Phase I Report for the South River Drainage Project

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City of Salem, MA

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1. INTRODUCTION

1.1 PURPOSE

This report presents Woodard & Curran's findings and recommendations for the first phase of the South River Drainage Improvement Project. The purpose of the project is to develop a comprehensive long-term solution to prevent or reduce the severity of frequent flooding in the low lying areas of the South River Basin. Phase 1 represents the initial planning to understand;

- the general condition of the watershed,
- the frequency, magnitude and extent of flooding experienced in the past,
- the availability of information pertaining to the existing watershed and drainage infrastructure, and
- assessment of information required to proceed with development and assessment of potential mitigative measures.

Phase 1 concludes with a summary of potential flood mitigation measures to be considered for further evaluation as well as some recommendations that may be implemented in the short-term. Phase II of the project is envisioned to consist of conducting field surveys and studies to identify specific mitigation measures that should be implemented to achieve the project objectives. The implementation of the selected measures, including permitting, design and construction would be conducted in Phase III.

1.2 BACKGROUND

The low lying areas of the South River watershed have been plagued with flooding problems for nearly a century. Development resulting in increased runoff rates and volumes coupled with encroachment and loss of natural wetland storage areas have resulted in an existing stormwater infrastructure unable to handle runoff from the watershed. Runoff collects in the lower lying areas of the watershed where there is little elevation difference between the land and mean high water. During periods of high tide, the South River can not discharge to the ocean and there is insufficient storage below flood elevations to contain the flood waters. As a result, frequent flooding occurs, damaging private and public property as well as rendering roadways impassable, residential properties uninhabitable and businesses inoperable. In some instances the flooding persists for days.

1.3 STUDY AREA

The Study Area was defined through a series of meetings and discussions with the following stakeholders:

- Mayor's Staff
- City Engineer
- City Council members

In addition to these meetings, a community workshop was conducted to solicit input from homeowners and business owners on the frequency and extent of historical flooding to further refine the limits of the Study Area.

Based on these discussions, the Study Area was defined as the low lying areas of the South River watershed located downstream of the Boston and Maine Railroad, just east of the Highland Park/Golf Course, to the South River outfall into Salem Harbor at New Derby Street (See Figure 1). The area encompasses approximately 250 acres. The area is densely developed with residential uses along the southern end of Jefferson Avenue and western shores of Rosies Pond. Industrial and business uses dominate the northern end of Jefferson Avenue and Canal Street. Additional residential areas are located to the east of Canal Street. Salem State College is a major land owner in the southeasterly portion of the Study Area.

Three primary locations within the Study Area are most prone to frequent flooding. The following is a brief description of these areas. The location of these areas relative to the overall Study Area are shown in Figure 1.

- **Jefferson Avenue Neighborhood**

  The area along Jefferson Avenue between Laurent Street and Ocean Avenue West including Brooks Street is a low lying residential area. The most affected area comprises approximately 9 acres where house lot elevations are typically between Elev. 11 and 12, or only 2 to 3 feet above Mean High Water (Elev. 9.0). Flooding of this area is predominately caused by heavy rainfall events, many coinciding with periods of high tide in Salem Harbor. Flooding is further exacerbated during periods of high groundwater. The Jefferson Avenue neighborhood is served by a local flood protection works consisting of levees and a stormwater pumping station that were constructed in mid 1970's. These devices have not protected the area as a result of multiple breaches of the flood levees and stormwater pump station failures in recent years. A discussion of these protection works and recent failures is provided in subsequent sections of this report.

- **Canal Street**

  The portion of Canal Street between St. Paul Street and Forest Street has experienced flooding as a result of heavy rainfall events as well as during periods of astronomical high tides. Portions of Canal Street, in front of MacDonald's Restaurant and the Salem State College O'Keefe Parking Lot, are the lowest lying areas along Canal Street. Together these areas comprise approximately 10 acres of fully developed watershed. Canal Street elevations range between Elev. 9 and 12, at or near Mean High Water (Elev. 9). Flooding along Canal Street is predominately a result of surcharging of the area drainage systems from the limited difference in grades between these areas and the South River. According to business owners, these locations are reportedly flooded as frequently as once or twice a month with or without a rainfall event. Dry weather flooding coincides with astronomical high tides and large base flow in the South River.

- **Geneva Street**

  The portion of Geneva Street between Hancock Street and Roslyn Street has been subject to historic flooding. The drainage system serving this area is independent of the Canal Street drainage system. The system connects directly into the South River Conduit downstream of the system serving Canal Street. Nevertheless, the Geneva Street system is subject to the same surcharging conditions from the South River Conduit. The area affected by flooding is

approximately 2.5 acres. There is limited storm drainage and topographic data available for this area. Based on review of information provided by homeowners in the area, it is unclear if the flooding results from insufficient collection capacity, surcharging from the South River, or both.

It is interesting to note, although these areas have experienced frequent and persistent flooding they are not identified as lying in the 100-year floodplain according to the effective Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Map (FIRM). FEMA's Flood Insurance Rate Study (FIS) however indicates the 10-, 50-, and 100-year stillwater elevations for Salem Harbor are approximately 12.8, 13.7 and 14 respectively. These elevations indicate that these areas lie below storm surge elevations and that protection of these areas with tide gates is required.

The preceding sections of this report summarize Phase 1. Section 2.0 outlines the date collected and summarizes the approach taken to conduct the Phase 1 study. A detailed description of where the Study Area sits in the South River watershed and the major drainage infrastructure is provided in Section 3.0. Section 4.0 summarizes the flood control measures that have been implemented within the watershed and describes the results of recent flooding events in the Study Area. Woodard & Curran's findings and recommended approach to move forward with a comprehensive plan to mitigate future flooding is provided in Sections 5.0 and 6.0, respectively.

2. DATA COLLECTION AND REVIEW

Woodard & Curran reviewed a number of documents, conducted interviews with various stakeholders and made field observations of the South River watershed to document and understand;

- past flooding problems,
- previous efforts undertaken to address flooding issues, and
- the frequency and magnitude of flooding.

The finding and recommendations presented in this report are based on the review of the following documents, interviews, and observations made under Phase 1 of the project.

Documents Reviewed

- "Report on Flood Control for South River – Salem" by Camp, Dresser & McKee dated August 5, 1966.
- "Surface Flooding and Drainage Investigation Canal Street and Salem State College" by New England Civil Engineering Corp., dated May 2006.
- Letter from Northeast Massachusetts Mosquito Control and Wetlands Management District to the City of Salem, dated March 24, 2005.
- Memorandum to William Luster from Stanton W. Bigelow dated March 27, 1991 regarding "Condition of Tide Gates, South River Channel."
- Project plans entitled "Proposed Flood Control Pipe Conduit, Channels and Pump Station, South River" by Camp, Dresser & McKee dated November 1973.
- City of Salem topographic mapping entitled "Salem, Massachusetts Topographic and Planimetric Survey" by New England Survey Service, Inc., dated 1965.
- "City of Salem In-Progress Storm Water Drainage Map" by Woodard & Curran dated June 2004.
- Project Plans and relevant memorandums to "City of Salem, Massachusetts South River Flood Control Program Rosies Pond Drain" by Camp, Dresser & McKee dated August 5, 1966.
- City of Salem Department of Public Services map of stormwater and sanitary sewer mapping.
- Meteorological data from the following agencies:
    - National Weather Service
    - Northeast Regional Climate Center at Cornell University

- National Oceanographic and Atmospheric Administration's Regional Climate Centers and National Climatic Data Center

- "Flood Insurance Study, City of Salem, Massachusetts, Essex County" by the Federal Emergency Management Agency (FEMA) dated February 5,, 1985.

- "Flood Insurance Rate Map, City of Salem, Massachusetts, Essex County" by the Federal Emergency Management Agency (FEMA) dated August 5, 1985.

Public Outreach

In addition to the documents outlined above, Woodard & Curran conducted a number of interviews with public officials, past and present city employees, residents and business owners. Additional documentation was provided by various residents and business owners relative to recent flooding within the Study Area. Woodard & Curran participated in a community workshop on February 26, 2007, which was well attended by residents and business owners in the affected areas. The purpose of the workshop was to understand the flooding issues that have occurred in the past and ensure proper definition of the Study Area.

Field Observations

The document review and public outreach efforts were supplemented by conducting several field visits throughout December 2006 and January 2007 to document the overall conditions of the watershed and make first hand observations of the most flood-prone locations within the Study Area. This work included conducting observations of major hydraulic structures throughout the Study Area that were readily accessible.

Project Datum

All elevation herein are referenced to City of Salem, Massachusetts base.

3. SOUTH RIVER WATERSHED

An understanding of the South River hydrology and how the flood prone areas lie within the watershed is important to evaluate what mitigation opportunities may be available to address future flooding. The South River watershed drains approximately 1,370 acres of the west central portion of Salem. The watershed can generally be described as urbanized, with less densely developed areas located within the watersheds headwaters and nearly full built-out in the downstream portions of the watershed. The following is a brief description of the drainage area and major drainage facilities of the South River Basin watershed. For discussion purposes, the watershed have been divided into six subwatersheds based their context of contribution to flooding. Figure 2 depicts the boundary of the watershed, subwatershed boundaries and identifies the major drainage facilities located within the watershed.

Headwaters

The South River flows in southeasterly direction from the headwaters located northeast of Highland Avenue, in the Gallows Hill area, to the Boston & Maine Railroad. The upper reaches of the watershed are generally characterized by steep slopes and ledge outcrops. Development within the watershed above Highland Avenue is predominately residential in nature. Development along Highland Avenue is a mixture of residential, commercial and municipal uses (schools, hospitals, etc.). Below Highland Avenue, the watershed remains largely undeveloped through Highland Park and the golf course. The area is drained by a number of small streams 3- to 4-feet wide with low banks and several large wetland areas.

The South River is conveyed under the Boston and Maine Railroad through a 4.5-foot wide by 6-foot high culvert. The river flows approximately 1,000 feet in the southeast direction to the first Jefferson Avenue crossing. The river through this area has undergone to varying degrees, channelization resulting from development encroachment, although some of the natural floodplain exists in this reach of the river. The river crosses under Jefferson Avenue through three 54-inch diameter concrete culverts where the South River enters Rosies Pond.

Rosies Pond

Rosies Pond subcatchment receives runoff from densely developed residential areas along southerly end of Jefferson Avenue as well as from properties along Parallel, Adams, Kimball and Bertini Streets. Runoff from several industrial and business properties along the west side of Canal Street also contributes to Rosies Pond.

Flow from Rosies Pond is controlled by two drainage features, a low lying berm at the northeasterly end of the pond and the Rosies Pond Bypass. Stormwater is impounded in Rosies Pond by a low lying berm, reportedly constructed as an access drive for construction of a sewer pipeline, located immediately

upstream and to the south of the Boston and Maine Railroad. Flows, under low-flow conditions, are controlled by four 12-inch diameter culverts under the berm. Field observations made in this area indicate the berm and culverts are showing signs of settlement and erosion as well as sediment accumulation. During high-flow conditions, stormwater flows over the berm continue north downstream into the Jefferson Avenue neighborhood. Also during periods of high-flow a portion of the stormwater exiting Rosies Pond is conveyed through the Rosies Pond Bypass to the Forest River. Flow diverted to the Forest River through the bypass no longer contributes to flooding in the downstream reaches of the South River. The South River is conveyed from Rosies Pond under the Boston and Maine Railroad through a 12-foot arched culvert into the Jefferson Avenue area.

Jefferson Avenue Neighborhood

After passing under the Boston and Maine Railroad, the river is channelized through several residential backyards on the south side of Lawrence Street and crosses under Lawrence Street through a 3-foot wide by 8-foot high concrete culvert. The river continues to flow north through the rear yards of the residential properties between Brooks Street and Wheatland Street. A levee, part of the local flood protection works constructed in the mid 1970's, runs along the Brooks Street side of the river protecting the low lying residential areas along Brooks Street and Jefferson Avenue. The levee directs the river through a concrete floodwall channel to the second crossing under Jefferson Avenue consisting of a 10-foot wide by 4-foot high culvert.

The South River turns towards the east and runs parallel to Jefferson Avenue behind a number of residential properties to the intersection of the Dove Street with Jefferson Avenue. The flood control levee extends from the Jefferson Street flood wall to Dove Street. Runoff from the 9 acre area protected by the flood control levee is collected by a subsurface storm drainage system and conveyed to the Ocean Avenue West Pump Station. The pump station lifts the stormwater over the flood control levee and discharges into the South River behind the pump station at the west end of Ocean Avenue West. Runoff from upper portions of the watershed, including runoff from the hospital, high school and high school athletic fields contribute flows along this reach of the river. The river flows under the Dove Street through twin corrugated metal pipe arch culverts. The river again crosses Jefferson Avenue, approximately 200 feet downstream of Dove Street through three 48-inch diameter and one 54-inch diameter culverts where the river enters Mill Pond.

Mill Pond

The contributing drainage area to Mill Pond includes industrial properties located between Jefferson Avenue and the Boston & Maine Railroad as well as remaining portions of the upper watershed west of Jackson Street. Runoff the upper reaches is conveyed to Mill Pond via several storm drainage systems. Mill Pond meanders in a southeastern direction towards the Boston and Maine Railroad where it enters the South River Conduit.

South River Conduit

The South River Conduit conveys the river from Mill Pond, under Canal Street, northeast, Riley Plaza and New Derby Street, to Salem Harbor. The outfall is located through a sheet metal bulkhead located approximately 200 feet east of the intersection of Lafayette Street and New Derby Street. The South River Conduit consists of a number of miscellaneous and irregular constructions with expanding and contracting waterway areas, bends, old bridge and canal sections contributing to a reach with a high

resistance to flow and poor hydraulic efficiency. The South River conduit is protected from tidal fluctuations entering the structure through two tide gates located at the outfall. A detailed description of the construction type and size of the conduit is provided in the previously referenced report entitled "Report on Flood Control for South River – Salem" by Camp, Dresser & McKee dated August 5, 1966.

The South River Conduit drains an additional 266 acres located to the north and south of the Conduit. These tributary drainage areas consist of densely developed portion of downtown Salem. Runoff from these areas, including the Geneva Street portion of the Study Area, is collected by various storm drainage systems and discharged directly into the conduit a various locations along its length.

Canal Street

Two primary subsurface drainage systems collect and convey runoff from the southeastern portions of the watershed to the South River Conduit. Runoff from business and industries along Canal Street and the properties between Canal Street and the Boston and Maine Railroad is collected in storm drains in Canal Street. This drainage system runs along Canal Street and combines with a second subsurface drainage system that serves Salem State College's O'Keefe Parking Area and side roads entering Canal Street from the east. The systems combine in St. Paul Street were the flow enters the South River Conduit.

4. FLOOD HISTORY AND PREVIOUS MITIGATION MEASURES

The low lying areas of the South River watershed have been plagued with flooding problems for nearly a century. The first and only comprehensive flood study to address flooding in the South River watershed was conducted by the Commonwealth of Massachusetts Department of Public Works (Department) in August, 1966. The study included a detailed hydrologic and hydraulic evaluation of the South River watershed which resulted in the recommendation for the construction of several flood protection projects. The following summarizes the recommendations contained in the study as well as provides a discussion as to what degree the recommendations were implemented.

- Construction of a local flood protection works in the Jefferson Avenue neighborhood. A flood control levee and floodwall was constructed in the mid 1970's between the low lying residential areas of Brooks Street and Jefferson Avenue and the South River. This work also included increasing the hydraulic capacity of the Jefferson Avenue culvert. A stormwater pump station was constructed at the end of Ocean Avenue West to collect and pump stormwater from the areas behind the levee. Although these improvements were constructed, it is unclear from the available data if the levee and floodwalls were constructed to elevation 15 as designed.

- Replacement of the South River Conduit tide gates that were found to be leaking at the time. (The tide gates were subsequently replaced again in April 1999.)

- Construction of a 66-inch diameter bypass pipe and small dam in the upper reaches of the watershed. The purpose of the bypass was to divert runoff from Mill Pond to the upstream wetland area along the Boston and Maine Railroad to reduce peak discharges at downstream culverts and the proposed local flood protection works.

- Acquisition and/or protection of key existing wetland storage areas. Review of aerial photographs and maps dating back 40 years suggests additional encroachment in the South River floodplain has occurred.

The intent of the measures was to protect the Jefferson Avenue neighborhood from future flooding. The protection works were designed to adequately drain runoff from a 10-year storm event at the time of high tide (Elev. 9). The corresponding joint frequency of the design storm was estimated to occur once every 50-years. The study did not address flooding in the Canal Street or Geneva Street areas. However, these areas have benefited from the recommendations to replace the tide gates and limits placed on further encroachment into the floodplain.

Despite the installation of various flood control measures by the Department, the Study Area has experienced six major flooding events since 1996. These storms occurred on the following dates:

- October 19-22, 1996
- June 13-14, 1998
- March 22-23, 2001
- March 31 - April 1, 2004
- October 7-16, 2005
- May 12-15, 2006

During these events the portions of the Study Area were completely inundated rendering roadways impassable for days. Residential and business properties were flooded up to depths of approximately 5 feet, resulting damage to building foundations, loss of essential utilities, and loss of personal property (automobiles, clothing, appliances, etc.). In the most severely impacted areas, residences were rendered uninhabitable and businesses were forced to close for days and in some instances for weeks to affect repairs.

Following the October 19-22, 1996 storm event, the City undertook a number of steps in efforts to reduce the frequency and severity of flooding. The following is a brief description of these efforts.

- In October 1997, the City of Salem obtained funding from the Housing and Urban Development Disaster Recovery Program to fund four hazard mitigation projects. Three of the four projects were directed at reducing the frequency and severity of flooding along the South River. These projects included the following;
    - Replacement of the South River Tide Gates,
    - Repair of the Brooks Street and Jefferson Avenue flood levee that was damaged in the October 1996 storm
    - Construction of the Rosies Pond Bypass.

  Prior to implementation of these improvements the area experienced the June 13-14, 1998 storm event. During this event, the Ocean Street West pump station failed and additional damage to the Jefferson Avenue flood levee occurred. Repairs to the Brooks Street and Jefferson Avenue levee were completed in July, 1998 and the South River Tide Gates were replaced in April, 1999. The City of Salem also undertook a number of upgrades to the Ocean Avenue West Pump Station during this timeframe.

The Brooks Street levee was breached again during the March 22-23, 2001 storm event although the Ocean Avenue West Pump Station was functioning. The breach resulted in the pump station being inundated by floodwaters exceeding the pumps capacity. As a result Jefferson Avenue, Brooks Street and surrounding residential properties were flooded. The city followed the storm with emergency repairs to the levee.

- The Rosies Pond Bypass was constructed in June, 2001. The purpose of the bypass was to divert flows from Rosies Pond to the Forest River watershed. A flow diversion structure was constructed adjacent to the abandoned railroad bed along the eastern shore of Rosies Pond. The structure consists of a concrete box structure with adjustable weir and trash rack to prevent debris from clogging the diversion pipe. The diversion pipe runs approximately 3,000 feet south along the abandoned railroad bed to the Forest River tidal estuary. Tide gates were specified at the end of the diversion pipe to prevent high tides in the Forest River estuary from backing up through the diversion pipe and entering Rosies Pond.

- The watershed continued to experience damaging floods in April 2004, October 2005, and May 2006. The city undertook emergency measures to repair the flood levee that again breached. The city also sought and received an Order of Conditions (OOC) from the Salem Conservation Commission and Massachusetts Department of Environmental Protection (MADEP) to conduct additional repairs to the levee. The work included raising portions of the levee that had been damaged from the flood events. The OOC is currently under appeal with MADEP. As a result, these repairs have not been implemented.

- The City of Salem also requested assistance from the Northeast Massachusetts Mosquito Control and Wetlands Management District (NMMCWMD) for control of vegetation in the Forest River and South River wetlands basins. In April, 2005 the NMMCWMD issued the result of a field investigation and provided a proposal to conduct ditch maintenance and vegetation control to improve the hydraulic capacity and reduce mosquito breeding habitat along the South River and Forest Rivers. The investigation found numerous areas where sediment and debris adversely affects the flood carrying capacity of the river. In addition they found several areas along the river as well as in Mill and Rosies ponds where vegetation encroachment further restricts the capacity of the river and promotes mosquito breeding. The NMMCWMD is no longer allowed to undertake such maintenance activities without permits. As such the NMMCWMD's recommendations have not been implemented to date.

5. FINDINGS

Woodard & Curran has concluded the following based on review of the aforementioned documentation, site visits and public outreach conducted under Phase 1.

Hydraulic Capacity

Flooding within the South River watershed is the result of the existing storm drainage structures having inadequate capacity to convey runoff to Salem Harbor. A major contributor to the inadequate capacity is the limited difference in elevations of the affected areas and Mean High Tide. Previous studies concluded the South River Conduit's capacity varies from approximately 70 cubic feet per second (cfs) during mean tide to 3 cfs during high tide before flooding would occur in the Jefferson Avenue area. Since the Canal Street and Geneva Street areas lie at slightly lower elevations there is less capacity in the South River Conduit before flooding of these areas would occur. Peak runoff rates into the South River Conduit for a 10-year storm event were predicted in 1966 to be approximately 54 cfs. During periods of high tide the rate runoff from the watershed exceeds the capacity of the conduit and as a result floodwaters are stored temporarily in the floodplain until the tide recedes. There is insufficient volume in the floodplain below flood elevations. As a result floodwaters rise into the low lying portions of the Study Area during periods of heavy rain, particularly when the rain coincides with high tides in Salem Harbor.

Flood Susceptibility

In an effort to understand the magnitude of rainfalls events that contribute to flooding, Woodard & Curran obtained and reviewed meteorological data for the six most recent flood events and compared the results to historical rainfall data. The 24-hour daily rainfall totals for the six storm events were obtained for Beverly, Massachusetts (the closest location to the project site with a complete record of the six storm events) from the National Weather Service and the Northeast Regional Climate Center at Cornell University. These rainfall totals were compared to historical daily rainfall totals recorded for the month (at Newburyport, MA – closest location to the project site with comparable data) in which the storms occurred during a period record from 1893 to 2006 available through National Oceanographic and Atmospheric Administration's Regional Climate Centers and National Climatic Data Center. Table 1 summarizes the meteorological data collected for the project.

Table 1 - Meteorological Data

Date of Event	Total Storm Rainfall @ Beverly (inches)	Peak 24-hour Rainfall @ Beverly(inches)	Date of Peak 24-hour Rainfall Occurrence	Storms Monthly Historical Rank @ Newburyport
October 19-22, 1996	8.8	5.2	October 20,1996	1
June 13-14, 1998	6.0	4.4	June 13,1998	1
March 22-23, 2001	5.4	4.5	March 22,2001	1
March 31 - April 2, 2004	7.2	2.6	April 1, 2004	Not in Top 10
October 7-16, 2005	7.7	2.7	October 15, 2005	3
May 12-15, 2006	10.7	5.2	May 14, 2006	1 (5/15/06) and 2 (5/14/06)

Table 1 indicates the one-day rainfall totals for four of the six storms ranked the greatest recorded rainfall depth experienced in the region for the month in which the storm occurred in the 113-year period of record. The peak 24-hour rainfall depths for these storms ranged between 4.4 and 5.2 inches of rainfall. Although the peak 24-hour rainfall events for the March 31 – April 2, 2004 and October 7-16, 2005 events were not ranked as the greatest one-day rainfall, significant flooding occurred as a result of prolonged multi-day event that resulted in over 7 inches of rainfall. The May 12-15, 2006 storm event was significant since the greatest and second greatest rainfall totals occurred on successive days. Based on this data it appears that storm events contributing 3 inches or more of rainfall in a 24-hour period or events with less rainfall in a 24-hour period but followed extended durations of precipitation create major flooding in the Study Area.

The frequency and severity of flooding resulting from these storms indicate the existing flood protection works installed in the 1970s are not functioning as intended. The flood control levee protecting the Jefferson Avenue neighborhood has failed numerous times over the last eleven years. The failure is the result of the South River overtopping the earthen levee and eroding the berm. When the levee fails floodwaters inundate the Jefferson Avenue neighborhood since the Ocean Avenue West Pump Station does not have the capacity to remove the floodwaters resulting from the breach. The pump station appears to have sufficient has the capacity to remove runoff generated from catchments intended to serve. Based on these observations, it is unclear if the protection afford by the levee has decreased as a result of additional development within the headwaters of the watershed or if the top elevation of the levee is at the elevation originally specified.

Three of the six storm events evaluated as part of this study occurred following the construction of the Rosies Pond bypass. The capacity of the bypass, like the South River Conduit, is heavily influenced by tide levels in the Forest River. Speculation has been made that the bypass may not have been constructed properly. As-built plans for the bypass were not available to assess if the final construction deviated from the intended design. Furthermore, reports from various municipal employees have indicated the bypass structure may have been blocked with debris during one or several of these events. It is impossible to predict if the damage resulting from these storm events would have been greater had the bypass not been installed. However, it is reasonable to conclude that if there are construction deficiencies in the bypass or a tendency for clogging of the bypass the effectiveness of the bypass would be compromised.

Institutional Controls

Flooding within the South River watershed has been aggravated as the result of additional development pressures in the watershed. The 1966 flood study, identified that additional development in the headwaters would serve as a continued threat to flooding in the Study Area. A comparison of recent aerial photographs with historic mapping indicates additional development within the headwaters has occurred since 1966. Since none of the South River watershed is in a mapped flood zone by FEMA, the area does not benefit from the floodplain encroachment and peak discharge rate controls afforded under the National Flood Insurance Program or the Massachusetts Wetlands Protection Act (310 CMR 10.00). Nevertheless, these regulations do not place controls of peak volumes of runoff which also have the potential to contribute to downstream flooding.

Maintenance

Flooding is exacerbated by the overall condition of the South River and associated hydraulic structures. The Northeast Massachusetts Mosquito Control and Wetlands Management District (NMMCWMD) identified several locations along the South River where overgrown vegetation and sediment accumulation has thereby reducing the flood carrying capacity of the river and culverts. Field observations made by Woodard & Curran indicate the condition of the earthen berm and culverts controlling flows from Rosies Pond have deteriorated. Also, several reports indicate catch basins and pipes throughout the Study Area clogged with debris and sediment. Although, these conditions may contribute to flooding, restoration and increased maintenance on the existing infrastructure will have limited impact on the frequency and magnitude of flooding in the South River watershed.

6. RECOMMENDATIONS

A comprehensive watershed approach is recommended to eliminate or reduce the frequency and extent of future flooding within the Study Area. Woodard & Curran recommends the implementation of both the short-term and long-term measures. The short-term measures can be implemented within a one-to two-year time frame where as the long-term measures should be considered for further evaluation in Phase II of the project.

6.1 SHORT-TERM MEASURES

A number of short-term measures have been identified that should be implemented to minimize flood impacts to the Study Area. These measures focus on activities that can be implemented within one to two years, have nominal cost and focus on ensuring the existing infrastructure operates as efficiently as possible to minimize the risk of future flooding.

- **Institutional Controls**

  Institutional controls should be implemented in the South River Watershed to minimize flooding impacts that may result from future development within the watershed. These controls could take the form of a Floodplain Overlay District, implemented through ordinance or local by-laws, that would place strict stormwater and floodplain management performance standards on future development proposals within the district. The goal of the standards would be prohibit further encroachment into the floodplain, and limit both the rate and volume of runoff from future development proposals to pre-development conditions. In 2005 Woodard & Curran drafted a model Stormwater and Low Impact Development (LID) ordinance that applies to development and redevelopment activities in the City of Salem. Much of the performance standards outlined in the LID Ordinance were developed to achieve these objectives.

- **Operations and Maintenance Program**

  Commence an aggressive operations and maintenance program for the existing storm water drainage systems within the Study Area. The city storm drainage system consists of a number of siphons and pipes with little or no slope that by their nature are prone to clogging. Proper maintenance of the storm water drainage system will ensure the existing systems are working to their capacity thereby minimizing the flooding impacts. This program should include, but not be limited to, developing a routine schedule for conducting street sweeping, cleaning catch basins, and cleaning and inspection of pipes. Woodard & Curran has developed a GIS database of stormwater assets within the Study Area. This database should be used to maintain maintenance records and identify problematic areas that may require more frequent attention.

- **Inspection and Cleaning of the South River Conduit**

  A detailed inspection should be conducted of the South River Conduit. Based on discussions with present and former City staff, we are not aware of a detailed inspection of this major drainage system since 1966. The conduit should be inspected for overall condition, deposition of sediment and debris that would cause blockage or reduction in the hydraulic capacity of the conduit. This conduit serves as the backbone of the drainage system and blockage of this structure would have significant impact on flooding within the Study Area. During the inspection the tide gates should be inspected to ensure proper functioning. Debris and accumulated

sediment should be removed from the conduit to restore the flood carrying capacity of the conduit. Future inspections should be included in the above referenced Operations and Maintenance Program.

- **Rosies Pond Bypass Engineering Evaluation**

  An engineering investigation of the Rosies Pond Bypass should be conducted to evaluate if the bypass is functioning properly and if modifications to the existing system would improve the capacity of the bypass. The investigation should include the following;

  - An as-built survey to confirm the bypass was built as intended and identify deficiencies, if any.

  - A hydraulic evaluation to determine if the inlet configuration can be modified to improve performance. Improvements for consideration should be; lower the inlet elevation; increasing the size of the inlet, and changing the inlet configuration to be less prone to clogging.

- **Vegetation and Sediment Removal**

  The City, in conjunction with NMMCWMD, should commence the permitting process with the Conservation Commission, Massachusetts Department of Environmental Protection and US Army Corps of Engineers to remove the overgrown vegetation and accumulated sediment in the South River that was identified by The Northeast Massachusetts Mosquito Control and Wetlands Management District (NMMCWMD).

- **Temporary Repairs to the Brooks Street Levee**

  Temporary repairs to the Brooks Street levee should be conducted to restore the levee to pre-storm elevations. It is our understanding that this work was been permitted with the Salem Conservation Commission however the decision has been appealed to the MADEP. These repairs should be implemented following resolution of the appeal.

6.2 LONG-TERM MEASURES

New flood control measures must be implemented in the South River watershed to reduce the frequency and extents of flooding. The selection of appropriate measures needs to be determined through a detailed study of the overall watershed. The interaction of the existing storm drainage system with flood flows in the South River is complex and is further complicated by the tidal influences of Salem Harbor. As a result, implementation of a mitigation measure in one location may have an unintended consequence in another location within the watershed. Woodard & Curran recommends that Phase II of the South River Drainage Improvement Project include a detailed investigation and feasibility analysis of potential mitigative measures. The following is the recommended scope of work for Phase II.

1. Obtain topographic mapping of the Study Area. Presently no comprehensive mapping of the Study Area exists. The City obtained aerial photos suitable for one-inch equals forty-feet mapping in April of 2004. However, topographic mapping was not developed from these photos. A ground control survey should be conducted such that topographic mapping can be developed from the photos.

2. Supplement the above referenced mapping with a locational survey of major drainage features within the Study Area and at select locations within the watershed.

3. Develop detailed hydrologic and hydraulic models of the existing watershed to establish a baseline condition.

4. Conduct flow measurements at specific locations within the watershed to calibrate the above referenced models to ensure the models are predicting the watershed's response.

5. Evaluate the feasibility, benefits and costs of alternative mitigation measures. Alternative measures that should be considered, but not necessarily limited to, include:

    - Construct a stormwater pump station at the outfall of the South River Conduit.
    - Construct a stormwater pump station at the confluence of the drainage systems serving Canal Street and Salem State College O'Keefe parking lot drainage system and the South River Conduit.
    - Increase the capacity of the South River Conduit through construction of additional storm drainage conduit along the conduit alignment.
    - Construct a second Rosies Pond Bypass.
    - Raise the elevation and/or reinforce the flood levee in the Jefferson Avenue watershed.
    - Construct flood storage areas in the upper reaches of the watershed.
    - Purchase and demolish the most effected properties and place the properties in a floodplain conservation program. Flood-proof affected roadways.
    - Identify and remove hydraulic restrictions that may exist in the local storm drainage system in the Canal Street and Geneva Street areas.
    - Evaluate, and repair or remove, which ever is appropriate, the earthen berm and culvert outlet to Rosies Pond.
    - Raise the elevation of affected areas.

6. Develop a screening process to identify the appropriate mitigation measures or set of measures that should be implemented.

7. Develop a permitting and implementation schedule.

8. Identify potential funding mechanisms to implement the recommended mitigation measures. Mechanisms that should be considered include the following:

    - Development of a Stormwater Utility
    - State Revolving Funds (SRF)
    - Incorporation of some improvements with MHD's planned upgrade of Canal Street
    - Grants from the following sources:
        - MA office of Coastal Zone Management – Coastal Nonpoint Source Grant and Coastal Pollution Remediation Programs
        - MA Environmental Trust – General Grants
        - MA Executive Office of Environmental Affairs – Watershed Improvement Grants
        - MA Department of Environmental Protection (MADEP) - Section 319 Nonpoint Source Competitive Grants and Section 604B Water Quality Management Planning Programs
        - MADEP and Massachusetts Water Pollution Abatement trust – Clean Water State Revolving Fund (CWSRF)

The City of Salem received a State and Tribal Assistance Grant (STAG) in the amount of $178,044 from the United States Environmental Protection Agency (EPA). The City's cost share requirement for this grant is 45%. Based on initial discussions with the EPA, Woodard & Curran established the grant monies remain available and may be used to conduct Phase II of the South River Drainage Improvement Project.

Figure 1-1: Study Area