influential on flood mitigation planning for the Township, including identifying properties for buyout.

As of October 2012, the Township owns or is in the process of acquiring 11 properties along Riverside Drive, in Blocks 50401 and 50408. The intention is to demolish all structures on the sites, grade the sites and establish grass growth. The sites will be maintained as flood plain areas. In the future, as funding becomes available, additional RL sites should be acquired if economically justified. Preferred alternatives would include flood proofing or elevating the structures, as appropriate. Flood depths and other conditions at each structure will influence the selection of the appropriate action. Locations of the remaining identified repetitive loss properties are as follows:

Table 2.5-1 Repetitive Loss Property Locations

Street	**RL Properties**
Riverside Drive *Excludes 11 acquired in 2012	18 *
Snyder Ave	5
Woodland Avenue (includes side on Maple Street)	5
Hinchman Avenue	4
Third Avenue	3
West Main Street and Main Street	3
Maple Street	2
Hewetson Road	2
Second Avenue	2
First Avenue	2
Others (scattered locations, 1 per street)	7
TOTAL	**53**

Each repetitive loss structure should be evaluated for the appropriate action (flood proof, elevation, acquisition or other measures). For the sites recommended for acquisition, a plan

should be prepared prioritizing the remaining buyouts and providing for modification of the sites as appropriate to enhance the flood protection of remaining structures. For example, it may be beneficial to excavate the acquired sites to provide additional flood plain storage volume in compensation for filling some other areas or for constructing floodwalls or earthen berms along the river. An overall plan would facilitate the coordination of these flood mitigation elements.

2.6 Master Drainage Plan

The *Master Drainage Plan*, prepared by Elson T. Killam Associates, revised December 1980, includes a list of prioritized projects. This 1980 plan also included recommendations for an emergency flood warning procedure and a proposed stormwater management ordinance. The 1980 report did not include projects for mitigation from major riverine flooding. The recommended projects were grouped into "Large Scale Projects" (require services of a contractor) and "Small Scale Projects" (potentially could be undertaken with municipal forces) and given weighted priority points based upon the number of residences and businesses that would benefit (40% weight), essential services affected (25% weight), estimated cost (20% weight), and flooding frequency of the area (15% weight). The resulting priority evaluations and 1980 estimated project costs are presented on the tables below. Current costs would be significantly higher than the 1980 estimated project costs.

Table 2.6-1A Priority Evaluation of Large Scale Drainage Projects

Rank	Large Scale Projects	1980 Estimated Cost	Priority Points
L1	Peck Meadow Brook	$1,500,000	220
L2	Hinchman & Corey Road Area	300,000	205
L3	Woodland Avenue Area	215,000	180
L4	Sunset Bay Area	230,000	180
L5	Franklin Road Area	195,000	180
L6	Morris Ave. at Savage Road	140,000	175
L7	Holly Drive Area	80,000	160
L8	Burton Lane Area	110,000	150
L9	NJ Foundation for Blind	340,000	125
	TOTAL LARGE SCALE PROJECTS (1980 est.)	**$3,110,000**	

Further review of the Large Scale Projects will be presented below in Section 3 of this Report. In addition to the Large Scale Projects, a recommendation was made to evaluate the Rockaway River bridges in coordination with the County of Morris due to the effect of the bridges on flooding in Denville center and providing access to St. Clare's Hospital. A listing of key bridges on the Rockaway River and on the Den Brook is provided below in Section 3 of this Report.

Table 2.6-1B Priority Evaluation of Small Scale Drainage Projects

Rank	Small Scale Projects	1980 Estimated Cost	Priority Points
S1	Dayton and Avondale Roads	$45,000	190
S2	Commanche Trail	15,000	180
S3	Indian Lake Area (3 individual projects)	9,000	170
S4	First Avenue Area	40,000	160
S5	Diamond Spring Road	17,000	155
S6	Morris Avenue at Cedar Lake Road	24,000	140
S7	Ford & Kitchell Road Area	23,000	140
S8	West Riverside Drive	8,000	140
	TOTAL SMALL SCALE PROJECTS (1980 est.)	**$181,000**	

The majority of the Small Scale Projects provide for installation of relatively short reaches of storm sewer piping and inlets to provide for improved local stormwater drainage in areas subject to overland flow or ponding of water where the existing pipes are undersized or there are no storm sewers. Since these projects could possibly be undertaken by Township forces, it would be efficient to undertake these improvements in association with other work in the areas, such as when roads are being repaved. No further review is made in this Report of these Small Scale Projects.,

2.7 USACE Upper Rockaway River Report

2.7.1 Prior Reports

The Upper Rockaway River has been the subject of numerous investigations by the US Army Corps of Engineers (USACE) over the past 8 decades. Several of these studies are summarized in the Reconnaissance Study *Upper Rockaway River, New Jersey, Flood Control and Environmental Restoration Study*, authorized in 1997. Pertinent information from some of the prior studies is summarized below.

In 1948, a recommendation was made for consideration of a reservoir and channel modifications. The concept provided for replacement of Lake Denmark and Picatinny Lake Dams on Green Pond Brook by new structures, intended to provide protection to Picatinny Arsenal. Reconstruction of these dams was again recommended in a 1962 updated survey report. A 1973 supplemental report again recommended replacement of these dams along with local protection including levees in the Township of Denville. In the absence of a non-Federal sponsor for the comprehensive basin-wide plan, no further authorization was forthcoming and Congress authorized the Passaic River Basin Study.

A Technical Report for a multipurpose project including hydroelectric facilities, water supply and flood control was issued in March 1980, and a *Flood Control Feasibility Report, Upper Rockaway River, Morris County, New Jersey*, was dated May 1987. The 1987 Draft Report presented an array of alternatives (16 alternative plans) of which several plans were then considered to be potentially economically feasible. However, a Phase I General Design Memorandum issued in 1990 concluded that there were no economically feasible alternatives warranting Federal involvement. Essentially this means that the identified benefits did not outweigh the anticipated costs. The 1990 study indicated that the earlier conclusions were based on preliminary estimates while the more detailed investigations found that there were decreases in estimated damages, significant cost increases and substantial costs to mitigate environmental impacts of each plan.

There were also studies done by others that were considered by the USACE. One of these studies was the *Upper Rockaway River Watershed Study Stormwater Management Plan*, dated 1990, conducted by Morris County. This study concluded that regional, area-wide detention

basins could be effective in reducing flooding. This information was included by the USACE in the Plan Formulation for further study. Five of the six identified detention sites were found to potentially be hydrologically effective in reducing the downstream 100-year peak water surface elevations (by an estimated average of 0.75 to 1.0 foot):

1. Rockaway River – Longwood Valley Basin (found potentially effective)
2. Green Pond Brook – Route 15 Basin (found not effective)
3. Dalrymple Pond – Center Grove Basin (enlargement of existing basin, found potentially effective)
4. Mill Brook – Palmer Road Basin (found hydrologically effective, but with significant environmental issues)
5. Beaver Brook – Meriden Lyonsville Road Basin (found potentially effective)
6. Stony Brook – Upstream Deer Lake Basin (found potentially effective)

Based upon the findings of the Reconnaissance Study authorized in 1997, a recommendation was made to develop a Project Study Plan and proceed to the feasibility phase. By resolution dated May 7, 1997, Congress authorized "the study of the Upper Rockaway River, Morris County, New Jersey for the feasibility of providing flood damage and environmental restoration." A cost sharing agreement was executed in 1999 with the State of New Jersey Department of Environmental Protection as local sponsor. A public scoping process was conducted in 2003 to determine the acceptability of the plans that are economically justified.

2.7.2 The 2008 Report

2.7.2.1 Overview

With consideration of public comments, a draft report was released in 2008 - *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report*, USACE, dated June 2008 (documents include Main Report and 2 additional volumes with Appendices.)

As stated in the 2008 Report, the prior studies of the Rockaway River did not result in any comprehensive plan that was in the "Federal interest." "Plans were either rejected due to high

cost, lack of economic justification, major environmental impacts, or lack of public acceptability." The Report did identify a potentially feasible solution to flooding problems (the Plan), consisting of the following principal elements:

1. A 3-mile long diversion culvert from Dover to Rockaway Borough (discharging to Lake Estling.)
2. Channel improvements consisting of approximately 6.7 miles of bioengineered channel reconstruction (25-foot channel cut within the river banks, from Rockaway Borough through Denville and ending in Boonton Town below the Powerville Dam.)
3. Removal and replacement of Powerville Dam with a crest gate structure.

Although the Plan was estimated to have a benefit/cost ratio of 1.3, further development and environmental assessment of the Plan was halted in 2006 due to significant public concern regarding key aspects of the Plan and the subsequent withdrawal of non-Federal partnership support by the NJDEP. Thus the 2008 draft Report represents results of investigations and analyses up to the time of termination of further work in 2006. The Report states (p. vi) that the primary public concerns included:

- Project cost,
- Level of protection provided by the project, and
- Potential adverse environmental impacts to Lake Estling.

Thus the 2008 Report documents the investigations that were undertaken and "presents a potentially feasible solution to flooding problems in the watershed", but does not contain a recommendation to continue forward due to the local objections. The Report does contain the statement, "The New York District and the NJDEP will work with the local municipalities to help resolve their outstanding concerns in order to re-examine this project in the future."

Information contained in the 2008 Alternative Plan Formulation Report is reviewed below to identify the potential benefits to the Township of Denville that may be associated with the key components of the Project.

The 2008 Report identified 335 residential and 186 non-residential, for a total of 521 structures within the 500-year floodplain in the Township of Denville. Of these structures, 335 are identified as being in the 100-year floodplain. Based upon the characteristics and elevations of these structures, the benefits associated with reduced flood elevations are estimated for the purposes of comparing alternative plans and establishing the benefit/cost ratio. Table 6-3 in the 2008 Report indicates that the estimated annual damage value (August 2004 price levels) under existing conditions is $1,932,960 in Denville. The bulk of this estimated damage is in economic reach 102 of the Rockaway River, from the confluence with Den Brook to Route I-80, which contains 229 residential and 164 non-residential, for a total of 393 structures in the 500-year floodplain, with an estimated annual damage value of $1,147,590. The next highest damage reach is between Pocono Road and Den Brook, with 22 residential and 5 non-residential, for a total of 27 structures in the 500-year floodplain, with estimated annual damages of $636,040. Thus these two contiguous reaches of the river account for 92% of the estimated annual flood damages in the Township.

Table 6-4 – Preliminary Screening of Alternative Plans of the 2008 Report lists several flood management measures (e.g. levees, channel modifications, reservoirs, diversions and combinations) and indicates them to be screened out or further evaluated. The only structural measure selected for evaluation was "diversion" (thus the tunnel from Dover to Lake Estling). The following plans regarding protection in Denville are noted:

- Plan 2 – Denville only levee system – includes relocation of the Upper Rockaway River – Screened out: Limited protection, aesthetic impacts, and environmental impacts.
- Plan 2A – NJ Foundation for Blind levee – protects approximately 20 structures – limited protection – Screened out: Limited protection, marginal economic viability.
- Plans 4 – Channel modifications - 100-year protection for Boonton, Denville, Rockaway and Dover – Screened out: Environmental impacts, extensive infrastructure (bridge) modifications, and limits on channel modifications due to development.
- Plan 5 – Channel modifications -25-year protection for Boonton and Denville –limited protection level – Screened out: Not economically justified.

- Plans 6 through 9 – reservoir (detention) plans at Longwood Valley, Green Pond Brook and Beaver Brook, and a combination of Longwood Valley with Green Pond – Screened out: Not supported by non-Federal interests or not economically justified.

While the above "Screened out" measures were not considered further as primary plans, some of the elements (e.g. channel or dam modifications) were reconsidered as components in specific reaches of the river in combination with the primary plan (i.e. diversion).

Five alternative plans (A through E) were further evaluated with alternative components for the 4 major reaches of the river: (1) Dover Area, (2) Rockaway & Upper Denville Area, (3) Denville Area, and (4) Lower Denville Area to Powerville. For the reach 3 – Denville, the alternative plans considered the following:

- Plan A - Diversion, levees, walls & backflow gates
- Plans B and C - Nonstructural
- Plans D and E - Limited channel improvements

For the Lower Denville Area, dam modifications were also considered for Plans A, D and E.

Section 6.13.2 of the 2008 Report states, "After detailed analysis, Alternative Plan A was determined to not be feasible based on anticipated excessive mitigation costs, public opposition, and technical issues." Plan A was eliminated from further analysis. The diversion culvert included under Plan A would run from Dover to the Rockaway River in Denville, discharging just upstream of its confluence with Den Brook. The diversion culvert was shortened for other alternatives. The levees and floodwalls included in Denville under this alternative were intended to provide local protection from the backwater caused by the peak flow discharging from the diversion culvert. Interior drainage facilities (pump stations, backflow gates) were also included, along with modification of the Powerville Dam, with a mechanical gate that would be lowered for storm events expected to be greater than the 2-year flood.

Plans B and C included only non-structural measures for Denville, while Plan B included only non-structural measures for all areas. Thus affected structures would be removed or elevated above the design flood level. However no new protection would be provided for roads and other external areas or facilities (outbuildings, cars, and athletic fields) and public emergency costs would not be expected to be significantly reduced. Plan B was optimal for a 5-year level of protection with a benefit/cost (B/C) ratio of 1.23. The B/C ratio was 1.02 for the 10-year level of protection, and 0.79 and 0.64 for the 25 and 100-year levels of protection, respectively.

Alternative Plan C included the diversion culvert from Dover, but only non-structural measures for the other areas. The B/C ratio was estimated to be slightly more than 1.0 for the 10, 25 and 100-year design levels.

Alternative Plan D included the diversion culvert with a 25-year level of protection for Dover, but only a 2-year level of protection for Denville Township and Boonton Township with channel modifications in place. The B/C ratio was estimated at 1.32 for this alternative, with net annual benefits (annual benefits less annual costs) of $1.9 million.

Alternative Plan E also includes the culvert from Dover with a 25-year level of protection and approximately a 2-year level of protection for Denville and Boonton with channel modifications in place. The B/C ratio was estimated at 1.25 for this alternative, with net annual benefits of $1.6 million.

As can be concluded from the above, the considered alternatives primarily focused on providing protection for Dover and provided very little flood protection for the Township of Denville. Alternative Plan A included floodwalls and levees in Denville, but these were intended to address the effects of backwater caused by the discharge from the long diversion culvert. Alternative Plans B and C consisted only of non-structural measures for Denville and Alternatives D and E provided only a 2-year level of protection for Denville. This minimal benefit for Denville is reflected on the USACE flood

The Denville area components of the USACE Study alternatives were narrowed to non-structural measures and 2-year level protection channel modifications.

inundation maps that accompany the 2008 Report and show very little reduction in flood levels in the Township.

Following preliminary screening of environmental impacts of the various alternatives and with comparison of the B/C ratios, the USACE identified Alternative Plan D, with 25-year protection for Dover and 2-year level of protection for Denville, as the National Economic Development (NED) Plan. Normally this would become the recommended plan, unless there was a Locally Preferred Plan (LPP) of acceptable scope, impacts and benefits. However since by the time the NED Plan was identified there was no longer a non-Federal sponsor, the evaluation was terminated and no recommended plan was identified.

2.7.2.2 The NED Plan

The NED Plan (Alternative Plan D25) description is summarized as follows:

Key components:

1. A 3-mile long diversion culvert (9.6' wide by 9.6' high; capacity 1,814 cubic feet per second) from Dover to Rockaway Borough.
2. Downstream channel improvements (downstream of diversion structure discharge point)
    a. Upstream of Denville the channel modification would consist of a 25-foot wide channel cut and lowering of a weir.
    b. The portion within Denville and downstream to North Main Street in Boonton Town, just downstream of the Powerville Dam, would consist of a 25-foot channel cut within the river banks for a length of 6.7 miles.
3. Removal and replacement of Powerville Dam with a crest gate structure.

Estimated cost:

Based upon 2008 cost estimates escalated to the mid-point of construction in 2010 (refer to Table 11-1 in the 2008 USACE Report), the Project Cost was estimated at approximately $111 million exclusive of State required mitigation costs. Of this cost, approximately 83% would be

associated with the diversion structure and 17% would be associated with the channel modifications. The channel modifications through Denville and downstream constitute approximately 88% of the total length of channel modifications under Alternative Plan D25. Thus the Project Cost associated with the channel modifications through Denville and downstream to Powerville would be approximately $17 million, exclusive of State required mitigation costs.

Benefits to Denville:

1. For the 2-year and 5-year events, Denville is expected to see up to 0.5 foot reduction in flood depths.
2. For the 25-year event, Denville is expected to see greater than 0.5 foot reduction in flood depths.
3. For the 100-year event, Denville is expected to see approximately 0.2 foot reduction in flood depths.
4. Of the estimated approximately $8 million Flood Damage Reduction Benefits for Plan D, the value for Denville was estimated at $523,300 based upon a 1 to 2-year level of protection (August 2003 price levels, Table H-15, Appendix H, page H-51 of 2008 Report). By comparison, for the non-structural alternatives in Denville the flood damage reduction benefits for Denville range from $0.4 million to $1.4 million, depending upon whether only non-structural measures are implemented upstream (lesser benefits) or structural measures (including the diversion culvert) are constructed upstream.

Benefits and Costs for Alternative Plan D25:

With an estimated Project Cost of $17 million for the channel modification portion of Alternative Plan D25 through Denville and downstream, the estimated annual cost for this portion would be approximately $1.1 million, based upon a simple ratio of annual and total costs for the entire Project. As indicated above, the annual benefits were estimated at $523,300. This would yield a Benefit/Cost (B/C) ratio of 0.523/1.1 or approximately 0.48 which is significantly less than a minimum of 1.0 for Federal consideration. This estimated B/C ratio is approximate only, based

upon interpolation of data presented in the USACE 2008 Report. More detailed investigation may yield a refinement of costs and the B/C ratio.

Based upon the information obtained from the USACE 2008 Report, channel modification of the Rockaway River does not appear to be a cost effective solution to the flooding problems in Denville. Non-structural measures may have some merit.

3.0 Evaluation of Potential Projects

Based upon the review of the prior investigations, previously identified projects are reviewed below. These descriptions include some modifications or updates of concepts previously presented, as well as some new concepts for reducing flood risk.

3.1 Review of Large Scale Projects from *Master Drainage Plan*

The list of Large Scale Projects included in the *Master Drainage Plan*, prepared by Elson T. Killam Associates, revised December 1980, is repeated below, and followed by suggested modifications for future consideration. Current costs for all projects would be significantly higher than the 1980 estimated project costs.

Table 3.1-1 Priority Evaluation of Large Scale Drainage Projects

Rank	Large Scale Projects	1980 Estimated Cost	Priority Points
L1	Peck Meadow Brook	$1,500,000	220
L2	Hinchman & Corey Road Area	300,000	205
L3	Woodland Avenue Area	215,000	180
L4	Sunset Bay Area	230,000	180
L5	Franklin Road Area	195,000	180
L6	Morris Ave. at Savage Road	140,000	175
L7	Holly Drive Area	80,000	160
L8	Burton Lane Area	110,000	150
L9	NJ Foundation for Blind	340,000	125
	TOTAL LARGE SCALE PROJECTS (1980 est.)	**$3,110,000**	

3.1.1 – L1 Peck Meadow Brook

Peck Meadow Brook enters the Township from the southwest from the Township of Parsippany-Troy Hills, upstream of Fox Hill Road, crosses the railroad just downstream of Industrial Road, flows under Route I-80 and discharges to the Den Brook a short distance upstream of the confluence of the Den Brook with the Rockaway River. Consequently the lower portion of Peck Meadow Brook is affected by backwater from the Den Brook and the Rockaway River.

The 1980 *Master Drainage Plan* provides the following information: The Peck Meadow Brook drains an area of approximately 530 acres. Approximately 55% of the drainage area is within the Township. The waterway is relatively flat, with an average slope of less than 0.3%, and flooding has been reported along almost the entire one-mile length of the brook in the Township. The principal causes of flooding along the brook are the backwater from the Rockaway River and Den Brook, inadequate culverts under several roads and the railroad and the flat narrow channel of the brook. "During periods of high water level in the Rockaway River, several houses and the low points of Cooks Road and Richwood Place become flooded. When these two roads are inundated, approximately 45 homes have no vehicular access."

Recommended improvements included:

1. Stormwater detention and channel improvements
2. Culvert improvements at Cooks Road, Richwood Place and Fox Hill Road
3. Pump station with a tide gate at Route I-80

A review of the *Severe Repetitive & Repetitive Properties* map (see Section 2.5 above) reveals that only two repetitive loss properties are reported for the Peck Meadow Brook area, with one located on Hall Avenue and one on Witt Avenue, both within about 600 feet of the upstream side of Route I-80. The FEMA flood delineation map indicates a large flood plain between Route I-80 and the railroad crossing of the brook, with a 100-year flood width of about 250 feet at Richwood Road and at Cooks Road. Upstream of the railroad, the 100-year flood plain is based upon approximate methods, not detailed modeling, but shows flooding near the ends of Adelaide Place and Bowers Place.

Preliminary plans for improvements in the Peck Meadow Brook area were prepared in the early 1980s. However the improvements were not implemented due to costs and environmental concerns. Since completion of the 1980 *Master Drainage Plan*, there have been significant changes in available data (FEMA maps 1985, NJDEP flood delineation maps 1986) and in regulations affecting allowable work in freshwater wetlands areas and flood hazard areas

(including Flood Hazard Area Control Act Rules effective November 2007). It is doubtful that extensive channel improvements would be permitted by the NJDEP under current rules without extensive justification. Replacement of bridges and culverts and installation of a stormwater pumping station would be more likely to receive approval provided such work does not cause adverse impacts downstream.

With improved data available, a review should be made of the extent of flooding and an inventory of structures (including first floor elevations) within the flood plain should be prepared. Alternatives for protection of the structures should be considered (including elevation of the structures and acquisition of repetitive loss properties). Consideration should be given to raising the elevation of Cooks Road or Richwood Road (or both) and enlarging the culvert to provide at least one access route during high water conditions.

Raising Cooks Road may be more practical then raising Richwood Road since there are few houses adjacent to the reach of Cooks Road that would need to be elevated. If existing flooding upstream of the railroad does not adversely affect existing structures and is found to be acceptable, thus providing no justification for replacement of the railroad culvert, then consideration can be given to the limited capacity of the railroad culvert and the upstream storage and detention provided by the railroad restriction. Thus the Cooks Road and Richwood Road culverts could be sized appropriately based upon the limited flow conveyed through the railroad culvert. One or both roads would need to be elevated based upon the backwater elevation from the Rockaway River and Den Brook and the limited conveyance required for the flow in the brook.

Consideration could also be given to installing back flow control devices (tide gates) on the two culverts under Route I-80, either with or without a pumping station, depending upon the timing and duration of the peak flows on the Rockaway River, Den Brook and Peck Meadow Brook. Tide gates provide very little resistance to flow out of the gate, but would prevent backwater from the Rockaway River from flowing back into the low areas along Peck Meadow Brook at

times when the Rockaway River water level is high and there is little flow in Peck Meadow Brook.

Prudent planning and analyses could result in a project that would address the most severe needs of the area and have minimal environmental impacts.

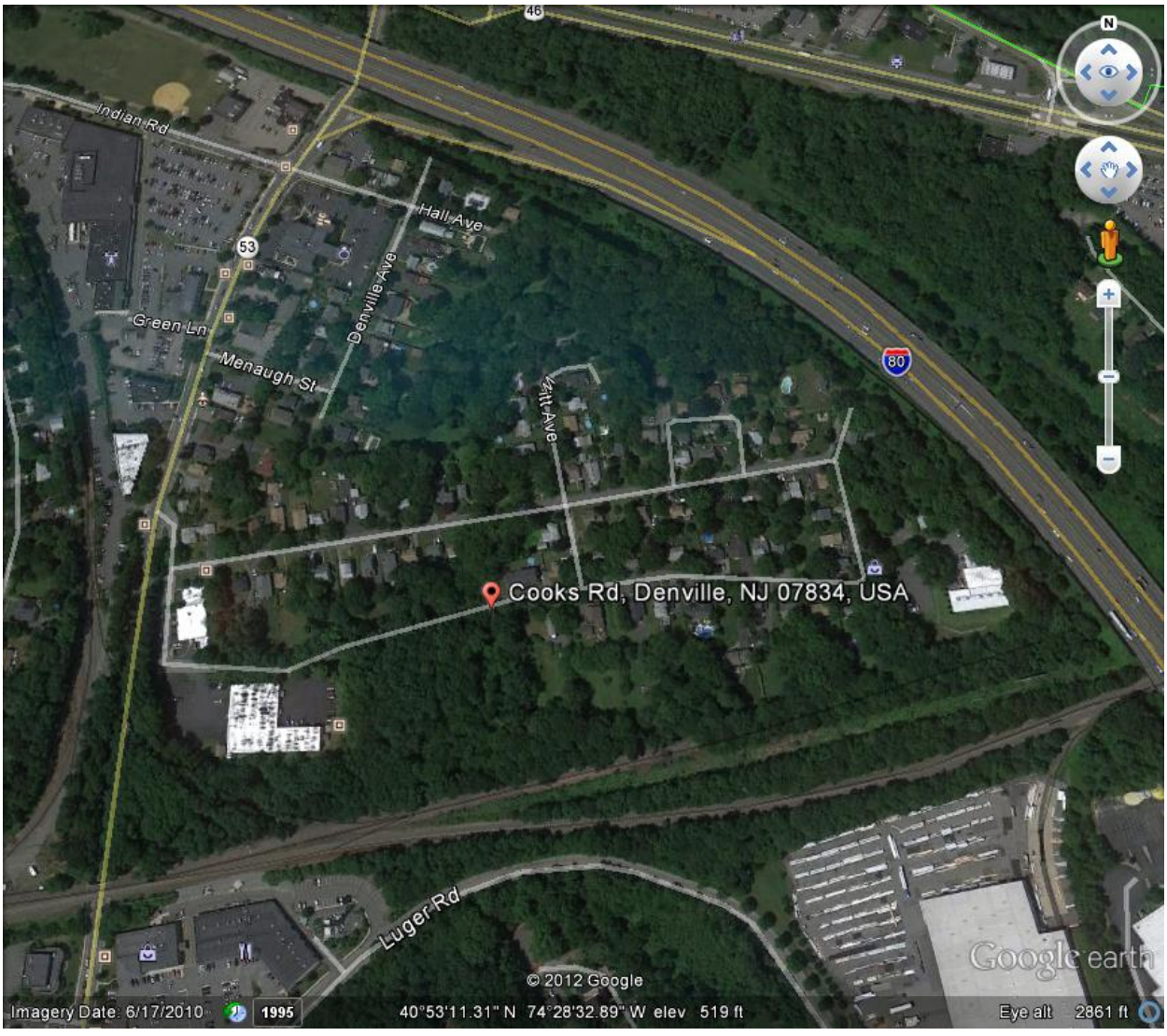


Figure 3.1.1 – 1 Aerial Photograph of Peck Meadow Brook Near Cooks Road

3.1.2 L2 - Hinchman & Corey Road Area

The Hinchman Avenue and Cory Road Area is within the 100-year flood plain of the Rockaway River, which flows along the north side of this area upstream of Diamond Spring Road. The majority of the storm sewers serving this area drain south to the Den Brook, which is heavily influenced by backwater from the Rockaway River near the intersection of Broadway and Route 46.

The recommended improvements in the 1980 *Master Drainage Plan* provide for splitting the drainage systems in this area so that the flow from approximately Edgewood Road and north would be conveyed via two new systems to the Rockaway River. The remaining area to the south of Edgewood Road would continue through existing systems to the Den Brook, with a tide gate installed at the outlet on the downstream side of Route 46. The improvements were sized to accommodate a 25-year design flow, with the understanding that greater storms would result in inundation of most of the area due to overflow from the Rockaway River.

A review of hydraulic analyses of the Rockaway River and the Den Brook completed after the 1980 *Master Drainage Plan* was issued reveal that the difference in the 100-year flood elevation of the Rockaway River from the mouth of the Den Brook to Riverside Drive at the Hinchman Avenue intersection is approximately 2 feet. With consideration of the losses for Den Brook at the Route 53 crossing (about 1 foot), the tail water elevation at Den Brook on the downstream side of Route 46 but upstream of Route 53 is about one foot lower than the water elevation in the Rockaway River near Hinchman Avenue and Riverside Drive East. Thus storm sewers flowing to the existing outfall at Den Brook on the downstream side of Route 46 would have a tail water elevation about one foot lower than storm sewers discharging to the Rockaway River near Hinchman Avenue and Riverside Drive East.

Most of the Hinchman Avenue & Cory Road Area is inundated by the 50 and 25-year flood overflows from the Rockaway River. However, the overland flow from the 10-year flood does not overflow a natural ridge that runs along the alignment of Gardner Road. Therefore it would be possible to provide for improved drainage of the area to the south of Gardner Road by

keeping that storm system separate from the system serving the area to the north of Gardner Road. This concept could be refined to provide for improved drainage for a design storm somewhere between the 10-year and 25-year storm if the ridge along Gardner road can be elevated, such as by slightly raising the road elevation or by constructing a low floodwall or earthen berm along the rear of properties on the north side of Gardner Road.

Additional relief from frequent flooding can be achieved by preventing backflow from the Den Brook into the Hinchman Avenue and Cory Road storm sewer system and installing a stormwater pump station near Route 46 to convey the storm flow to the Den Brook at times when the water level in the Den Brook is too high to allow flow by gravity. The Project would include construction of a below ground pump station chamber with a connection to the existing storm sewer on the upstream side of NJ Route 46. The pump station would contain pumps sized to accommodate a range of flows and a trash rack on the pump chamber inlet. The pumps will discharge to a new pipeline which will be installed by jacking the pipe under NJ Route 46, with no disruption to traffic during the construction. A back flow restriction device would be installed on the existing storm sewer pipe outlet on the downstream side of NJ Route 46. The device will be connected directly to the end of the existing pipe. A backflow control device will also be installed on the pump station discharge line to prevent brook water from backing up into the pump station when it is not operating. The Project would include associated manholes and piping as needed to connect the existing storm sewer to the pump station, provide access to the trash rack and to accommodate the pump discharge. The pumps would operate automatically based upon the water levels in the pump chamber. Electrical controls will be installed in secured cabinets elevated above the 100-year flood level.

In association with storm drainage improvements in this area, it would be appropriate to include the following:

1. Revise the plan for storm sewer improvements to split the systems at the natural ridge near Gardner Road. Drain the area south of Gardner Road to the Den Brook and the area north of Gardner Road to the Rockaway River. (Differs from the split at Edgewood Road shown in the 1980 *Master Drainage Plan*).

2. Provide a pump station near the system discharge at Route 46.
3. Provide a tide gate at the storm sewer outlet at Route 46.
4. Separate the Hinchman Avenue & Corey Road storm sewer system from that serving Route 46 (to prevent having Route 46 stormwater back up in the Hinchman Avenue & Corey Road system).
5. Evaluate the need for tide gates at the storm sewer outlets at the Rockaway River.
6. Raise the elevation of the existing ridge along the alignment of Gardner Road, such as by raising the road elevation or constructing a low floodwall or berm along the rear of properties on the north side of Gardner Road.

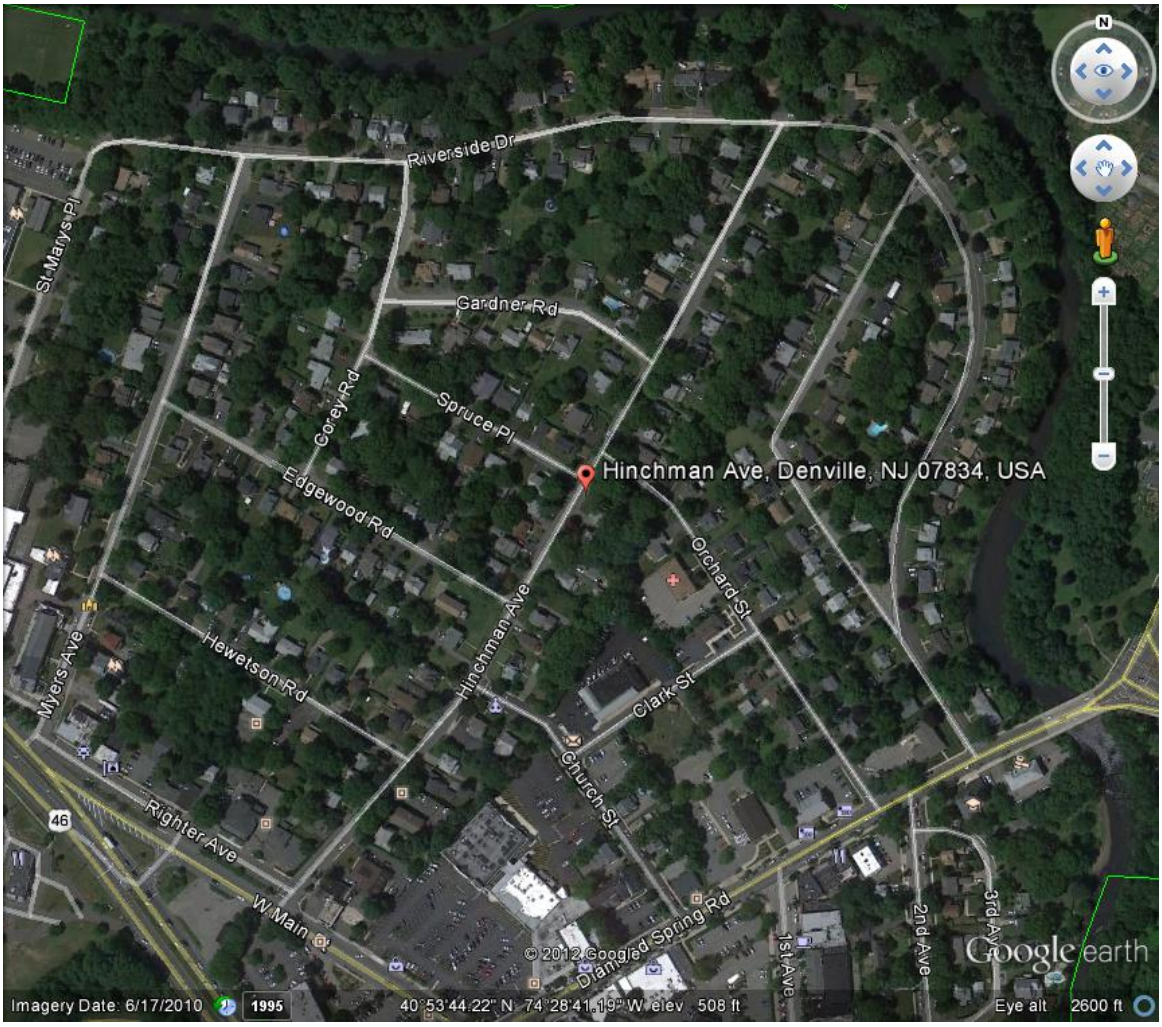


Figure 3.1.2 – 1 Aerial Photograph of Hinchman Ave & Corey Rd Area

3.1.3 L3 - Woodland Avenue Area

Woodland Avenue is located in the flood plain of the Den Brook between US Route 46 and Route I-80. The area to the west of Elm Street is in the flood plain which is impacted by the backwater from the Rockaway River. Route 46 adjacent to this area is also inundated by the 100-year flood in the Rockaway River. The *Severe Repetitive & Repetitive Properties* map (see Section 2.5 above) shows 5 repetitive loss properties in this area, located near the intersection of Woodland Avenue and Maple Street (a paper street right-of-way, not developed). It is interesting to note that there appear to be 9 other structures on Woodland Avenue at lower elevations and closer to Den Brook that are not listed as repetitive loss properties.

The 1980 Master Drainage Plan proposed the construction of an earth berm with top elevation 508 feet (NGVD 29) to be constructed between Woodland Avenue and the Den Brook, running from an abandoned railroad bed to US Route 46. Runoff from Route 46 and the Lake Arrowhead area would be diverted directly to Den Brook and a flap gate would be installed on the outfall serving Woodland Avenue. It was anticipated that the Woodland Avenue area would be protected up until Rockaway River water overflowed the low portion of Route 46, at approximately the 25-year flood condition.

More recent estimates of flood elevations indicate that floods somewhat less than the 25-year flood would overtop Route 46 in this area. However, changes in land use along the south side of Route 46, as appear on recent aerial photographs of the area, may have raised the elevation required for overland flow across Route 46 into the Woodland Avenue area. Detailed review of current surface grades in this area would be required to refine the estimated overflow elevation and associated flood recurrence estimate. However, even with higher elevations along Route 46, it would still be necessary to construct a berm from the railroad to the higher ground and construct the previously proposed storm sewers.

For further consideration of alternatives for protection of this area, the following is suggested:

1. Document the location and first floor elevation of structures in the area.

2. Compare the first floor elevations to the various flood elevations to estimate the potential recurrence of damages.
3. Determine the current surface elevations along Route 46 to determine the elevation of overflow from the Rockaway River, and associated recurrence frequency.
4. Update the proposed top elevation and length of the earth berm, associated storm sewer sizes and alignments, and estimated costs.
5. Estimate the costs of buyouts and elevation of impacted structures.
6. Compare relative levels of protection and the costs of the alternatives prior to selecting a plan for mitigation.

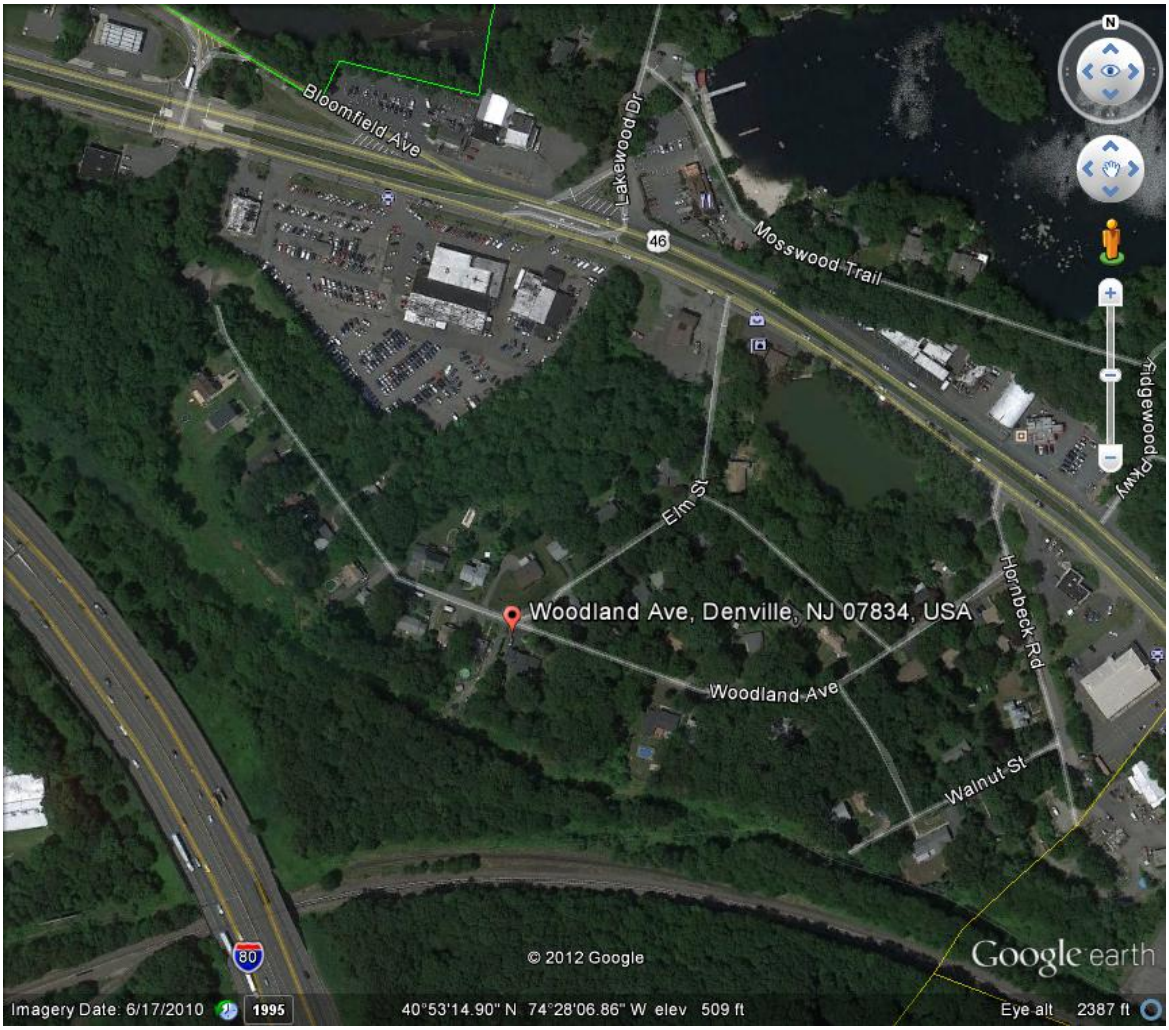


Figure 3.1.3 – 1 Aerial Photograph of Woodland Ave. Area

3.1.4 L4 - Sunset Bay Area

The Sunset Bay area is located between Route I-80 and Indian Lake. However the area between Sunset Trail and Franklin Road does not drain to either Sunset Bay or Indian Lake since it is lower than the water levels of these lakes. This area drains across Route I-80 and Route 46 to the Rockaway River through a 2,500-foot long network of undersized storm sewers, road culverts and open ditches.

The low back yard areas bounded by Sunset Trail, Franklin Road and Fernwood Trail appear to have been the primary areas of frequent flooding. No repetitive loss properties are identified in this area, and the area is not within a delineated flood plain. Since these low areas cannot drain by gravity to the nearby lakes, and since the cost of a new gravity system is greatly affected by the distance to the Rockaway River and the need to cross Route I-80 and Route 46, consideration should be given to providing a small stormwater pump station for this area as an alternative to a new gravity sewer.

The following approach is suggested:

1. Determine which properties and structures (if any) experience frequent flooding and to what extent.
2. Delineate the area that would need to be served by a local pump station (may be in the range of 6 to 10 acres).
3. Estimate the cost of a small pump station, a tide gate to prevent backflow from the downstream system, and associated storm sewer improvements.

3.1.5 L5 - Franklin Road Area

The Franklin Road project reviewed in the 1980 Master Drainage Plan pertained to drainage improvements along Franklin Road between Route 46 and the railroad, which would be undertaken in association with a major road improvement program for that reach of road. This system was planned to discharge to the adjacent lakes and is not pertinent to the current flood mitigation program.

3.1.6 L6 - Morris Ave. at Savage Road

This project addressed a local drainage problem related to a small stream adjacent to Morris Avenue between Morris Catholic High School and Harriman Avenue. No repetitive loss properties are identified in this area and the project area is not within a delineated flood plain. As such, this project would not be included in a flood mitigation program.

3.1.7 L7 - Ford & Kitchell Road Area

This project addressed a local drainage problem on a single property at the corner of Ford Road and Kitchell Road. No repetitive loss properties are identified in this area and the project area is not within a delineated flood plain. As such, this project would not be included in a flood mitigation program.

3.1.8 L8 - Burton Lane Area

The Burton Lane area has reportedly experienced drainage problems for many years, primarily at two properties located on the downhill (east) side of Burton Lane. The area drains to the southeast to Lake Lenore. No repetitive loss properties are identified in this area and the project area is not within a delineated flood plain. As such, this project would not be included in a flood mitigation program.

3.1.9 L9 - NJ Foundation for Blind

The New Jersey Foundation for the Blind Lodge 230 is located on Diamond Spring Road adjacent to Diamond Springs Pond and upstream of the former Morris Canal crossing of the Rockaway River. The property is within the delineated flood plain of the river, although no repetitive loss properties have been identified in the immediate area. Much of the flood plain is occupied by the Rockaway River Country Club golf course. The 1980 *Master Drainage Plan* stated that the Lodge is subject to frequent and severe flooding as a result of high flood stage in the Rockaway River, with the ground floor elevation of the then existing structure at elevation 502.5 feet while the approximate 100-year peak elevation in the Rockaway River was estimated at 505.0 feet (NGVD 29). The NJDEP 1986 flood delineation maps and profiles indicate the

peak water surface elevation for a 100-year flood at 505.5 feet (NGVD 29) and for the NJ Flood Hazard Area Flood at elevation 506.8 feet.

The 1980 *Drainage Master Plan* estimated that the former Morris Canal piers in the river increased the upstream flood elevations for the 10-year and 100-year floods by approximately 0.5 foot and 1.5 feet respectively. However, the 1986 NJDEP flood profiles show no increase in flood elevation for the 100-year or NJFHA Floods at the remaining abutments and piers. The 1985 FEMA flood profiles show approximately 0.5 foot or less increase for a range of flows from the 10-year through the 500-year floods. Thus the Morris Canal piers do not appear to have significant influence on the flood levels at the NJ Foundation for Blind property or upstream as long as they are maintained free of debris. However, they reportedly frequently become partially obstructed with large debris and consideration should be given to removing the piers.

Both the NJDEP and FEMA flood profiles show the 100-year flood elevation at 504.0 feet at the upstream side of Bush Road, which crosses the river at a location approximately 4,500 feet downstream of the Morris Canal crossing and more than a mile downstream of the NJ Foundation for Blind property, and at elevation 502.9 feet at the downstream boundary of the Township. Lowering of the flood stage of the river would require extensive improvements extending well downstream of the Township limits. Thus local relief can be achieved only by elevating the structures above the flood level or by isolating the structures from the overflow of flood waters from the river.

The 1980 *Master Drainage Plan* proposed the construction of an earthen levee from the high ground on the western side of the Foundation property to the high ground at the rear of private homes to the east of the Foundation property. The top of levee was proposed at a minimum of elevation 506 feet to provide protection from the 100-year flood. Under current design standards additional freeboard or protection from a breach failure of the levee when overtopped during greater storms will be appropriate. Some storm sewer improvements, including a tide gate, were proposed in association with the dike construction to divert local storm flow around the levee and to protect the interior area from backflow from the river.

It was recognized that the levee would be constructed in the flood plain of the river and thus would constitute an encroachment. Construction of the levee would also reduce the flood plain storage volume of this reach of the river since the 100-year flood would no longer be stored in the area within the levee. Since completion of the 1980 *Master Drainage Plan*, the floodway for the Rockaway River has been delineated by the NJDEP and FEMA. Review of the 1986 NJDEP maps reveals that the proposed levee would need to be shifted only slightly to be outside of the delineated floodway. However, the issue of loss of flood plain storage volume would require mitigation to replace the storage inside the levee protection area with an equivalent volume somewhere in the nearby hydraulic reach of the river, in accordance with the requirements of the NJ Flood Hazard Area Control Act Rules (effective November 2007) which provide for no net loss of flood plain storage volume. If freshwater wetlands are in the project area, mitigation for any adverse impact on such wetlands will also be required.

A scaled down version of the levee considered in 1980 was constructed at the site sometime after the 1980 *Master Drainage Plan* was issued. The smaller levee appears to be intended to provide some protection only to the Foundation for Blind building. Additional levee construction or other measures would be needed to afford protection to the neighboring homes.

The following approach is suggested if further consideration is to be given to this project:

1. Confer with the Foundation to determine whether any changes have been made to reduce potential flood damages (such as flood proofing at the structure), and review the extent of damages sustained in recent flood events (including August 2011 Hurricane Irene). Evaluate the current need for the project.
2. Review the extent of the flood plain and elevations for the 100-year and NJ Flood Hazard Area flood on the site and adjacent properties.
3. Determine (confirm) the first floor elevation of the Foundation structure and the low nearby houses. Compare the first floor elevations to the 100-year and NJFHA elevations.

4. Identify whether potential benefits are limited to the Foundation property or also pertain to nearby properties for the 100-year and NJFHA flood levels. Select a design level of protection.
5. Delineate the location of potentially impacted freshwater wetlands.
6. Revise and refine the limits of the levee to stay out of the delineated floodway, minimize impacts on wetlands, and minimize the drainage area tributary to the inside of the levee.
7. Update and revise as needed the proposed storm sewer system improvements required to minimize flow to the interior of the levee and prevent backflow from the river.
8. Evaluate the holding capacity of the on-site pond to contain the interior runoff during the period of high water levels in the river. Decide whether any pump facilities are needed.
9. Revise the levee alignment and design to minimize the fill volume and to provide appropriate freeboard or other protection from failure due to overtopping. Consider inclusion of a protected emergency overflow section. Determine the need for easements.
10. Update construction cost and project cost estimates. Determine permitting requirements and potential for approval. Evaluate viability of the project.

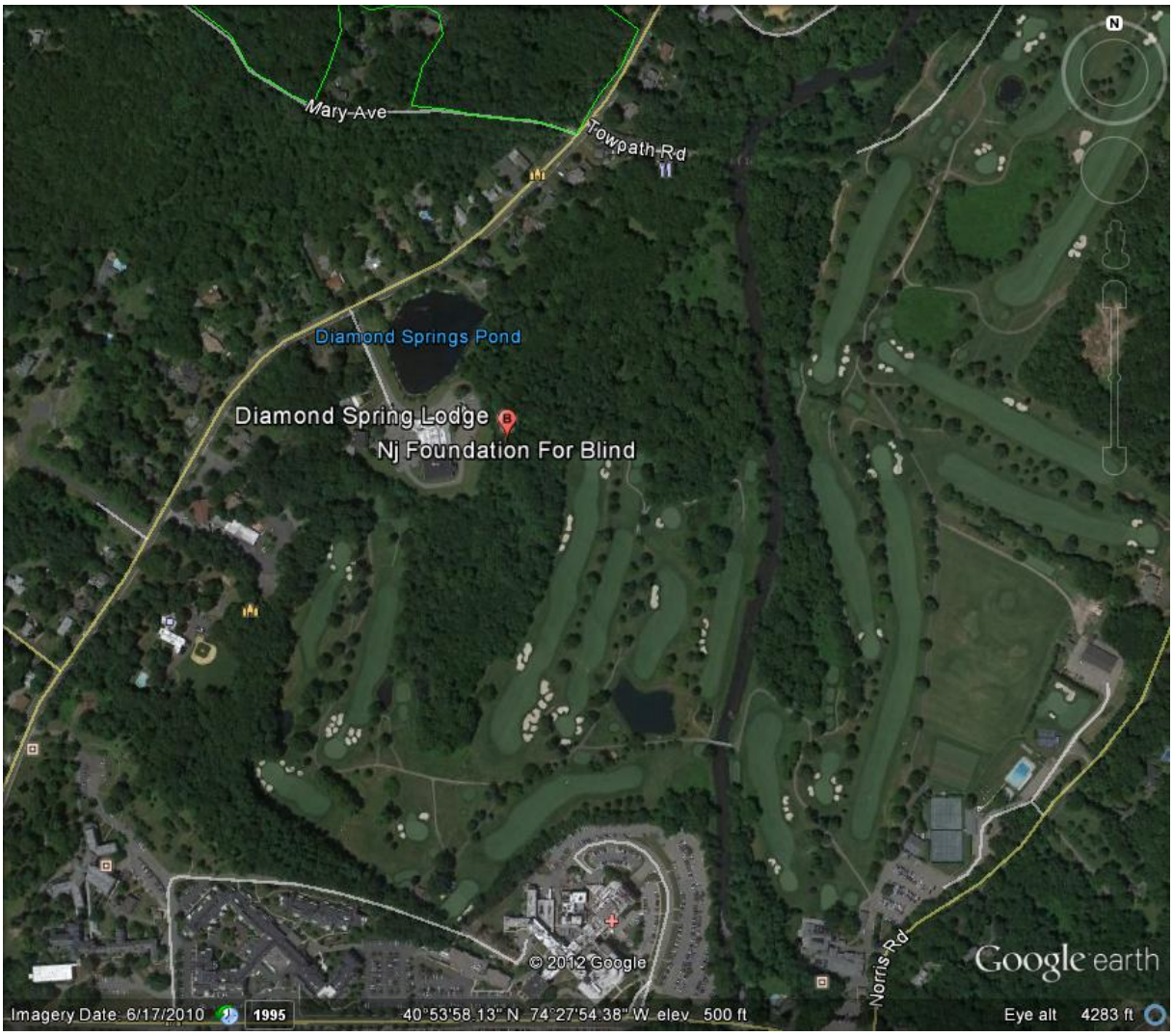


Figure 3.1.9 – 1 Aerial Photograph of NJ Foundation for Blind near diamond Springs Road.

3.1.10 Bloomfield Avenue Area

The 1980 *Master Drainage Plan* included recommendation for minor storm sewer improvements on First Avenue, which have since been constructed. This system drains through the parking lots on Bloomfield Avenue, across Route 46 to the Den Brook. The 1980 recommendations for improvements also included a tide gate for the outlet of this storm sewer system at Route 46.

The frequency of flooding in the parking lots between Bloomfield Avenue and Route 46, just south of First Avenue, could be reduced through construction of a below ground pump station chamber with a connection to the existing storm sewer on the upstream side of NJ Route 46. The pump station would contain pumps sized to accommodate a range of flows and a trash rack on the pump chamber inlet. The pumps will discharge to a new pipeline which will be installed by jacking the pipe under NJ Route 46, with no disruption to traffic during the construction. A back flow restriction device will be installed on the existing storm sewer pipe outlet on the downstream side of NJ Route 46. The device will be connected directly to the end of the existing pipe. A backflow control device would also be installed on the pump station discharge line to prevent brook water from backing up into the pump station when it is not operating. The project would include associated manholes and piping as needed to connect the existing storm sewer to the pump station, provide access to the trash rack and to accommodate the pump discharge. The pumps would operate automatically based upon the water levels in the pump chamber. Electrical controls will be installed in secured cabinets elevated above the 100-year flood level.

In association with consideration of improvements in the Bloomfield Avenue area, the connection of the First Avenue storm sewer system with that serving Second Avenue should be reviewed. It may be appropriate to remove the connection between these street systems to prevent backup of water from the lower areas into the First Avenue system.

In association with storm drainage improvements in this area, it would be appropriate to include the following:

1. Provide a pump station near the storm sewer system discharge at Route 46.
2. Provide a tide gate at the storm sewer outlet at Route 46.
3. Separate the First Avenue storm sewer system from that serving Second Avenue (to prevent having Second Avenue stormwater back up in the First Avenue system).
4. Evaluate the need for tide gates at the storm sewer outlets for Second and Third Avenues at the Rockaway River.

3.2 Review of Bridges and Other River Structures

The flat slope of the channel bottom and the relatively narrow channel width along the Rockaway River greatly restrict the conveyance capacity of the channel, resulting in extensive overbank flow and wide flood plains along the river. While implementation of a major channel widening and deepening project is highly unlikely, maintenance of the existing channel is extremely important. Snags and debris should be removed from the river channel and immediately along its banks. Debris in the channel and overbank area will impede the flow of water, resulting in higher flood levels.

Particular attention should be paid to maintaining the waterway openings at bridges and other river crossings. The flood profiles developed by the NJDEP and by FEMA are based upon clear openings in the bridges. Accumulation of sediment or debris in the structure opening will reduce the capacity and raise the upstream water level to higher than the elevation presented in the NJDEP and FEMA documents.

Improvements at structures along the Rockaway River could result in some reduction of peak water surface elevations along the river. However, approval from the NJDEP to make such improvements would be contingent upon demonstrating that no adverse impacts are cause through the associated loss of flood plain storage volume, or that any such adverse effects are adequately mitigated. The basic rule is that flood improvements can cause no negative effects on others.

The portion of the Rockaway River relevant to flooding in the Township runs from upstream of the Boonton Reservoir, through the Town and Township of Boonton and through Denville to its boundary with Rockaway Borough. Immediately upstream of the Boonton Reservoir, the Rockaway River passes under I-287 and its entrance ramp, a railroad crossing and Morris Avenue in the Town of Boonton. Each crossing has a relatively large opening for passage of flow. Upstream of Morris Avenue in Boonton, the river passes through Grace Lord Park and then under W. Main Street, also in the Town of Boonton. Further upstream, the river crosses

into the Township of Boonton, under the N. Main Street Bridge and then over the Powerville Dam. Within the reach affected by normal backwater from the dam, the river passes under Powerville Road. Further upstream the river enters Denville Township and crosses under Bush Road and then passes through the former Morris Canal crossing near the Foundation for Blind. Continuing upstream, the river passes under the Rockaway River Country Club golf cart bridge, Pocono Road and Diamond Spring Road, then circles around to the north side of Riverside Drive in Denville and under Savage Road and I-80, then continues upstream into Rockaway Borough, where it is joined by Beaver Brook.

Key structures from the Powerville Dam in Boonton upstream to I-80 are listed below with estimated peak water surface elevations and hydraulic losses through each structure for the 50 and 100-year floods, as shown on the FEMA flood hazard area delineation maps. The table also indicates whether the indicated flood elevation is over or under the road as shown on the FEMA profiles. A comparison of the FEMA 100-year flood profiles with the NJDEP 100-year flood profiles indicates substantial agreement between the two. The NJDEP does not adopt the 50-year flood profile.

The purpose of showing the hydraulic loss through each structure is to serve as an indication of how much the flood profile might be lowered by replacement of the bridge with a larger structure. As can be seen below, the computed losses through the several bridges are all relatively minor, with little benefit to be gained in Denville by replacement of any single bridge. The 1980 *Master Drainage Plan* did include the recommendation to replace the Bush Road Bridge and the Pocono Road Bridge to provide some additional capacity during more frequent storms (i.e. the 10-year flood) and to raise the bridges and their approach roads to maintain access across the structures during a 100-year storm. Replacement of the Diamond Spring Road Bridge and Savage Road Bridge was also recommended for consideration for traffic safety and flood reduction purposes. These recommendations should be reconsidered in light of the detailed hydraulic analyses and flood delineation mapping prepared since completion of the *Master Drainage Plan*.

Table 3.2 – 1 Hydraulic Losses Through Key Structures on the Rockaway River			
Structure	**Size (c. 1980)**	**WS Elevation and (Loss) Through Structure, With Flood Level Over or Under Road**	
		FEMA 100-year Flood	**FEMA 50-year Flood**
N. Main Street Bridge		490.8' *	
Powerville Dam	Crest 120 feet Crest El. 492.1'	498.1' *	
Powerville Road Bridge	102' x 12'	499.1' (0.8') *	
Bush Road Bridge	70' x 13'	503.9' (0.3') Under	502.8' (0.3') Under
Former Morris Canal Crossing (piers)	4 openings at 22.5' wide	505.6' (0.6') No deck	504.4' (0.4') No deck
Golf Course Bridge	50' x 8'	505.8' (none) Over	504.6' (0.2') Over
Pocono Road Bridge	76' x 8'	506.8' (0.5') Over	505.7' (0.5') Over
Diamond Spring Road Bridge	98' x 8.5'	508.7' (0.6') Over	507.0' (none) Under
Savage Road Bridge	65' x 12'	511.2' (0.5') Under	509.4' (0.1') Under
Route 80 Bridge	133' x 16'	511.8' (0.1') Under	510.5' (none) Under
Note: * Indicated data obtained from NJDEP flood profile of Rockaway River.			

As noted in the 1980 *Master Drainage Plan*, the grade of the Rockaway River between the Powerville Dam and the center of Denville is extremely flat. The 100-year flood at the crest of the Powerville Dam is approximately elevation (El.) 498.1 feet while the river inverts at Pocono Road and Diamond Spring Road in Denville are approximately El. 493 and 496 feet, respectively. The ground surface in the Riverside Drive area is approximately El. 502 feet. Thus there is very little hydraulic gradient in this reach of the river due to backwater effects of the Powerville Dam, which was constructed sometime in the early 1800s. In the *Master Drainage Plan*, it was estimated that the river channel has less than one fourth of the capacity required to convey a 100-year peak flow estimated in excess of 5,000 cubic feet per second within the

channel. Dredging or widening the channel would be extremely expensive and would have significant environmental impacts of concern.

As noted in the table above, there is a significant difference in the 100-year flood elevation across the Powerville Dam. Immediately downstream of the dam the 100-year flood is estimated at El. 490.8 while immediately upstream of the dam the estimate is 498.1 feet, for a differential of 7.3 feet. Removal of the dam would not result in the 100-year flood levels in Denville being 7.3 feet lower since some of this benefit would be lost in the five miles of channel between the dam and the center of Denville. The *Master Drainage Plan* did recommend that the effects of the Powerville Dam be considered in the evaluation of flood risk reduction facilities for Denville. As will be reviewed below, the US Army Corps of Engineers (USACE) has given consideration to modifying the dam by installation of a control structure in place of the existing spillway to allow the crest elevation to be lowered during a flood event and thus reduce the upstream backwater effects. However the USACE study that addressed this alternative has been terminated without recommendation of any project for the Rockaway River

Based upon the above review of conditions along the Rockaway River from the Boonton Reservoir to and through the Township of Denville, the following concepts were further considered in the development of this Report:

1. Modification of the Powerville Dam to reduce upstream backwater effects
2. Modification or replacement of the following structures:
    a. Bush Road Bridge
    b. Pocono Road Bridge
    c. Diamond Spring Road Bridge
    d. Savage Road Bridge

To obtain a general understanding of the combined effects of the several structures along the Rockaway River, HMM utilized and modified a copy of the USACE HEC-RAS computer model (computes water surface profiles) of the Rockaway River developed by the USACE for the

Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report (see below). The model was run for existing conditions for a range of flows (2, 10, 50 and 100-year events). The model was also modified by removing the Powerville Dam and the bridges between the dam and Route I-80 from the model and computing the water surface elevations for the same range of flows. Complete removal of the structures from the model presents a best case scenario representing the best possible benefits associated with improving the structures. Actual replacement of the structures would be expected to have a lesser degree of benefit since there will still be some hydraulic loss at each structure.

The results of this comparative analysis are presented on Table 3.2 – 2 below. No channel modifications are associated with either of these two conditions.

Table 3.2 – 2 Effects of Removal of Bridges and Powerville Dam On Water Surface Elevations Upstream of Bridge Location

	Existing Conditions	All Bridges Removed	Difference in Flood Elev.
Location/Event	**Elev. (ft)**	**Elev. (ft)**	**(ft)**
Bush Road 2-Year	498.78	498.47	-0.31
10-Year	500.46	500.09	-0.37
50-Year	502.28	501.78	-0.50
100-Year	503.11	502.53	-0.58
Pocono Road 2-Year	501.54	501.19	-0.35
10-Year	503.86	503.01	-0.85
50-Year	505.95	504.96	-0.99
100-Year	506.39	505.81	-0.58
Diamond Spring Road 2-Year	503.22	503.07	-0.15
10-Year	505.46	504.86	-0.60

50-Year	507.63	506.58	-1.05
100-Year	508.23	507.29	-0.94
Savage Road 2-Year	506.20	506.18	-0.02
10-Year	507.89	507.75	-0.14
50-Year	509.74	509.28	-0.46
100-Year	510.49	509.92	-0.57

As indicated above, removal of the Powerville Dam and bridges up to Bush Road produces a reduction in flood elevation of approximately 0.3 to 0.6 foot. At Pocono Road the benefit increases to 0.4 to 1.0 foot. At Diamond Spring Road the benefit ranges from 0.2 to 1.1 foot, and at Savage Road the benefit diminishes from near zero for a 2-year event up to 0.6 foot for a 100-year event. The results of the backwater model were further reviewed to distinguish between the benefits associated with bridge replacement and those associated with modification of the Powerville Dam. The following table presents the losses through each of the above bridge structures as an illustration of the relative impacts of each bridge.

Table 3.2 – 3 Hydraulic Losses Through Each Bridge Location

	Existing Conditions	**No Bridge at Location**	**Difference**
Location/Event	**Loss (ft)**	**Loss (ft)**	**(ft)**
Bush Road 2-Year	0.02	0	-0.02
10-Year	0.03	0.01	-0.02
50-Year	0.12	0	-0.12
100-Year	0.20	0	-0.20
Pocono Road 2-Year	0.23	0.02	-0.21
10-Year	0.70	0.03	-0.67
50-Year	0.82	0.03	-0.79
100-Year	0.38	0.04	-0.34

Location/Event			
Diamond Spring Road 2-Year	0.08	0.04	-0.04
10-Year	0.26	0.04	-0.22
50-Year	0.59	0.04	-0.55
100-Year	0.68	0.04	-0.64
Savage Road 2-Year	0.02	0.02	0
10-Year	0.02	0.02	0
50-Year	0.13	0.03	-0.10
100-Year	0.24	0.03	-0.21

From the above table, it is apparent that there is no significant hydraulic benefit to replacement of the Bush Road Bridge or the Savage Road Bridge, with each having approximately 0.2 foot of loss through the existing structure for the 100-year flood. Losses through the Pocono Road Bridge and through the Diamond Spring Road Bridge could be reduced somewhat by replacement of the bridges, but the benefit would be limited to values on the order of one-half foot of reduction of flood elevation for storms in the range of 10 to 100-year events. While it would be difficult to justify the replacement of these bridges based upon these limited benefits, the opportunity to improve hydraulic conditions at each bridge should be considered when it becomes necessary to replace the bridges for other reasons, such as structural problems.

The benefits of lowering the flood elevation at the Powerville Dam will diminish as the distance from the dam increases upstream along the Rockaway River. The benefit to Denville of modifying the Powerville Dam can be seen through review of the flood elevations at the downstream side of Bush Road under existing conditions and with the Powerville Road Bridge and dam removed, as indicated in Table 3.2-4 below.

Table 3.2 – 4 Effects of Removal of Powerville Dam and Powerville Road Bridge On Water Surface Elevations in Denville			
	Existing Conditions	**Dam and Bridge Removed**	**Difference in Flood Elev.**
Location/Event	**Elev. (ft)**	**Elev. (ft)**	**(ft)**
Bush Road 2-Year	498.76	498.47	-0.29
10-Year	500.43	500.08	-0.35
50-Year	502.16	501.78	-0.38
100-Year	502.91	502.53	-0.38

As indicated above, the benefits to Denville of removal of the Powerville Dam and Powerville Road Bridge are estimated at less than 0.4 foot for floods in the range of 2 to 100-year events. In combination with the replacement of the Pocono Road Bridge and the Diamond Spring Road Bridge, the benefits could potentially be increased to a value on the order of approximately one foot for severe storms. While this will not solve the flood problems in Denville, it could help reduce the frequency of flooding or level of damages for some structures.

Another characteristic of the Powerville Dam to consider is that it tends to flatten the hydraulic gradient of flows in the upstream channel, thus reducing channel velocities and allowing additional deposition of sediment. This effect is likely greater in the reach of channel in Boonton Township and significantly diminished where the river crosses into Denville, as illustrated by the minimal (less than 0.4 foot) increase in water surface elevation at Bush Road associated with the Powerville Road Bridge and the dam, as shown in Table 3.2-4 above. However, lowering of the dam crest elevation could have some limited benefit over time by reducing sediment deposition in the channel in Boonton Township.

The *Morris County Multi-Jurisdictional Hazard Mitigation Plan, Third Final Draft – July 23, 2010* included a Mitigation Action Plan in Section 9. For Boonton Township, the list included "Analysis/Risk assessment of Powerville Dam" to address the dam failure hazard. Addressing

this hazard may involve modification of the dam. In the event that the Powerville Dam requires major modification or rehabilitation in the future, consideration should be given to incorporating modifications to reduce upstream backwater effects on the Rockaway River. Denville should communicate this concern to the officials of the Township of Boonton, to the NJDEP Bureau of Dam Safety and Flood Control, and to the dam owners.

Further discussion regarding these concepts is presented below in association with consideration of information obtained from the USACE 2008 Report.

3.3 Concepts from the USACE Upper Rockaway River Report Project

The findings of the *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report*, USACE, dated June 2008 (documents include Main Report and 2 additional volumes with Appendices) were reviewed in Section 2.7 of this Report. While the USACE investigations and analyses were terminated in 2006 by direction of the NJDEP, the 2008 Report does present the basis for the selection of a National Economic Development (NED) Plan, identified as Alternative Plan D25, which would require further environmental and economic evaluation prior to selection as a recommended plan for design and construction if a decision is made to return to this Plan.

Alternative Plan D25 provided for a diversion channel from Dover to Rockaway Borough, channel modifications upstream of and through Denville to the Powerville area, and modification of the Powerville Dam. The benefit afforded to Denville under this Plan was that of a 2-year level of protection, with approximately 0.5 foot reduction in flood depths for the 2, 5 and 25-year floods and 0.2 foot reduction for the 100-year event. As indicated in Section 2.7.2, the Benefit/Cost (B/C) ratio for the channel modification portion of Alternative Plan D25 through Denville and downstream is estimated at approximately 0.48, which is significantly less than a minimum of 1.0 for Federal consideration of a Project.

The above B/C ratio is approximate only, based upon interpolation of data presented in the USACE 2008 Report. More detailed investigation may yield a refinement of costs and the B/C

ratio. However, based upon the characteristics of the Rockaway River through Denville and the fact that the USACE estimates did not include the cost of State required mitigation, which would be expected to be significant for channel modifications, it is doubtful that a channel modification project would be justified on a B/C ratio basis.

However, there are some elements presented in the 2008 Report that merit further consideration, including continued implementation of non-structural measures. Also it may be possible to utilize levees, berms and floodwalls at select locations and closure structures at major elevated roadways to provide flood protection to selected portions of the flood prone areas, where such measures can be practically and effectively implemented. For example, as indicated under Section 3.1 of this Report, levees, berms or some minor increase in elevation along natural drainage divides (e.g. near Gardner Road) may afford some protection against frequently recurring flood events.

The USACE 2008 Report did review concepts for upstream detention facilities that were previously found to have some benefits as documented in the 1990 Morris County study. However, the USACE screened out these measures due to lack of support from non-Federal interests, and in some cases considered not economically justified. Given the frequent recurrence of major flood damage in Denville and the fact that the USACE study was completed prior to Hurricane Irene and thus did not include the damages of Irene in the stage-damage frequency evaluation, perhaps re-evaluation would be in order. The Township should seek the assistance of Morris County in revisiting the 1990 regional study and reassessing the benefits and costs. Implementation of upstream detention could benefit not only Denville, but also other municipalities, depending upon the location of the facilities.

3.4 Projects from Morris County Multi-Jurisdictional Hazard Mitigation Plan

The *Morris County, New Jersey, Multi-Jurisdictional Hazard Mitigation Plan*, Third Final Draft – July 23, 2010, includes several Mitigation Actions for Denville in Section 9 of the document. A total of 14 items were listed as follows:

1. Backup power (generator) for Municipal Building

2. Building Code update (for seismic and wind)
3. Retention Basin Improvement for Den Brook #1
4. Retention Basin Improvement for Den Brook #2
5. Retention Basin Improvement for Den Brook #3
6. Feasibility study to install check valves (on) stormwater runoff system
7. Construct Den Brook protection berm
8. Risk assessment and analysis of Lake Estling Dam (for dam failure)
9. Remove silt (from) three areas on Rockaway River
10. Acquisition/elevation of nine severe repetitive loss properties on Riverside Drive, Snyder Avenue, and Woodland Avenue
11. Acquisition of six repetitive loss properties on Hinchman Drive
12. Acquisition of 29 repetitive loss properties on Riverside Drive
13. Acquisition/elevation of five repetitive loss properties on Snyder Avenue
14. Develop an all-hazards public education and outreach program for hazard mitigation and preparedness.

These mitigation actions should be updated based upon changes and refinements since July 2010. The identification of repetitive loss properties has been revised in 2012 as described in Section 2.5 of this Report. The low areas along the lower reach of Den Brook currently serve as natural detention areas when flooded by overflow from the stream. With consideration of the large drainage area and the effects of backwater from the Rockaway River, modification of these areas to provide additional flood storage is not likely to provide any significant additional benefits. Silt removal, stormwater check valves (tide gates) and construction of a berm near the lower end of Den Brook are addressed in other sections of this Report.

Items 1, 2, 8 and 14 deserve further review and consideration, if not already addressed by the Township.

4.0 Projects for Further Consideration

Based upon the review of the prior investigations as presented in Section 3 of this Report, the projects suggested for further consideration are listed below. For a more detailed description of the prior proposals and basis for recommended actions, see the corresponding portions of Section 3 of this Report. The suggested actions for each of the projects recommended for further consideration are presented below.

4.1 Recommendations Based Upon Review of Large Scale Projects from 1980 *Master Drainage Plan*

The list of Large Scale Projects included in the *Master Drainage Plan*, prepared by Elson T. Killam Associates, revised December 1980, is modified below to include only the projects recommended herein for further consideration. The project for the stormwater pump station in the parking lots at Bloomfield Avenue is also included below.

Table 4.1-1 Priority Evaluation of Large Scale Drainage Projects

Rank	Large Scale Projects	1980 Estimated Cost	Priority Points
L1	Peck Meadow Brook	$1,500,000	220
L2	Hinchman & Corey Road Area	300,000	205
L3	Woodland Avenue Area	215,000	180
L4	Sunset Bay Area	230,000	180
L9	NJ Foundation for Blind	340,000	125
	TOTAL LARGE SCALE PROJECTS (1980 est.)	**$2,585,000**	

Current costs for all projects would be significantly higher than the 1980 estimated project costs.

4.1.1 – L1 Peck Meadow Brook

Recommended actions to address flooding along the Peck Meadow Brook within the Township of Denville include the following:

1. Assess existing flooding impacts - With improved data available, a review should be made of the extent of flooding and an inventory of structures (including first floor elevations) within the flood plain should be prepared.
2. Evaluate alternatives - Alternatives for protection of the structures should be considered (including elevation of the structures and acquisition of repetitive loss properties).
3. Modify Cooks Road or Richwood Road culverts - Consideration should be given to raising the elevation of Cooks Road or Richwood Road (or both) and enlarging the culvert to provide at least one access route during high water conditions. Raising Cooks Road may be more practical then raising Richwood Road since there are few houses adjacent to the reach of Cooks Road that would need to be elevated.
4. Evaluation of detention effects of railroad culvert - If existing flooding upstream of the railroad does not adversely affect existing structures and is found to be acceptable, thus providing no justification for replacement of the railroad culvert, then consideration can be given to the limited capacity of the railroad culvert and the upstream storage and detention provided by the railroad restriction. Thus the Cooks Road and Richwood Road culverts could be sized appropriately based upon the limited flow conveyed through the railroad culvert. One or both roads would need to be elevated based upon the backwater elevation from the Rockaway River and Den Brook and the limited conveyance required for the flow in the brook.
5. Pump station with tide gate at Route I-80 - Consideration could also be given to installing back flow control devices (tide gates) on the two culverts under Route I-80, either with or without a pumping station, depending upon the timing and duration of the peak flows on the Rockaway River, Den Brook and Peck Meadow Brook. Tide gates provide very little resistance to flow out of the gate, but would prevent backwater from the Rockaway River from flowing back into the low areas along Peck Meadow Brook at times when the Rockaway River water level is high and there is little flow in Peck Meadow Brook.

4.1.2 L2 - Hinchman & Corey Road Area

Recommended actions to address flooding in the Hinchman Avenue and Cory Road Area include giving further consideration to the following:

1. Revise the plan for storm sewer improvements to split the systems at the natural ridge near Gardner Road. Drain the area south of Gardner Road to the Den Brook and the area north of Gardner road to the Rockaway River. (Differs from the split at Edgewood Road shown in the 1980 *Master Drainage Plan*).
2. Provide a pump station near the system discharge at Route 46.
3. Provide a tide gate at the storm sewer outlet at Route 46.
4. Separate the Hinchman Avenue & Corey Road storm sewer system from that serving Route 46 (to prevent having Route 46 stormwater back up in the Hinchman Avenue & Corey Road system).
5. Evaluate the need for tide gates at the storm sewer outlets at the Rockaway River.
6. Raise the elevation of the existing ridge along the alignment of Gardner Road, such as by raising the road elevation or constructing a low floodwall or berm along the rear of properties on the north side of Gardner Road.

4.1.3 L3 - Woodland Avenue Area

Recommended actions to address flooding in the Woodland Avenue Area (adjacent to Den Brook but also affected by the Rockaway River) include giving further consideration to the following:

1. Document the location and first floor elevation of structures in the area.
2. Compare the first floor elevations to the various flood elevations to estimate the potential recurrence of damages.
3. Determine the current surface elevations along Route 46 to determine the elevation of overflow from the Rockaway River, and associated recurrence frequency.
4. Update the proposed top elevation and length of the earth berm, associated storm sewer sizes and alignments, and estimated costs.
5. Estimate the costs of buyouts and elevation of impacted structures.

6. Compare relative levels of protection and the costs of the alternatives prior to selecting a plan for mitigation.

4.1.4 L4 - Sunset Bay Area

The following approach is suggested to address flooding in the Sunset Bay Area (local flooding complicated by long length of outfall storm sewer):

1. Determine which properties and structures (if any) experience frequent flooding and to what extent.
2. Delineate the area that would need to be served by a local pump station (may be in the range of 6 to 10 acres).
3. Estimate the cost of a small pump station, a tide gate to prevent backflow from the downstream system, and associated storm sewer improvements.

4.1.5 L9 - NJ Foundation for Blind

The following approach is suggested for further consideration to address flooding at the Foundation for Blind and nearby structures in the Rockaway River flood plain:

1. Confer with the Foundation to determine whether any changes have been made to reduce potential flood damages (such as flood proofing at the structure), and review the extent of damages sustained in recent flood events (including August 2011 Hurricane Irene). Evaluate the current need for the project.
2. Review the extent of the flood plain and elevations for the 100-year and NJ Flood Hazard Area flood on the site and adjacent properties. Compare to the elevation of the top of the existing berm at the site.
3. Determine (confirm) the first floor elevation of the Foundation structure and the low nearby houses. Compare the first floor elevations to the 100-year and NJFHA elevations.
4. Identify whether potential benefits are limited to the Foundation property or also pertain to nearby properties for the 100-year and NJFHA flood levels. Select a design level of protection.
5. Delineate the location of potentially impacted freshwater wetlands.

6. Revise and refine the limits of the levee to stay out of the delineated floodway, minimize impacts on wetlands, and minimize the drainage area tributary to the inside of the levee.
7. Update and revise as needed the proposed storm sewer system improvements required to minimize flow to the interior of the levee and prevent backflow from the river.
8. Evaluate the holding capacity of the on-site pond to contain the interior runoff during the period of high water levels in the river. Decide whether any pump facilities are needed.
9. Revise the levee alignment and design to minimize the fill volume and to provide appropriate freeboard or other protection from failure due to overtopping. Consider inclusion of a protected emergency overflow section. Determine the need for easements.
10. Update construction cost and project cost estimates. Determine permitting requirements and potential for approval. Evaluate viability of the project.

4.1.6 Bloomfield Avenue Area Pump Station

To address flooding of the parking lots between Bloomfield Avenue and Route 46 and adjacent areas, the following actions are recommended:

1. Provide a pump station near the storm sewer system discharge at Route 46.
2. Provide a tide gate at the storm sewer outlet at Route 46.
3. Separate the First Avenue storm sewer system from that serving Second Avenue (to prevent having Second Avenue stormwater back up in the First Avenue system).
4. Evaluate the need for tide gates at the storm sewer outlets for Second and Third Avenues at the Rockaway River.

4.2 Evaluation of Bridges and Other River Structures

Based upon the review of conditions along the Rockaway River from the Boonton Reservoir to and through the Township of Denville, only minimal benefits may be achieved in Denville through modification of the Powerville Dam and the bridge structures along the river. However, the benefits of modifying the bridges when they are scheduled for replacement due to structural problems or other issues should not be ignored. A comprehensive master plan should be developed for appropriate sizing of the bridge openings and setting road elevations to provide maximum benefits as the bridges are eventually replaced over time. This master plan for this

reach of the Rockaway River should be developed in coordination with Morris County and assistance from the USACE as may be available (see below). The following concepts and actions are recommended for further consideration and evaluation as part of the development of a long range program:

1. Modification of the Powerville Dam to reduce upstream backwater effects
2. Modification or replacement of the following structures:
    a. Bush Road Bridge – for emergency access purposes
    b. Pocono Road Bridge
    c. Diamond Spring Road Bridge
    d. Savage Road Bridge (not recommended for replacement)
3. The evaluation of the bridge modifications and replacements should include consideration of: hydraulic losses and potential benefits, individually and in combination; potential upstream effects during greater than the design storm that may be associated with raising the elevation of the bridges and approach roads; emergency access restrictions and needs under existing and proposed conditions.

4.3 Recommendations Based Upon Segments of the USACE Upper Rockaway River Report

The *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report,* USACE, dated June 2008 describes a selected plan based upon analyses completed up to the time the work was terminated in 2006 due to withdrawal of support of the local sponsor (NJDEP). No final recommendations were made. However, the 2008 Report documents that the selected plan would provide only a 2-year level of protection for Denville. Due to this low level of protection afforded, there are no elements of the USACE 2008 Report plan that would be cost effective for Denville to implement for local flood risk management.

However, there are some measures discussed in the 2008 Report that are worthy of further consideration. These include:

1. Non-structural measures (flood proofing, elevation, acquisition). The appropriate measure and cost-effectiveness would need to be determined on an individual structure basis.
2. Long range planning for improved hydraulic capacity at selected bridges and modification of the Powerville Dam when replacement or modification of these structures is planned for other reasons.
3. Stormwater detention in upstream areas. The USACE screening showed some potential benefits to upstream detention. If local objections can be overcome, detention may become a viable element of an overall flood risk reduction program consisting of a combination of measures.

In addition, Denville should initiate communications with the USACE regarding the potential for their further evaluation of the modification of the Powerville Dam, bridge replacements and upstream detention, or assistance and data they may provide to Denville and Morris County if a local evaluation is to be undertaken to develop an appropriate long range program.

4.4 Other Considerations and Actions

1. In the evaluation of the above recommended actions, it may be determined that it is impractical to achieve the original desired level of protection (e.g. 100-year) due to financial, environmental or other constraints. Consideration should be given to the concept of implementing segments (e.g. levee, pump station) of the considered improvements to provide a 25-year or 50-year level of protection where the benefits are reasonable in view of the associated costs.

2. The Township is already effectively utilizing the acquisition alternative to reduce the potential for future flood damage risk. This practice should continue where appropriate.

The remaining 53 identified repetitive loss properties (see Table 2.5-1 of this Report) should be evaluated and prioritized for acquisition or other appropriate action (e.g. flood proofing, elevation). Concept plans should be developed for preservation of acquired property including preservation of floodplains, excavation or regrading to provide increased flood storage volume, possible alignment of floodwalls or berms along the river, etc.

For structures which will remain in the floodplain, consideration should be given to implementing flood proofing measures (both wet and dry methods as applicable). Reference should be made to FEMA literature and technical guidance, which should be made readily available to the public through links on the Township web page and copies made available in the Township library.

3. The flood warning system resources available to the Township should be reviewed and utilized. FEMA, USGS and other agencies are continuing to provide additional resources, such as on line digital flood maps, weather alerts and flood depth mapping. While these specific resources are not currently available to the Township, it is anticipated that they will become available within a few years. Periodic communications with FEMA, the NJDEP and other agencies may provide information regarding the expected implementation of these resources for the Township.

4. Request Morris County to update the *Morris County Multi Jurisdictional Hazard Mitigation Plan* (July 2010), specifically with respect to actions along the Upper Rockaway River from Boonton Town through Denville to Dover.

5. Review and update the Denville Township Flood Hazard Area Ordinance. It should be consistent with FEMA requirements. Also, updating will be required when FEMA issues the new digital mapping to replace the prior paper maps.

6. Continue to promote stream cleaning efforts for removal of debris and targeted areas of sediment buildup. Bridge openings must be maintained. Removal of debris from the

channel helps reduce the risk of bridge openings becoming obstructed during a storm. For the same reason, fallen tree trunks and large branches should be removed from the floodplain adjacent to the river channel. Overbank flooding could carry these materials into the river and result in obstructions at bridges.

7. Remove in-channel obstructions to flow, particularly any structures that may catch debris and obstruct free flow of the river. This would include the remaining piers at the former Morris Canal crossing of the river. While the piers introduce little hydraulic loss if kept free of debris, they present a hazard in the river when debris accumulates and reduces the hydraulic capacity at that location.

8. In association with items 6 and 7 above, periodically undertake a visual survey of the river through the Township to document locations of significant sediment accumulation which could reduce hydraulic capacity of the channel, particularly at bridges. For critical locations that experience repetitive build up of sediment, consideration should be given to installing river vanes or other measures to inhibit sediment accumulation.

9. Stormwater management is usually looked upon as a measure to mitigate the impacts of new development or redevelopment. However, stormwater management measures can be implemented to mitigate the impacts of existing development. This is the approach taken by stormwater utilities, which commonly assess fees based upon the amount of impervious cover in a watershed and thus encourage property owners to reduce their effective impervious cover by implementing stormwater management measures. At present there is no legislation or regulation in New Jersey that requires owners of existing developed property to retrofit their sites to address stormwater impacts. However, a cooperative effort of municipalities in the watershed could have positive benefits. The municipalities could start by addressing the stormwater impacts of municipal lands, including school property. An effort of this type is being considered in the Rahway River Watershed.

10. To the extent requested by the Township and permitted by the authorized budget, HMM will assist the Township in implementing items under the Action Plan. Tasks within this scope might include meetings with the USACE, the NJDEP, or other agencies, updating project cost estimates, preparation of additional exhibits (e.g. showing flood damage areas, improvements to be considered further, C-1 Waters and associated 150-foot and 300-foot buffers, Riparian Zone limits), or other Action Plan items in accordance with Township needs.

4.5 Focus on Denville Center

As indicated in the USACE 2008 Report (see page 2.14 of this Report) the bulk of the reported flood damage in Denville is along the reach of the Rockaway River between the confluence with Den Brook and the I-80 crossing. This Denville Center area has suffered repetitive flood losses for decades. Several concepts for flood mitigation in this area were presented at the public meeting of January 29, 2013. Further evaluation and refinement of these concepts is recommended to address flooding issues in this area.

Images from the January 29, 2013 presentation are included for reference on the following pages. The basic concepts include the following:

1. Improve storm sewer outfalls to Den Brook by installing modern back flow prevention devices. These devices will reduce the potential for water from Den Brook to back up in the storm systems serving the Hinchman Avenue – Cory Road area and the Bloomfield Avenue area near First Avenue. The improvements would be designed to work in coordination with stormwater pump stations considered for these two outfall locations.
2. Consider installation of low flood walls with moveable flood gates across the road at key locations, such as at the Route 53 underpass at of Route 46 and at Route 46 near the mouth of Den Brook.
3. Raise the road elevation slightly along Gardner Road between Corey Road and Hinchman Avenue.
4. Evaluate the alternatives for flood proofing or elevating houses.

5. Remove the piers at the former crossing of the Morris Canal across the Rockaway River.

4.0 Projects for Further Consideration

Based upon the review of the prior investigations as presented in Section 3 of this Report, the projects suggested for further consideration are listed below. For a more detailed description of the prior proposals and basis for recommended actions, see the corresponding portions of Section 3 of this Report. The suggested actions for each of the projects recommended for further consideration are presented below.

4.1 Recommendations Based Upon Review of Large Scale Projects from 1980 *Master Drainage Plan*

The list of Large Scale Projects included in the *Master Drainage Plan*, prepared by Elson T. Killam Associates, revised December 1980, is modified below to include only the projects recommended herein for further consideration. The project for the stormwater pump station in the parking lots at Bloomfield Avenue is also included below.

Table 4.1-1 Priority Evaluation of Large Scale Drainage Projects

Rank	Large Scale Projects	1980 Estimated Cost	Priority Points
L1	Peck Meadow Brook	$1,500,000	220
L2	Hinchman & Corey Road Area	300,000	205
L3	Woodland Avenue Area	215,000	180
L4	Sunset Bay Area	230,000	180
L9	NJ Foundation for Blind	340,000	125
	TOTAL LARGE SCALE PROJECTS (1980 est.)	**$2,585,000**	

Current costs for all projects would be significantly higher than the 1980 estimated project costs.

4.1.1 – L1 Peck Meadow Brook

Recommended actions to address flooding along the Peck Meadow Brook within the Township of Denville include the following:

1. Assess existing flooding impacts - With improved data available, a review should be made of the extent of flooding and an inventory of structures (including first floor elevations) within the flood plain should be prepared.
2. Evaluate alternatives - Alternatives for protection of the structures should be considered (including elevation of the structures and acquisition of repetitive loss properties).
3. Modify Cooks Road or Richwood Road culverts - Consideration should be given to raising the elevation of Cooks Road or Richwood Road (or both) and enlarging the culvert to provide at least one access route during high water conditions. Raising Cooks Road may be more practical then raising Richwood Road since there are few houses adjacent to the reach of Cooks Road that would need to be elevated.
4. Evaluation of detention effects of railroad culvert - If existing flooding upstream of the railroad does not adversely affect existing structures and is found to be acceptable, thus providing no justification for replacement of the railroad culvert, then consideration can be given to the limited capacity of the railroad culvert and the upstream storage and detention provided by the railroad restriction. Thus the Cooks Road and Richwood Road culverts could be sized appropriately based upon the limited flow conveyed through the railroad culvert. One or both roads would need to be elevated based upon the backwater elevation from the Rockaway River and Den Brook and the limited conveyance required for the flow in the brook.
5. Pump station with tide gate at Route I-80 - Consideration could also be given to installing back flow control devices (tide gates) on the two culverts under Route I-80, either with or without a pumping station, depending upon the timing and duration of the peak flows on the Rockaway River, Den Brook and Peck Meadow Brook. Tide gates provide very little resistance to flow out of the gate, but would prevent backwater from the Rockaway River from flowing back into the low areas along Peck Meadow Brook at times when the Rockaway River water level is high and there is little flow in Peck Meadow Brook.

4.1.2 L2 - Hinchman & Corey Road Area

Recommended actions to address flooding in the Hinchman Avenue and Cory Road Area include giving further consideration to the following:

1. Revise the plan for storm sewer improvements to split the systems at the natural ridge near Gardner Road. Drain the area south of Gardner Road to the Den Brook and the area north of Gardner road to the Rockaway River. (Differs from the split at Edgewood Road shown in the 1980 *Master Drainage Plan*).
2. Provide a pump station near the system discharge at Route 46.
3. Provide a tide gate at the storm sewer outlet at Route 46.
4. Separate the Hinchman Avenue & Corey Road storm sewer system from that serving Route 46 (to prevent having Route 46 stormwater back up in the Hinchman Avenue & Corey Road system).
5. Evaluate the need for tide gates at the storm sewer outlets at the Rockaway River.
6. Raise the elevation of the existing ridge along the alignment of Gardner Road, such as by raising the road elevation or constructing a low floodwall or berm along the rear of properties on the north side of Gardner Road.

4.1.3 L3 - Woodland Avenue Area

Recommended actions to address flooding in the Woodland Avenue Area (adjacent to Den Brook but also affected by the Rockaway River) include giving further consideration to the following:

1. Document the location and first floor elevation of structures in the area.
2. Compare the first floor elevations to the various flood elevations to estimate the potential recurrence of damages.
3. Determine the current surface elevations along Route 46 to determine the elevation of overflow from the Rockaway River, and associated recurrence frequency.
4. Update the proposed top elevation and length of the earth berm, associated storm sewer sizes and alignments, and estimated costs.
5. Estimate the costs of buyouts and elevation of impacted structures.

6. Compare relative levels of protection and the costs of the alternatives prior to selecting a plan for mitigation.

4.1.4 L4 - Sunset Bay Area

The following approach is suggested to address flooding in the Sunset Bay Area (local flooding complicated by long length of outfall storm sewer):

1. Determine which properties and structures (if any) experience frequent flooding and to what extent.
2. Delineate the area that would need to be served by a local pump station (may be in the range of 6 to 10 acres).
3. Estimate the cost of a small pump station, a tide gate to prevent backflow from the downstream system, and associated storm sewer improvements.

4.1.5 L9 - NJ Foundation for Blind

The following approach is suggested for further consideration to address flooding at the Foundation for Blind and nearby structures in the Rockaway River flood plain:

1. Confer with the Foundation to determine whether any changes have been made to reduce potential flood damages (such as flood proofing at the structure), and review the extent of damages sustained in recent flood events (including August 2011 Hurricane Irene). Evaluate the current need for the project.
2. Review the extent of the flood plain and elevations for the 100-year and NJ Flood Hazard Area flood on the site and adjacent properties. Compare to the elevation of the top of the existing berm at the site.
3. Determine (confirm) the first floor elevation of the Foundation structure and the low nearby houses. Compare the first floor elevations to the 100-year and NJFHA elevations.
4. Identify whether potential benefits are limited to the Foundation property or also pertain to nearby properties for the 100-year and NJFHA flood levels. Select a design level of protection.
5. Delineate the location of potentially impacted freshwater wetlands.

6. Revise and refine the limits of the levee to stay out of the delineated floodway, minimize impacts on wetlands, and minimize the drainage area tributary to the inside of the levee.
7. Update and revise as needed the proposed storm sewer system improvements required to minimize flow to the interior of the levee and prevent backflow from the river.
8. Evaluate the holding capacity of the on-site pond to contain the interior runoff during the period of high water levels in the river. Decide whether any pump facilities are needed.
9. Revise the levee alignment and design to minimize the fill volume and to provide appropriate freeboard or other protection from failure due to overtopping. Consider inclusion of a protected emergency overflow section. Determine the need for easements.
10. Update construction cost and project cost estimates. Determine permitting requirements and potential for approval. Evaluate viability of the project.

4.1.6 Bloomfield Avenue Area Pump Station

To address flooding of the parking lots between Bloomfield Avenue and Route 46 and adjacent areas, the following actions are recommended:

1. Provide a pump station near the storm sewer system discharge at Route 46.
2. Provide a tide gate at the storm sewer outlet at Route 46.
3. Separate the First Avenue storm sewer system from that serving Second Avenue (to prevent having Second Avenue stormwater back up in the First Avenue system).
4. Evaluate the need for tide gates at the storm sewer outlets for Second and Third Avenues at the Rockaway River.

4.2 Evaluation of Bridges and Other River Structures

Based upon the review of conditions along the Rockaway River from the Boonton Reservoir to and through the Township of Denville, only minimal benefits may be achieved in Denville through modification of the Powerville Dam and the bridge structures along the river. However, the benefits of modifying the bridges when they are scheduled for replacement due to structural problems or other issues should not be ignored. A comprehensive master plan should be developed for appropriate sizing of the bridge openings and setting road elevations to provide maximum benefits as the bridges are eventually replaced over time. This master plan for this

reach of the Rockaway River should be developed in coordination with Morris County and assistance from the USACE as may be available (see below). The following concepts and actions are recommended for further consideration and evaluation as part of the development of a long range program:

1. Modification of the Powerville Dam to reduce upstream backwater effects
2. Modification or replacement of the following structures:
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    d. Savage Road Bridge (not recommended for replacement)
3. The evaluation of the bridge modifications and replacements should include consideration of: hydraulic losses and potential benefits, individually and in combination; potential upstream effects during greater than the design storm that may be associated with raising the elevation of the bridges and approach roads; emergency access restrictions and needs under existing and proposed conditions.

4.3 Recommendations Based Upon Segments of the USACE Upper Rockaway River Report

The *Upper Rockaway River, New Jersey, Flood Damage Reduction and Ecosystem Restoration, Alternative Plan Formulation Report,* USACE, dated June 2008 describes a selected plan based upon analyses completed up to the time the work was terminated in 2006 due to withdrawal of support of the local sponsor (NJDEP). No final recommendations were made. However, the 2008 Report documents that the selected plan would provide only a 2-year level of protection for Denville. Due to this low level of protection afforded, there are no elements of the USACE 2008 Report plan that would be cost effective for Denville to implement for local flood risk management.

However, there are some measures discussed in the 2008 Report that are worthy of further consideration. These include:

1. Non-structural measures (flood proofing, elevation, acquisition). The appropriate measure and cost-effectiveness would need to be determined on an individual structure basis.
2. Long range planning for improved hydraulic capacity at selected bridges and modification of the Powerville Dam when replacement or modification of these structures is planned for other reasons.
3. Stormwater detention in upstream areas. The USACE screening showed some potential benefits to upstream detention. If local objections can be overcome, detention may become a viable element of an overall flood risk reduction program consisting of a combination of measures.

In addition, Denville should initiate communications with the USACE regarding the potential for their further evaluation of the modification of the Powerville Dam, bridge replacements and upstream detention, or assistance and data they may provide to Denville and Morris County if a local evaluation is to be undertaken to develop an appropriate long range program.

4.4 Other Considerations and Actions

1. In the evaluation of the above recommended actions, it may be determined that it is impractical to achieve the original desired level of protection (e.g. 100-year) due to financial, environmental or other constraints. Consideration should be given to the concept of implementing segments (e.g. levee, pump station) of the considered improvements to provide a 25-year or 50-year level of protection where the benefits are reasonable in view of the associated costs.

2. The Township is already effectively utilizing the acquisition alternative to reduce the potential for future flood damage risk. This practice should continue where appropriate.

The remaining 53 identified repetitive loss properties (see Table 2.5-1 of this Report) should be evaluated and prioritized for acquisition or other appropriate action (e.g. flood proofing, elevation). Concept plans should be developed for preservation of acquired property including preservation of floodplains, excavation or regrading to provide increased flood storage volume, possible alignment of floodwalls or berms along the river, etc.

For structures which will remain in the floodplain, consideration should be given to implementing flood proofing measures (both wet and dry methods as applicable). Reference should be made to FEMA literature and technical guidance, which should be made readily available to the public through links on the Township web page and copies made available in the Township library.

3. The flood warning system resources available to the Township should be reviewed and utilized. FEMA, USGS and other agencies are continuing to provide additional resources, such as on line digital flood maps, weather alerts and flood depth mapping. While these specific resources are not currently available to the Township, it is anticipated that they will become available within a few years. Periodic communications with FEMA, the NJDEP and other agencies may provide information regarding the expected implementation of these resources for the Township.

4. Request Morris County to update the *Morris County Multi Jurisdictional Hazard Mitigation Plan* (July 2010), specifically with respect to actions along the Upper Rockaway River from Boonton Town through Denville to Dover.

5. Review and update the Denville Township Flood Hazard Area Ordinance. It should be consistent with FEMA requirements. Also, updating will be required when FEMA issues the new digital mapping to replace the prior paper maps.

6. Continue to promote stream cleaning efforts for removal of debris and targeted areas of sediment buildup. Bridge openings must be maintained. Removal of debris from the

channel helps reduce the risk of bridge openings becoming obstructed during a storm. For the same reason, fallen tree trunks and large branches should be removed from the floodplain adjacent to the river channel. Overbank flooding could carry these materials into the river and result in obstructions at bridges.

7. Remove in-channel obstructions to flow, particularly any structures that may catch debris and obstruct free flow of the river. This would include the remaining piers at the former Morris Canal crossing of the river. While the piers introduce little hydraulic loss if kept free of debris, they present a hazard in the river when debris accumulates and reduces the hydraulic capacity at that location.

8. In association with items 6 and 7 above, periodically undertake a visual survey of the river through the Township to document locations of significant sediment accumulation which could reduce hydraulic capacity of the channel, particularly at bridges. For critical locations that experience repetitive build up of sediment, consideration should be given to installing river vanes or other measures to inhibit sediment accumulation.

9. Stormwater management is usually looked upon as a measure to mitigate the impacts of new development or redevelopment. However, stormwater management measures can be implemented to mitigate the impacts of existing development. This is the approach taken by stormwater utilities, which commonly assess fees based upon the amount of impervious cover in a watershed and thus encourage property owners to reduce their effective impervious cover by implementing stormwater management measures. At present there is no legislation or regulation in New Jersey that requires owners of existing developed property to retrofit their sites to address stormwater impacts. However, a cooperative effort of municipalities in the watershed could have positive benefits. The municipalities could start by addressing the stormwater impacts of municipal lands, including school property. An effort of this type is being considered in the Rahway River Watershed.

10. To the extent requested by the Township and permitted by the authorized budget, HMM will assist the Township in implementing items under the Action Plan. Tasks within this scope might include meetings with the USACE, the NJDEP, or other agencies, updating project cost estimates, preparation of additional exhibits (e.g. showing flood damage areas, improvements to be considered further, C-1 Waters and associated 150-foot and 300-foot buffers, Riparian Zone limits), or other Action Plan items in accordance with Township needs.

4.5 Focus on Denville Center

As indicated in the USACE 2008 Report (see page 2.14 of this Report) the bulk of the reported flood damage in Denville is along the reach of the Rockaway River between the confluence with Den Brook and the I-80 crossing. This Denville Center area has suffered repetitive flood losses for decades. Several concepts for flood mitigation in this area were presented at the public meeting of January 29, 2013. Further evaluation and refinement of these concepts is recommended to address flooding issues in this area.

Images from the January 29, 2013 presentation are included for reference on the following pages. The basic concepts include the following:

1. Improve storm sewer outfalls to Den Brook by installing modern back flow prevention devices. These devices will reduce the potential for water from Den Brook to back up in the storm systems serving the Hinchman Avenue – Cory Road area and the Bloomfield Avenue area near First Avenue. The improvements would be designed to work in coordination with stormwater pump stations considered for these two outfall locations.
2. Consider installation of low flood walls with moveable flood gates across the road at key locations, such as at the Route 53 underpass at of Route 46 and at Route 46 near the mouth of Den Brook.
3. Raise the road elevation slightly along Gardner Road between Corey Road and Hinchman Avenue.
4. Evaluate the alternatives for flood proofing or elevating houses.

5. Remove the piers at the former crossing of the Morris Canal across the Rockaway River.

A.1 Reference Maps

This Report includes a set of 19 reference maps in this Appendix for ready reference. Copies of each map are available in larger size (24" x 36" sheets) for detailed review.

A.2 Color Maps

A set of 5 color maps depicts flood limits on aerial photographic background images. These 5 maps were developed by HMM utilizing the HEC-RAS hydraulic model of the Rockaway River as provided by the USACE.

The first map illustrates variations in the depth of flooding across the center of Denville for the 100-year flood event. The other 4 maps show the area of inundation for a range of storm events including the 10, 25, 50 and 100-year flood events. It is important to note that these 4 maps do not indicate the depth of inundation in the affected areas, but rather show the horizontal extent of inundation during the peak period of the indicated flood event. Each of these maps also shows the 100-year floodway limits.

Downtown Denville Flood Inundation Map,

1. *Flood Depth Map* – shows estimated 100-year event flood depths in 2-foot increments from 0 to 6 ft., and areas of 6 ft. or greater flood depth. Also shows the floodway limits. This map is useful for understanding the variations in flood depth across the area and for planning for flood mitigation measures. For example, flood proofing of residential structures may be practical where flood depths are less than 2 feet, elevation may be practical up to 6-foot depth areas, while acquisition may be appropriate in areas with 6-feet or more of flood depth, particularly within the floodway. The map is intended only as a guide and map elevation accuracy is plus or minus one foot. Actual elevations and conditions at each structure must be evaluated to make a final decision.

2. *10 Year Flood Event* – This map shows a distinction between areas flooded directly by overflow from the Rockaway River and those areas flooded by Den Brook during the 10-year flood event. Note the ridge at Gardner Road separating the two major inundation

sources. Taking advantage of this natural ridge would allow implementation of flood mitigation measures to afford some protection from frequent flooding in the Hinchman Avenue & Corey road Area. See Section 3.1.2 of the Report. The low area near Broadway is also affected primarily by backwater from Den Brook rather than overland flow from the Rockaway River during a 10-year event. This condition allows some flood relief to be implemented as described in Section 3.1.10 of this Report. Similarly, at Woodland Avenue some local protection can be achieved if the Rockaway River does not overflow the adjacent reach of Route 46 near the mouth of Den Brook. See Section 3.1.3 of this Report.

3. *25 Year Flood Event* – The 25-year inundation crosses the Gardner Road ridge and also crosses Broadway, Bloomfield Avenue and Route 46 near Woodland Avenue and at other locations, linking the inundation from the Rockaway River overflow with that from Den Brook. For floods of this magnitude provision for local flood relief becomes more difficult.

4. *50 Year Flood Event* – The inundation area increases in extent and depth for the 50-year flood event, shrinking the non-flooded area near the center of the map.

5. 100 Year Flood Event – The 100-year flood inundation area claims additional area in Denville, including most of Route 46 through the center of the Township.

A.3 NJDEP Flood Hazard Delineation Maps and Profiles

The State of New Jersey Department of Environmental Protection (NJDEP) has adopted a series of maps entitled, "Delineation of Floodway and Flood hazard Area" for the Rockaway River through Denville and for Tributary No.1 up through Rock Ridge Lake. The delineations of the floodway, 100-year flood limit and NJ flood hazard area limit are shown on background topographic maps developed from aerial photography from April 1978. Copies of relevant maps and of a profile of the Rockaway River from the Town of Boonton through Denville are included herein.