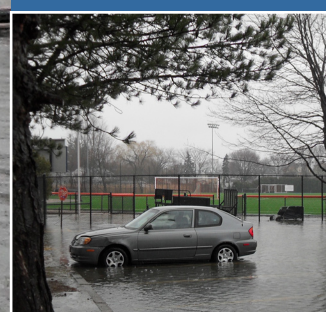
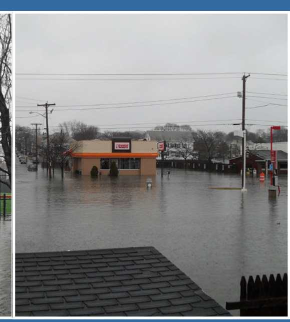
WOODARD & CURRAN

Phase II Report for the South River Drainage Improvement Project





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COMMITMENT & INTEGRITY DRIVE RESULTS

Project No: 218953.02

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TABLE OF CONTENTS

SECTION		PAGE NO.
Executive Summary		
1.	**INTRODUCTION**	**1-3**
1.1	Purpose	1-3
1.2	Background	1-3
1.3	Report Organization	1-3
2.	**EXISTING CONDITIONS DESCRIPTION**	**2-3**
2.1	Watershed Description	2-3
2.2	Study Area	2-3
3.	**BASELINE CONDITIONS DEVELOPMENT**	**3-3**
3.1	Approach	3-3
3.2	Model Development	3-3
3.2.1	Data Collection	3-3
3.2.2	Hydrologic Data	3-3
3.2.3	Hydraulic Data	3-3
3.3	Baseline Conditions Model	3-3
3.4	Meteorological Data	3-3
3.5	Results	3-3
4.	**ALTERNATIVES ANALYSIS**	**4-3**
4.1	Approach	4-3
4.2	Description and Findings	4-3
4.3	Findings & Recommendations	4-3
5.	**CANAL STREET/SALEM STATE UNIVERSITY IMPROVEMENTS**	**5-3**
5.1	Description of Improvements	5-3
5.2	Construction Costs	5-3
5.3	Regulatory Permitting Requirements	5-3
5.4	Easements	5-3
5.5	Recommended Studies	5-3
5.6	Summary & Implementation Plan	5-3
6.	**ROSIES POND/BROOKS STREET/JEFFERSON AVENUE AREA IMPROVEMENTS**	**6-3**
6.1	Description of Improvements	6-3
6.2	Construction Costs	6-3
6.3	Regulatory Permitting Requirements	6-3
6.4	Easements	6-3
6.5	Recommended Studies	6-3
6.6	Summary & Implementation Plan	6-3

LIST OF TABLES

TABLE	PAGE NO.
Table 3-1 – 24-hour Precipitation Depths	3-3
Table 3-2 – Tidal Conditions	3-3
Table 3-3 – Subwatershed Hydrologic Input Parameters	3-3
Table 3-4 – Meteorological Data from NWS & NRCC	3-3
Table 3-5 – Meteorological Data from Most Recent Significant Events	3-3
Table 3-6 – Baseline Conditions Results – Peak Flow Rates (cfs)	3-3
Table 3-7 – Baseline Conditions Results – Peak Water Surface Elevations (feet)	3-3
Table 5-1 – Pump Station Flow Rates vs. Storage Volumes (100-year Rainfall Event)	5-3
Table 5-2 – Summary of Estimated Construction Costs	5-3
Table 5-3 – Implementation Plan	5-3
Table 6-1 – Summary of Retaining Wall/Earthen Berm Improvements	6-3
Table 6-2 – Summary of Estimated Costs	6-3
Table 6-3 – Implementation Plan (Projects Not Eligible for FEMA Funding)	6-3
Table 6-4 – Implementation Plan (Projects Eligible for FEMA Funding)	6-3

LIST OF FIGURES

FIGURE	
Figure 1:	USGS Map
Figure 2:	South River Watershed
Figure 3:	Land Uses
Figure 4:	Soils
Figure 5:	Existing Peak Water Surface Elevations – Golf Course
Figure 6:	Existing Peak Water Surface Elevations – Rosies Pond
Figure 7:	Existing Peak Water Surface Elevations – Jefferson Ave. Area & Mill Pond
Figure 8:	Existing Peak Water Surface Elevations – Canal Street and Salem State Area
Figure 9:	Canal Street/Salem State University Improvements – Upper Watershed
Figure 10:	Canal Street/Salem State University Improvements – Lower Watershed
Figure 11:	Jefferson Avenue/Brooks Street Area Improvements
Figure 12:	Rosies Pond Area Improvements

APPENDICES

Appendix A: Cleaning & Inspection Program

Appendix B: Alternatives Analysis Results

Appendix C: Cost Estimate for Canal Street/Salem State University Area Improvements

Appendix D: Cost Estimate for Rosies Pond/Brooks Street/Jefferson AVenue Area Improvements

EXECUTIVE SUMMARY

Woodard & Curran was engaged by the City of Salem, Massachusetts to perform Phase II 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 watershed.

The low-lying areas of the South River watershed have been plagued with flooding problems for nearly a century. Runoff collects in these areas where there is little elevation difference between the ground surface and mean high water. During periods of high tide, the South River cannot discharge to the ocean, and there is insufficient storage below flood elevations to contain the floodwaters. In addition, increased development and floodplain encroachment have decreased the area of natural wetland storage and the capacity of the existing stormwater infrastructure to collect and convey runoff. As a result of these factors, frequent flooding occurs, damaging private and public property as well as rendering roadways impassable, residential properties uninhabitable, and businesses inoperable. In some instances, flooding persists for days.

The low-lying areas of South River watershed generally fall downstream of the MBTA railroad, just east of the Highland Park/Golf Course, and extend on through the outfall of South River Conduit into Salem Harbor at New Derby Street. There are three locations that are most prone to frequent flooding: the Rosies Pond/Brooks Street/Jefferson Avenue area, the Canal Street/Salem State University area, and Geneva Street. These areas are densely developed with residential uses along the southern end of Jefferson Avenue and the western shores of Rosies Pond and with industrial and business uses along the northern end of Jefferson Avenue and Canal Street. Additional residential areas are located to the east of Canal Street. Salem State University is a major land owner in the southeasterly portion of Canal Street.

The project is currently being conducted in three phases. Phase I of the project, which was completed in 2007, focused on understanding the general condition of the watershed and its flooding history. Phase II, which is outlined in this report, focused on identifying specific mitigation measures that can be implemented to prevent or reduce the severity of frequent flooding in the low-lying areas. The implementation of the recommended measures, including permitting, design and construction will be conducted as a future Phase III.

Phase II was conducted in the following stages in an effort 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 watershed:

- conducting field surveys and studies throughout the watershed;
- implementing interim measures such as removing sediment and debris from the existing stormwater drainage infrastructure and developing a rehabilitation plan to identify and improve drainage infrastructure in need of repair;
- developing a baseline conditions hydrologic/hydraulic model of the watershed to understand the existing hydrologic condition of the watershed and the hydraulic performance of the South River; and
- identifying specific mitigation measures that should be implemented to achieve the project objectives.

These efforts demonstrated that the Rosies Pond/Brooks Street/Jefferson Avenue and Canal Street/Salem State University areas must each be physically separated from interaction with the tide in order to reduce the frequency and extent of flooding within each of these areas. This finding was based on the following:

- both areas were found to be heavily influenced by tidal conditions, especially during significant rainfall events;
- improvements directed at solely altering the rate and volume of runoff through South River were not found to be independently effective since they did not protect from the tide; and
- flood mitigation measures in one area generally had little or no benefit to the other area due to the influence of the tide.

It was also predicted that flooding along Geneva Street is independent of the hydraulic conditions along South River. Flooding within this area was found to be a result of the existing drainage system within the area having limited capacity to collect and convey runoff.

As a result of these findings, the following improvements are recommended for the flood prone areas.

Canal Street/Salem State University Area

Woodard & Curran recommends constructing a pump station and enlarging the existing stormwater collection and conveyance system within the Canal Street/Salem State University area. These measures are recommended to protect the area from flooding for up to the 100-year rainfall event. The pump station is recommended to eliminate backwater conditions from South River that are due to high tide. Improvements to the existing drainage system would be necessary to realize the full benefit of the pump station since the existing system is undersized to handle runoff from a 100-year rainfall event. It is estimated that the costs associated with these improvements is between $11,700,000 and $16,300,000.

Rosies Pond/Brooks Street/Jefferson Avenue Area

Woodard & Curran recommends raising existing earthen berms and constructing additional retaining walls and/or berms within the Rosies Pond/Brooks Street/Jefferson Avenue area. Overall, these recommendations propose to raise the level of flood protection provided by existing measures (constructed in the 1970s) from a ~10-year event to a 100-year event. Protection is provided by minimizing floodwater encroachment from South River during the 100-year event. In addition, improvements identified in the Ocean Avenue West Pump Station Assessment (performed in 2009) are also recommended for implementation. The improvements identified in this Assessment consider flooding issues that are independent of floodwater encroachment from South River, and are directed at addressing potential localized flooding. It is estimated that the costs associated with these improvements is between $2,910,000 and $3,210,000.

Geneva Street

Woodard & Curran recommends flooding along Geneva Street be addressed independently of flood mitigation improvements along South River. The City of Salem is currently undertaking an extensive catch basin cleaning program that may reduce the frequency and magnitude of flooding along Geneva Street. It is recommended that the City evaluate the effectiveness of this program prior to evaluating physical alterations to the exiting drainage system that are directed at increasing the collection and conveyance capacity of the system.

1. INTRODUCTION

1.1 PURPOSE

Woodard & Curran has completed Phase II 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 watershed.

Phase I of the project focused on understanding the general condition of the watershed and its flooding history, compiling readily available information pertaining to the watershed and its drainage infrastructure, and identifying the information required to develop and assess potential flood mitigation measures in subsequent phases of the project.

Phase II of the project, which is outlined in this report, focuses on the following:

- conducting field surveys and studies throughout the watershed;
- implementing interim measures such as removing sediment and debris from the existing stormwater drainage infrastructure;
- developing a baseline conditions hydrologic/hydraulic model of the watershed to understand the existing hydrologic condition of the watershed and the hydraulic performance of the South River; and
- identifying specific mitigation measures that should be implemented to achieve the project objectives.

This report summarizes the results of Phase II and concludes with a recommended approach for long-term flood protection and the anticipated construction costs, scheduling requirements, regulatory permitting, easements, and additional study/engineering efforts required to implement the recommended measures. The implementation of the recommended measures, including permitting, design and construction will be conducted as a future Phase III of the project.

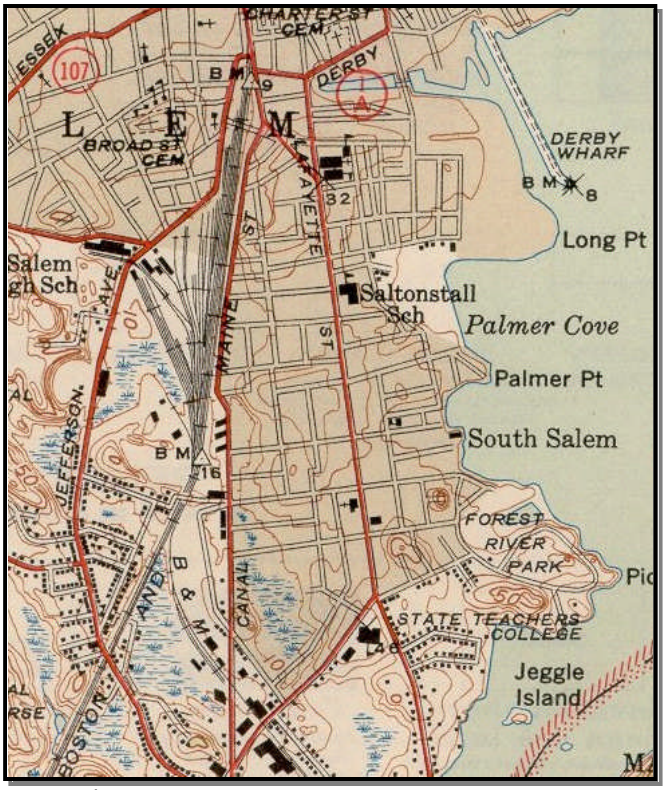
1.2 BACKGROUND

The low lying areas of the South River watershed have been plagued with flooding problems for nearly a century. Increased runoff volumes and rates resulting from development and floodplain encroachment have decreased the area of natural wetland storage and the capacity of the existing stormwater infrastructure to collect and convey runoff. Exerts from USGS maps dated 1893 and 1944 are provided in this section to illustrate the progression of development and floodplain encroachment within low lying areas of the South River watershed. The exerts demonstrate significant floodplain encroachment between 1893 and 1944 in the low lying areas of the watershed, and the most recent USGS map

**Exert from USGS Map dated 1893.*

(found in Figure 1) illustrates that the natural wetland area has almost been completely depleted. These factors have contributed to the flooding problems experienced today throughout the South River watershed.

Runoff currently collects in the lower lying areas of the watershed where there is little elevation difference between the ground surface and mean high water. During periods of high tide, the South River cannot discharge to the ocean, and there is insufficient storage below flood elevations to contain the floodwaters. 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, flooding persists for days.



*Exert from USGS Map dated 1944.

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. Despite the installation of various flood control measures by the Department over the past decades, the South River watershed has experienced six major flooding events since 1996. As a result, the City has identified the need to develop a comprehensive long-term solution to prevent or reduce the severity of frequent flooding in the low lying areas of the watershed.

1.3 REPORT ORGANIZATION

This report for Phase II of the South River Drainage Improvement Project provides the following:

- a description of the South River watershed,
- a description of flood prone areas, or the Study Area, within the watershed,
- an outline of the data collection activities conducted,
- an overview of the baseline conditions hydrologic/hydraulic model,
- a discussion of the alternative analysis performed to identify the approach for long-term flood protection within the watershed, and
- a discussion of the recommended alternatives for flood prone areas in the watershed.

The report is organized as follows:

- Section 2 of the report outlines the existing condition of the South River watershed, the Study Area, and a brief history of flooding issues within the watershed.

- Section 3 discusses the development of the baseline conditions hydrologic/hydraulic model and provides the results of the baseline conditions analysis.

- Section 4 the methodology used to evaluate the performance of various opportunities for long-term flood protection with in the watershed is discussed.

- Sections 5 and 6 identify and discuss the recommended alternatives for flood prone areas in the watershed. Specifically, Section 5 discusses recommended alternatives for the Canal Street and Salem State University areas, and Section 6 discusses recommended alternatives for Rosies Pond/Brooks Street/Jefferson Avenue areas.

2. EXISTING CONDITIONS DESCRIPTION

An understanding of the South River hydrology and the relation between flood prone areas and the overall watershed is important to identify potential flood mitigation measures. This section of the report provides a description of the South River watershed along with a description of flood prone areas, or the Study Area, within the watershed.

2.1 WATERSHED DESCRIPTION

The South River watershed drains approximately 1,400 acres of the west-central portion of Salem. The watershed can generally be described as urbanized, with less densely developed areas located within the watershed headwaters and nearly fully built-out in downstream portions. The following descriptions outline areas of the watershed and its major drainage facilities. Figure 2 depicts the overall boundary of the South River watershed and the 45 subwatershed boundaries that have been identified for this study. Figure 2 also identifies 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-foot wide by 6-foot high culvert. The river flows approximately 1,000 feet in the southeast direction to the first crossing of Jefferson Avenue and South River. 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 one 54-inch and two 48-inch diameter concrete culverts where the South River enters Rosies Pond.

Rosies Pond

Rosies Pond subwatershed 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 northwesterly 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 two 24-inch and two 15-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. Rosies Pond Bypass was constructed in the early 2000's as a means to reduce the volume and flow rate of stormwater through downstream flood prone areas of the watershed. 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 neighborhood.

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 7.5-foot wide by 5-foot high concrete culvert. The river continues to flow north through the rear yards of the residential properties between Brooks Street and Wheatland Street. An earthen berm, 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 earthen berm 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 earthen berm extends from the Jefferson Street flood wall to Dove Street. Runoff from the 9-acre area protected by the earthen berm 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 earthen berm and discharges it into the South River behind the pump station at the west end of Ocean Avenue West. Runoff from upper portions of the watershed, including some runoff from the hospital, high school and high school athletic fields contribute runoff 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 two 48-inch, one 54-inch, and one 66-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 south 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 to 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. 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 east and west 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 (discussed in the following section of this report), is collected by various storm drainage systems and discharged directly into the conduit at various locations along its length. Runoff from approximately 165.8 of the 266 acres enters South River Conduit through siphons under the MBTA railroad.

Canal Street/Salem State University

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 discharges into the South River Conduit in the St. Paul Street area.

A second subsurface drainage system serves Salem State University's O'Keefe Center Parking Area and side roads entering Canal Street from the east. This drainage system also enters the South River Conduit in the St. Paul Street area.

2.2 STUDY AREA

The Study Area comprises flood prone areas within the South River watershed. The Study Area was defined in Phase I through a series of meetings and discussions with the Mayor's Staff, City Engineer, Department of Public Works, Conservation Commission, and 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 MBTA railroad, just east of the Highland Park/Golf Course, to the South River outfall into Salem Harbor at New Derby Street. 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 University 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.

Rosies Pond/Brooks Street/Jefferson Avenue Area

The Rosies Pond/Brooks Street/Jefferson Avenue area commences along the eastern perimeter of Rosies Pond and continues along a portion of South River that lies between the Massachusetts Bay Transit Authority (MBTA) railroad and Lawrence Avenue. The area then extends downstream between Wheatland Street and Brooks Street. The final reach of the area lies along an area west of Jefferson Avenue, between Dove Avenue and Laurent Street. The area falls within the following subwatersheds of South River Watershed, as illustrated on Figure 2: 5, 6, 7, 9, and 10. Roads within the area include, but are not limited to: Parallel Street, Lawrence Avenue, Brooks Street, Jefferson Avenue, and Dove Avenue.

During significant rainfall events, residential properties along Rosies Pond are often inundated with runoff from upstream reaches. Flooding is further exacerbated during periods of high groundwater. When the water surface elevation within Rosies Pond exceeds Elev. 13, residential structures along the eastern perimeter begin to experience some degree of flooding. During the 100-year rainfall event, it is estimated that approximately two acres of residential property and seven residential structures experience some level of flooding. Currently, there is no protection against flooding along this portion of Rosies Pond.

The area that lies between the MBTA railroad and Lawrence Avenue is also subject to frequent flooding. When the water surface elevation in South River through this area exceeds Elev. 13, residential structures adjacent to the South River begin to experience some degree of flooding. Flooding is further exacerbated during periods of high groundwater. During the 100-year rainfall event, it is estimated that 0.5 acres of residential property and three residential structures experience some level of flooding. Currently, there is no protection against flooding along this portion of the Project Area.

The remaining portion of the area, which runs along Jefferson Avenue and Brooks Street, is often subject to backwater conditions when the South River Conduit reaches capacity. Capacity is generally exceeded during significant rainfall events and periods of high tide. Currently, this area contains a series of earthen berms that lie along the banks of South River. The earthen berms were constructed to protect approximately 10 acres of mostly residential property against backwater conditions. When stormwater from South River Conduit backups to an elevation greater than that of the earthen berms (Elev. 12.5-13.3), the earthen berms overtop causing flooding to adjacent residential properties. When the berms overtop, the stormwater pump station that services the area becomes inundated, causing the pump station to fail. Flooding is further exacerbated during periods of high groundwater.

Canal Street/Salem State University Area

The Canal Street/Salem State University area has been defined as the watershed that currently contributes stormwater to the existing stormwater drainage infrastructure along Canal Street, between St. Paul Street and Forest Street, and through the Salem State University O'Keefe Center parking area. These systems collect runoff from commercial, industrial, and residential properties and throughout the area and convey it to the South River Conduit. Collectively, the two drainage systems collect runoff from approximately 85 acres of fully developed watershed.

The area falls within the following subwatersheds of South River Watershed, as illustrated on Figure 2: 12A, 12B, 16S, 15S, 14S, 13S, 12S, 11S, 10S, 9S, 8S, 17S, 19S, 20S, 9S, and 5S. Roads within the Project Area include, but not limited to, portions of the following: Canal Street, St. Paul Street, Laurel Street, Meadow Street, Ocean Avenue, Hersey Street, Forest Avenue, Day Avenue, Charles Street, Pacific Street, Broadway, Hazel Street, Linden Street, Wisteria Street, and Lussier Street.

The area has experienced flooding as a result of heavy rainfall events as well as during periods of high tides. The portion of Canal Street in front of the McDonald's Restaurant, and the Salem State University O'Keefe Center parking area, are the lowest lying within the area. Flooding within the Project Area is predominately due to surcharging from low-lying catch basins. According to business owners, low-lying catch basins are reportedly flooded as frequently as once or twice a month with or without a rainfall event (note: dry weather flooding occurs when high tide coincides with large base flow). The lowest lying catch basins, and thus the catch basins that experience the most surcharge, are located in front of 150 Canal Street (McDonald's Restaurant) and in the Salem State University (formerly Salem State College) O'Keefe Parking Lot. These elevations have been identified as Elev. 8.9 and Elev. 8.0 (per City of Salem base), respectively, and fall below Mean High Water (Elev. 9.2). The remaining catch basins within the Project area generally fall between Elev. 9 and 12, which are near or at Mean High Water.

The area is the lowest lying within the South River Watershed. The drainage systems servicing the area convey runoff to the South River Conduit, which also services the remainder of the 1,400-acre South River Watershed. Given these factors, the area is often subject to backwater conditions when the South River Conduit reaches capacity or is subject to high tide conditions. In addition, drainage systems in the area do not have the capacity to convey runoff during significant rainfall events, which further exacerbates flooding within the area. Capacity is limited as a result of undersized infrastructure and limited elevation differential along the infrastructure.

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.

3. BASELINE CONDITIONS DEVELOPMENT

A detailed hydrologic and hydraulic analysis of the South River watershed was conducted to evaluate the present hydrologic condition of the watershed and to serve as the basis to evaluate potential mitigation measures to reduce the frequency and extent of flooding within the Study Area. This section of the report discusses the development of the baseline conditions hydrologic/hydraulic model and provides the results of the baseline conditions analysis.

3.1 APPROACH

A baseline conditions hydrologic/hydraulic model of the South River watershed was developed to estimate the peak rate and volume of runoff from the subwatersheds and the peak water surface elevations through South River. Representations of existing hydrologic/hydraulic features within the watershed were incorporated into the model to accurately predict these values. SewerGEMs® V8i modeling software, Copyright 2010 Bentley Systems Incorporated, was utilized to develop the model. The following discusses the hydrologic and hydraulic methodologies implemented to estimate the peak rate and volume of runoff from the South River subwatersheds and the peak water surface elevations through South River.

Hydrologic Methodology

The hydrologic methodology applied in the analysis followed methods developed by the Soil Conservation Services (SCS) for estimating runoff from small urban watersheds. The volume of runoff generated by a subwatershed is determined primarily by the infiltration characteristics and moisture of the subwatershed's underlying soil, the type of surface cover and retention characteristics, the antecedent rainfall, and the amount of precipitation. The rate of runoff is primarily determined by the travel time, or the time at which all points in the subwatershed contribute runoff. The travel time is determined by the slope, length of flow path, depth of flow, and roughness along the flow path. The peak rate of runoff is based on the relationship of these parameters, the total subwatershed area, and time distribution of precipitation during a given rainfall event.

Data used to develop the baseline conditions hydrologic model include the rainfall data and the land uses, soil types, time of concentrations values, and topography of the 45 subwatersheds. Descriptions of this data and an illustration of the 45 watersheds are provided in Section 3.2.2 and Figure 2, respectively.

Hydraulic Methodology

Water surface elevations through a conveyance structure, such as a closed conduit or open channel, are determined primarily by the flow rate through the structure, its slope, geometry, and roughness characteristics. The boundary condition at the downstream end of the conveyance feature also effects the water surface elevation in the structure.

Input parameters used to develop the baseline conditions hydraulic model include invert elevations, structure geometry, roughness parameters, and the tidal conditions at the outfalls of the conveyance structures. Descriptions of these parameters are included in Section 3.2.3.

3.2 MODEL DEVELOPMENT

The baseline conditions model was developed to reflect the existing condition of the South River watershed. The proceeding sections discuss the data that was collected to develop the model and the parameters that were used.

3.2.1 Data Collection

Information pertaining to the watershed, South River, and drainage infrastructure was obtained from a series of documents that were reviewed or developed for the project. Documents included design plans, record drawings, reports for flood studies previously performed within the watershed, and existing conditions surveys. Documents were supplemented with inspection videos, flow metering, and observations made during site visits. The following provides an overview of the documents reviewed and field observations performed for 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 University” 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 February 2001.
- “Salem State University O’Keefe Athletic Center, Salem, MA, Stormwater Study,” by Judith Nitsch Engineering, Inc., dated June 20, 2005.
- Letter from Rizzo Associates, Inc. to Pepi Associates, Inc. dated April 3, 1991 regarding “Proposed Salem Police Station Drainage.”
- Project plans entitled “Salem – Grade Crossing Eliminations,” by Singstad & Saillir Consulting Engineers, dated 1955.

- 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.
- "Ocean Avenue West Pump Station Assessment Report, City of Salem, MA" by Woodard & Curran dated March 9, 2009.
- "2009 South River Metering Program, City of Salem, Massachusetts" by New England Civil Engineering Corporation dated February 2010.

Field Observations

The document review was supplemented by site visits conducted during the duration of the project 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.

A metering program was also conducted for the South River in 2009 by New England Civil Engineering Corporation. Data was obtained between April 2008 and December 2009 from a series of flow meters and depth sensors that were placed at various locations along South River. The flow meters and depths sensors were used to measure the rate and depth of stormwater, respectively. The data obtained from the program provided insight to the hydrologic and hydraulic response of the watershed and was applied during development of the baseline conditions hydraulic and hydrologic model.

Video inspections of infrastructure within the South River watershed, including the South River Conduit, were conducted to document the condition of the infrastructure and confirm the physical configuration of the infrastructure. This effort was performed in conjunction with a cleaning program that was implemented to remove sediment and debris from the conduits. The findings of these efforts, along with recommendations for improving infrastructure found to be in need of repair, can be found in APPENDIX A of this report.

Topographic surveys were also conducted as part of the project in Spring 2009, and included the following:

- Planimetrics and topographic contours at one-foot intervals of the Study Area;
- Planimetrics and topographic contours at two-foot intervals of the South River Watershed;

- "Existing Conditions Survey of Canal Street," by WSP-Sells, dated February 20, 2009; and
- Geometry and location of hydraulic structures along South River from Highland Avenue down to the inlet of South River Conduit at Mill Pond.

3.2.2 Hydrologic Data

Rainfall Events

The baseline conditions analysis was performed for the 10-, 25-, 50-, and 100-year 24-hour synthetic rainfall events. These events are defined as having a one in ten (10%), one in twenty-five (4%), one in fifty (2%), and one in a hundred (1%) chance of occurring or being exceeded in any given year, respectively. Rainfall depths used in the analysis were obtained from rainfall data maps included in "Technical Paper 40 – Rainfall Frequency Atlas of the United States." A Type-III rainfall distribution, as developed by the National Resource Conservation Service (NRCS), was used in the analysis as this was the recommended distribution of this portion of the United States. The analysis assumed the antecedent runoff condition (ARC) as normal. The total precipitation depth associated with each rainfall event is outlined in Table 3-1.

Table 3-1 – 24-hour Precipitation Depths

Rainfall Event (Frequency)	Depth (inches)
10-year	4.5
25-year	5.3
50-year	6.0
100-year	6.7

Land Use

Geographic land use data was compiled from data layers available on the Massachusetts Geographic Information System (MassGIS) website (http://www.mass.gov/mgis/.htm). The MassGIS Land Use datalayer has 37 land use classifications interpreted from 1:25,000 aerial photographs The most current land use datalayer available on the MassGIS website used for this report was created by the Executive Office of Transportation and Construction using aerial photography from 1990/1991. Woodard & Curran then updated the land use layer using similar methodology from 1:5,000 Color Ortho Imagery captured in 2005 and further supplemented this with record plans and as-built plans of development that was constructed post-2005 and direct observation through field reconnaissance efforts conducted during the duration of the project. Land uses are illustrated in Figure 3.

Soils

Soils information used in the analysis was compiled from datalayers available on the Massachusetts Geographic Information System (MassGIS) website (http://www.mass.gov/mgis/.htm). The Soils datalayer has been automated from 1:25,000 published soils surveys as provided on various media by the United States Department of Agriculture Natural Resources Conservation Service. All soils data released by MassGIS have been "SSURGO-certified," which means they have been reviewed and approved by the

NRCS and meet all standards and requirements for inclusion in the national release of county-level digital soils data. Soils are illustrated in Figure 4.

Topography

The South River watershed and subwatersheds were delineated using topographic mapping obtained for this phase of the project. Topographic mapping for the entire South River watershed was provided by Fugro Earthdata in Spring 2009. The mapping was developed based on aerial photometry taken in 2009 and provided at two foot contour intervals. Topographic mapping in the Study Area was supplemented by additional topographic mapping at one-foot intervals. This mapping was provided by WSP-Sells in Spring 2009 and was developed based on aerial photometry taken in 2008.

Time of Concentration

Time of concentration values and were developed for each of the calculated drainage areas based upon prevalent topographic patterns, slopes, and ground cover conditions using Urban Hydrology for Small Watersheds TR-55 methodology.

3.2.3 Hydraulic Data

Infrastructure

Physical characteristics, such as size, location and elevation, of major hydraulic infrastructure (culverts, open-channels, outlet control devices, ponds, drainage systems) were obtained by field surveys conducted by WSP-Sells during the duration of the project and supplemented with record as-built information, design plans, topographic surveys, or video inspections. All elevations were obtained using the City of Salem, Massachusetts sewer datum.

Tidal Conditions

Tidal conditions were set at the outfall to the South River Conduit. The baseline conditions analysis was performed using mean water (MW) and mean high water (MHW) elevations. Elevations were obtained from the National Oceanic and Atmospheric Administration (NOAA) and are outlined in Table 3-2.

Table 3-2 – Tidal Conditions

Condition	Elevation (feet)*
MW	4.6
MHW	9.2

**Datum = City of Salem Sewer Datum*

3.3 BASELINE CONDITIONS MODEL

The baseline conditions hydrologic/hydraulic model was developed utilizing the information outlined in Section 3.2. Based on this information, the input parameters of the watershed were determined and input into the SewerGEMs® V8i modeling software.

Input parameters for the 45 subwatersheds comprising the South River watershed (illustrated on Figure 2) were input into SewerGEMs® to simulate the rate and volume of runoff from each subwatershed. Input parameters included the subwatershed area, time of concentration, and weighted curve number, which considers the area, land use, and soil type of the subwatershed. Hydrologic inputs for the baseline conditions model are summarized in Table 3-3 found on the following page.

Input parameters for the hydraulic conveyance structures throughout the South River watershed include invert elevations, physical geometry, roughness parameters, and the boundary condition, or tidal conditions, at the outfalls. These parameters were input into SewerGEMs® to simulate the water surface elevations in the conveyance structures of South River.

Table 3-3 – Subwatershed Hydrologic Input Parameters

Watershed	Area (acres)	Curve Number	Time of Concentration (hr.)
1	158.2	77	1.34
2	251.3	77	1.53
3	231.5	68	1.79
3A	57.4	85	0.94
3B	28.7	83	0.77
3C	77.1	78	1.44
4	57.9	88	0.26
5	38.5	94	1.17
5A	4.1	94	0.25
5B	6.9	94	0.25
5C	8.5	93	0.25
5D	42.1	92	0.46
6	18.5	92	0.25
7	2.4	92	0.25
8	10.2	92	0.25
9	9.2	93	0.25
10	12.3	80	0.25
11A	14.2	88	N/A*
11B	28.0	88	0.39
11C	46.0	88	0.40
12A	14.2	98	0.25
12B	7.7	98	0.25
13	3.0	92	0.25
14A	10.1	92	0.25
14B	11.5	92	0.25
14C	1.0	92	0.25
15	8.4	92	0.25
16	99.4	91	0.25
17	16.2	93	0.25
18	66.4	93	0.25
19	29.5	94	0.25
5S	6.1	83	0.23
6S	4.4	79	0.54
8S	4.8	98	0.12
9S	14.6	83	0.43
10S	3.8	83	0.22
11S	1.5	83	0.12
12S	3.0	83	0.25
13S	2.6	83	0.15
14S	4.0	83	0.27
15S	6.8	90	0.20
16S	1.5	94	0.08
17S	2.4	98	0.08
19S	4.9	82	0.30
20S	2.5	88	0.13

*Time at which this watershed begins contributing runoff to South River appeared greater than the duration of the evaluated synthetic rainfall events. Therefore, this value was not incorporated into model.

3.4 METEOROLOGICAL DATA

In an effort to understand the magnitude of rainfalls events that contribute to flooding, meteorological data was obtained and reviewed for the eight most recent flood events.

The 24-hour daily rainfall totals for 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 (NWS) and the Northeast Regional Climate Center at Cornell University (NRCC). 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 3-4 summarizes the meteorological data collected for these six events.

Table 3-4 – Meteorological Data from NWS & NRCC

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)

The 24-hour rainfall event totals for the two most recent storm events were obtained from the metering program conducted by New England Civil Engineering Corporation. The program was conducted in Salem, and the meteorological data presented in Table 3-5 summarizes the data collected for these two events.

Table 3-5 – Meteorological Data from Most Recent Significant Events

Date of Event	Total Storm Rainfall @ Beverly (inches)	Estimated Return Frequency (per TP-49)
March 13-15, 2010	8.26	~50-year
March 29-31, 2010	6.49	~10-year

3.5 RESULTS

Key findings from the baseline conditions analysis are outlined below. Findings are provided for flood prone areas in the Study Area in addition to other areas of the South River watershed such as the golf course. Please note that additional areas and roadways not discussed in the proceeding outline may be subject to localized flooding due to storm drainage system constraints and are not considered as part of this evaluation. Figure 5, Figure 6, Figure 7, and Figure 8 illustrate the extents of flooding predicted by the baseline conditions model for areas along South River.

- The influence of high tide conditions on low-lying areas of the South River watershed is greatest during the 10-year event.

- Riverine flooding controls peak water surface elevations along South River during the 50- and 100-year event.

- From the metering program, it was observed the existing tide gates occasionally provide protection during frequent rainfall and mean tide events. During less frequent rainfall and high tide events, the tide gates do not offer much protection to low-lying areas since there is limited volume to store stormwater within South River Conduit. As a result, when the tide gates are closed, the conduit fills quickly and generates backwater conditions on low lying areas.

<u>Brooks Street/Jefferson Avenue Area</u>

- Refer to Figure 7 for illustration of flood extents predicted by the baseline conditions model for this area.

- Critical elevation of Jefferson Avenue berm was identified as the lowest elevation along the berm (Elev. 12.5 feet).

- Critical elevation of Brook Street berm was identified as the lowest elevation along the berm (Elev. 13.3 feet).

- Both berms provide protection for the 10-year event under mean high tide conditions. Approximately 0.2 to 0.8 feet of freeboard is available along the berms for this event.

- Peak water surface elevations along the berm exceed the critical elevation resulting in flooding in this area for the 25-, 50-, and 100-year rainfall event under mean tide conditions. Overtopping results in flooding of numerous residential properties and a portion of Jefferson Avenue. It has been estimated that 10 acres of residential property and 30 residential properties are subject to some degree of flooding when the earthen berms overtop during the 100-year rainfall event.

- Dove Avenue, which is an entrance to the hospital, overtops during storms greater than the 50-year event.

- The Ocean Avenue pump station is designed for 10-year event. The analysis assumes the area protected by the pump station is inundated for storms in excess of the 10-year event.

<u>Rosies Pond Area</u>

- Refer to Figure 6 for illustration of flood extents predicted by the baseline conditions model for this area.

- Critical elevation identified as lowest residential structure elevation in this area which falls along Parallel Street (approximately Elev. 13 feet).

- Rosies Pond Bypass diverts flow from Rosies Pond during the 10-, 25-, 50-, and 100-year rainfall events. Flow may be diverted during more frequent rainfall events not investigated in this study.

- The inlet of the Rosies Pond Bypass has limited capacity to alleviate flooding at Rosies Pond and along downstream segments of the South River. In addition, downstream stormwater connections further limit the capacity of the bypass to convey stormwater from Rosies Pond.

- Residential structures along Parallel Street and structures along Canal Street flood during the 10-year event. Additional structures along Parallel Street and Canal Street flooded for the 25-, 50-, and 100-year events. During the 100-year rainfall event, it is estimated that approximately two acres of residential property and seven residential structures experience some level of flooding. Structures may flood during more frequent events not investigated in this study.

- Overtopping onto Canal Street was observed for more significant rainfall events.

Mill Pond / Jefferson Avenue

- Refer to Figure 7 for illustration of flood extents predicted by the baseline conditions model for this area.

- Critical elevation was identified as the lowest structure elevation in this area along Jefferson Avenue (approximately Elev. 11 feet).

- Stormwater is contained within Mill Pond with the exception of Paper Recycling property and building for the 10-year event. For the 100-year event, more extensive flooding is observed in this area resulting in additional areas and structures being flooded.

Golf Course

- Refer to Figure 5 for illustration of flood extents predicted by the baseline conditions model for this area.

- In the area upstream of the MTBA railroad crossing, the critical elevation is identified as the lowest structure elevation in this area at Read Street (approximately Elev. 25 feet).

Canal Street / Salem State University

- Refer to Figure 8 for illustration of flood extents predicted by the baseline conditions model for this area.

- Canal Street area critical elevation was identified as the catch basin at McDonald's (Elev. 8.9 feet).

- Salem State University critical elevation was identified as the catch basin at O'Keefe Center parking area (Elev. 8.0 feet).

- Limited hydraulic capacity for both systems was observed for the 10-, 25-, 50-, and 100-year rainfall events regardless of tide conditions.

- Flooding is observed in the Canal Street and Salem State University areas for the 10-, 25-, 50-, and 100-year events and is exasperated and prolonged during high tide events.

- Canal Street and Salem State University O'Keefe Center parking areas are hydraulically connected when the peak water surface elevation in either system reaches an elevation between Elev. 10 and 11 feet due to local topography.

- Peak water surface elevations were predicted to between Elev. 13.1 to 14.1 feet during all storm events for both the Canal Street and Salem State University O'Keefe Center parking areas.

Geneva Street

- Critical elevation identified as lowest catch basin rim elevation along this area of Geneva Street (approximately Elev. 16 feet).

- Flooding along Geneva Street does not appear to be influenced by backwater conditions from South River Conduit.

- Flooding appears to be the result of the existing drainage system having limited capacity to convey stormwater from the area to South River Conduit.

Table 3-6 provides the peak flow rates for the rainfall events studied at various locations along South River.

Table 3-6 – Baseline Conditions Results – Peak Flow Rates (cfs)

Description	10-year MHW	25-year MHW	50-year MW	100-year MW
SRC Outfall	379	434	494	570
SRC @ Canal Street	233	286	323	350
SRC Entrance @ Mill Pond	224	277	313	339
Golf Course	251	280	303	320

Table 3-7, found on the following page, provides the maximum water surface elevation along various locations of South River. Figure 5, Figure 6, Figure 7, and Figure 8 illustrate the extents of flooding discussed that result from these elevations.

Table 3-7 – Baseline Conditions Results – Peak Water Surface Elevations (feet)

Description	Critical Elev.[1]	10-year MHW	25-year MHW	50-year MW	100-year MW
SRC Outfall		9.5	9.8	6.1	6.1
SRC @ Canal Street	14.3	11.1	11.4	11.4	13.1
SRC Inlet at Mill Pond	11.0	11.3	11.6	11.6	13.2
O'Keefe Center Parking Area	8.0	13.1	14.0	14.1	14.1
McDonald's Catch Basin	8.9	13.1	14.0	14.1	14.1
D/S Mill Pond	11.0	11.3	11.7	11.7	13.3
U/S Mill Pond	11.0	11.9	12.2	12.2	13.9
D/S Jefferson Ave. Culvert (3)	14.6	12.0	12.3	12.3	13.9[2]
U/S Jefferson Ave. Culvert (3)	14.6	12.0	12.3	12.3	14.0[2]
D/S Dove Ave. Culvert	13.7	12.1	12.4	12.4	14.0
U/S Dove Ave. Culvert	13.7	12.1	12.4	12.4	14.1
D/S Jefferson Ave. Berm	12.5	12.2	12.5	12.5	14.1
U/S Jefferson Ave. Berm	12.5	12.3	12.6	12.7	14.3
D/S Jefferson Ave. Culvert (2)	15.1	12.4	12.7	12.8	14.4
U/S Jefferson Ave. Culvert (2)	15.1	12.4	12.7	13.0	14.4
D/S Brook St. Berm	13.3	12.5	12.8	13.0	14.5
U/S Brook St. Berm	13.3	13.1	13.5	13.8	15.1
D/S Lawrence Ave. Culvert	16.0	13.2	13.6	13.9	15.2
U/S Lawrence Ave. Culvert	16.0	13.5	14.1	14.3	15.2
D/S Rosies Pond Outlet	13.0	13.8	14.4	14.6	15.5
U/S Rosies Pond	14.0	14.8	15.2	15.5	15.8
D/S Jefferson Ave. Culvert (1)	17.5	14.9	15.3	15.6	15.9
U/S Jefferson Ave. Culvert (1)	17.5	15.5	15.8	16.1	16.4
D/S Box Culverts	16.0	15.7	16.1	16.4	16.6
U/S Box Culverts	19.2	17.4	18.3	18.9	19.2
Golf Course Pond	25.0	19.3	20.3	21.0	21.8
D/S Diversion Structure	25.0	21.1	21.4	21.6	22.0
D/S Diversion Pond		22.0	22.3	22.7	23.1
Diversion Structure Pond	30.0	23.7	24.6	25.3	26.0
D/S Highland Ave. Culvert	96.4	82.7	82.7	82.8	82.8
U/S Highland Ave. Culvert (Pond)	96.4	86.6	87.4	88.1	88.7

[1]Critical elevation denotes lowest elevation of a roadway crossing at culverts, rim elevation at the lowest point on a drainage system, lowest point of an earthen berm, or ground surface elevation of adjacent structures. Elevations provided on the table that are denoted in red signify the critical elevation as been exceeded at that location for the specific rainfall event.

[2]Although elevation does not exceed critical elevation, stormwater encroachment observed in this area.

4. ALTERNATIVES ANALYSIS

Woodard & Curran conducted an alternatives analysis to perform an initial screening of potential remedies to flooding within the Study Area. This section of the report discusses:

- the approach taken to perform the alternatives analysis,
- a description of the alternatives analyzed, and
- the findings of the analysis.

In addition, an overview of the measures that were found to potentially be most effective at reducing the frequency and extent of flooding in the Study Area is provided. These measures are further analyzed and developed to a conceptual level in Section 5 and Section 6.

4.1 APPROACH

The baseline conditions hydrologic/hydraulic model presented in Section 3 was used as the basis for performing the alternatives analysis. The model was revised to incorporate the flood mitigation measures associated with each alternative, which included changes to the watershed's physical features and hydrologic patterns. The response of the model indicated the alternative's potential effectiveness at reducing the frequency and extent of flooding. The predicted peak water surface elevations along South River for each alternative were compared to:

- peak water surface elevations generated under baseline conditions, and
- critical elevations[1].

This information was used by Woodard & Curran to evaluate alternative's potential effectiveness at mitigating flooding through the Study Area. Based on discussions with representatives of the City, the 100-year rainfall event was selected to measure the effectiveness of the alternatives throughout the Canal Street/Salem State University area and the Rosies Pond, Brooks Street, and Jefferson Avenue area. Geneva Street was not considered in the analysis of the alternatives since the baseline conditions analysis demonstrated that flooding within this area was not influenced by backwater conditions from South River. It was therefore anticipated that the alternatives would not reduce the magnitude and frequency of flooding within this area since they were directed at improving the hydrologic/hydraulic conditions along South River.

Thirteen alternatives were identified and evaluated at the preliminary screening level. The alternatives were generally focused at reducing the influence of tidal conditions and/or the volume and flow rate of stormwater through flood prone areas. Specifically, the alternatives focused on the following:

- increasing flood storage in the upper reaches of the South River watershed;

[1] A critical elevation represents the elevation established by Woodard & Curran at which flooding becomes a concern, and may include the elevation of a roadway crossing at a culvert, rim elevation of the lowest structure along a drainage system, the overtopping elevation of an earthen berm, or ground surface elevations of adjacent structures.

- diverting stormwater from the upper reaches of the watershed;
- stormwater pumping at various locations within the watershed; and
- increasing the hydraulic capacity of existing infrastructure.

A description of the alternatives and results of the analysis are provided in the proceeding section.

4.2 DESCRIPTION AND FINDINGS

The thirteen alternatives analyzed in this study are outlined below. Please note some of the alternatives are combinations of other alternatives and are denoted as such in the outline.

- Alternative 1 – Increase the Capacity of South River Conduit
- Alternative 2 – Provide flow Diversion from Golf Course
- Alternative 3 – Construct a new stormwater Pump Station on Canal Street and Salem State University Drainage Systems (combination of Alternatives 8 & 9)
- Alternative 4 – Construct a new Stormwater Pump Station at the Outlet of South River Conduit
- Alternative 5 – Increase Storage at Rosies Pond
- Alternative 6 – Construct a new Stormwater Pump Station at the O'Keefe Center Parking Area
- Alternative 7 – Provide Hydraulic Improvements to Rosies Pond Bypass and/or Inlet Structure
- Alternative 8 – Construct a new Stormwater Pump Station on Salem State University Drainage System (at St. Paul Street)
- Alternative 9 – Construct a new Stormwater Pump Station on Canal Street Drainage System (at St. Paul Street)
- Alternative 10 – Increase the Capacity of the Salem State University Drainage System
- Alternative 11 – Increase the Capacity of the Canal Street Drainage System
- Alternative 12 – Increase the Capacity of both the Canal Street and Salem State Drainage Systems (combination of Alternatives 10 & 11)
- Alternative 13 – Maximize Storage at Golf Course

The following thirteen tables describe each alternative and the alternative's potential effectiveness at mitigating flooding. Descriptions of the physical changes to the watershed and/or drainage infrastructure associated with each alternative are also included. Quantitative results of the analysis are presented in Appendix B.

Alternative 1 – Increase the Capacity of South River Conduit
Description: The size of South River Conduit was enlarged to evaluate the benefits of increasing its capacity to convey stormwater from upstream flood prone areas, which include: • Rosies Pond, • Brooks Street and Jefferson Avenue, and • the Canal Street/Salem State University area. This alternative was simulated in the baseline conditions model by doubling the number of barrels of the existing infrastructure (e.g., in locations were there are two barrels, the number of barrels was increased to four). No modifications to invert elevations, conduit size, and conduit geometry were made.
Results • Does not provide meaningful flood protection during periods of high tide. Additional measures to mitigate flooding caused by high tide conditions would be required. • Provides reductions in peak water surface elevations during rainfall events that do not coincide with high tide conditions. Reductions were predicted to extend upstream to up to Brook Street; however, peak water surface elevations remain at or above critical for the 100-year event. • Does not benefit the Canal Street/Salem State University area. Recommendation: Further consideration of this alternative is not recommended as it would require additional measures, such as a pump station, to mitigate flooding caused during high tide conditions. The cost to collectively implement these measures is relatively high compared to other viable alternatives and is therefore not recommended for further consideration.

Alternative 2 – Flow Diversion from Golf Course

Description: Stormwater currently conveyed through the golf course was diverted away from South River to reduce the volume and flow rate of stormwater through downstream flood prone areas, which include:

- Rosies Pond, and
- Brooks Street and Jefferson Avenue.

The volume of diverted stormwater was that generated by approximately 800 acres of the most upstream reaches of the South River watershed. Consequently, this alternative also reduced the volume and flow rate of stormwater through South River Conduit. This alternative was simulated in the baseline conditions model by removing the watersheds that contribute runoff to the golf course, thus eliminating their contribution of runoff from the model.

Results

- Significant peak water surface elevation reductions (1-2 feet) along Rosies Pond for all evaluated rainfall events, however, elevations were still predicted to remain above critical for the 100-year rainfall event.
- Less significant peak water surface reductions along Brooks Street and Jefferson Avenue (0-12 inches) for all evaluated rainfall events, however, elevations were predicted to be above critical for the 100-year rainfall event.
- No meaningful change in peak water surface elevations to Canal Street and Salem State University drainage systems.
- Provides little to no benefit during high tide conditions.
- Decreases the duration of flooding in flood prone areas.
- Assumes all stormwater from the golf course was diverted to the Forest River, which may have adverse impacts to the Forest River and would require additional studies to understand its feasibility.

Recommendation: Further consideration of this alternative is not recommended as it does not meet the project's objectives for mitigating flooding. Localized measures would be required. Localized measures have the potential to independently provide flood protection and would therefore negate the need to implement this alternative.

Alternative 3 – Pump Station on Canal Street and Salem State University Drainage Systems
This alternative combines Alternatives 8 and 9, which are discussed further in this section. Description: A pump station was provided at the downstream-most end of the Canal Street and Salem State University drainage systems (at St. Paul Street). The pump station would convey stormwater from the Canal Street and Salem State University watersheds (in their entirety) to a location other than the South River Conduit. This alternative was simulated in the baseline conditions model by removing the hydraulic connection between the Canal Street/Salem State University drainage systems and South River Conduit.
Results • New stormwater collection and conveyance systems needed within the area to realize full benefit. Local drainage systems are currently undersized to convey stormwater during significant rainfall events. • Protects the Canal Street and Salem State University watersheds from backwater conditions from South River Conduit. • No meaningful benefits predicted to areas outside of Canal Street/Salem State University as flooding was still predicted in these areas. Recommendation: A pump station on the Canal Street and Salem State University drainage systems is a viable alternative as it protects from high tide. However, improvements directed at enlarging the local drainage systems would also be needed to for the pump station to be effective.

Alternative 4 – Pump Station at the Outlet of South River Conduit
Description: A pump station was provided at the outlet of South River Conduit to eliminate the influence of the tide on the South River watershed, which also increased the capacity of South River Conduit to convey stormwater from upstream flood prone areas that include: • Rosies Pond, • Brooks Street and Jefferson Avenue, and • the Canal Street and Salem State University watersheds. This alternative was simulated in the existing conditions model by eliminating tidal conditions from the model.
Results • No meaningful flood protection for evaluated rainfall events greater than the 10-year event due to limited capacity and elevation of the South River Conduit. • Improvements directed at increasing the hydraulic capacity of South River Conduit would be needed to realize full benefit. • Eliminates the tidal influence on South River Conduit. • Does not benefit the Canal Street/Salem State University area unless additional hydraulic improvements are made to these systems (as described in Alternatives 10, 11, and 12). Recommendation: Further consideration of this alternative is not recommended as it would require additional improvements, such as enlarging and/or lowering the elevation of the South River Conduit, in order for the pump station to be effective. The cost to collectively implement these measures is relatively high in comparison to other viable alternatives and is therefore not recommended for further consideration.

Alternative 5 – Increase Storage at Rosies Pond
Description: The storage capacity of Rosies Pond was increased to reduce the volume and flow rate of stormwater through downstream flood prone areas, which include: • Rosies Pond, • Brooks Street and Jefferson Avenue. Consequently, this alternative also reduced the flow rate of stormwater through South River Conduit. This alternative was simulated in the model by increasing the storage capacity at Rosies Pond by enlarging the footprint of the pond to the extent practical.
Results • Only way to increase storage is by increasing areal extent of pond or by raising the water surface elevation. • Does not provide meaningful benefits to downstream flood prone areas such as Brooks Street and Jefferson Avenue as these areas are subject to tidal conditions. • Would require purchase of properties intended to be protected with implementation of this alternative. Recommendation: Further consideration of this alternative is not recommended as it does not meet the project's objectives for mitigating flooding. Localized measures would be required. Localized measures have the potential to independently provide flood protection and would therefore negate the need to implement this alternative.

Alternative 6 – Pump Station at the O'Keefe Center Parking Area
Description: A pump station was provided at the Salem State University O'Keefe Center parking area to convey stormwater from the flood prone area. This alternative was simulated in the baseline conditions model by separating the Salem State University drainage system at the O'Keefe Center parking area from South River Conduit. The remainder of the existing Salem State University drainage system downstream of the O'Keefe Center parking area continued to discharge to South River Conduit.
Results • Eliminates the influence of backwater conditions O'Keefe Center parking area from South River Conduit. • Area would need to be raised or physically separated to eliminate flood encroachment from Canal Street. • New collection and conveyance systems may be needed to realize full benefit. • No meaningful benefit to Rosies Pond/Brooks Street/Jefferson Avenue area. • No meaningful benefit to flooding along Canal Street. Recommendation: A pump station serving the O'Keefe Center parking area is a viable alternative to protect the area from high tide; however, flooding would still be expected in the area due to floodwater encroachment from Canal Street. Therefore, improvements directed at reducing flooding along Canal Street would also be necessary.

Alternative 7 – Hydraulic Improvements to Rosies Pond Bypass and/or Inlet Structure
Description: Modifications to the Rosies Pond Bypass pipe and inlet structure were made to convey additional stormwater from Rosies Pond. This alternative would divert stormwater away from South River to reduce the volume and flow rate of stormwater through downstream flood prone areas, which include: • Rosies Pond, and • Brooks Street and Jefferson Avenue. Consequently, this alternative also reduces the volume and flow rate of stormwater through South River Conduit. This alternative was simulated in the baseline conditions model by increasing the capacity of the Rosies Pond Bypass pipe and inlet structure.
Results • Existing inlet structure found to have minimal capacity to convey stormwater from Rosies Pond during significant rainfall events. • Discussions with the City have indicated that the Bypass may be nearing capacity due to increased runoff from new developments. • Quantitative results are not provided for this alternative as it should be implemented in conjunction with future developments that propose to discharge stormwater into the bypass. • Results are expected to be similar to those presented for other alternatives that divert stormwater from South River. These alternatives include Alternative 2. Evaluation of this alternative predicted flood protection will not be achieved for up to the 100-year rainfall event due to high tide conditions. Recommendation: Further consideration of this alternative is not recommended as it does not meet the project's objectives for mitigating flooding. Localized measures would be required. Localized measures have the potential to independently provide flood protection and would therefore negate the need to implement this alternative.

Alternative 8 – Pump station on Salem State University Drainage System (at St. Paul Street)
Description: A pump station was provided at the downstream most end of the Salem State University drainage system near St. Paul Street to convey stormwater from the Salem State University watershed (in its entirety) to a location other than the South River Conduit. This alternative was simulated in the baseline conditions model by removing the hydraulic connection between the Salem State University drainage system and South River Conduit.
Results • Eliminates the influence of backwater conditions due to high tide on the drainage system from South River Conduit. • Area would need to be raised or physically separated to eliminate flooding encroachment from Canal Street. • Improvements to the existing Salem State University collection and conveyance systems needed to realize full benefit. • No meaningful benefit to flooding along Canal Street. • Peak water surface elevation along the Salem State University drainage system falls below the critical elevation for events less than the 10-year event; however, flooding in the area would still be expected due to flooding encroachment from Canal Street. • Contribution of stormwater from Salem State University to South River Conduit was reduced consequently lowering peak water surface elevations along Brooks Street and Jefferson Avenue. Flooding, however, was still predicted along these areas since peak water surface elevations are predicted to be above critical elevations. Recommendation: A pump station serving Salem State University drainage system is a viable alternative to protect the system and contributing area from high tide; however, flooding would still be expected along the system due to floodwater encroachment from Canal Street. Therefore, improvements directed at reducing flooding along Canal Street would also be necessary.

Alternative 9 – Pump Station on Canal Street Drainage System (at St. Paul Street)
Description: A pump station was provided at the downstream most end of the Canal Street drainage system near St. Paul Street to convey stormwater from the Canal Street watershed (in its entirety) to a location other than the South River Conduit. This alternative was simulated in the baseline conditions model by removing the hydraulic connection between the Canal Street drainage system and South River Conduit.
Results • Eliminates the influence of backwater conditions due to high tide on the drainage system from South River Conduit. • Area would need to be raised or physically separated to eliminate flooding encroachment from O'Keefe Center parking area. • Improvements to the existing Canal Street collection and conveyance systems needed to realize full benefit. • No meaningful benefit to flooding along Salem State University drainage system. • No meaningful benefit to the Rosies Pond/Brooks Street/Jefferson Avenue area. Recommendation: A pump station serving the Canal Street drainage system is a viable alternative to protect the system and contributing area from high tide; however, flooding would still be expected along the system due to floodwater encroachment from the Salem State University area. Therefore, improvements directed at reducing flooding along the Salem State University system would also be necessary.

Alternative 10 – Increase the Capacity of the Salem State University Drainage System
Description: The size of the Salem State University drainage system was enlarged to increase its hydraulic capacity to convey stormwater from the flood prone Salem State University watershed. This alternative was simulated in the baseline conditions model by doubling the number of conduits of the existing infrastructure (e.g., in locations were there was one conduit, the number of barrels was increased to two). No modifications to invert elevations, conduit size, and conduit geometry were made.
Results • Provides minimal benefits as a stand alone measure since flooding was still predicted in the area due to the drainage system being subject to backwater conditions from South River Conduit. Backwater conditions are exacerbated during high tide conditions. • Has potential to increase stormwater contributions from the area to South River Conduit, consequently raising peak water surface elevations in other flood prone areas such as Brooks Street, Jefferson Avenue, and Rosies Pond. This increase may exacerbate flooding in these areas. Recommendation: Increasing the capacity of the Salem State University drainage system is a viable alternative to minimize flooding resulting from undersized infrastructure; however, flooding would still be expected along the system due to floodwater encroachment from Canal Street and the influence of high tide. Therefore, improvements directed at reducing flooding along Canal Street would also be necessary in addition to measures directed at protecting against high tide, such as a pump station.

Alternative 11 – Increase the Capacity of the Canal Street Drainage System
Description: The Canal Street drainage system was enlarged to increase its capacity to convey stormwater from the flood prone areas of the Canal Street watershed. This alternative was simulated in the baseline conditions model by increasing the number of conduits of the existing infrastructure fivefold (e.g., in locations were there was one conduit, the number of barrels was increased to five). No modifications to invert elevations, conduit size, and conduit geometry were made.
Results • Peak water surface elevations in the drainage system were reduced for the evaluated events, however, flooding was still predicted in the area. • Provides minimal benefits as a stand alone measure since flooding is still predicted in the area due to the drainage system being subject to backwater conditions from South River Conduit. Backwater conditions are exacerbated during high tide conditions. • Has potential to increase stormwater contributions from the area to South River Conduit, consequently raising peak water surface elevations in other flood prone areas such as Brooks Street, Jefferson Avenue, and Rosies Pond. This increase may exacerbate flooding in these areas. Recommendation: Increasing the capacity of the Canal Street drainage system is a viable alternative to minimize flooding resulting from undersized infrastructure; however, flooding would still be expected along the system due to floodwater encroachment from the Salem State University area and the influence of high tide. Therefore, improvements directed at reducing flooding along the Salem State University system would also be necessary in addition to measures directed at protecting against high tide, such as a pump station.

Alternative 12 – Increase the Capacity of Both the Canal Street and Salem State Drainage Systems
This alternative combines Alternatives 10 & 11. Description: The Canal Street and Salem State University drainage systems were enlarged to increase their capacity to convey stormwater from the flood prone areas of the Canal Street and Salem State University watersheds. This alternative was simulated in the baseline conditions model by increasing the number of conduits of the existing infrastructure (fivefold for Canal Street and double for Salem State University). No modifications to invert elevations, conduit size, and conduit geometry were made.
Results • Flooding is predicted along the Canal Street drainage system for the evaluated events. • Provides minimal benefits as a stand alone measure since flooding was still predicted in the area due to the drainage system being subject to backwater conditions from South River Conduit. Backwater conditions are exacerbated during high tide conditions. • Has potential to increase stormwater contributions from the area to South River Conduit, consequently raising peak water surface elevations in other flood prone areas such as Brooks Street, Jefferson Avenue, and Rosies Pond. This increase may exacerbate flooding in these areas. Recommendation: Increasing the capacity of the Canal Street and Salem State University drainage systems is a viable alternative as it minimizes flooding resulting from undersized infrastructure. However, a pump station would also be needed to provide protection during high tide conditions.

Alternative 13 – Maximize Storage at Golf Course
Description: A flow control structure was provided at the outlet of the golf course to increase the stormwater storage capacity at the golf course and reduce the maximum flow rate of stormwater out of it and through downstream flood prone areas, which include: • Rosies Pond, and • Brooks Street and Jefferson Avenue. Consequently, the maximum stormwater flow rate through South River Conduit was also reduced. This alternative was simulated in the baseline conditions model by providing a flow control structure at the outlet of the golf course that reduces the rate of stormwater out of the golf course.
Results • Significant peak water surface elevation reductions (12-18 inches) along Rosies Pond area for all evaluated rainfall events, however, flooding was still predicted during the 100-year rainfall event. • Less significant peak water surface reductions along Brook Street and Jefferson Avenue (0-12 inches) for all evaluated rainfall events. Flooding was still predicted in these areas. • No change in peak water surface elevations along Canal Street and Salem State University drainage systems. • Provides little to no benefit during high tide conditions. • Increases flooding within the golf course and along private properties adjacent to the golf course. May require flood easements to implement. Recommendation: Further consideration of this alternative is not recommended as it does not meet the project's objectives for mitigating flooding. Localized measures would be required. Localized measures have the potential to independently provide flood protection and would therefore negate the need to implement this alternative.

4.3 FINDINGS & RECOMMENDATIONS

This preliminary alternatives analysis demonstrated that the Rosies Pond/Brooks Street/Jefferson Avenue and Canal Street/Salem State University areas must each be physically separated from interaction with the tide to reduce the frequency and extent of flooding within each area. This conclusion is based on the following findings:

- Both areas are low-lying and are therefore heavily influenced by tidal conditions.
- Flood mitigation measures in one area were generally found to have little or no benefit to the other area since both areas are tidally influenced.
- The period when flow rates through South River are at their greatest was found to likely coincide with high tide conditions during a significant rainfall event. As a result, flooding in low-lying areas is likely to occur due to the concurrence of these conditions.
- Alternatives directed solely at altering the rate and volume of runoff through South River were not found to be independently effective since they did not protect flood prone areas from the tide. These alternatives include Alternatives 1, 2, 5, 7, & 13.
- Alternative 4, which proposes to construct a pump station at the outlet of South River Conduit, was deemed not viable due to the extensive improvements to South River Conduit that are necessary to realize the full benefit of the pump station.

These findings demonstrated that localized measures, such as pump stations and physical barriers, are necessary to protect each area from interaction with the tide. It is recommended that these measures be implemented in conjunction with improvements to local infrastructure that has been found to be in need of repair or undersized.

Alternatives investigated along South River were not anticipated to reduce the frequency and magnitude of flooding within Geneva Street. Flooding within this area was found to be independent of hydraulic conditions along South River and the result of the existing drainage system in the area having limited capacity to collect and convey runoff. As a result, flooding along Geneva Street needs to be addressed independently of flood mitigation measures implemented along South River

An overview of the recommended measures for the Study Area is provided below. These measures are further evaluated and discussed at a conceptual level in Section 5 and Section 6 for the Canal Street/Salem State University area and the Rosies Pond/Brooks Street/Jefferson Avenue area, respectively.

Canal Street/Salem State University Area – Alternatives 3 & 12

Woodard & Curran recommends constructing a pump station (i.e., Alternative 3) and enlarging the existing stormwater collection and conveyance system within the Canal Street/Salem State University area (i.e., Alternative 12). These measures are recommended to protect the area from flooding for up to the 100-year rainfall event. The pump station is recommended to eliminate backwater conditions from South River that are due to high tide. Improvements to the existing drainage system would be necessary to realize the full benefit of the pump station since the existing system is undersized to handle runoff from a 100-year rainfall event. Further discussion pertaining to the recommended measures can be found in Section 5.

Rosies Pond/Brooks Street/Jefferson Avenue Area – Local Improvements

Woodard & Curran recommends raising existing earthen berms and constructing additional retaining walls and/or berms within the Rosies Pond/Brooks Street/Jefferson Avenue area. Overall, these recommendations propose to raise the level of flood protection provided by existing measures (constructed in the 1970s) from a ~10-year event to a 100-year event. Protection is provided by minimizing floodwater encroachment from South River during the 100-year event. In addition, improvements identified in the Ocean Avenue West Pump Station Assessment Report (performed in 2009) are also recommended for implementation. The improvements identified in this Assessment consider flooding issues that are independent of floodwater encroachment from South River, and are directed at addressing potential localized flooding. Further discussion pertaining to the recommended measures can be found in Section 6.

Geneva Street

The City of Salem is currently undertaking an extensive catch basin cleaning program that may reduce the frequency and magnitude of flooding along Geneva Street. Woodard & Curran recommends that the City evaluate the effectiveness of this program prior to evaluating physical alterations to the exiting drainage system that are directed at increasing the collection and conveyance capacity of the system.

5. CANAL STREET/SALEM STATE UNIVERSITY IMPROVEMENTS

The alternatives analysis demonstrated that localized improvements to the existing stormwater infrastructure within the Canal Street/Salem State University area are necessary to protect the area for up to the 100-year rainfall event. Specifically, the following measures were determined to be necessary to alleviate flooding in this area:

- Enlarging the existing drainage system
- Construction of a pump station

A description of the recommended measures and an outline of the potential costs and measures necessary for implementation are outlined below.

5.1 DESCRIPTION OF IMPROVEMENTS

The following recommendations must be implemented in conjunction with one another to successfully mitigate flooding issues. Implementing them independently would not provide meaningful flood protection to the Canal Street/Salem State University area.

Drainage System Improvements

Improvements to the existing drainage systems within the Canal Street/Salem State University area are recommended in order to address flooding issues due to undersized infrastructure. The improvements propose to enlarge the systems to a size capable of collecting and conveying runoff from a 100-year rainfall event. It is also recommended that the systems be improved so that one system services the upper-elevations of the area (approximately 45 acres) and the other services the remaining lower-elevation reaches (approximately 40 acres). This approach is being recommended due to the following:

- The upper-elevation reaches of the Canal Street/Salem State University area are not as influenced by backwater conditions to the extent as lower lying portions. Therefore, these areas do not need to be protected by a pump station and can continue to discharge to South River Conduit via a separate drainage system. These areas were identified in the baseline conditions analysis as being located above approximately Elev. 14. These improvements are illustrated on Figure 9.

- The lower-elevation reaches of the Canal Street/Salem State University area are heavily influenced by backwater conditions during high tide events. It is therefore necessary to physically separate these areas from interaction with the tide via a pump station and have a separate drainage system that conveys runoff from these areas to the new pump station. The baseline conditions analysis demonstrated that areas most influenced by high tide fall below approximately Elev. 14. These improvements are illustrated on Figure 10.

By considering this approach, the entire Canal Street/Salem State University area is not required to be serviced by the new pump station. Instead, only those areas needing protection from tidal conditions will discharge to the pump station. As a result, the size of the pump station and its infrastructure is minimized, which also lowers the potential capital costs as well as the operational and maintenance costs associated with the pump station.

Construction of Pump Station

A pump station within the Canal Street/Salem State University area is recommended to eliminate the influence of tidal conditions on low-lying portions of the area. The pump station is proposed to be located within the immediate area of flooding, either along Canal Street or the Salem State University O'Keefe Center parking area. A discharge pipe from the pump station would need to be constructed in conjunction with the pump station. The discharge pipe would convey stormwater from the pump station to its outfall. The possibility of implementing subsurface storage was also evaluated as part of the improvements.

It was estimated that the operating flow rate of the proposed pump station will be approximately 175 cfs for the 100-year rainfall event. This flow rate must be equal to the peak flow rate of runoff generated by the contributing watershed. The contributing watershed comprises the low-lying portions of the Canal Street/Salem State University, which is approximately 40 acres of highly developed area. Given these characteristics, the contributing watershed generates a high rate of runoff for the 100-year rainfall event. As a result, the operating flow rate of the proposed pump station must be sized to accommodate these flow rates. Otherwise, the contributing watershed will generate runoff quicker than the pump station can convey, which may result in flooding.

Preliminary analyses demonstrate that the discharge pipe necessary to convey 175 cfs from the pump may be a 4-foot by 10-foot box culvert. Given that the Canal Street/Salem State University area is highly developed, there may be technical constraints associated with locating a pipe of this size into the area. Potential constraints include existing utilities and right-of-ways and the need to obtain easements. Studies falling outside the scope of this study would be required to identify these constraints prior to the design and construction the discharge pipe.

The possibility of implementing subsurface storage upstream of the pump station was also considered as part of the improvements. This measure would consequently lower the required operating flow rate of the pump station, which would also reduce the size of its discharge pipe. The approach would help minimize any potential constraints associated with locating the pump station and discharge pipe into the area.

Table 5-1 is provided to demonstrate the relationship between storage, the operating flow rate of the pump station, and the size of the discharge pipe. The table demonstrates that as the volume of storage increases, the operating flow rate of the pump station decreases. The size of the discharge infrastructure also decreases since it is a direct function of the operating flow rate of the pump station. The information provided in Table 5-1 is only provided to demonstrate these relationships. The most cost-effective pump station/storage configuration cannot be recommended at this time since its selection is pending further studies as previously described.

Table 5-1 – Pump Station Flow Rates vs. Storage Volumes (100-year Rainfall Event)

Pump Station Operating Flow Rate	Storage Volume	Size of Discharge Pipe*
175 cfs (113 MGD)	0 acre-feet (0 gal.)	4' x 10' Box
40 cfs (26 MGD)	4.9 acre-feet (1,600,000 gal.)	36" Pipe
20 cfs (13 MGD)	6.8 acre-feet (2,200,000 gal.)	30" Pipe
10 cfs (6.5 MGD)	9.2 acre-feet (3,000,000 gal.)	18" Pipe

**Sizes are provided to represent the size infrastructure that may be required to convey stormwater from the pump station. The size and type of the infrastructure is dependent on the final configuration and design of the recommendations.*

Four alternatives for constructing a pump station are as follows:

- Pump Station Alt. 1 Construct a centrifugal pump station at the Salem State University O'Keefe Center parking area. Convey stormwater from the pump station through a route that extends west from the parking area, to and through the existing Marblehead Rail Trail, and to Salem Harbor or the Forest River. This alternative can potentially be implemented with or without storage.

- Pump Station Alt. 2 Construct a centrifugal pump station at a location along Canal Street in the vicinity of the existing McDonald's restaurant. Convey stormwater from the pump station through a route that extends east from Canal Street through Ocean Avenue and to Salem Harbor. Storage will likely be needed with this alternative given potential constraints with locating stormwater infrastructure along Ocean Avenue.

- Pump Station Alt. 3 Construct a centrifugal pump station at a location along Canal Street in the vicinity of the existing McDonald's restaurant. Convey stormwater from the pump station through a route that extends west from Canal Street to and through the rear of properties along the western side of Broadway, along the existing Rosies Pond Bypass route, through the existing Marblehead Rail Trail, and to Salem Harbor or the Forest River. This alternative can potentially be implemented with or without storage.

- Pump Station Alt. 4 Construct a screw pump station at a location along Lafayette Street in the vicinity of the existing Marblehead Rail Trail. Convey stormwater from the pump station directly into Salem Harbor. No storage was considered for this alternative.

Figure 10 illustrates the potential locations for the pump station, the discharge pipe route, and subsurface storage as outlined in the four alternatives. At this time, an alternative cannot be recommended as this recommendation is pending completion of future studies. Studies will be directed at understanding potential site constraints associated with constructing a pump station and its discharge pipe. Once these studies have been complete, the most cost-effective and technically feasible alternative can be identified.

5.2 CONSTRUCTION COSTS

Cost estimates were prepared for the recommended improvements and are presented in Table 5-2. The costs are based on vendor quotes, Woodard & Curran's experience with similar work, RSMeans Cost Data, and unit bid tabulations from the Massachusetts Highway Department. Each cost estimate considers the cost associated with improving the local stormwater drainage system and implementing one of the four pump station alternatives. As a result, four cost estimates are provided. Complete cost estimates can be found in Appendix C.

Table 5-2 – Summary of Estimated Construction Costs

Total Cost of Improvements	Estimated Cost Range
w/ Pump Station Alt. 1	\$12.5M - \$16.1M[1]
w/ Pump Station Alt. 2	\$11.7M - \$15.5M[2]
w/ Pump Station Alt. 3	\$12.8M - \$16.3M[1]
w/ Pump Station Alt. 4	\$12.3M - \$13.4M[3]

[1]*Range considers providing 0 to 3M gallons of subsurface storage.*
[2]*Storage must be provided given site constraints. Range considers providing 1.6M to 3M gallons of subsurface storage.*
[3]*Range is a function of discharge pipe routes considered for this alternative. Storage was not considered.*

5.3 REGULATORY PERMITTING REQUIREMENTS

Implementation of the project is anticipated to require obtaining the following permits/approvals:

- Notice of Intent – Massachusetts Wetland Protection Act
- 404 Army Corps of Engineers
- 401 Water Quality Certification
- Chapter 90 – Massachusetts Waterway License
- Environmental Notification Form – Massachusetts Environmental Protection Agency (need currently being assessed)

5.4 EASEMENTS

The majority of the work involved with implementing the improvements is proposed to occur within public right-of-ways and existing easements throughout the area. Additional access/construction easements will be required to facilitate the improvements and can only be identified during design of the improvements.

5.5 RECOMMENDED STUDIES

The following studies have been identified as being necessary prior to implementation of the recommended improvements:

- A utility study along routes where drainage system improvements are necessary and where potential locations for the pump station discharge pipe have been identified. The study will be performed to identify potential constraints with the existing utilities and recommended improvements.
- A topographic survey of integral areas to supplement surveys previously performed. Information needed from the survey includes property boundary information that is integral to identifying the need for additional easements and obtain right-of-way information.

- A wetlands study to characterize and delineate the wetlands within the vicinity of the proposed improvements and at the location of the proposed pump station outfall. Known wetland areas include Rosies Pond and the wetland area near Pickman Park and the Marblehead Rail Trail. The study will be performed to minimize potential impacts to wetland areas and identify rehabilitation measures, if necessary.

- An environmental evaluation related to constructing a new outfall and discharging stormwater from the proposed pump station into Salem Harbor.

- A geotechnical investigation along routes where drainage system improvements are necessary and where potential locations for the pump station discharge pipe have been identified. The investigation will be directed at assessing the structural integrity of the existing underlying soil matrix and identifying ledge.

5.6 SUMMARY & IMPLEMENTATION PLAN

Table 5-3 outlines the recommended implementation plan for moving ahead with the flood protection improvements. The plan outlines activities associated with identifying the most feasible and cost effective alternative for flood protection and the steps necessary to implement it. An estimated timeline is also provided with this table. Total estimated time for project completion is 49 months.

Table 5-3 – Implementation Plan

Action Item	Pump Station & Drainage System Improvements
RECOMMENDED FIRST STEP Develop Preliminary Design Report • Perform Utility Study • Select Preferred Pump Station Discharge Pipe Route • Select Preferred Pump Station & Storage Location • Identify Preliminary Sizing of Drainage System Improvements • Identify Easement & Right-of-Way Requirements • Update Projected Project Costs	4 mo.
Await Decision re: FEMA Funding	Anticipated October 2011
Appropriate Necessary Funds	2 mo.
Gather Data • Geotechnical Investigation • Environmental Evaluation • Wetlands Study • Additional Topographic Survey (Right of Way, Easements)	3 mo.
Perform Public Outreach • Right-of-Way & Easements	1 mo.

Permitting & Design
• Develop Plans & Specifications
• Prepare & Submit Permit Applications
  • 404 Army Corps of Engineers
  • 401 Water Quality Certification
  • Environmental Notification Form*
  • Notice of Intent
  • Chapter 90
	8 mo.

Perform Construction Level Design	4 mo.
Conduct Public Bidding	3 mo.
Construction	24 mo.
Total Estimated Duration	49 mo.

** Need currently being assessed.*

6. ROSIES POND/BROOKS STREET/JEFFERSON AVENUE AREA IMPROVEMENTS

The alternatives analysis determined that the Rosies Pond/Brooks Street/Jefferson Avenue area must be physically isolated from South River to limit floodwater encroachment for up to the 100-year event. It was also recommended that these improvements be implemented with upgrades to the existing Ocean Avenue West pump station and other stormwater infrastructure in the area. Specifically, the following measures are recommended:

- Construction of retaining walls and regrading of portions of the existing earthen berms
- Rehabilitation of the existing Rosies Pond control structure
- Improvements to the existing drainage system along Jefferson Avenue and Ocean Avenue West
- Rehabilitation of the existing Ocean Avenue West pump station
- Increasing the capacity of the existing Ocean Avenue West pump station to convey additional flow

A description of the recommended measures and an outline of the potential costs and measures necessary for implementation are outlined below.

6.1 DESCRIPTION OF IMPROVEMENTS

Retaining Wall & Earthen Berm Improvements

Improvements to existing earthen berms and retaining walls are recommended to limit floodwater encroachment from South River for storm frequencies up to the 100-year rainfall event. The SewerGEMS® baseline conditions analysis described in Section 3 determined that the existing berms and walls were currently configured to provide protection for a 10-year rainfall event. As a result, these berms/walls must be raised in elevation, and supplemented with additional walls to protect the area during a 100-year event. The recommended improvements are predicted to protect 12.5 acres of residential properties, 40 residential structures, and four roads from floodwater encroachment for the 100-year rainfall event.

The locations of the recommended improvements are illustrated on Figure 11. These locations were determined by Woodard & Curran with input from the City of Salem. Generally, improvements fall along residential properties where floodwater encroachment was predicted for a 100-year rainfall event. The top elevations of the new retaining walls and the improvements to existing measures were defined using the peak water surface elevations predicted by the SewerGEMS® model under baseline conditions. Top elevations were set to exceed peak water surface elevations for the 100-year event, consequently limiting floodwater encroachment from South River. This information is provided in Table 6-1.

Table 6-1 – Summary of Retaining Wall/Earthen Berm Improvements

Improvement	Description	Estimated Length	Approx. Average Wall Height	Top Elevation of Wall or Earthen Berm	100-year Water Surface Elevation
Wall-1	Improvements along the eastern perimeter of Rosies Pond	775 ft.	42 in.	16.5	15.8
Wall-2	Improvements between the MBTA railroad and Lawrence Avenue	235 ft.	36 in.	16.5	15.5
Wall-3	Improvements along the northern side of South River falling immediately downstream of Lawrence Avenue	200 ft.	24 in.	15.5	15.2
Wall-4	Improvements along the southern side of South River running parallel with Brooks Street and Wheatland Street	265 ft.	30 in.	15.5	15.2
Wall-5	Improvements perpendicular to the existing retaining wall falling immediately upstream of Jefferson Avenue	85 ft.	18 in.	15.5	15.2
Wall-6	Improvements to the existing retaining wall falling immediately upstream of Jefferson Avenue	220 ft.	Extend existing wall ~6 in. vertically	15.5	15.2
Berm-1	Improvements along the northern side of South River running parallel with Brooks Street	375 ft.	N/A	15.5	15.2
Berm-2	Improvements along the eastern side of South River running parallel with Jefferson Avenue	850 ft.	N/A	15	14.4

The work associated with constructing new retaining walls will also require minor regrading and the installation of new drainage collection systems at low points along the walls. The drainage systems will limit the accumulation of stormwater on the upgradient side of the walls by collecting and conveying it to South River. The systems will be constructed with flap gates to limit encroachment of floodwater from South River into these new systems.

The extent of work associated with raising the existing earthen berms is dependent upon the results of a future geotechnical investigation. A geotechnical investigation will be necessary to confirm subsurface soil conditions, strengths, and permeabilities and to identify subsurface issues related to raising the existing earthen berms, including increases in hydrostatic pressure. The geotechnical evaluation will provide the information necessary to understand the extent of work needed to raise the top elevation of the earthen berms and the costs associated with this work.

Rehabilitation of Rosies Pond Control Structure

Improvements to the existing control structure from Rosies Pond are recommended to restore its original flood mitigation capability. The existing structure is depicted on Figure 12 and comprises two 24-inch reinforced concrete pipes (RCP) and two 15-inch RCPs, all which fall under a berm. Improvements are recommended since the structure is showing signs of settlement, joint separation, misalignment, and erosion/sedimentation. These signs indicate the structure may not be functioning as intended and may also indicate that the structure is impacting flooding in areas directly downstream of it. Replacement of this structure with a hydraulically equivalent structure is recommended to maintain flows from Rosies Pond and protect down gradient properties and wetland resource areas.

Drainage System Improvements

Improvements to the existing drainage collection system along Jefferson Avenue and Ocean Avenue West are recommended to increase its collection and conveyance capacity. The locations of the recommended improvements are illustrated on Figure 11. Currently, the drainage system collects stormwater runoff from the contributing drainage area and conveys it to the existing Ocean Avenue West pump station. The Ocean Avenue West Pump Station Assessment Report[2] established the drainage system is only capable of conveying flows from less than the 10-year event. Therefore, improvements to the system are needed to allow it to collect/convey flows from the 100-year event. Improvements should be made in conjunction with pump station capacity upgrades, which are recommended and discussed further in this section.

Physical Rehabilitation of Ocean Avenue West Pump Station

Improvements to the existing Ocean Avenue West pump station are recommended to provide reliable long-term operation of the pump station[3]. The location of the pump station is illustrated on Figure 11. These measures minimize the potential for failure and consequently, localized flooding. The recommendations consider findings provided in the Ocean Avenue West Pump Station Assessment Report[2], which include the following:

- replacement of both pump flights, motors, gear reducers, and bearings;
- pump controls, building system upgrades and repairs;
- improvements to the building and grounds; and
- installation of permanent standby power.

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[2] Prepared for the City of Salem, MA by Woodard & Curran on March 9, 2009.
[3] It is estimated that the recommendations will provide for reliable operation for the next 35-50 years. These timeframes are based on typical life-expectancies assuming maintenance is performed as recommended by the manufacturer.

It should be noted that these recommendations do not consider upgrading the pump station to convey flows from the 100-year rainfall event. Those improvements are discussed in the next subsection.

Increase Capacity of Ocean Avenue West Pump Station

Upgrades to increase the capacity of the existing Ocean Avenue West pump station are recommended to raise the level of protection to a 100-year flood event. It is recommended that these upgrades be implemented with the pump station rehabilitation improvements previously outlined. The current capacity, or operating pump rate of the pump station, is estimated to be 8,700 gallons per minute (gpm). This flow rate is capable of servicing runoff from the contributing watershed for a 10-year rainfall event[4].

Woodard & Curran recommends that the flood mitigation capacity be increased by installing a stormwater storage structure to accommodate the additional volume of runoff generated by the 100-year rainfall event. Underground storage within the existing Ocean Avenue West right-of-way just upstream of the pump station is proposed, and the volume of necessary storage is estimated to be 25,000 cubic feet (ft^3).

Please note that Woodard & Curran did evaluate increasing the capacity of the pump station by installing an additional pump. However, this alternative was not considered further because of the higher upfront capital costs and long-term operation and maintenance costs as compared with the underground storage option.

The locations of the recommended improvements are illustrated on Figure 11.

6.2 CONSTRUCTION COSTS

Construction costs were estimated for the recommended improvements. These estimates are based on vendor quotes, Woodard & Curran's experience with similar work, RSMeans Cost Data, and unit bid tabulations from the Massachusetts Highway Department. Table 6-2 summarizes the cost estimate. Detailed cost estimates for each recommended improvement can be found in Appendix D.

Table 6-2 – Summary of Estimated Costs

Recommendation	Cost
Retaining Wall & Earthen Berm Improvements	$950,000 - $1,250,000*
Rehabilitation of Rosies Pond Control Structure	$95,000
Drainage System Improvements	$310,000
Rehabilitation of OAW Pump Station	$835,000
Increase Capacity of OAW Pump Station (storage)	$720,000
TOTAL:	**$2,910,000 - $3,210,000***

**A range is provided at this time since soil conditions along the existing earthen berms are unknown. This information is pending a future geotechnical evaluation.*

[4] Findings presented in the "Ocean Avenue West Pump Station Assessment Report, City of Salem, MA" prepared by Woodard & Curran, dated March 9, 2009.

6.3 REGULATORY PERMITTING REQUIREMENTS

Implementation of the improvements is anticipated to require obtaining the following permits/approvals. It should be noted that not all improvements will require each of the following:

- Notice of Intent – Massachusetts Wetland Protection Act
- 404 Army Corps of Engineers
- 401 Water Quality Certification
- Environmental Notification Form – Massachusetts Environmental Protection Agency (need currently being assessed)

6.4 EASEMENTS

The majority of the work involved with this project is proposed to occur within existing easements throughout the Rosies Pond and Jefferson Avenue neighborhood areas. However, additional access/construction easements will be required to facilitate the improvements and can only be identified during final design. It is anticipated that these easements will be limited to properties adjacent to the proposed improvements, as shown on Figure 11 and Figure 12.

6.5 RECOMMENDED STUDIES

The following activities are recommended prior to the design of the recommended improvements:

- A geotechnical investigation to assess the structural integrity of the existing soil matrix along Rosies Pond and South River where wall and earthen berm improvements are proposed.
- A topographic survey of integral areas to supplement surveys previously performed. Information needed from the survey includes the location and geometry of existing utilities and property boundary information that is integral to identifying the need for additional easements and obtain right-of-way information.
- A wetlands study to characterize and delineate the wetlands within the vicinity of the proposed improvements. Known wetland areas include Rosies Pond and South River. The study will be performed to minimize potential impacts to wetland areas and identify rehabilitation measures, if necessary.

6.6 SUMMARY & IMPLEMENTATION PLAN

Table 6-3 and Table 6-4 outline the recommended implementation plan for moving forward with the flood protection measures. Table 6-4 considers the retaining wall and earthen berm improvements. These improvements are currently being considered by FEMA for funding assistance, and as a result, a separate implementation plan has been provided for these specific improvements since their source of funding is pending this decision. The implementation plan for the remaining improvements is provided in Table 6-3. An estimated timeline is also provided with the tables. It should be noted that the timeline assumes the improvements discussed in this section are conducted independently of the Canal Street/Salem State improvements discussed in Section 5. A longer schedule would be required if these were combined into a single project.

Table 6-3 – Implementation Plan (Projects Not Eligible for FEMA Funding)

Action Item	Rehabilitation of Rosies Pond Control Structure		Drainage System Improvements		Physical Rehabilitation of OAW Pump Station		OAW Stormwater Storage	
<u>RECOMMENDED FIRST STEPS</u>								
Appropriate Necessary Funds	X	1 mo.	X	1 mo.	X	1 mo.	X	1 mo.
Data Gathering								
• Geotechnical Evaluation	X						X	
• Wetlands Delineation	X	3 mo.	X	3 mo.			X	3 mo.
• Additional Survey	X		X				X	
Permitting & Design								
• Develop Plans and Specifications	X		X		X		X	
• Prepare & Submit Permit Applications								
• 404 Army Corps of Engineers	X	6 mo.		6 mo.		6 mo.		6 mo.
• 401 Water Quality Certification	X							
• Environmental Notification Form*	X							
• Notice of Intent	X		X		X		X	
Construction Level Design	X	2 mo.	X	2 mo.	X	2 mo.	X	2 mo.
Public Bidding	X	3 mo.	X	3 mo.	X	3 mo.	X	3 mo.
Construction	X	1 mo.	X	3 mo.	X	2 mo.	X	2 mo.
Total Estimated Duration		16 mo.		18 mo.		14 mo.		17 mo.

**Need currently being assessed.*

Table 6-4 – Implementation Plan (Projects Eligible for FEMA Funding)

Action Item	Retaining Wall & Earthen Berm Improvements
RECOMMENDED FIRST STEP Await Decision re: FEMA Funding Appropriate Necessary Funds	Anticipated October 2011
Data Gathering* • Geotechnical Evaluation • Wetlands Delineation • Additional Topographic Survey (Right of Way, Easements)	3 mo.
Public Outreach • Right-of-Way & Easements	1 mo.
Develop Preliminary Design Report • Select Preferred Wall Type • Identify Easement and Right-of-Way Information • Identify Wetland Impacts & Rehabilitation Measures • Update Projected Project Costs	4 mo.

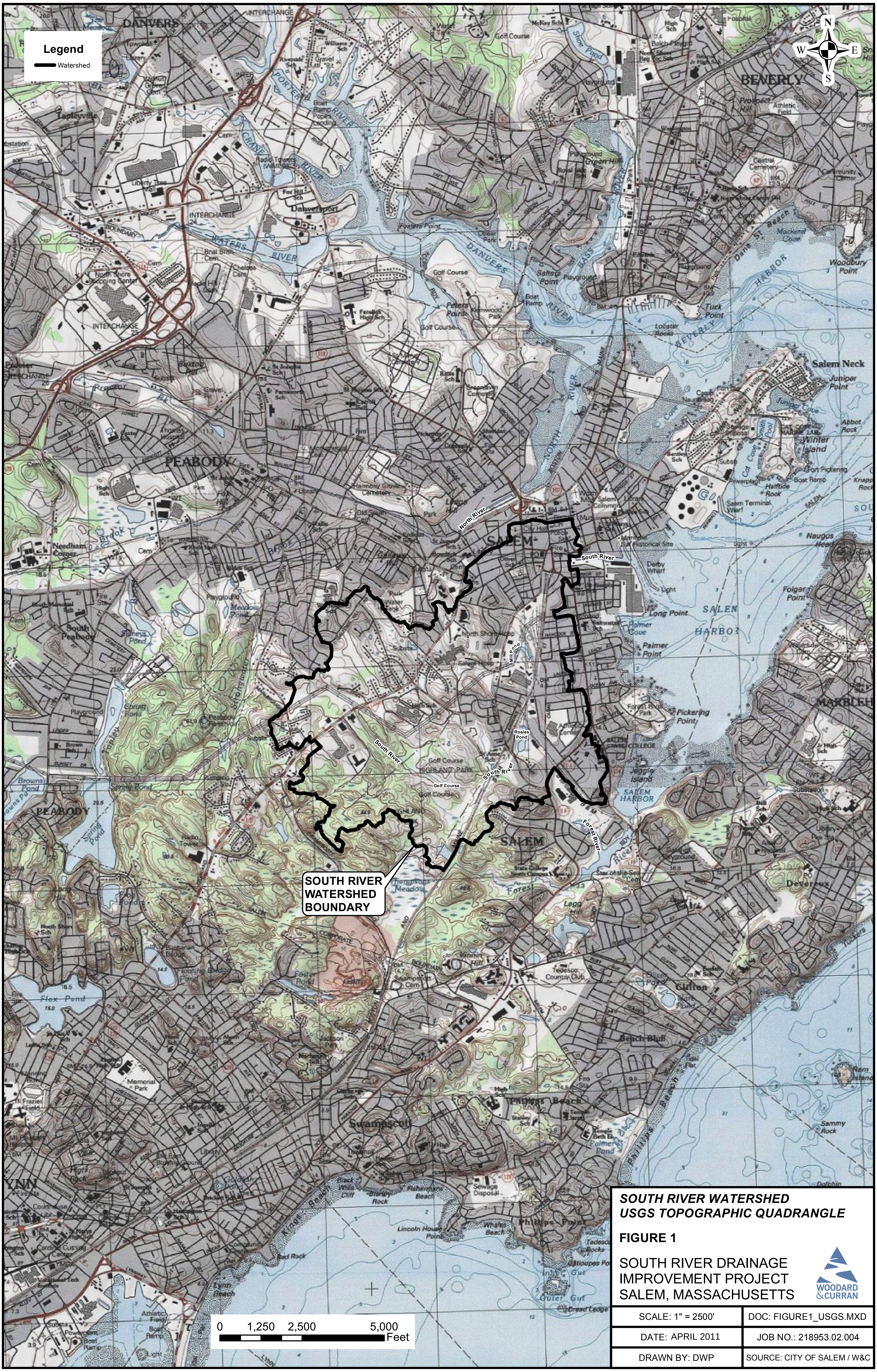
Permitting
• Develop Plans & Specifications
• Prepare & Submit Permit Applications
  • 404 Army Corps of Engineers
  • 401 Water Quality Certification
  • Environmental Notification Form**
  • Notice of Intent
  • Chapter 90
	8 mo.

Construction Level Design	4 mo.
Public Bidding	3 mo.
Construction	12 mo.
Total Estimated Duration	35 mo.

** Performed in conjunction with data gathering activities outlined in Table 6-3.*

***Need currently being assessed.*

Figure 1: USGS Map



SOUTH RIVER WATERSHED
USGS TOPOGRAPHIC QUADRANGLE

FIGURE 1

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 2500'	DOC: FIGURE1_USGS.MXD
DATE: APRIL 2011	JOB NO.: 218953.02.004
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 2: South River Watershed

Watershed #	Area (acres)	Curve Number	Time of Concentration (hr.)
1	158.2	77	1.34
2	251.3	77	1.53
3	231.5	68	1.79
3A	57.4	85	0.94
3B	28.7	83	0.77
3C	77.1	78	1.44
4	57.9	88	0.26
5	38.5	94	1.17
5A	4.1	94	0.25
5B	6.9	94	0.25
5C	8.5	93	0.25
5D	42.1	92	0.46
6	18.5	92	0.25
7	2.4	92	0.25
8	10.2	92	0.25
9	9.2	93	0.25
10	12.3	80	0.25
11A	14.2	88	N/A
11B	28.0	88	0.39
11C	46.0	88	0.40
12A	14.2	98	0.25
12B	7.7	98	0.25
13	3.0	92	0.25
14A	10.1	92	0.25
14B	11.5	92	0.25
14C	1.0	92	0.25
15	8.4	92	0.25
16	99.4	91	0.25
17	16.2	93	0.25
18	66.4	93	0.25
19	29.5	94	0.25
5S	6.1	83	0.23
6S	4.4	79	0.54
8S	4.8	98	0.12
9S	14.6	83	0.43
10S	3.8	83	0.22
11S	1.5	83	0.12
12S	3.0	83	0.25
13S	2.6	83	0.15
14S	4.0	83	0.27
15S	6.8	90	0.20
16S	1.5	94	0.08
17S	2.4	98	0.08
19S	4.9	82	0.30
20S	2.5	88	0.13

Notes:

1) Photo Date: April 2004
2) Topographic Information Obtained via Aerial Photography by Furgo EarthData - Spring 2009
3) Vertical Datum - City of Salem
4) Culverts and Drainage Information Obtained by Field Survey - Spring 2009 by WSP Sells

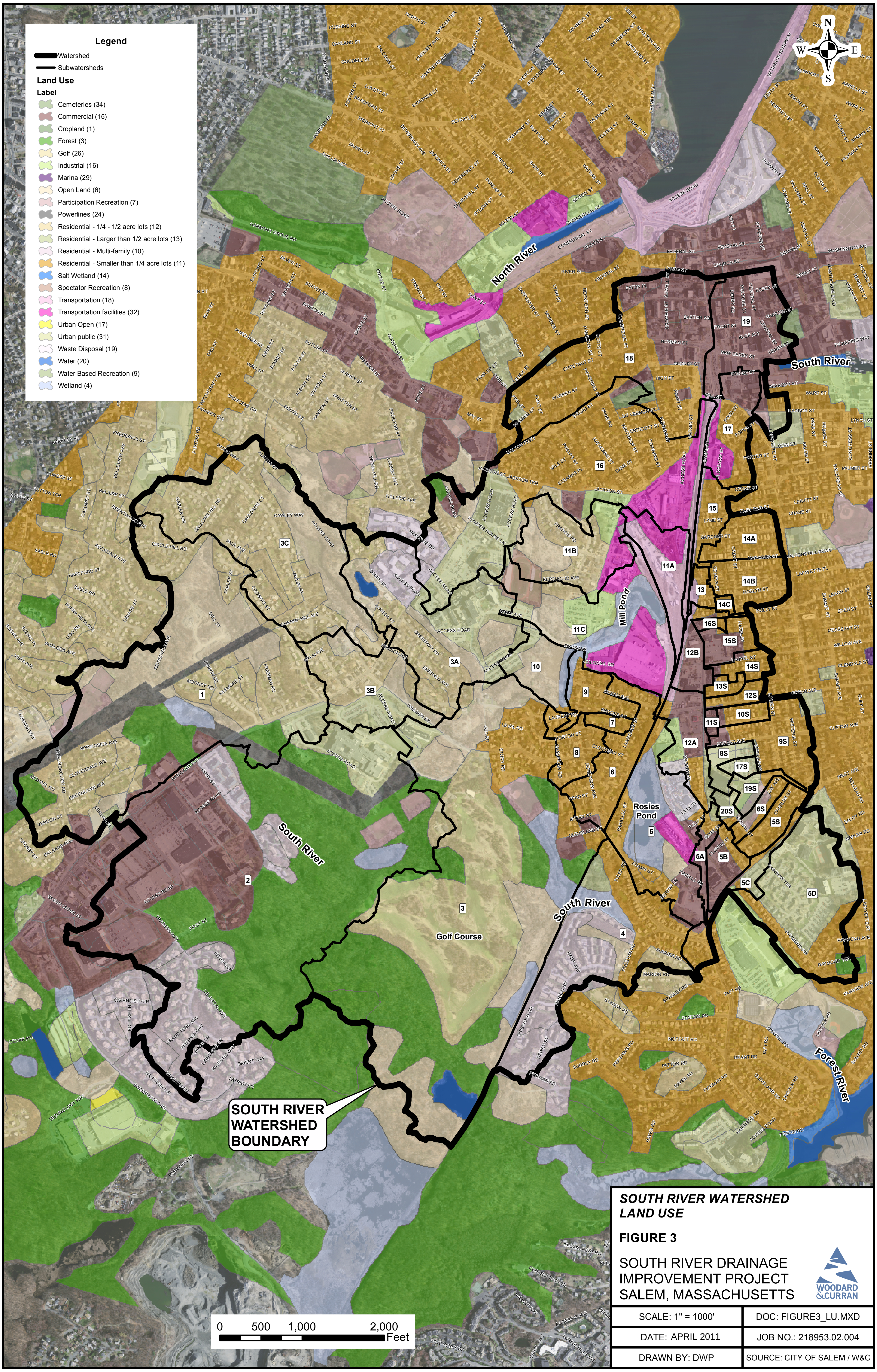
SOUTH RIVER WATERSHED

FIGURE 2

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT SALEM, MASSACHUSETTS

SCALE: 1" = 500'	DOC: FIGUREX.MXD
DATE: APRIL 2011	JOB NO.: 218953.001
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 3: Land Uses



SOUTH RIVER WATERSHED LAND USE

FIGURE 3

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 1000'	DOC: FIGURE3_LU.MXD
DATE: APRIL 2011	JOB NO.: 218953.02.004
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 4: Soils

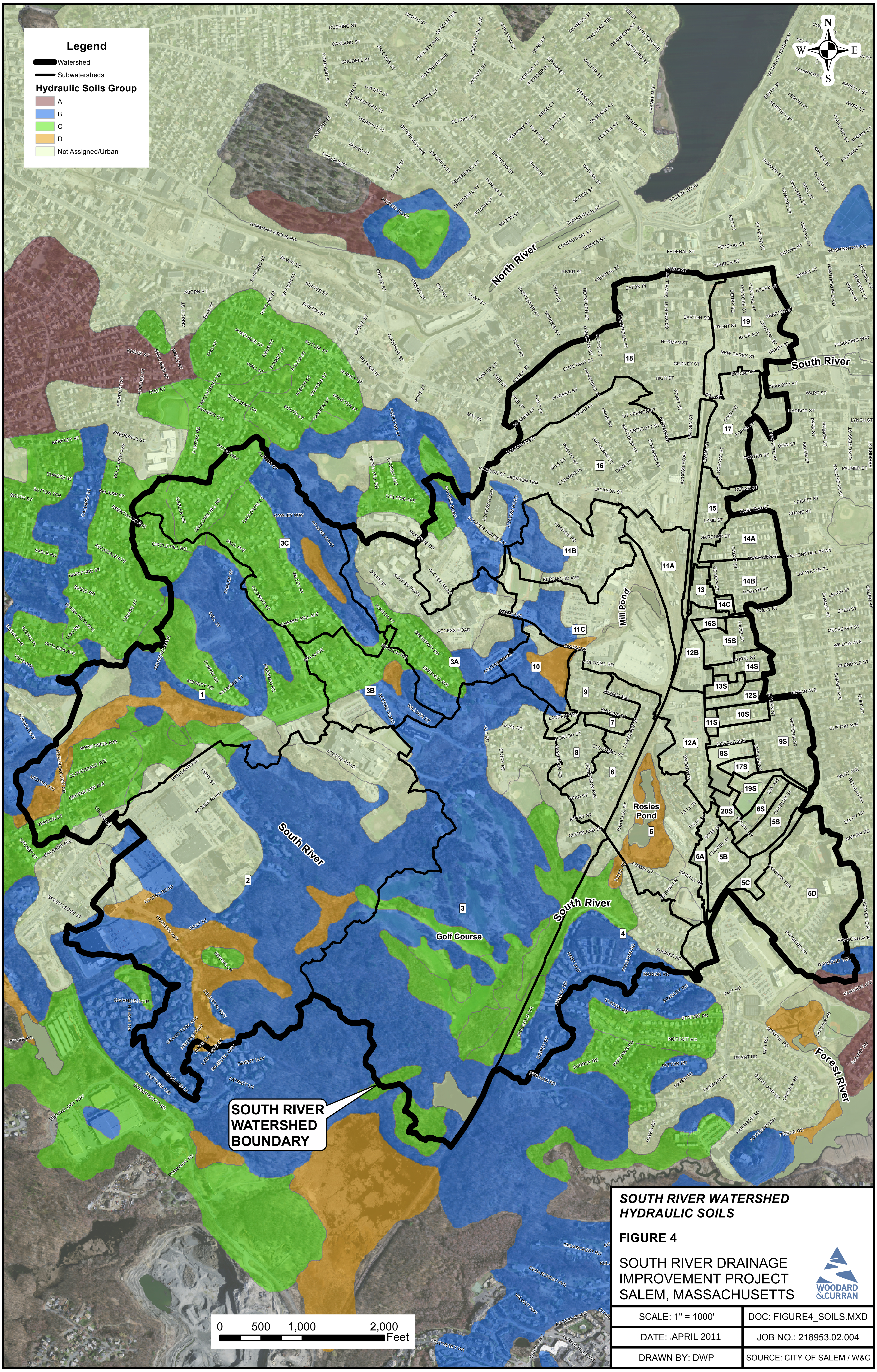
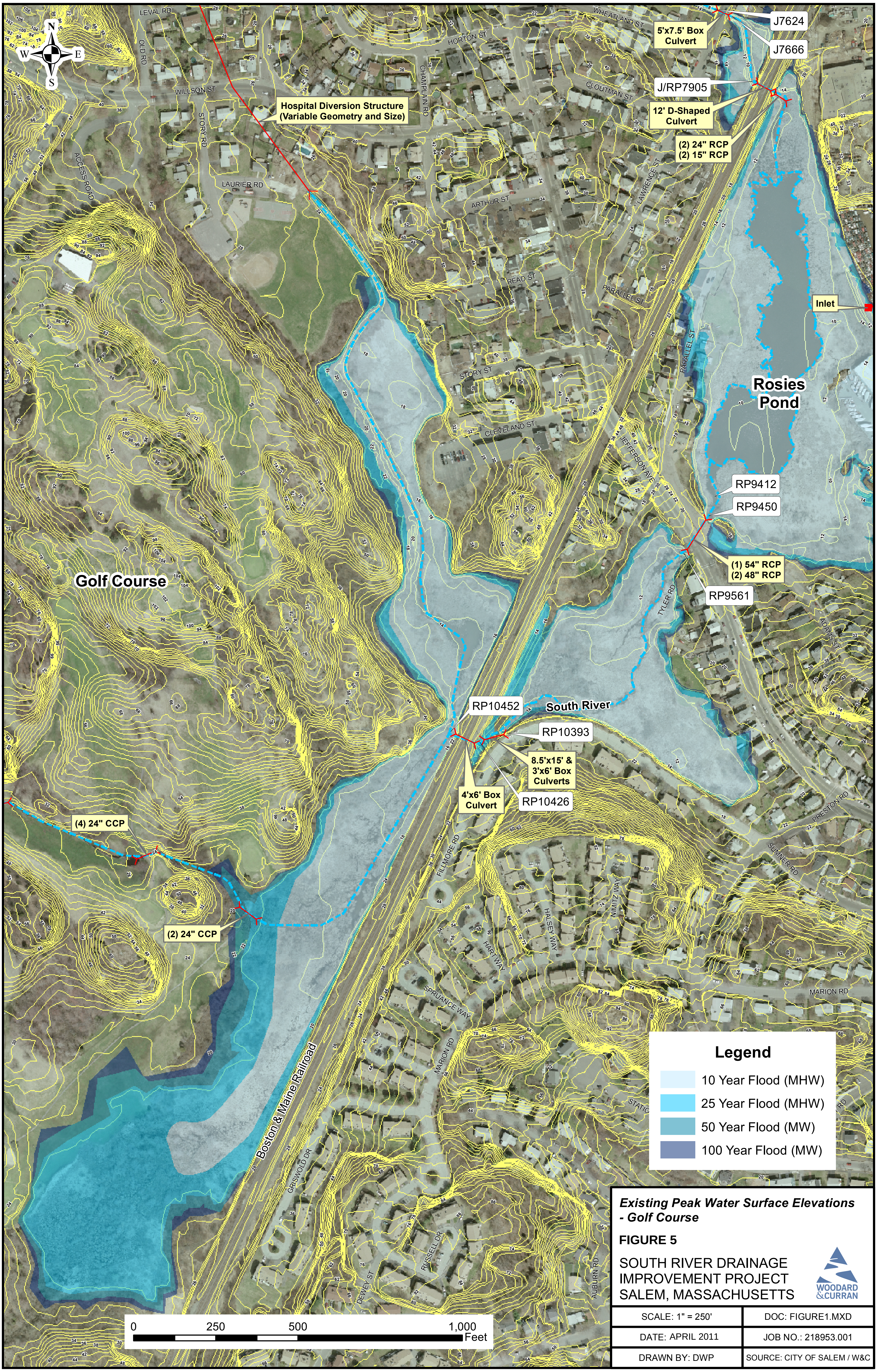

Legend
Watershed
Subwatersheds
Hydraulic Soils Group
A
B
C
D
Not Assigned/Urban
N
S
E
W
North River
South River
Mill Pond
Rosies Pond
Golf Course
Forest River
SOUTH RIVER WATERSHED BOUNDARY
0 500 1,000 2,000 Feet
SOUTH RIVER WATERSHED HYDRAULIC SOILS
FIGURE 4
SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT SALEM, MASSACHUSETTS
WOODARD &CURRAN
SCALE: 1" = 1000'
DOC: FIGURE4_SOILS.MXD
DATE: APRIL 2011
JOB NO.: 218953.02.004
DRAWN BY: DWP
SOURCE: CITY OF SALEM / W&C

Figure 5: Existing Peak Water Surface Elevations – Golf Course



Existing Peak Water Surface Elevations - Golf Course

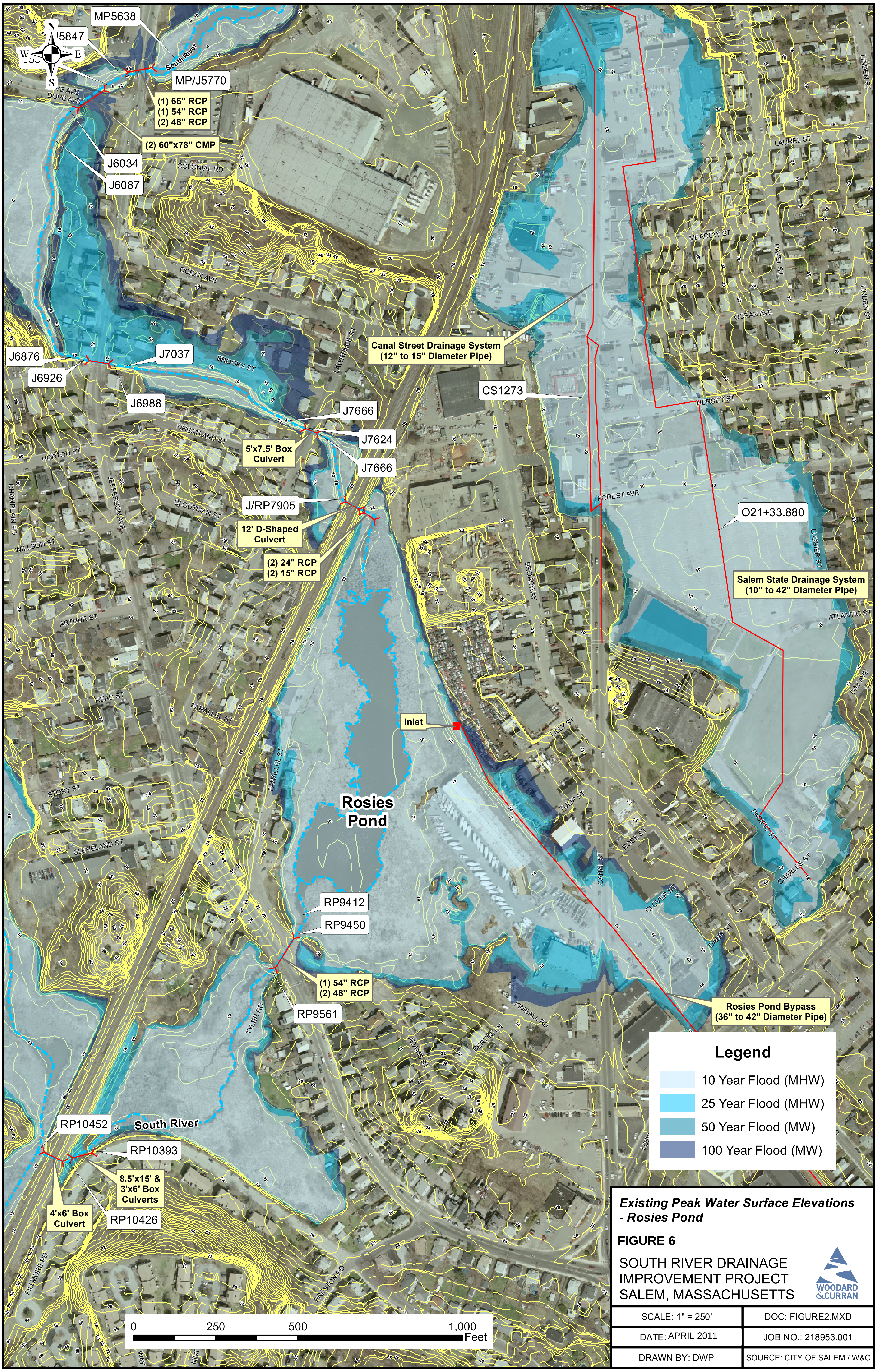
FIGURE 5

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 250'	DOC: FIGURE1.MXD
DATE: APRIL 2011	JOB NO.: 218953.001
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 6: Existing Peak Water Surface Elevations – Rosies Pond



Existing Peak Water Surface Elevations - Rosies Pond

FIGURE 6

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 250'	DOC: FIGURE2.MXD
DATE: APRIL 2011	JOB NO.: 218953.001
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 7: Existing Peak Water Surface Elevations – Jefferson Ave. Area & Mill Pond

Existing Peak Water Surface Elevations - Jefferson Ave Area & Mill Pond

FIGURE 7

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

SCALE: 1" = 250'	DOC: FIGURE3.MXD
DATE: APRIL 2011	JOB NO.: 218953.001
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 8: Existing Peak Water Surface Elevations – Canal Street and Salem State Area

Existing Peak Water Surface Elevations - Canal Street and Salem State Area

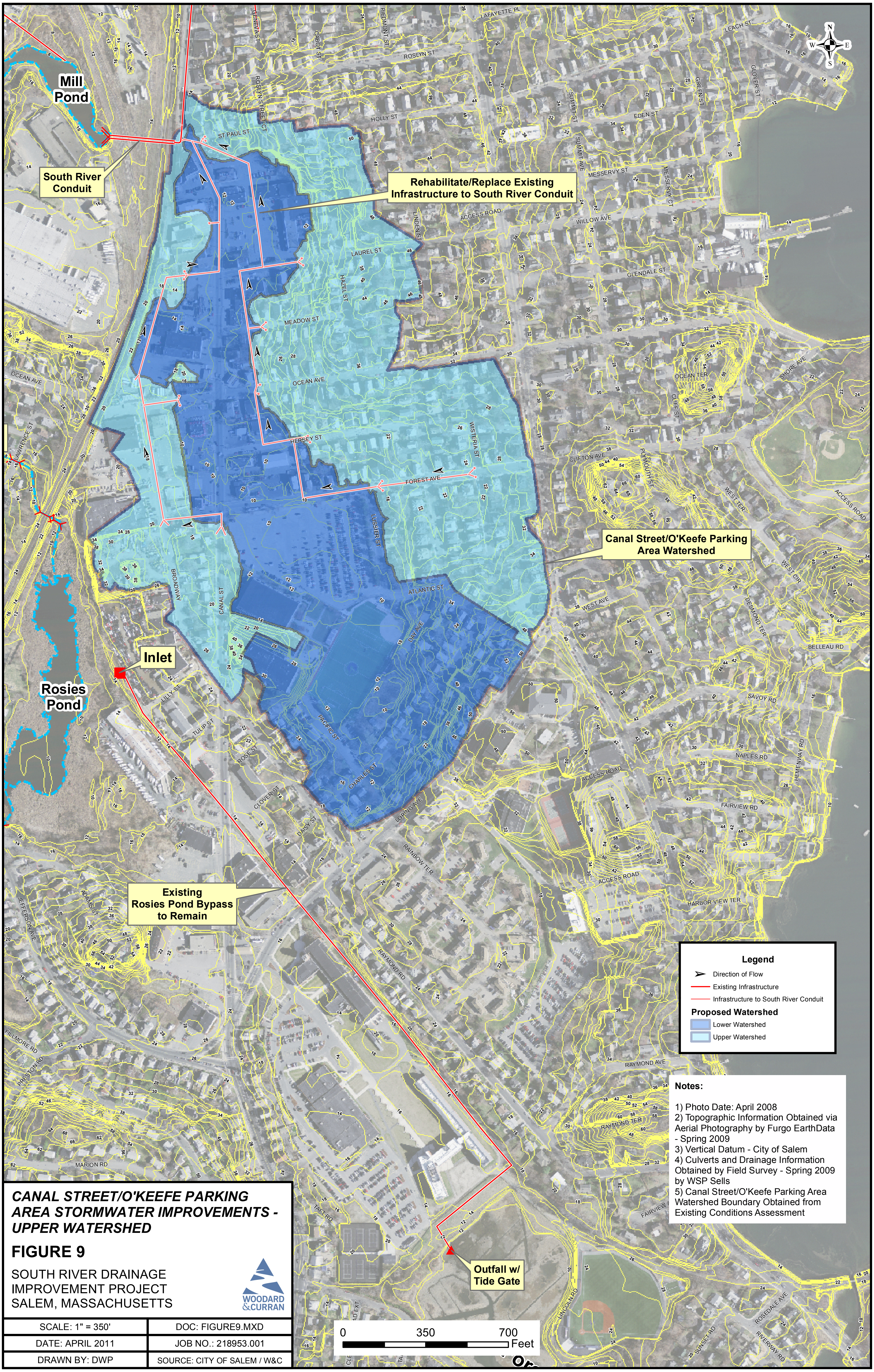
FIGURE 8

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 250'	DOC: FIGURE4.MXD
DATE: APRIL 2011	JOB NO.: 218953.001
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 9: Canal Street/Salem State University Improvements – Upper Watershed



CANAL STREET/O'KEEFE PARKING AREA STORMWATER IMPROVEMENTS - UPPER WATERSHED

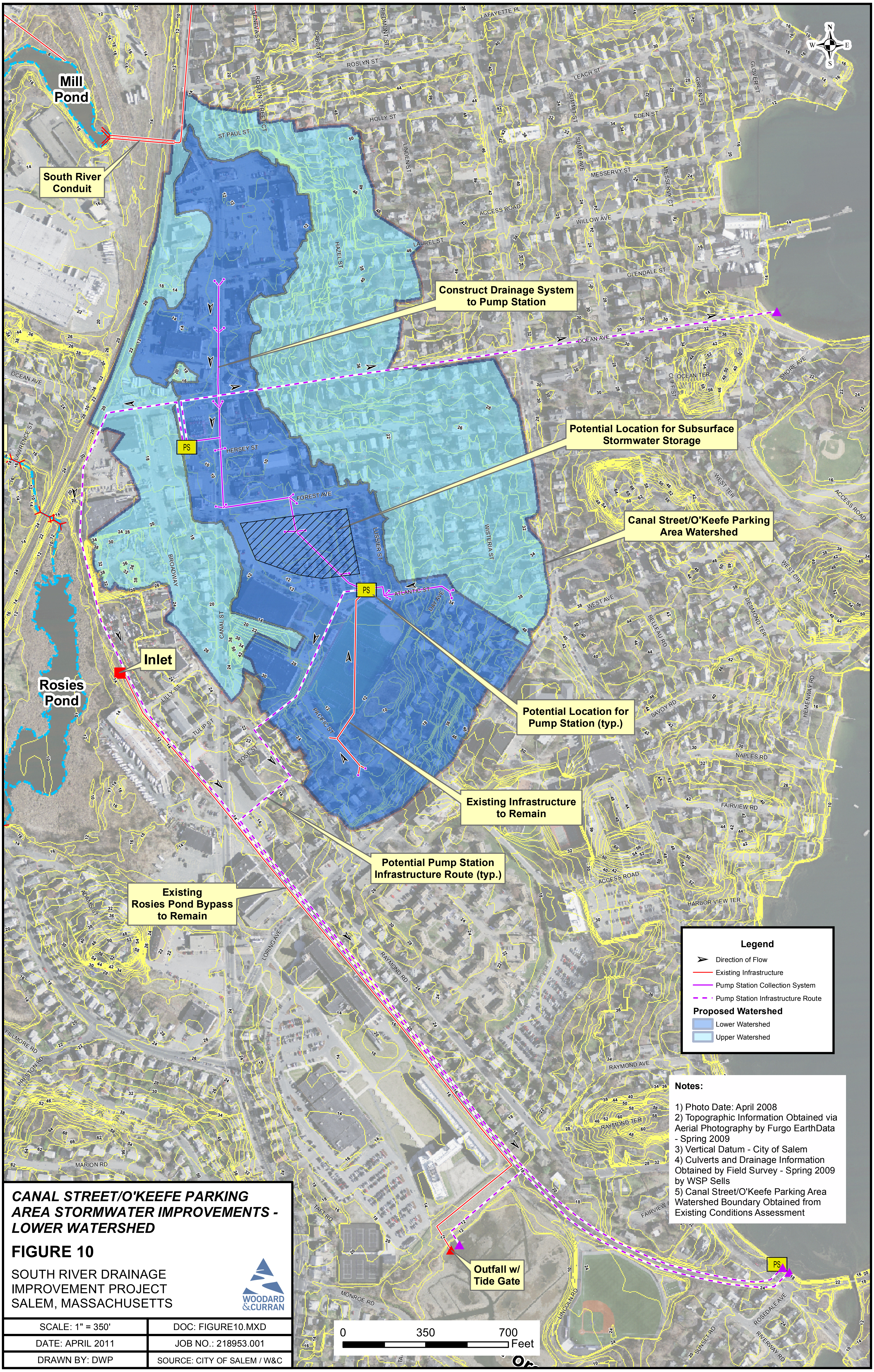
FIGURE 9

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 350'	DOC: FIGURE9.MXD
DATE: APRIL 2011	JOB NO.: 218953.001
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 10: Canal Street/Salem State University Improvements – Lower Watershed



CANAL STREET/O'KEEFE PARKING AREA STORMWATER IMPROVEMENTS - LOWER WATERSHED

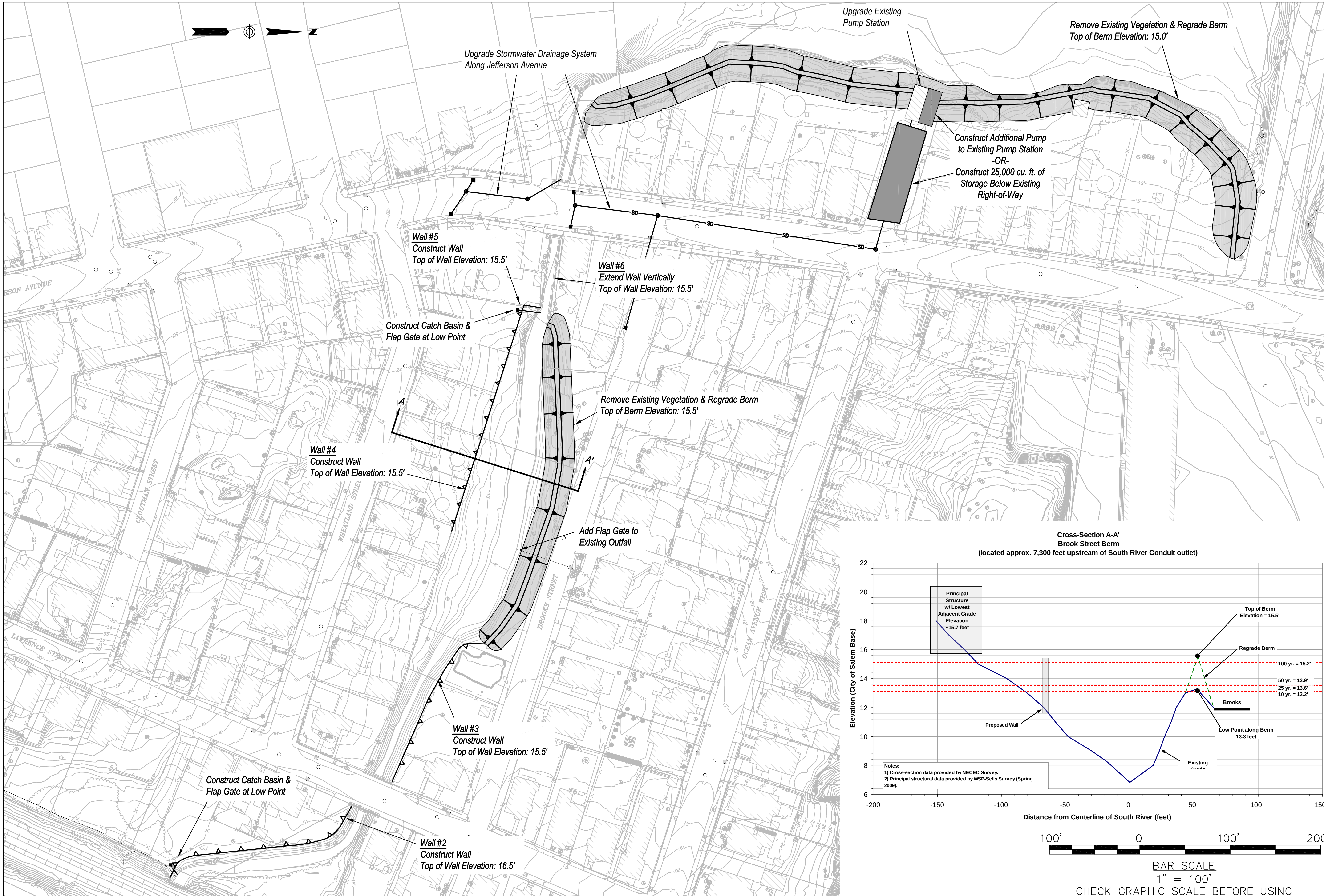
FIGURE 10

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 350'	DOC: FIGURE10.MXD
DATE: APRIL 2011	JOB NO.: 218953.001
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

Figure 11: Jefferson Avenue/Brooks Street Area Improvements



WOODARD & CURRAN

35 New England Business Center
Andover, Massachusetts 01810
866.702.6371 | www.woodardcurran.com

COMMITMENT & INTEGRITY DRIVE RESULTS

JEFFERSON AVENUE AREA STORMWATER INFRASTRUCTURE IMPROVEMENTS

DESIGNED BY: DAW
DRAWN BY: MAP
CHECKED BY: DAW
SW Improvements REV.dwg

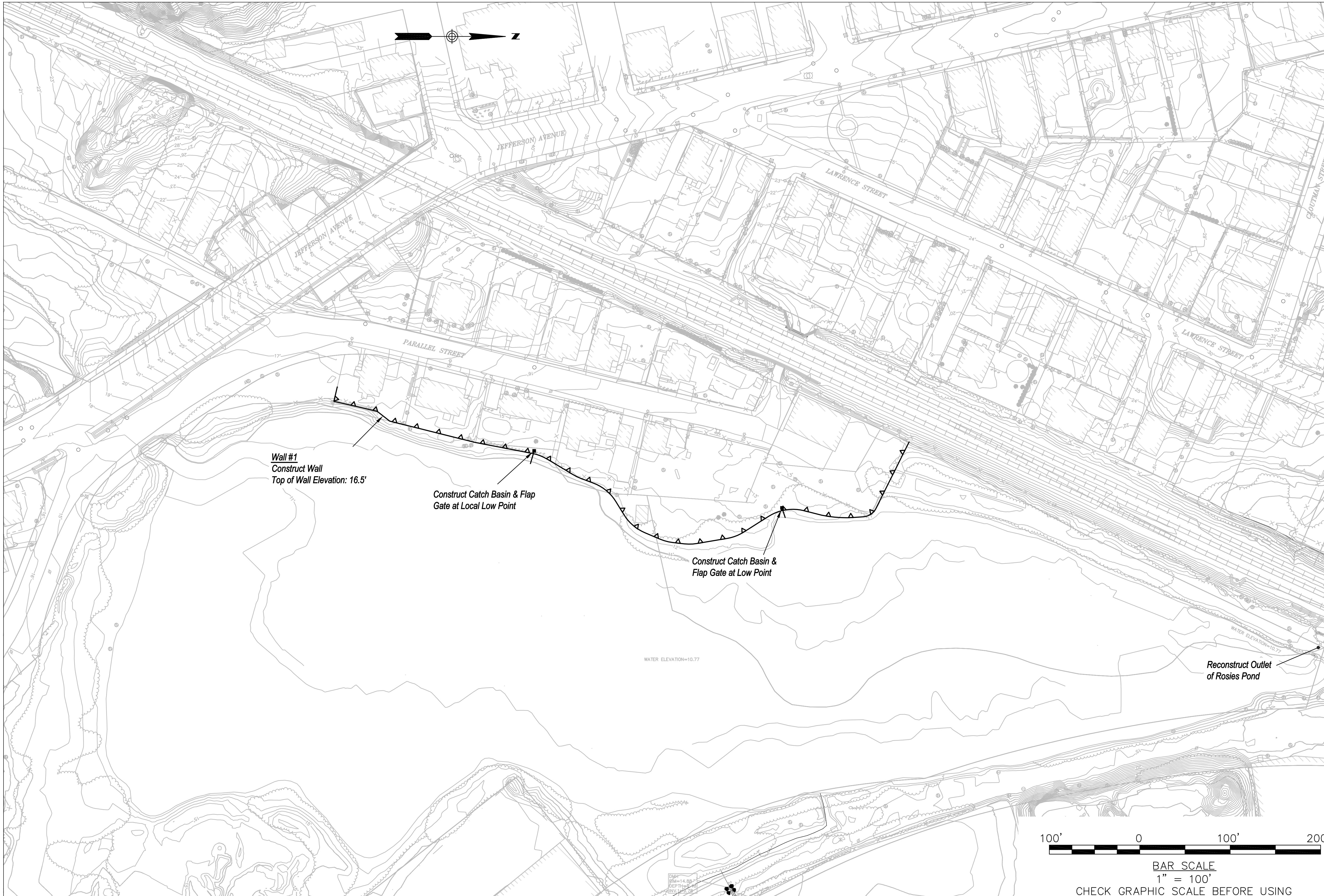
CITY OF SALEM, MASSACHUSETTS

SOUTH RIVER FLOOD MITIGATION PROJECT

JOB NO: 218953.02
DATE: April 2011
SCALE: 1" = 100'

11

Figure 12: Rosies Pond Area Improvements



35 New England Business Center
Andover, Massachusetts 01810
866.702.6371 | www.woodardcurran.com

COMMITMENT & INTEGRITY DRIVE RESULTS

WOODARD & CURRAN

ROSIES POND
STORMWATER INFRASTRUCTURE
IMPROVEMENTS

DESIGNED BY:	DAW	CHECKED BY:	DAW
DRAWN BY:	MAP	SW Improvements REV.dwg	

CITY OF SALEM, MASSACHUSETTS

SOUTH RIVER FLOOD
MITIGATION PROJECT

JOB NO: 218953.02
DATE: April 2011
SCALE: 1" = 100'

12

APPENDIX A: CLEANING & INSPECTION PROGRAM

CLEANING AND INSPECTION PROGRAM

The City of Salem, Massachusetts conducted a conditions assessment and cleaning program of principal drainage conduits serving the watershed during the spring of 2009. The purpose of the program was to remove sediment and debris from the conduits and inspect the drainage conduits for overall condition. A comprehensive inspection and cleaning of the South River Conduit, Canal Street and Salem State University drainage systems had not been conducted since 1966. As these systems serve as the backbone of the drainage system, and blockage of these systems would have a significant impact flooding within the Study Area, this effort was undertaken to maximize the hydraulic capacity of the existing infrastructure and identify future activities that may need to be undertaken to maintain functionality of the systems. The following provides an overall description of the program, the results of the program, and recommendations for areas requiring future repair or further in depth investigations to maintain the system.

DESCRIPTION

The program involved employing various methods of cleaning and inspection, which were dependent upon the size and location of drainage conduits. Small diameter conduits (generally less than 60-inches in diameter) were water jetted and inspections were performed by remote closed circuit television. Large diameter conduits were cleaned through a combination of water jetting and hand excavation. Inspections of the large diameter conduits were conducted by hand-held video camera.

The extents of the cleaning and inspections included the following infrastructure:

- Tide gates at the outfall into Salem Harbor.
- South River Drainage Conduit (from the outfall into Salem Harbor to the intersection of Canal Street and Street Paul Street, approximately 1,700 feet)
- Canal Street Drainage System (from St. Paul Street to the upstream limits, located in front on the O'Keefe Athletic Center, approximately 1,000 feet).
- Salem State University Drainage System (from St. Paul Street to Forest Street, approximately 1,300 feet).
- Two storm drainage siphons:
  - Riley Plaza Siphon (twin 36-inch siphons located under Washington Street).
  - Police Station Siphon (twin 18-inch siphons located between the Police Station and Canal Street).
- Two sanitary sewer siphons:
  - Front Street Siphon (twin 8-inch siphons located at the intersection of Washington Street and Front Street).
  - Mill Street Siphon (twin 18-inch siphons located in Mill Street between, Washington Street and Margin Street).

FINDINGS/RECOMMENDATIONS

Sediment/Debris Removal:

Cleaning of the above referenced systems resulted in the removal of approximately 300 tons of sediments and 30 tons of debris (tires, railroad ties, car parts, etc.).

Conditions Assessment:

Table 1 and Table 2 present a summary of key findings regarding the condition of the South River Conduit and siphons, respectively. In addition, recommendations and anticipated costs associated with improving the drainage infrastructure are provided. Summaries for the Canal Street and Salem State University area drainage systems are not provided as it is anticipated that these findings will be considered in conjunction with flood mitigation measures currently being recommended for the area. Recommendations are presented in the "Phase II Report for the South River Drainage Improvement Project," dated April 2011.

Full inspection reports are provided in Attachment A. Attachment B and Attachment C denote the location of these findings for South River Conduit and the siphons, respectively.

Table 1 – Summary of Findings for South River Conduit

	Location	Segment on Attachment B	Finding	Recommendation: Investigative Measure	Recommendation: Repair/Rehabilitation Measure	Estimated Cost
South River Conduit (Stationing begins at outfall and continues upstream)	Tide Gates at Outfall	A	Both tide gates were found not to seal properly. Infiltration into the South River Conduit was observed during periods of high tide.	None.	Replace existing tide gates.	$xxx,xxx
	Station 0+98 to 1+70	B	Ceiling slab was found to have heavy spalling over approximately half of its area. Many of the lower flanges of the steel beams are exposed and corroded. Remainder of the embedded steel beams may be actively corroding, as indicated by staining of unspalled concrete.	Develop and implement a detailed structural investigation to determine recommended remedial measures and budgetary cost estimate to repair ceiling.	Implement recommended remedial measures identified from future investigations.	$xx,xxx
	Between Stations 1+70 & 6+58	C	Several of the cast-in-place reinforced concrete beams near the intersection of New Derby and Washington Street were found to have exposed reinforcing bars which are actively corroding. One such beam contained a split along the bottom surface. Steel beams, in the portion of the structure where the ceiling consists of closely spaced steel beams with red brick infill, are showing moderate corrosion.	Develop and implement a detailed structural investigation to determine recommended remedial measures and budgetary cost estimate to repair beam and inhibit corrosion.	Implement recommended remedial measures identified from future investigations.	$xx,xxx
	Station 6+58 to 7+75	D	Sediment and timber debris was found in the 115' by 22' transition structure. At downstream limits of the structure, portions of the granite block wall have fallen into the drainage system and serve as a restriction to flow. This sediment and debris was not removed due to access limitations to this location.	None.	Remove granite block, sediment and functionally obsolete timber utility supports. Repair wall. Install access to grade to facilitate work and future access to chamber and down gradient sections of South River Conduit.	$xx,xxx
	Station 22+50+/- (Inspection station 16+40)	E	Granite slab from roof hanging.	None.	Remove hanging granite to prevent flow obstruction.	$xx,xxx
	Station 24+00+/- (Inspection station 14+60)	F	Bottom portions of steel sections of roof slab, composed of steel sections embedded in cast-in-place concrete, have severely deteriorated and pieces of bottom section are missing.	Develop and implement a detailed structural investigation to determine recommended remedial measures and budgetary cost estimate to repair ceiling.	Implement recommended remedial measures identified from future investigations.	$xx,xxx
	Station 26+00 to 30+00 (Inspection stations 9+00 to 12+00)	G	Old timber form work hanging from ceiling.	None.	Remove hanging timber to prevent debris from entering drainage system	$x,xxx
	Station 35+00 to 37+50 (Inspection stations 1+10 to 3+00)	H	Areas of flat cast-in-place reinforced concrete roof slabs are spalling and reinforcing bars are exposed.	Develop and implement a detailed structural investigation to determine recommended remedial measures and budgetary cost estimate to repair ceiling.	Implement recommended remedial measures identified from future investigations.	$xx,xxx

Table 2 – Summary of Findings for Siphons

<table>
<tr><th>Location</th><th>Type</th><th>Finding</th><th>Recommendation</th><th>Estimated Cost*</th></tr>
<tr><td>Front Street</td><td>Sewer</td><td>• Cast-in-place.
• Structures show evidence of leaking and/or corrosion.
• Riser section on each structure in need of repair/sealing.</td><td rowspan="4">• Isolation of one side of each double siphon to bypass flows or set up of bypass pumping system. Either approach shall include a backup plan and an emergency response plan.
• Removal of the cast iron inclined or vertical pipe at each end of the siphon. The pipes shall be cut inside the manhole structure from approximately 3-6 inches from the wall of the structure to the blind flange at the bottom.
• Piping in, and the access structures to, the siphons be rehabilitated
• Inversion of a cured-in-place pipe (CIPP) liner through the bottom of the invert, from manhole to manhole.
• Interior cemetitious grouting of the pre-cast concrete access structures to prevent infiltration through walls joints and the inverts.
• Interior grouting of all the structures is recommended to prevent infiltration to the manholes at the joints and the inverts.
• Installation of a new blind flange at the bottom of the siphon in each manhole, new wye or tee, and new ductile iron incline pipe to connect to existing using a solid sleeve coupling.
• For the two siphons that transport sewer flow, repair of damaged pipe is strongly recommended to remove infiltration from the sewer system. For the two drainage siphons, repairs are recommended but are not as high a priority.</td><td>$238,000</td></tr>
<tr><td>Riley Plaza</td><td>Drainage</td><td>• Cast-in-place.
• Structures in fairly good condition.
• Riser section on each structure in need of repair/sealing.
• Upstream structure did not have pipes in the manholes.</td><td>$297,000</td></tr>
<tr><td>Mill Street</td><td>Sewer</td><td>• Cast-in-place.
• Downstream structure in fairly good condition.
• Upstream structure shows signs of leaking and/or corrosion.
• Riser section on each structure in need of repair/sealing.
• No CCTV manhole inspection for the Mill Street structure that goes under the South River Conduit.</td><td>$424,000</td></tr>
<tr><td>Police Station & Canal Street</td><td>Drainage</td><td>• Cast-in-place.
• Structures show evidence of leaking and/or corrosion.
• Upstream structure did not have pipes in the manholes.</td><td>$273,000</td></tr>
</table>

**Full cost estimates are provided in ATTACHMENT .*

IMPLEMENTATION PLAN

Table 3 and Table 4 outline the recommended implementation plan for moving forward with the recommended improvements outlined in Table 1 and Table 2 for the South River Conduit and siphons, respectively.

Table 3 – Implementation Plan for South River Conduit

Action Item	South River Conduit Improvements
RECOMMENDED FIRST STEP Develop Preliminary Design Report • Consider recommended measures outlined in Table 1.	4 mo.
Appropriate Necessary Funding	2 mo.
Data Gathering • Consider recommended investigative measures outlined in Table 1.	3 mo.
Permitting • Develop Plans & Specifications • Develop & Submit Permit Applications	3 mo.
Construction Level Design	2 mo.
Public Bidding	2 mo.
Construction	12 mo.
Total Estimated Duration	28 mo.

Table 4 – Implementation Plan for Siphons

Action Item	Siphon Improvements
RECOMMENDED FIRST STEP Permitting • Develop Plans & Specifications* • Develop & Submit Permit Applications	4 mo.
Appropriate Necessary Funding	2 mo.
Construction Level Design*	4 mo.
Public Bidding	2 mo.
Construction	6 mo.
Total Estimated Duration	18 mo.

**Considers measures outlined in Table 2.*

ATTACHMENT A – INSPECTION REPORTS

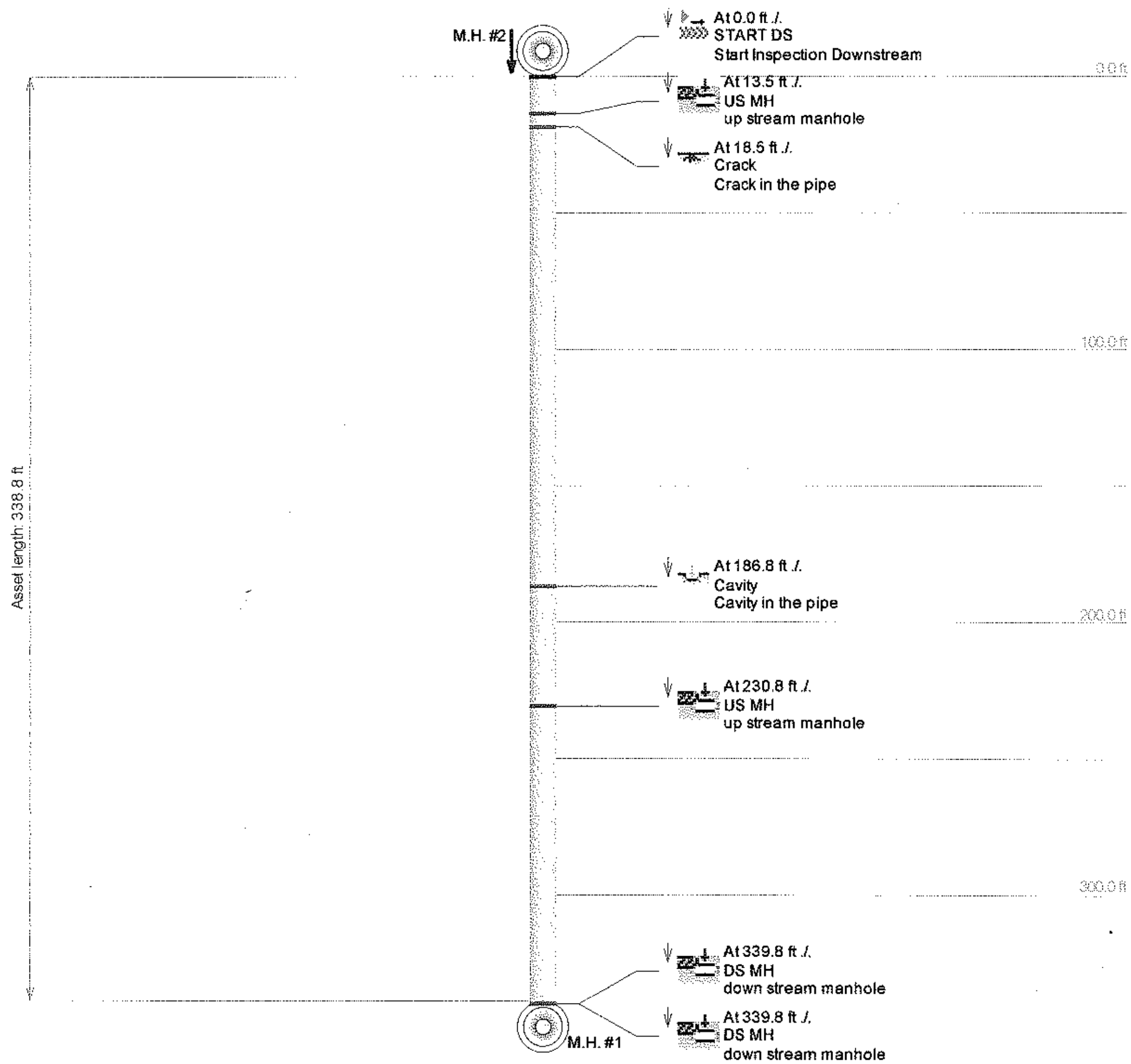
CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	East 72" Pipe	Salem Ma.	Canal St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
4/20/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream		Dry	



CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

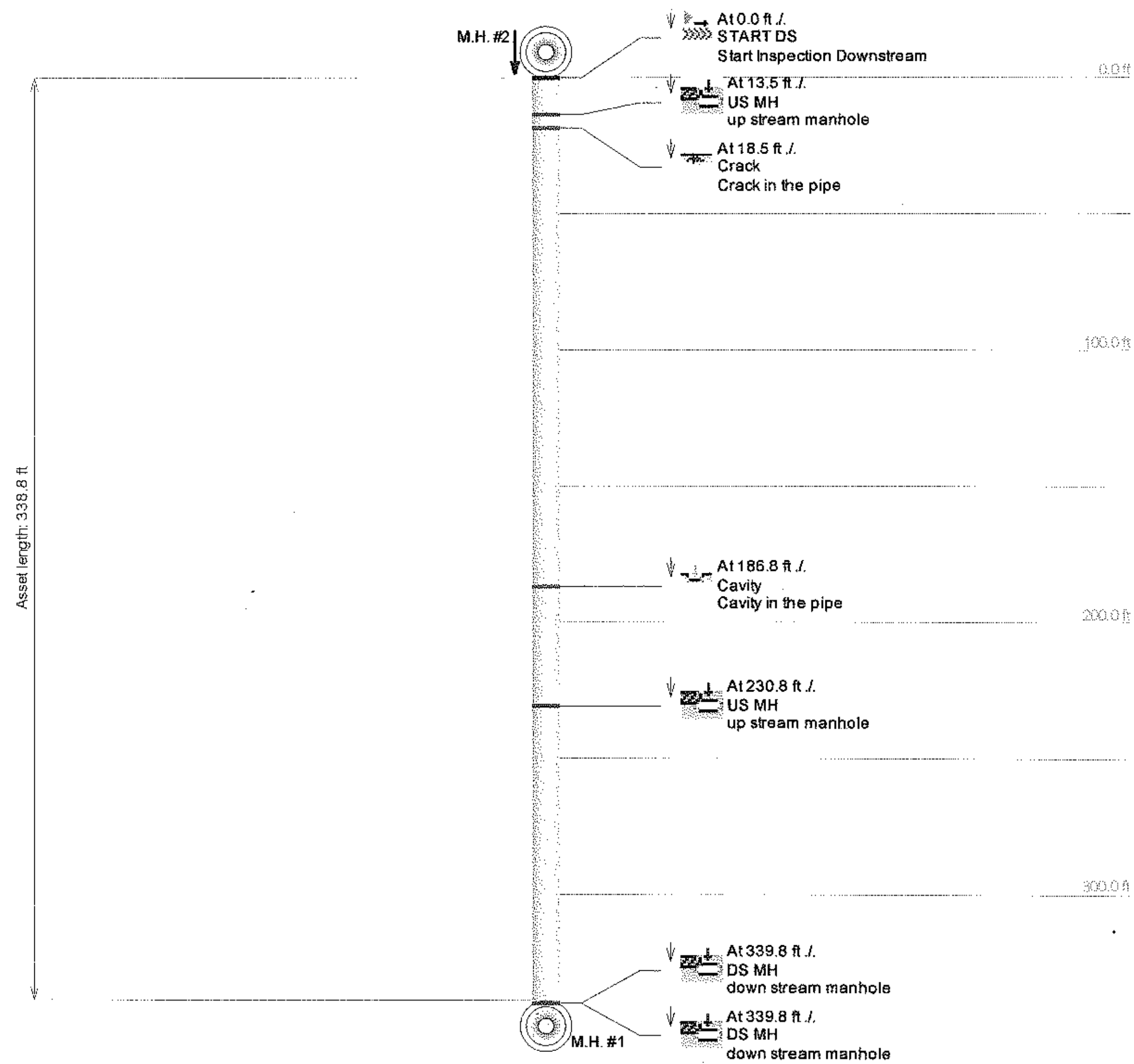
GRANITE XP
Pipeline Inspection and Integration Software

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	East 72" Pipe	Salem Ma.	Canal St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
4/20/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream		Dry	



CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

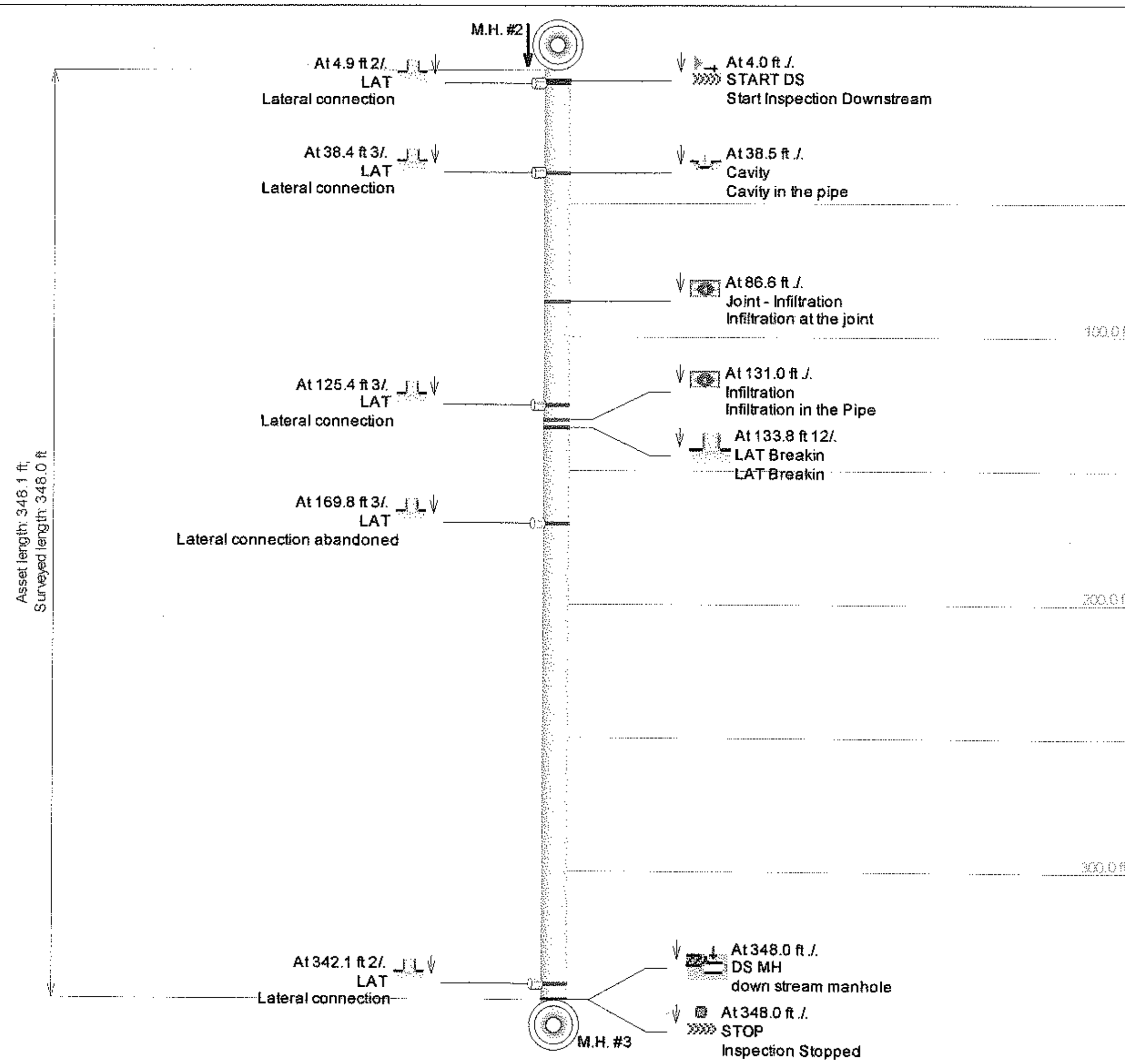
GRANITE XP
Pipeline Inspection and Integration Software

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	72" East	Salem, Ma.	Canal St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
4/20/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	348.0	Dry	



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GRANITE XP
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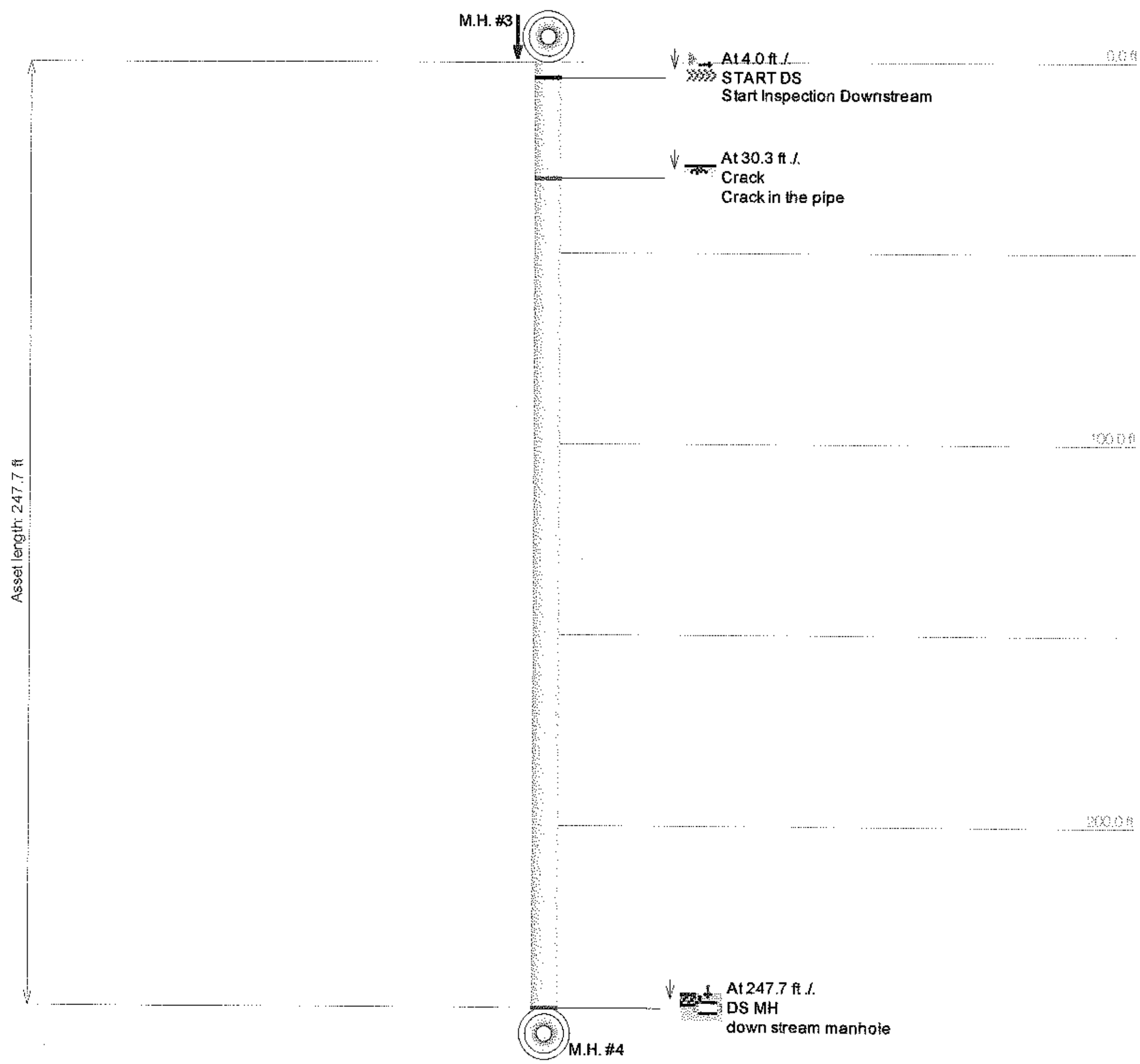
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	72" East	Salem, Ma.	Canal St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
4/20/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream		Dry	



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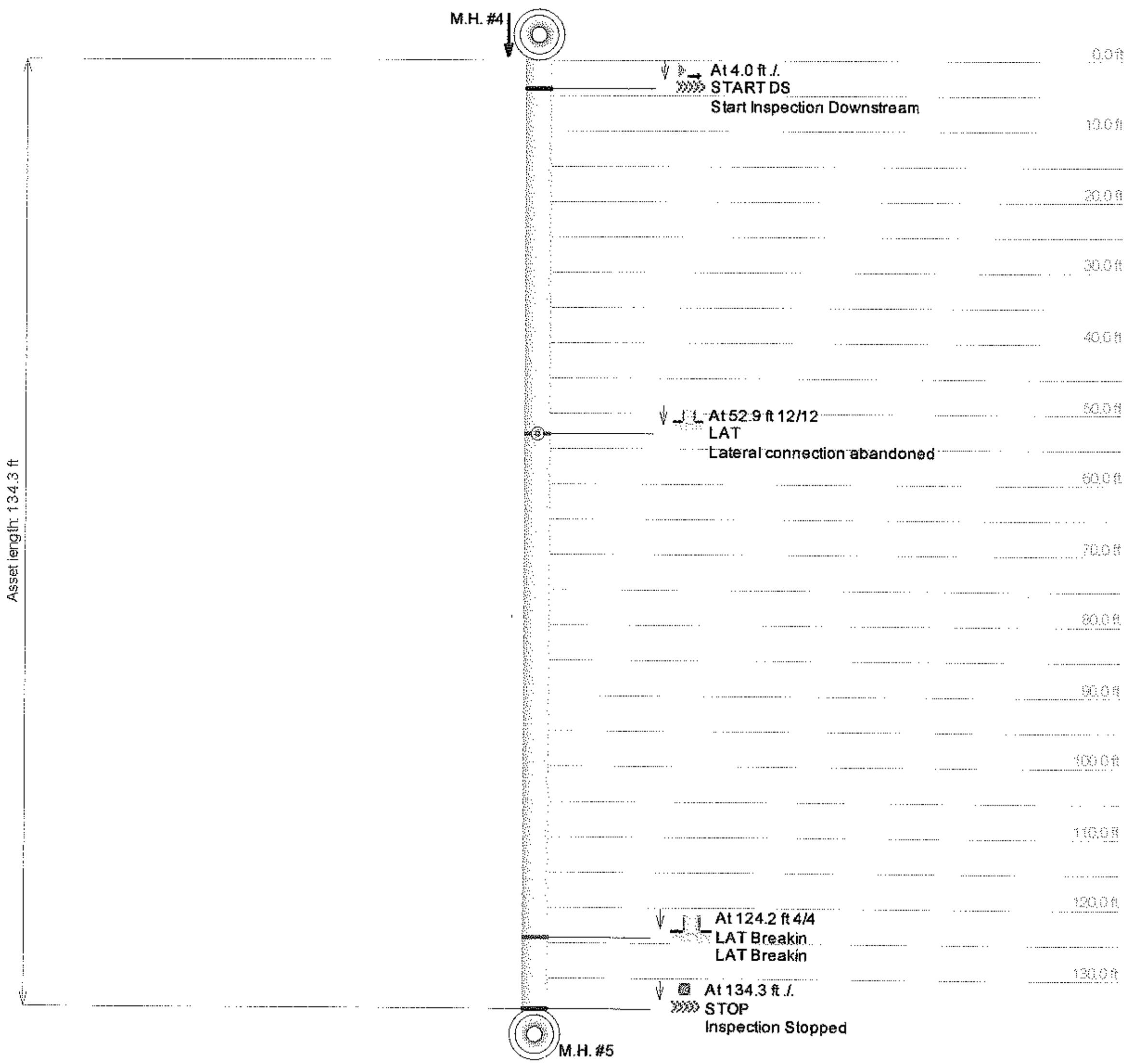
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	72" East	Salem, Ma.	Canal St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
4/20/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream		Dry	



GREEN
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June 5, 2009

CONSULTING SERVICES

CONTRACTING SERVICES

WASTE MANAGEMENT

CIVIL ENGINEERING

SITE DESIGN

Mr. David Knowlton, P.E.
City Engineer
City of Salem
120 Washington Street, 4th floor
Salem, Massachusetts 01970

RE: City of Salem, Drainage Conduit Cleaning and Inspection
Video Inspection Review

Dear Mr. Knowlton:

In accordance with the project manual for the above referenced project Green Environmental, Inc. (Green) has completed its review of the video inspections of the City of Salem Drainage Conduit. Based on our review of the inspection we're providing the following list of areas of concern:

8'x10' Box Culvert

@105'±	Crack in concrete roof.
@230'±	Wall collapsing around 12" pipe. (East Wall)
@305'±	Exposed rebar in roof section near east wall.
@365'±	Crack in concrete roof.
@380'±	Crack in concrete roof.
@433'±	Exposed rebar in concrete roof.
@460'±	Exposed rebar in roof near west wall.
@500'±	Crack in concrete & exposed rebar in roof.
@525'±	Crack in concrete roof.
@530'±	Exposed rebar in concrete roof.
@560'±	Crack in concrete roof, large piece of concrete missing.
@668'±	Exposed rebar in concrete roof.
@690'±	Exposed rebar in concrete roof.
@840'±	Exposed rebar in concrete roof near west wall.
@920'±	Fractured concrete & exposed rebar in concrete roof.
@940'±	Wall partially blocking drain pipe. (East Wall)
@950'±	Exposed rebar in concrete roof.
@1,050'±	Delaminating concrete & exposed rebar in roof.
@1,140'±	Drain pipe behind wall, pipe undermining wall. (East Wall)
@1,170'±	Crack in concrete roof.
@1,305'±	Sediment from pipe undermining wall.
@1,325'±	Fractured concrete & exposed rebar in concrete roof.
@1,440'±	Severely corroded steel beams in roof. (Ends @1,470'±)

52 Accord Park Drive
Norwell, MA 02061

Phone: (617) 479-0550

Fax: (617) 479-5150

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@1,640'± Granite roof section collapse.

Twin 72" (East Side) MH 5 – MH 6 (72" RCP)

@220'± Blocked lateral. (East Side)

Salem State Conduit MH 7B – MH 7AA (12" D.I.)

@92'± Grade rings from manhole covering pipe.

Salem State Conduit MH 7C – MH 7B (12" RCP)

@17'± Buried manhole. Coating coming off pipe on other side of manhole. Inspection stopped.

Salem State Conduit MH 7B – MH 7C (12" RCP)

@38'± Coating coming off pipe. (12 o'clock)
@100'± Coating coming off pipe. Inspection stopped.

Salem State Conduit MH 7D – MH 7C (12" D.I.)

@60'± Coating coming off pipe. Inspection stopped.

Salem State Conduit MH H1 – MH O2 (39" RCP)

@171'-215'± Roots in joints. (3 o'clock – 10 o'clock)

Salem State Conduit MH O1 – MH M1 (39" RCP)

@173'± Cluster of roots in joint. (4 o'clock)
@210'-215'± Clusters of roots in joints. (3 o'clock – 10 o'clock)

Salem State Conduit MH L2 – MH L3 (42" RCP)

@82'± Service connection in poor shape. Sediment & stone washing into pipe.

Salem State Conduit MH F1 – MH H3 (39" RCP)

@118'± Roots in joint. (4 o'clock)
@123'± Roots in joint. (2 o'clock)
@128'± Roots in joint. (10 o'clock)
@143'± Roots in joint. (2 o'clock)

Salem State Conduit MH L2 – MH L1 (39" RCP)

@77'± Infiltration at joint. (5 o'clock)
@82'± Infiltration at joint. (5 o'clock)

Salem State Conduit MH L1 – MH L2 (42" RCP)

@34'± Infiltration at joint. (5 o'clock)
@50'± Infiltration at joint. (6 o'clock)
@77'± Infiltration in pipe. (4 o'clock)

Salem State Conduit MH 3 – MH 2 (15" Clay)

@36'± Severely offset joint.

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@55'±	Broken pipe patched with brick.
@95'±	Sag in pipe.

<u>Salem State Conduit MH 9 – MH 10 (15" RCP)</u>

@58'±	Sag in pipe.

<u>Salem State Conduit MH 10 – MH 11 (15" RCP)</u>

@66'±	Sag in pipe.
@108'±	Sag in pipe.

<u>Salem State Conduit MH 11 – MH 12 (18" RCP)</u>

@13'±	Sag in pipe.
@66'±	Sag in pipe.

<u>Salem State Conduit MH 12 – MH 13 (15" RCP)</u>

@166'±	Infiltration at joint. (5 o'clock)
@256'±	Infiltration at joint. (12 o'clock)
@266'±	Infiltration at joint. (1 o'clock)
@267'±	Infiltration at joint. (5 o'clock)

<u>Salem State Conduit MH 1 – MH 2 (12" Clay)</u>

@25'±	Crack in pipe. (8 o'clock – 12 o'clock)
@30'±	Offset joint.
@60'±	Sag in pipe.
@101'±	Crack in pipe.
@113'±	Broken pipe.
@132'±	Offset joint.
@157'±	Sag in pipe.
@205'±	Sag in pipe.

<u>Salem State Conduit MH 3 – MH 4 (15" RCP)</u>

@12'±	Sag in pipe.
@104'±	Sag in pipe.

<u>Salem State Conduit MH 13 – MH 14 (18" RCP)</u>

@15'±	Infiltration at joint. (6 o'clock – 10 o'clock)
@45'±	Sag in pipe.
@62'±	Sag in pipe.
@69'±	Sag in pipe.
@266'±	Sag in pipe.

Thank you for the opportunity to provide these services to you. If you have any questions, please feel free to contact the undersigned directly at (617) 479-0550 ext. 233.

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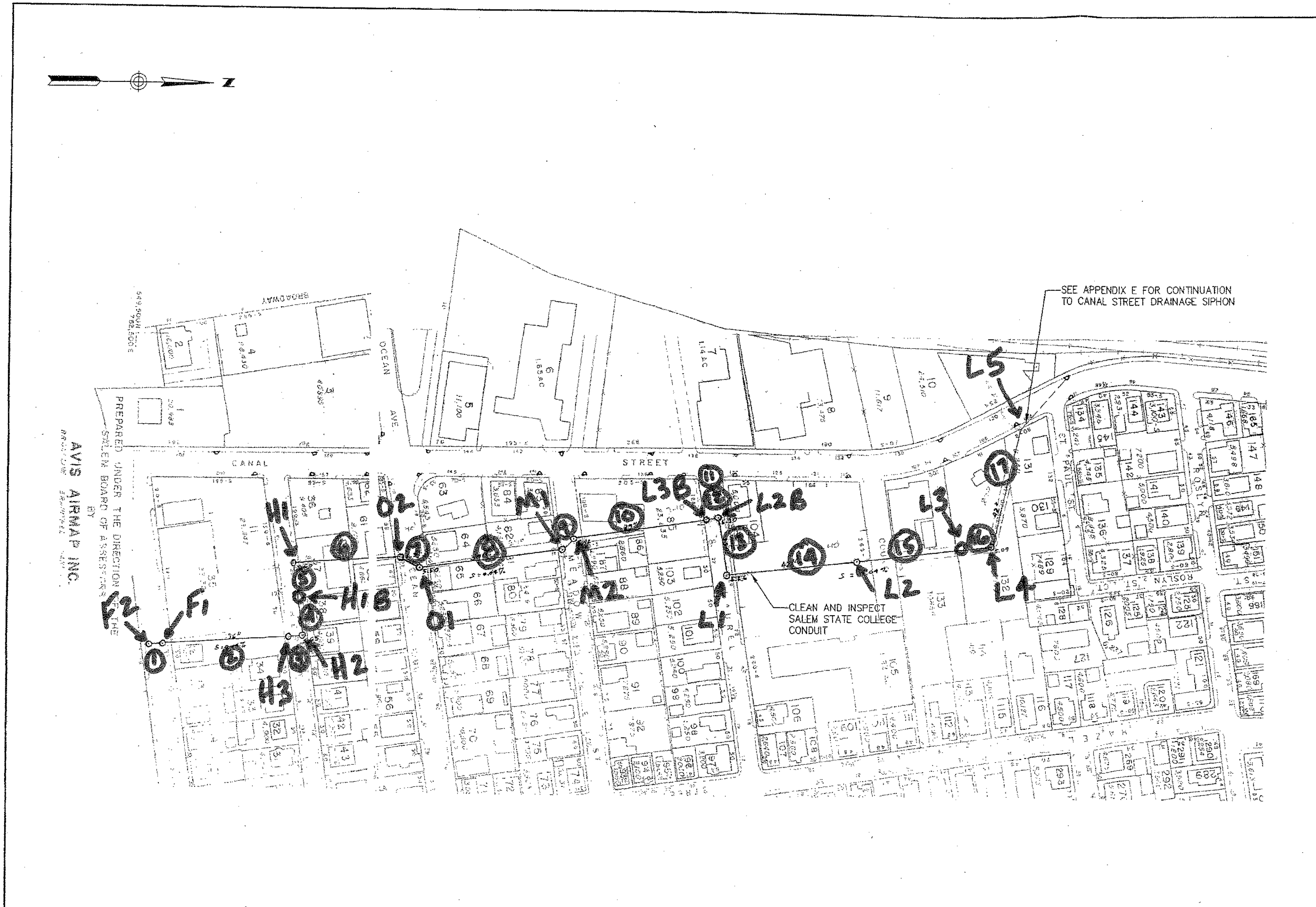
Very Truly Yours,
GREEN ENVIRONMENTAL, INC.

Jennifer W. Turcotte, P.E.
Project Manager



35 New England Business Center
Andover, Massachusetts 01810
866.702.6371 | www.woodardcurran.com

COMMITMENT & INTEGRITY DRIVE RESULTS

WOODARD & CURRAN

SALEM STATE COLLEGE CONDUIT

CITY OF SALEM, MA

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT

DESIGNED BY:	HCP
DRAWN BY:	HCP
CHECKED BY:	DAW
	Appendices.dwg
JOB NO:	218953
DATE:	December 2008
SCALE:	1"=150'

D

1

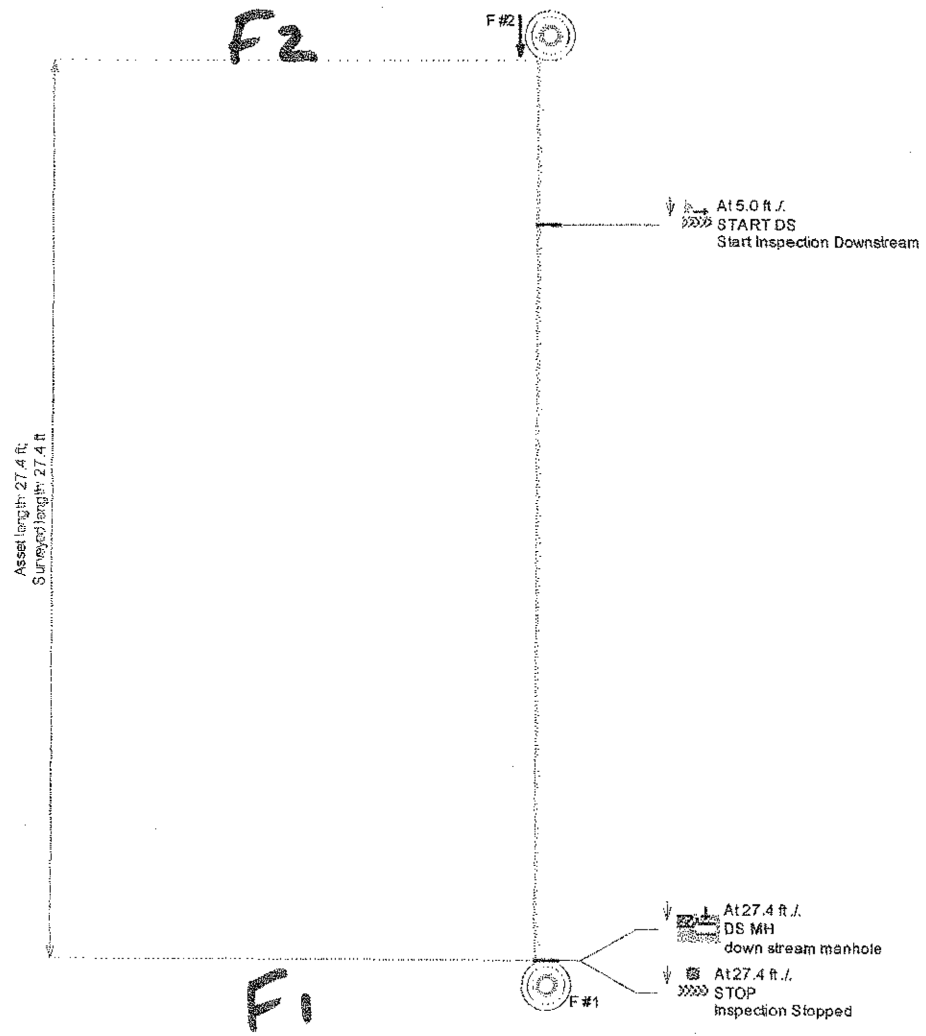
CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	Forest #3	Salem, Ma.	Forest Ave.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	36	36	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	27.4	Dry	



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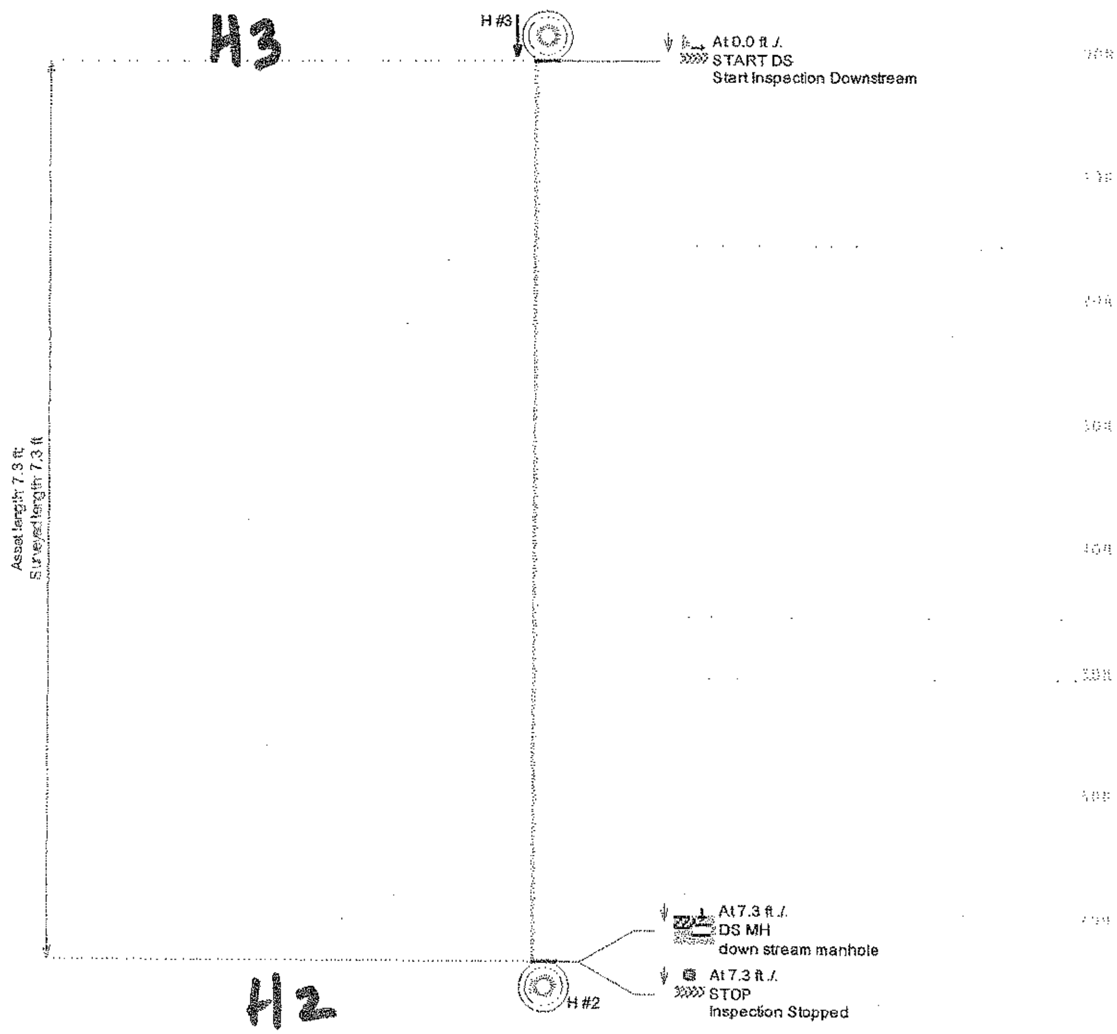
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	Forest #2	Salem, Ma.	Forest Ave

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	36	36	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	7.3	Dry	



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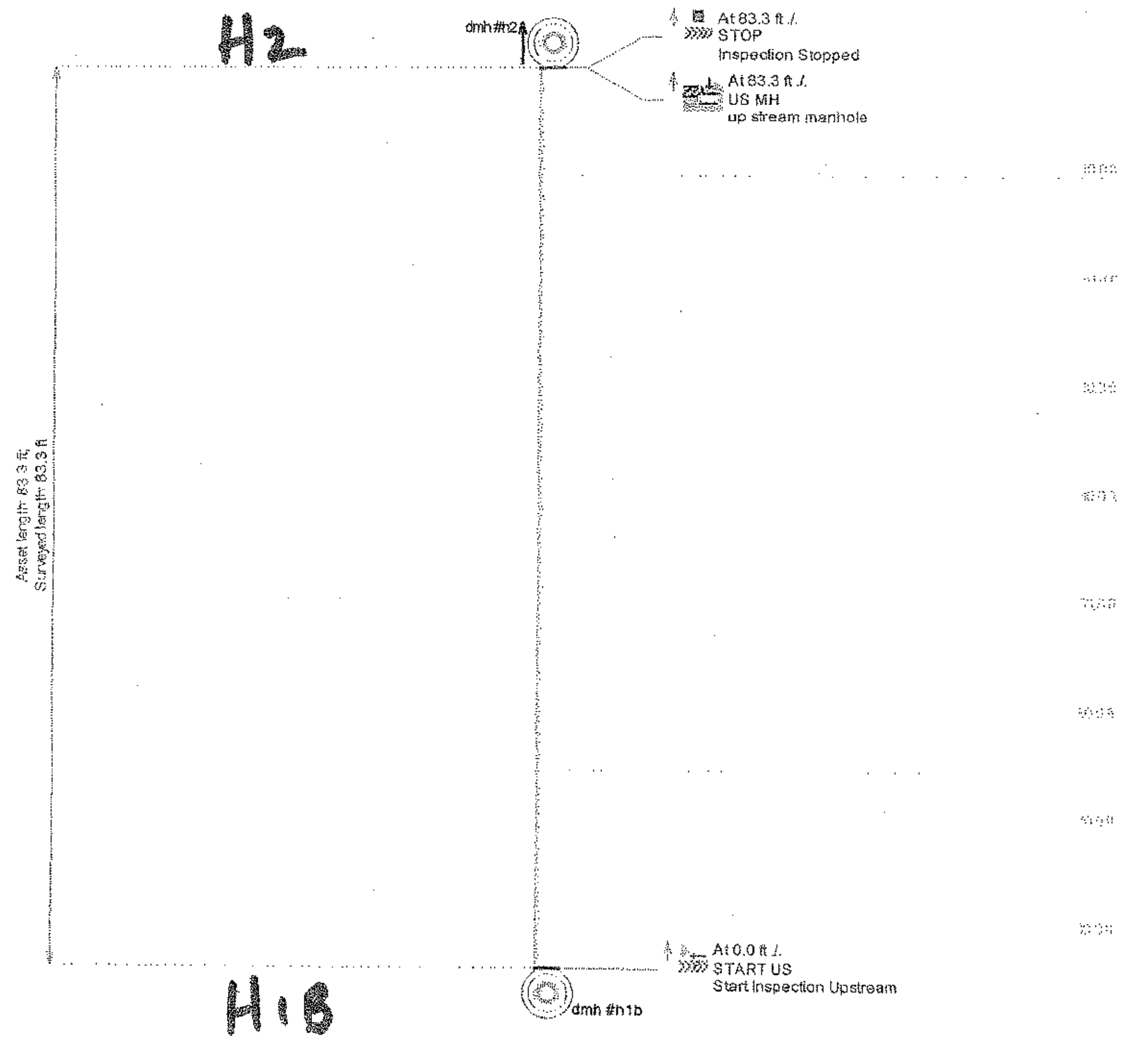
4

TV Inspection with Pipe Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	hersey dmh #2	salem ma	hersey st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	36	36	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	83.3	Dry	



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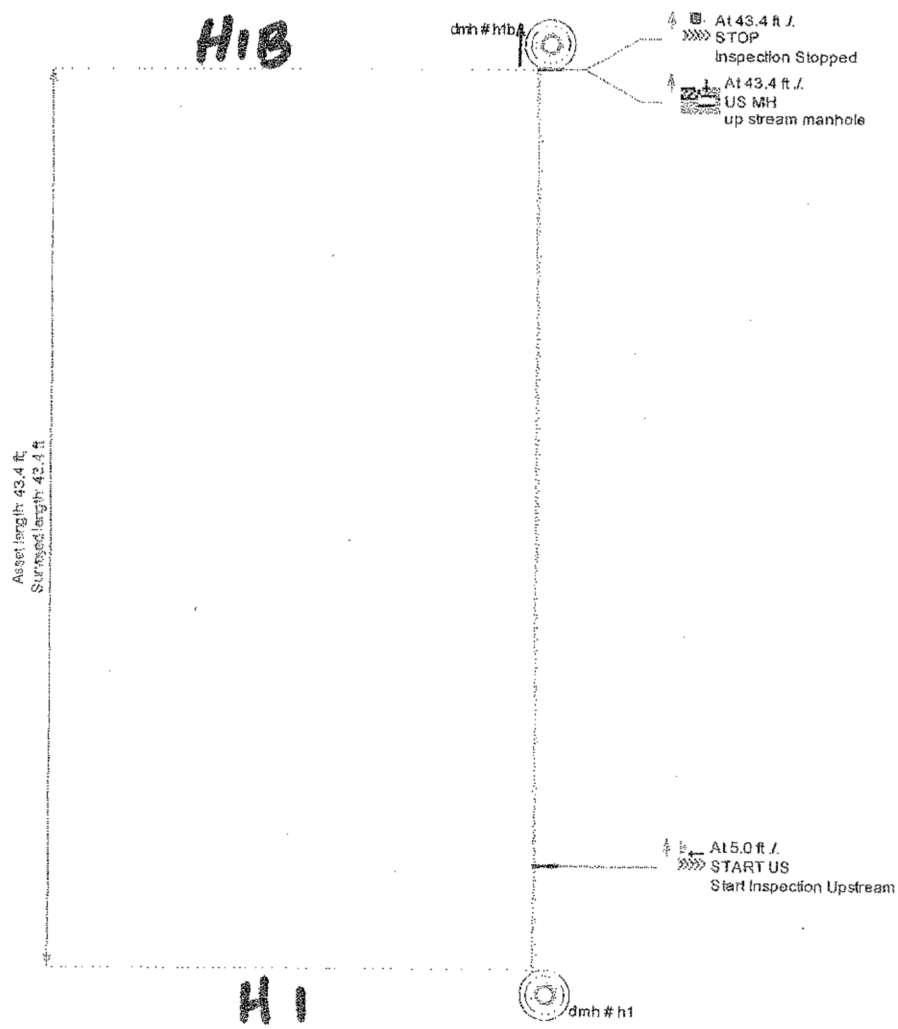
5

Project Name:	Asset ID:	City:	Address:
salem ma	hersey st #1	salem ma	hersey st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	36	36	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	43.4	Dry	



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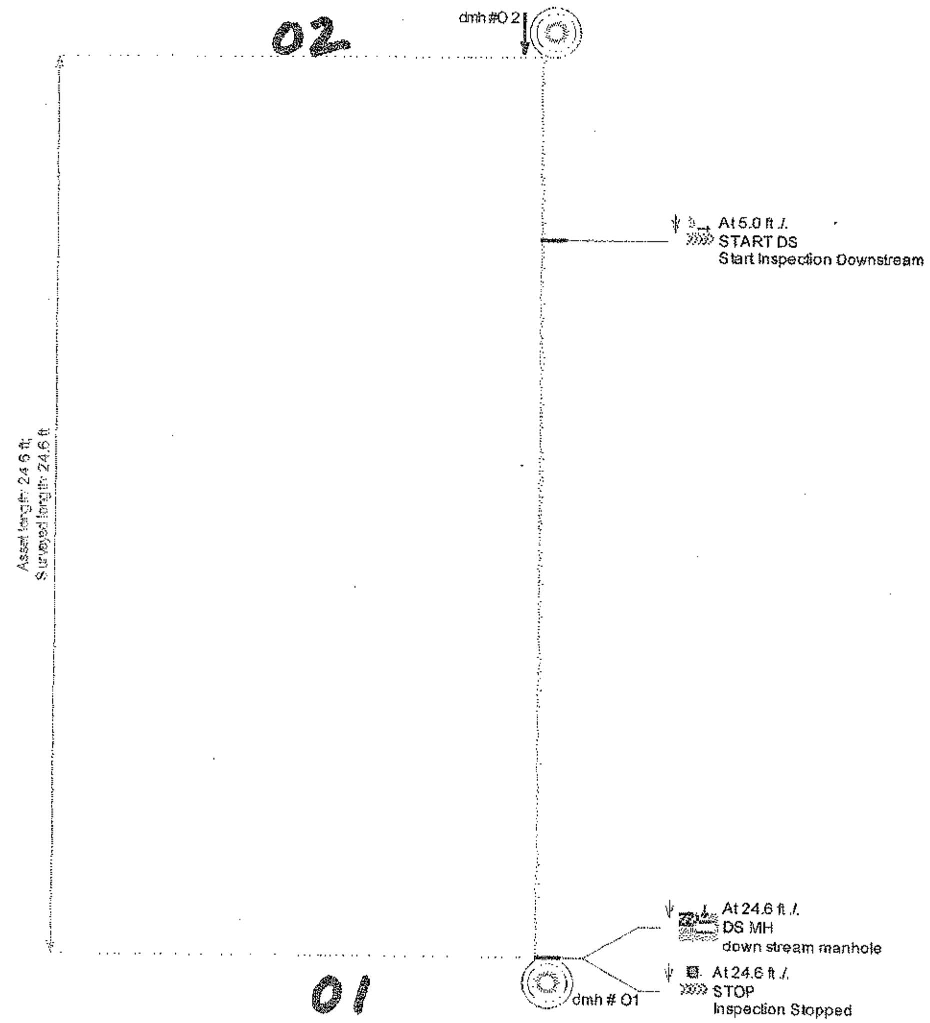
7

Project Name:	Asset ID:	City:	Address:	
salem ma	ocean st dmh #1	salem ma	ocean st	
Date	**Pipe Width:**	**Pipe Height:**	**Pipe Type:**	**Surface Condition:**
5/13/2009	39	39	Concrete Reinforced	Asphalt
Direction:	**Surveyed Footage:**	**Weather**	**Tape/Media #**	
Towards Downstream	24.6	Dry		



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Phone: 407-849-0190
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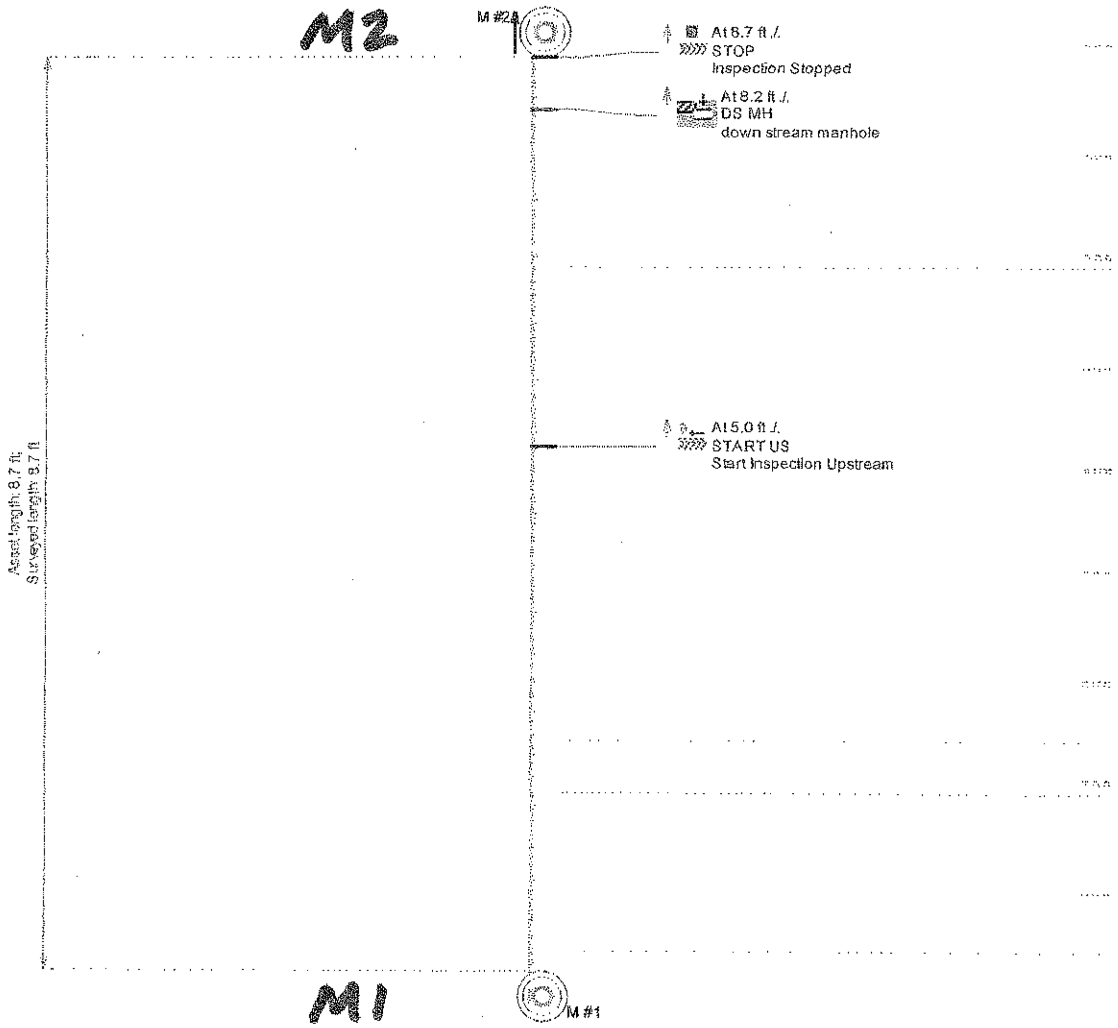
9

Project Name:	Asset ID:	City:	Address:
salem ma	meadow #1	Salem, Ma.	Meadow St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	8.7	Dry	



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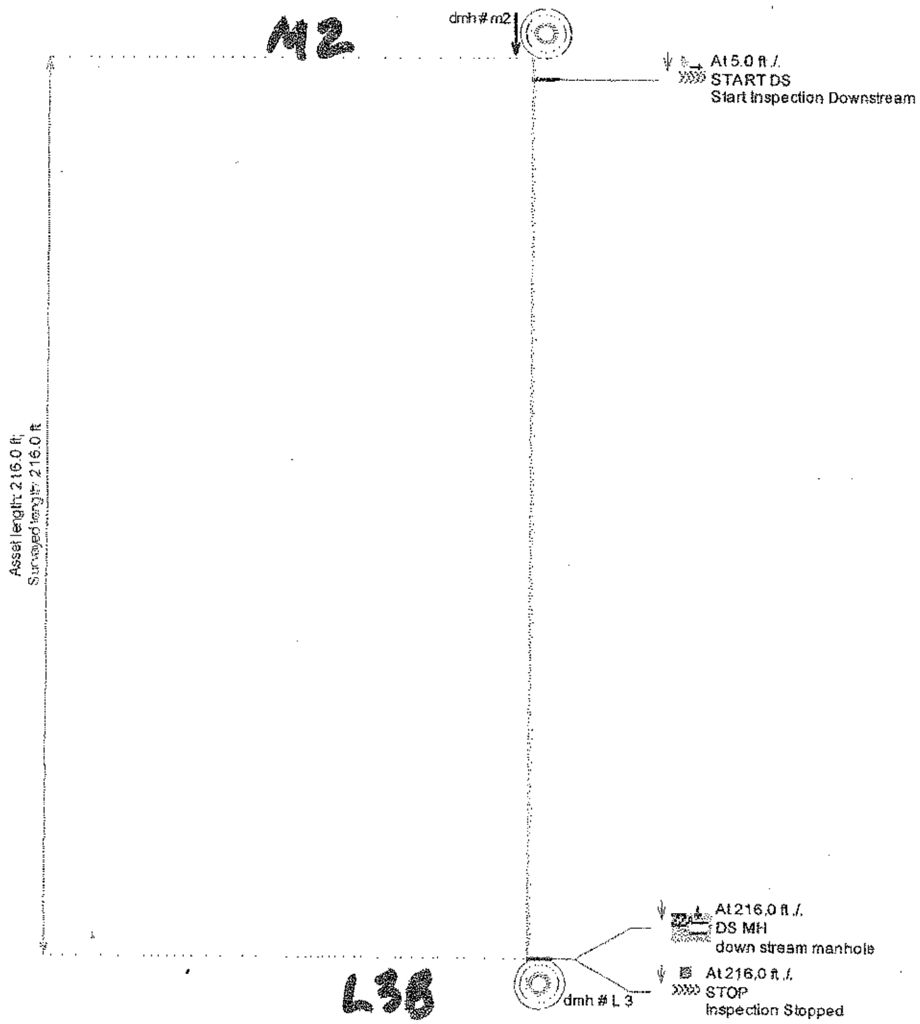
(10)

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	meadow dmh # 2	salem ma	weadow st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	216.0	Dry	



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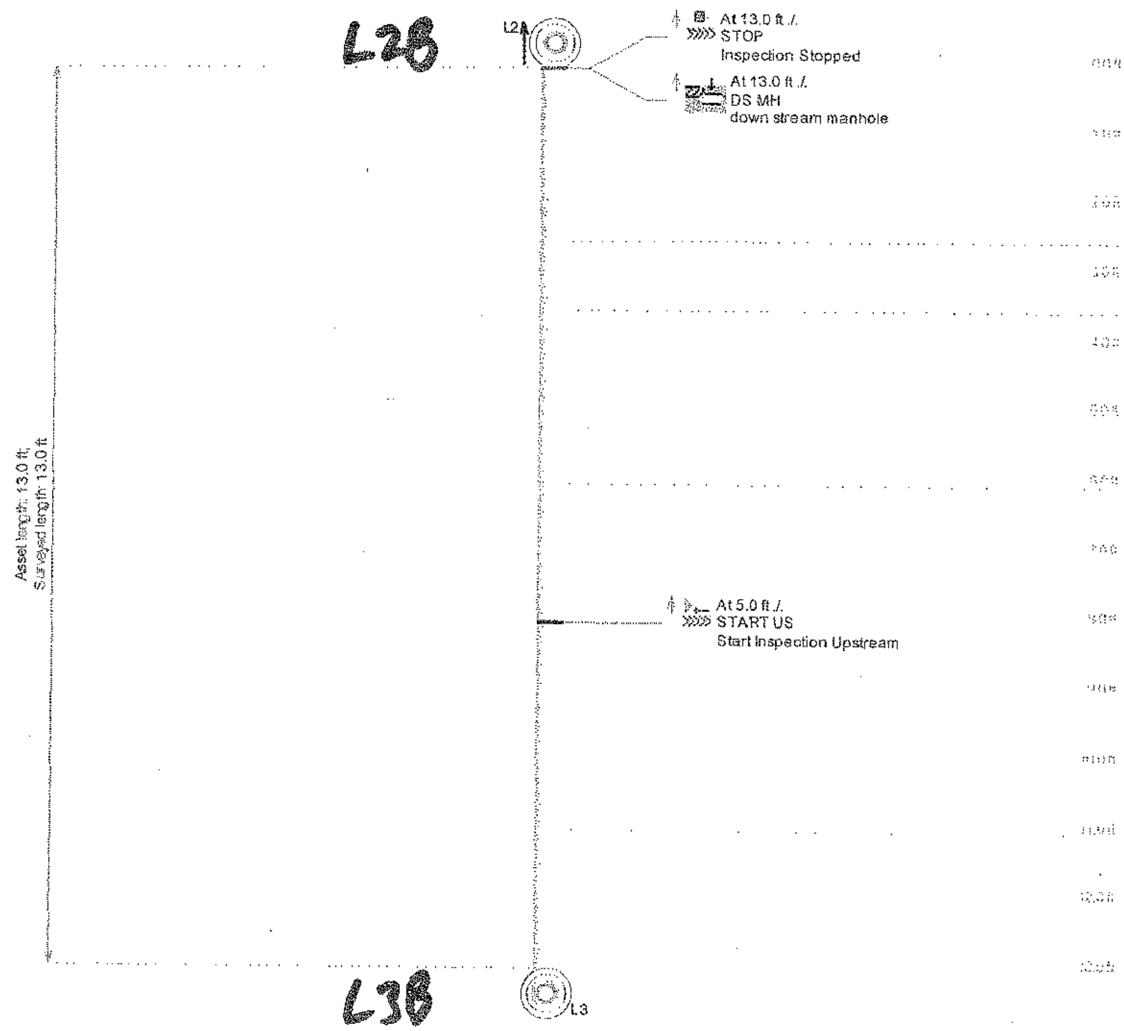
11

Project Name:	Asset ID:	City:	Address:
salem ma	Laurel #2	Salem, Ma.	Laurel St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	13.0	Dry	



L2B To L3B is DOUBLE BARREL PIPE (sump)

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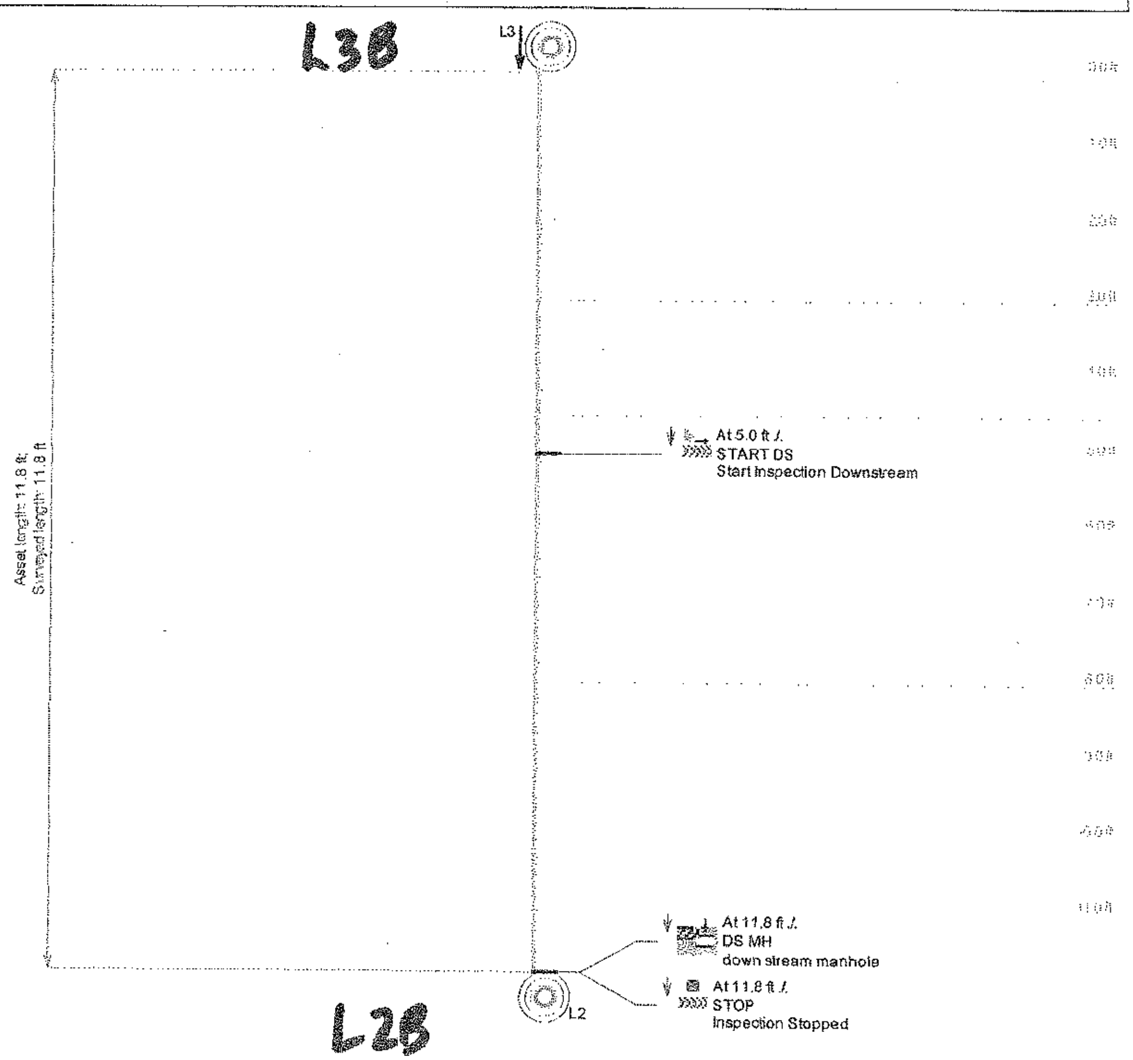
12

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	LAUREL#13	SALEM MA	LAUREL ST

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	11.8	Light Rain	



L2B TO L3B IS DOUBLE BARREL PIPE (SUMP)

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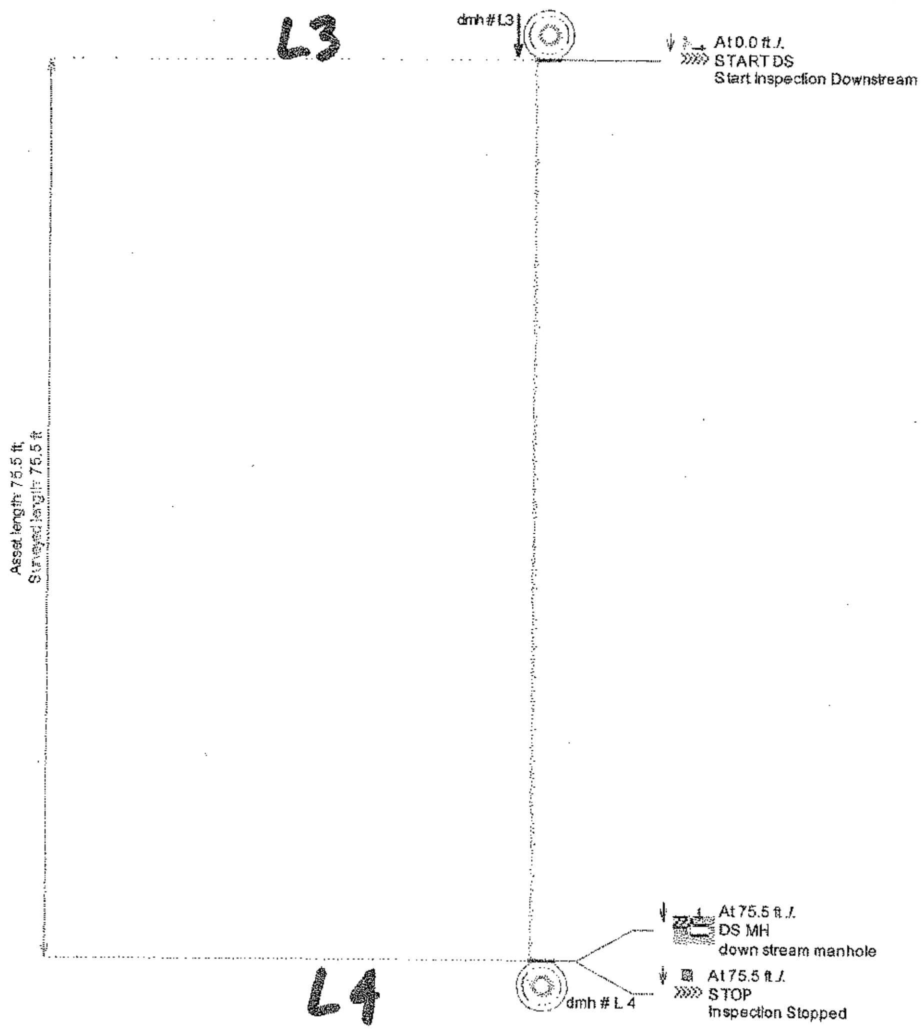
TV Inspection with Pipe-Run Graph

16

Project Name:	Asset ID:	City:	Address:
salem ma	side line #3	salem ,ma	laurel st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	42	42	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	75.5	Dry	



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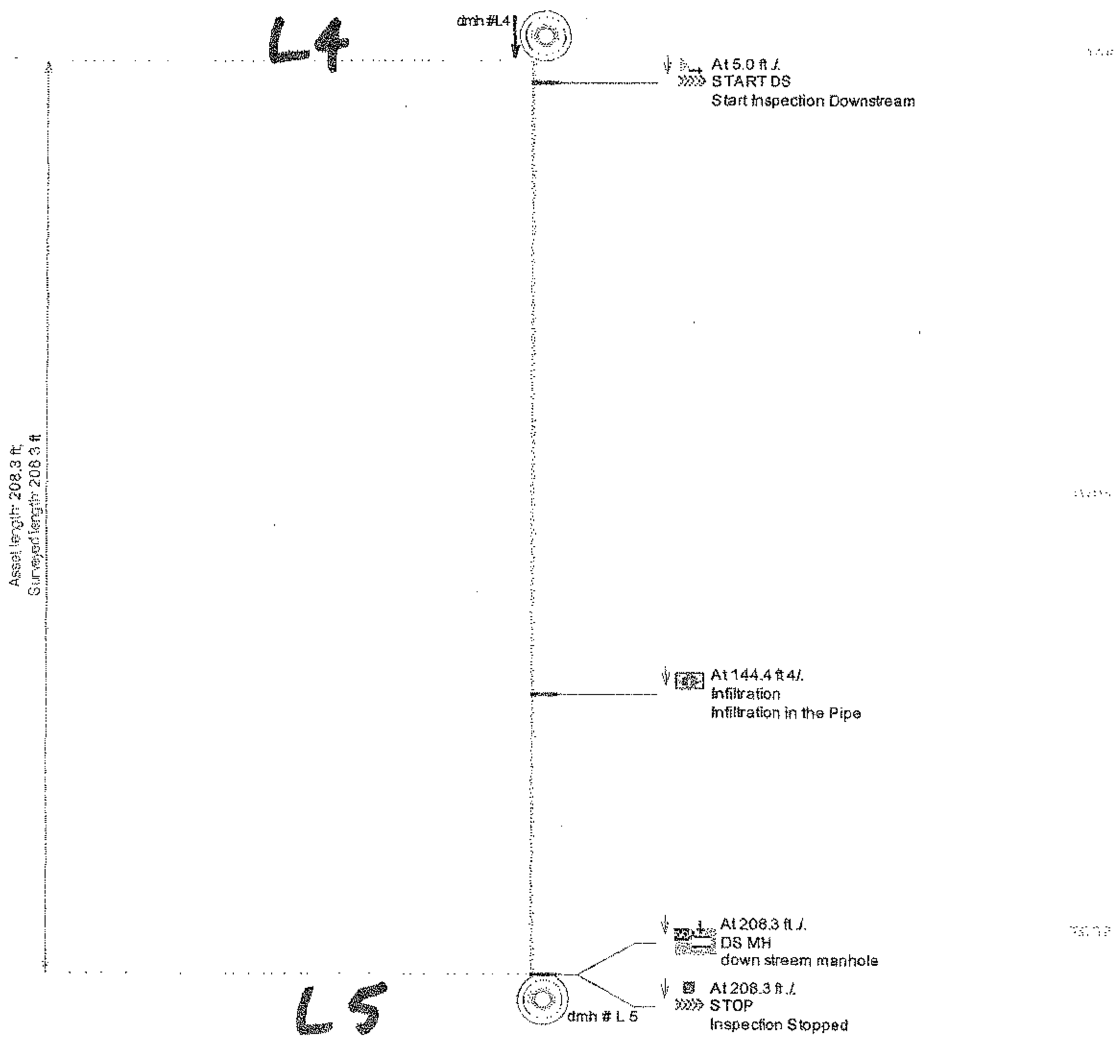
TV Inspection with Pipe Run Graph

17

Project Name:	Asset ID:	City:	Address:
salem ma	sidelines dmh#4	salea ma	laurel st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	42	42	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	208.3	Dry	



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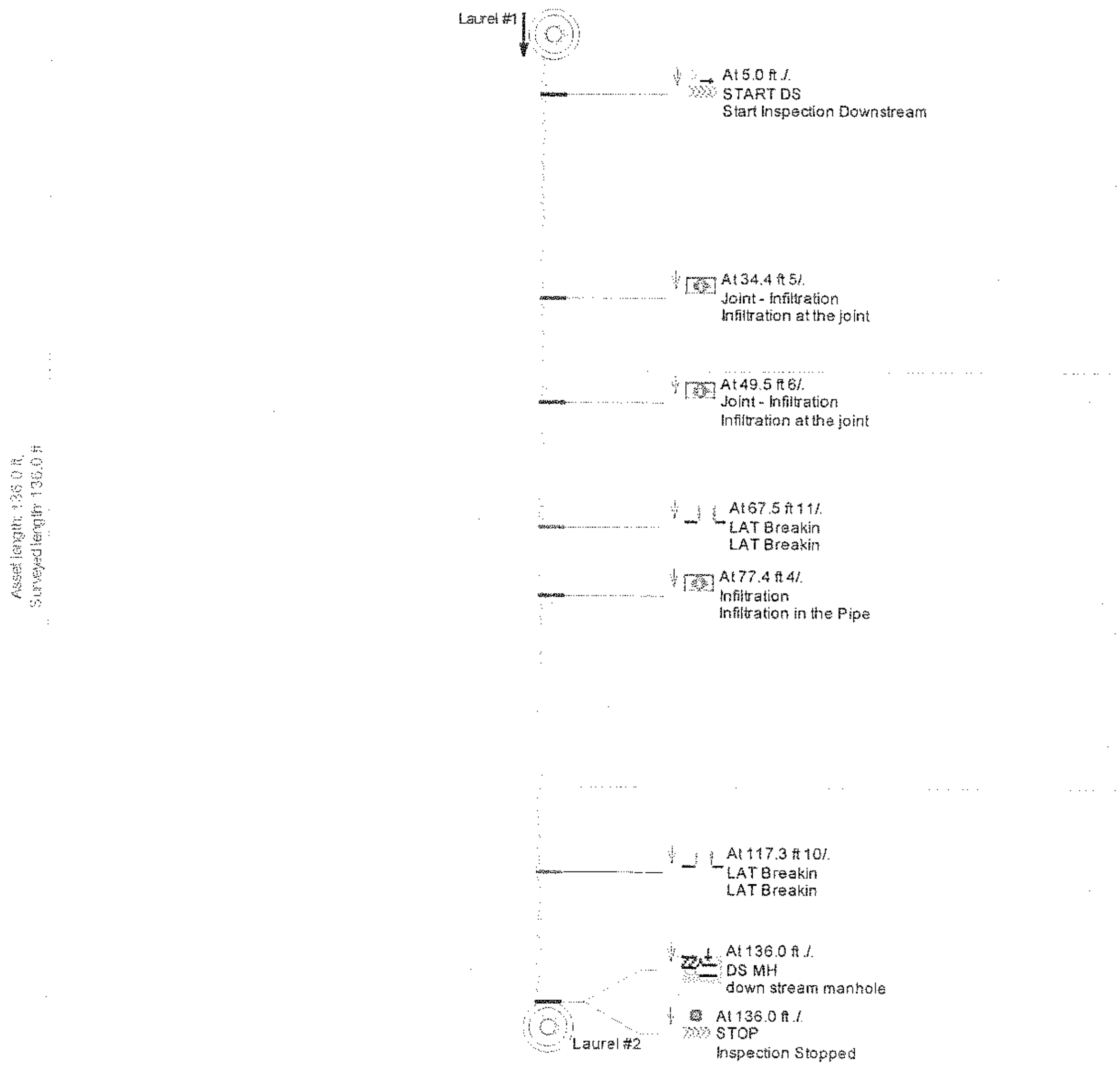
Project Name:	Asset ID:	City:	Address:
salem ma	Sideline #1	Salem, Ma.	Laurel St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	42	42	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	136.0	Dry	



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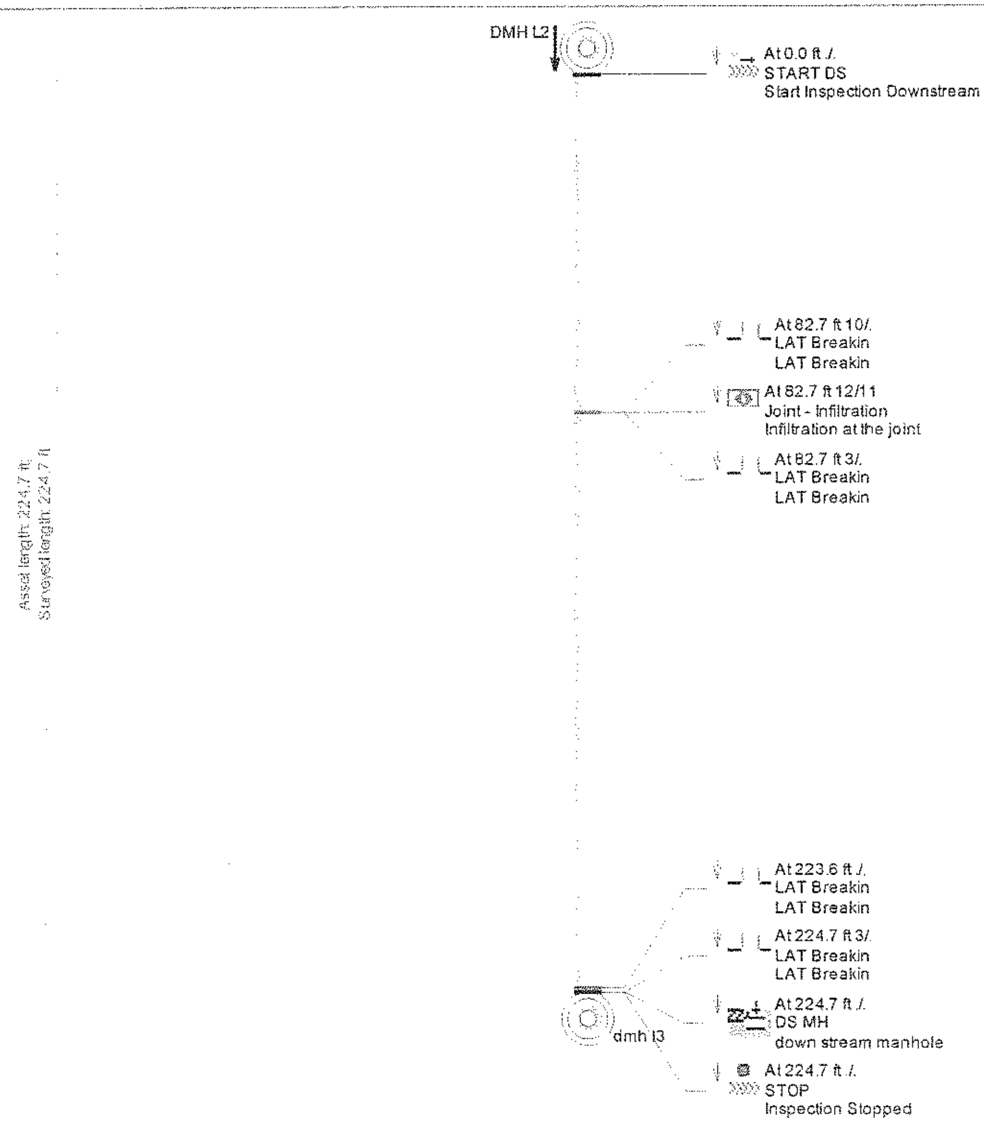
Project Name:	Asset ID:	City:	Address:
salem ma	side line #2	salem ,ma	laural st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	42	42	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	224.7	Dry	



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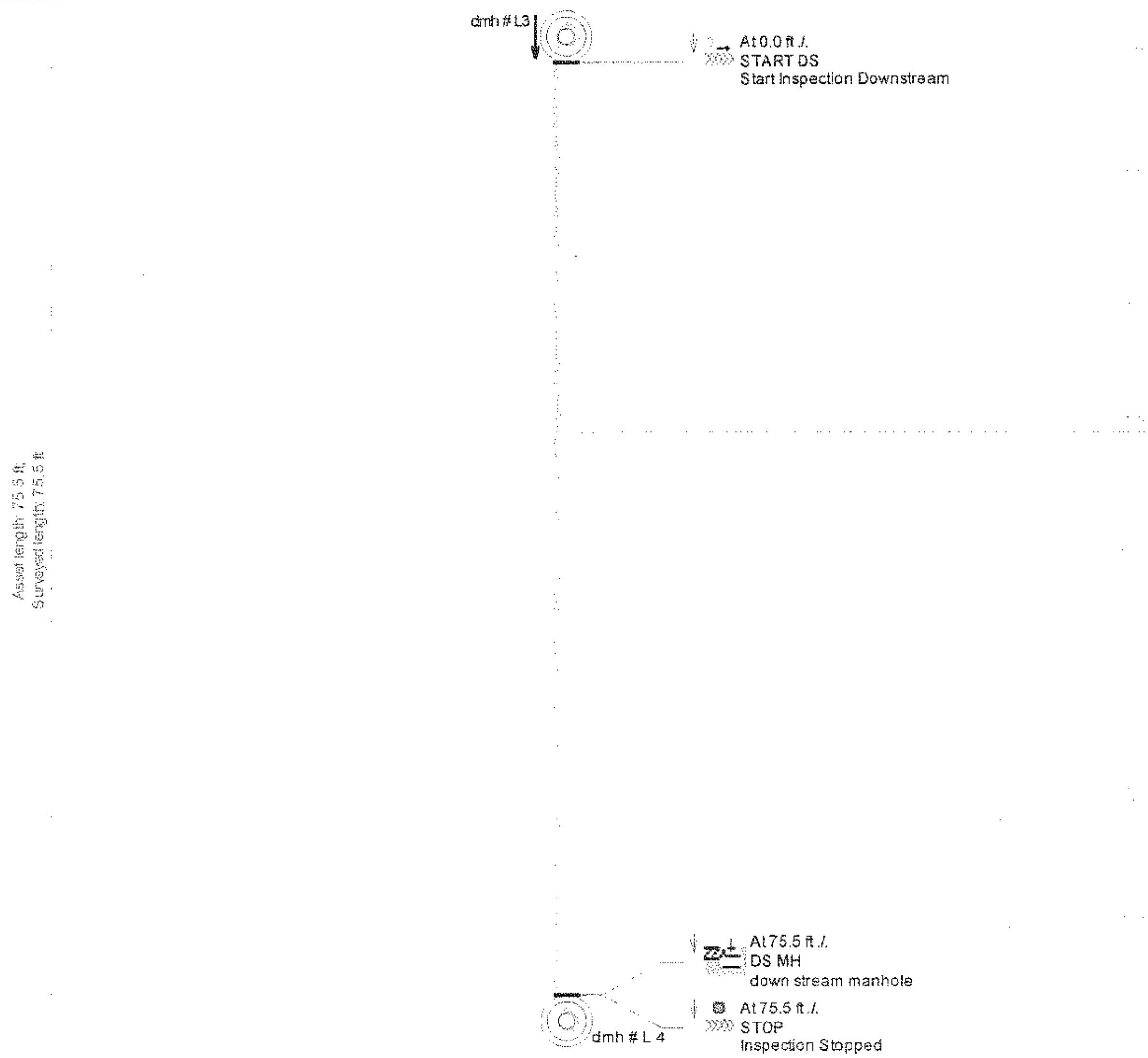
Project Name:	Asset ID:	City:	Address:
salem ma	side line #3	salem ,ma	laurel st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	42	42	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	75.5	Dry	



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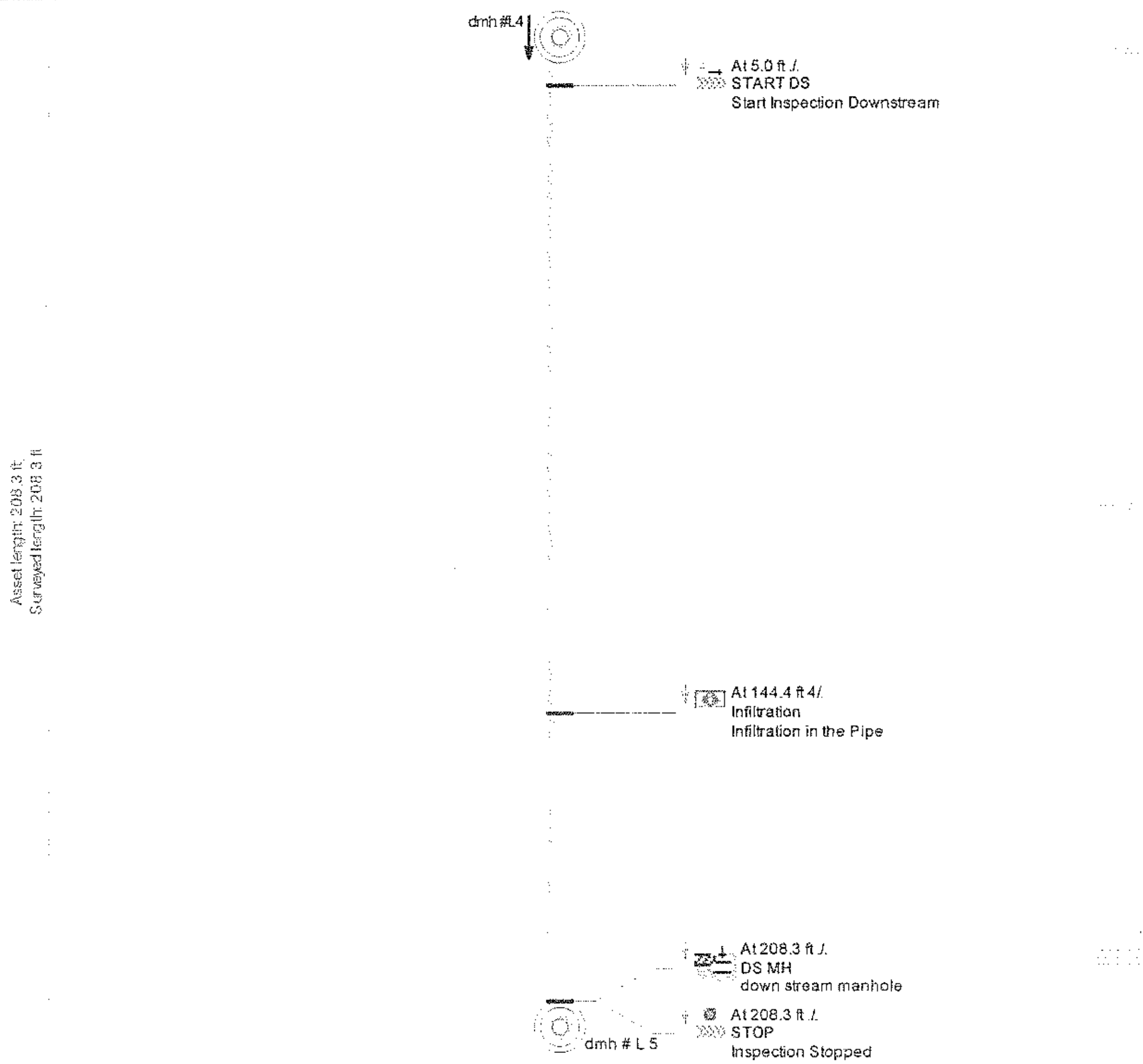
Project Name:	Asset ID:	City:	Address:
salem ma	sidelines dmh#4	salea ma	laurel st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	42	42	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	208.3	Dry	



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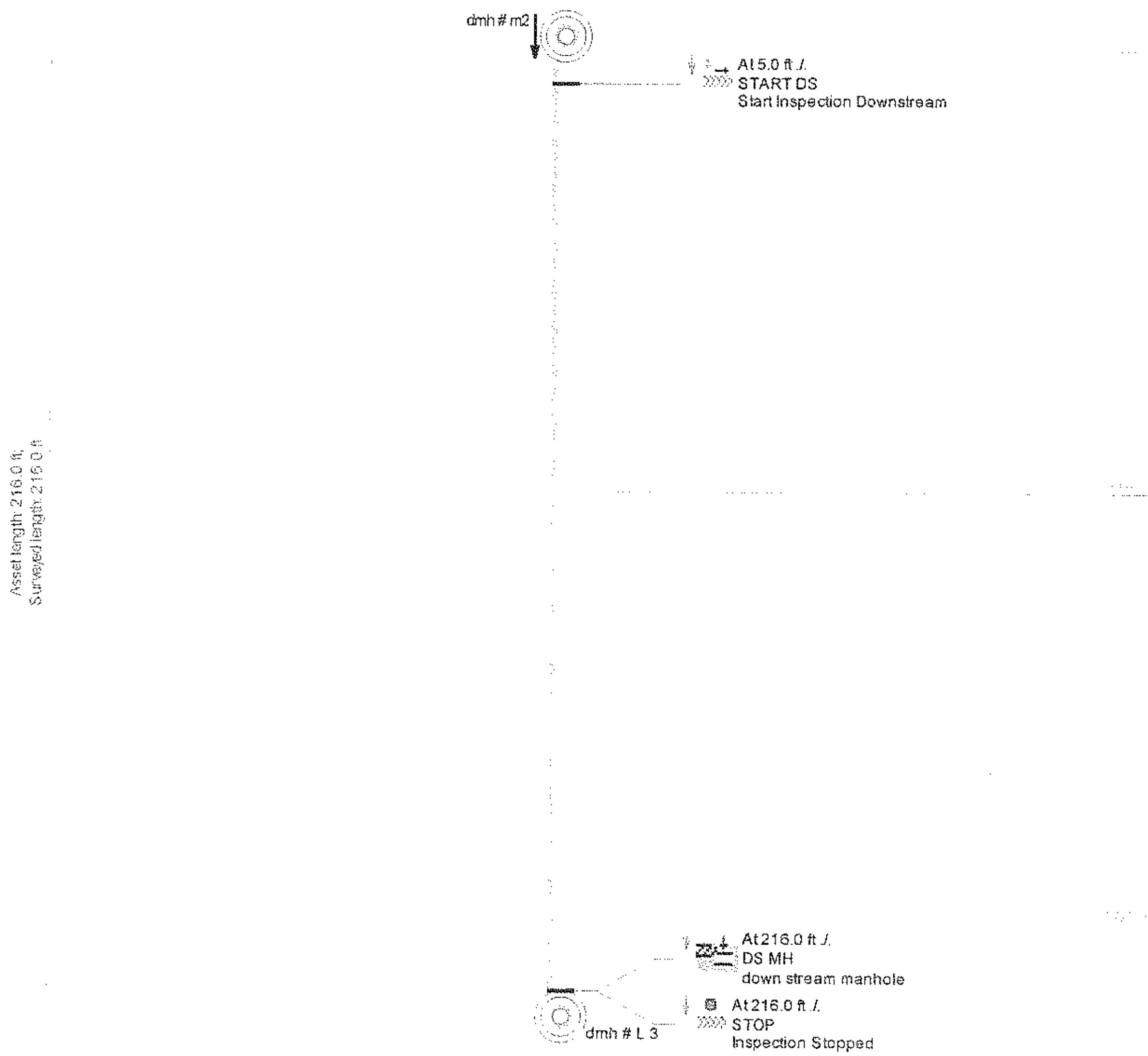
Project Name:	Asset ID:	City:	Address:
salem ma	meadow dmh # 2	salem ma	weadow st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/12/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	216.0	Dry	



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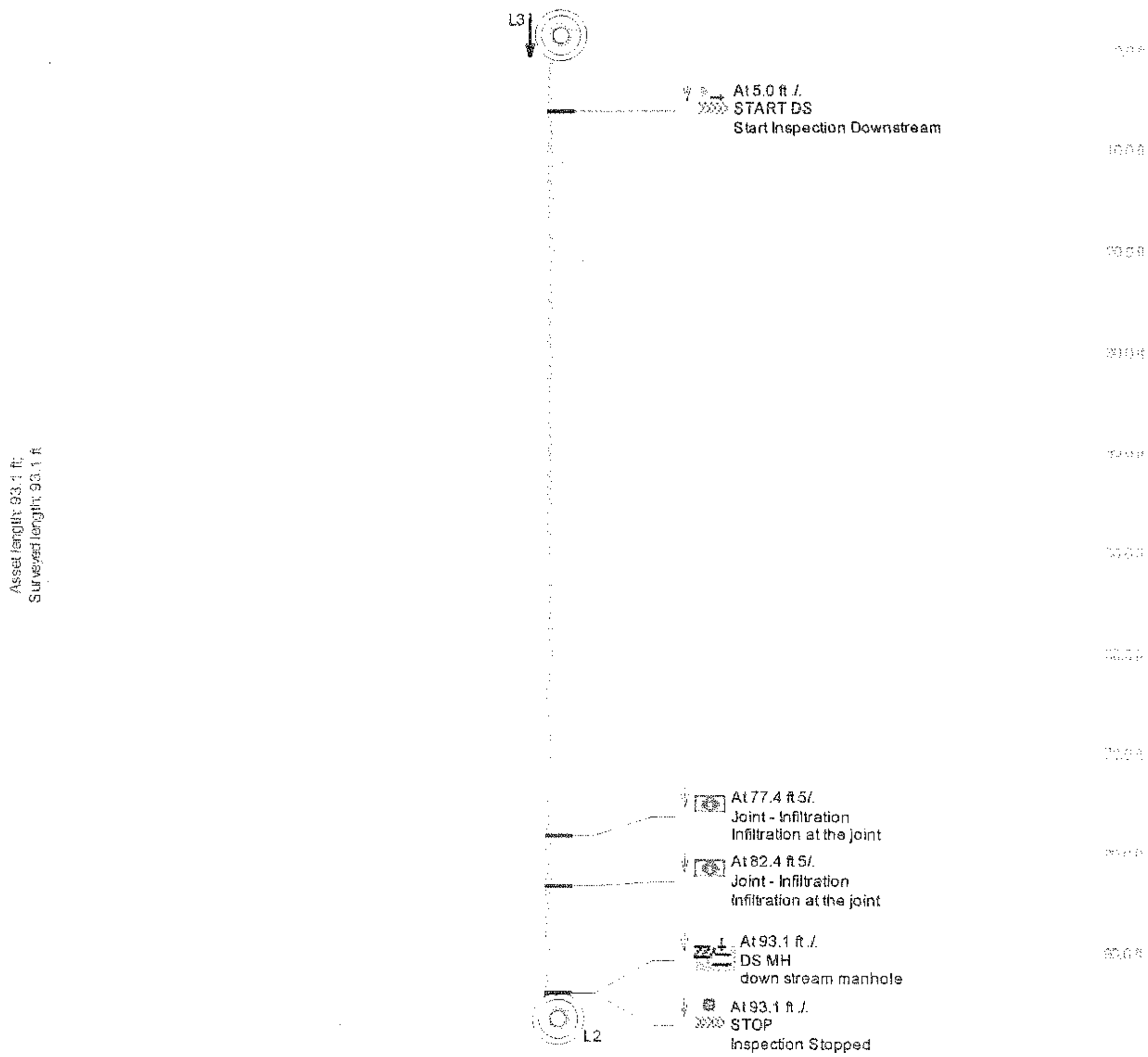
Project Name:	Asset ID:	City:	Address:
salem ma	laurel 12	salem ma	laurel st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	93.1	Dry	



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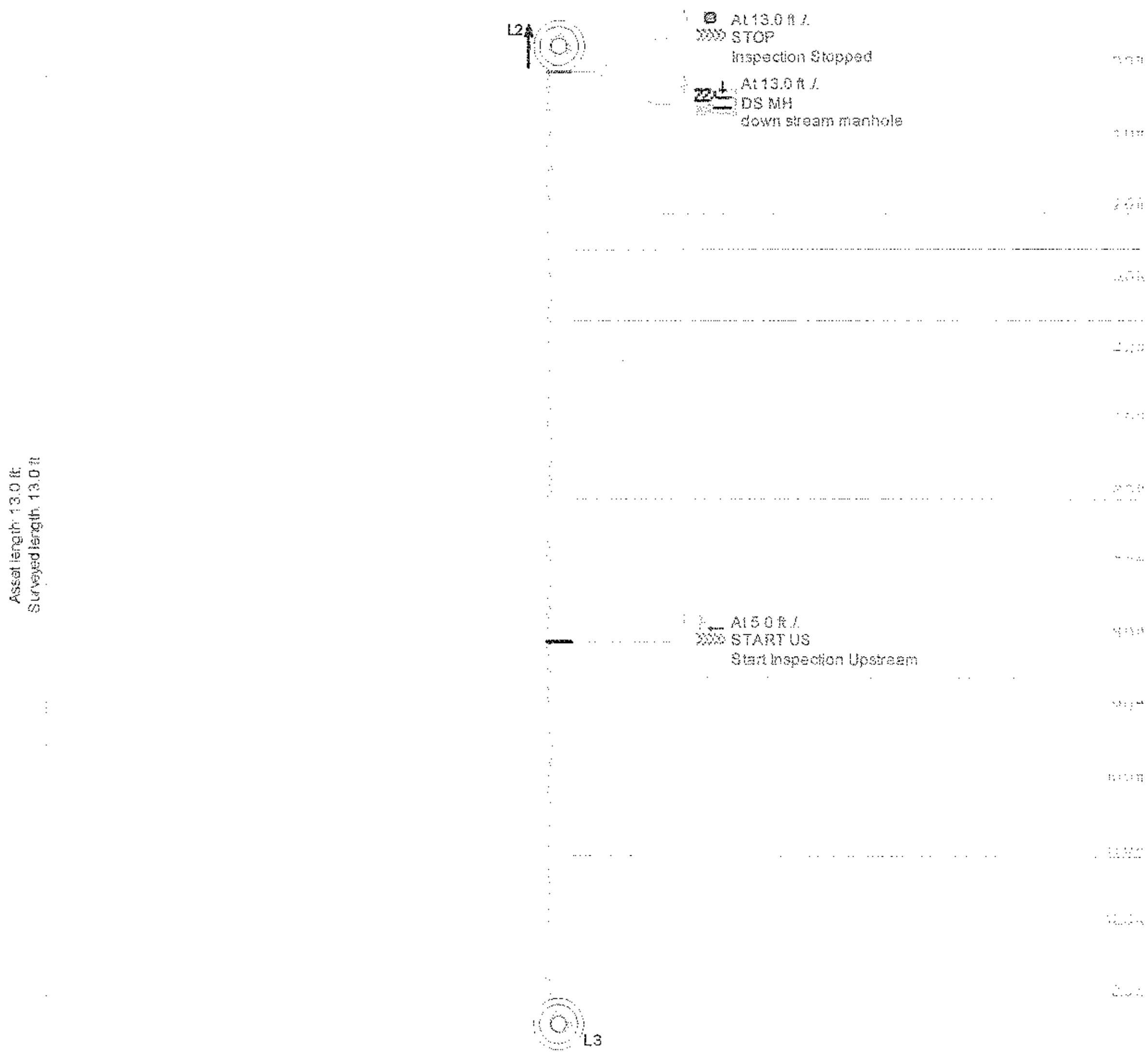
Project Name:	Asset ID:	City:	Address:
salem ma	Laurel #2	Salem, Ma.	Laurel St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	13.0	Dry	



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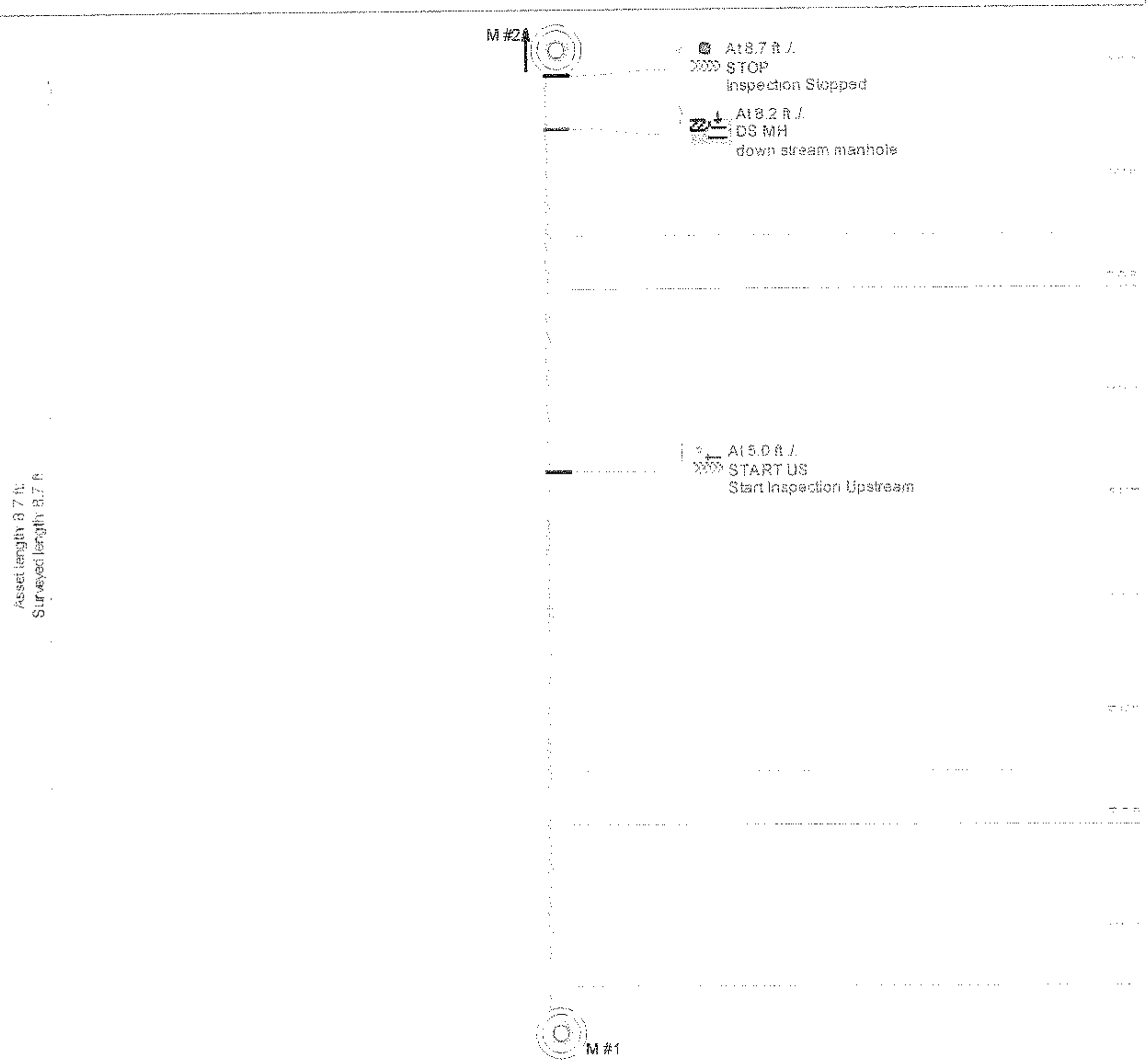
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

GRANITE Xp
Pipeline Inspection and Integration Software

Project Name:	Asset ID:	City:	Address:
salem ma	meadow #1	Salem, Ma.	Meadow St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	8.7	Dry	



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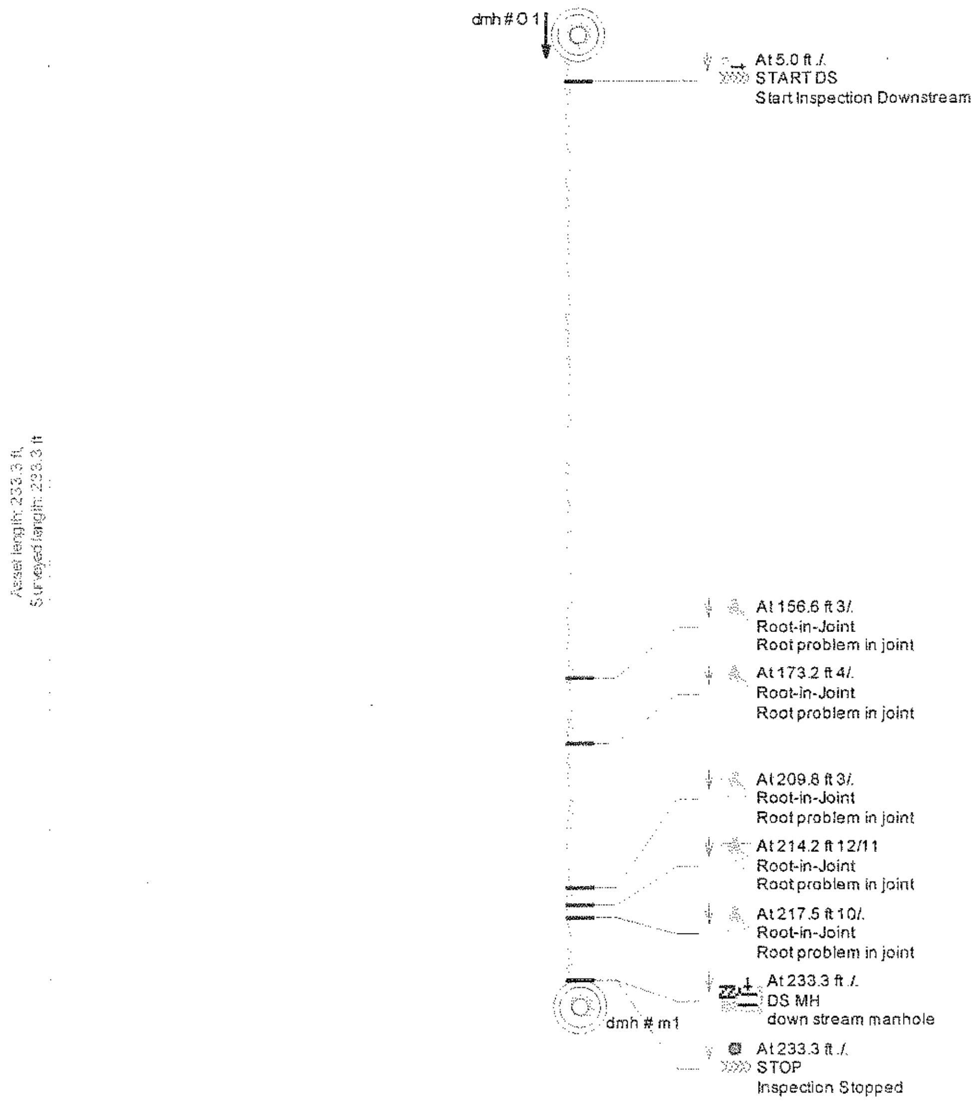
Fax: 407-425-1569

GRANITE XP
Pipeline Inspection and Integration Software

Project Name:	Asset ID:	City:	Address:
salem ma	ocean st	salem ma	ocean st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	233.3	Dry	



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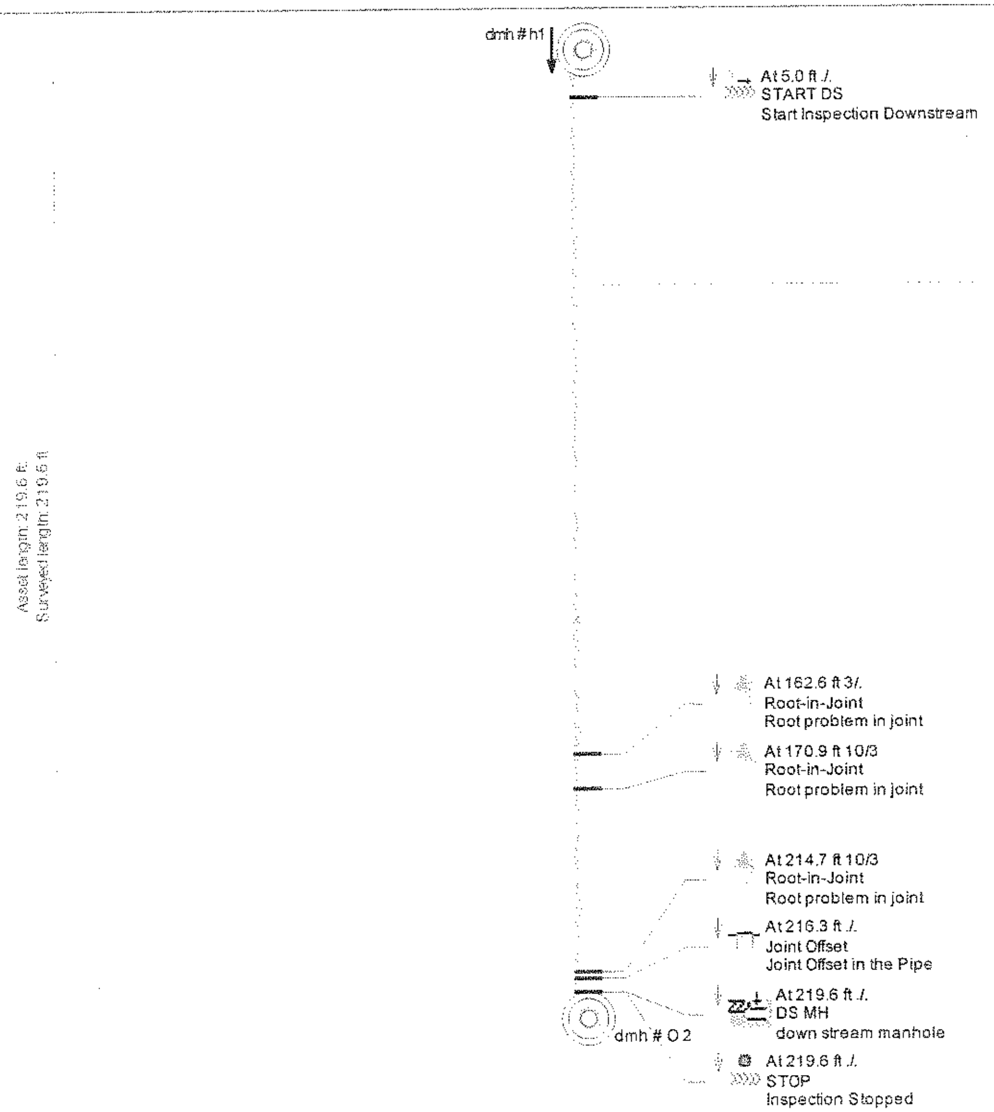
Project Name:	Asset ID:	City:	Address:
salem ma	hersey st	salem ma	hersey st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	219.6	Dry	



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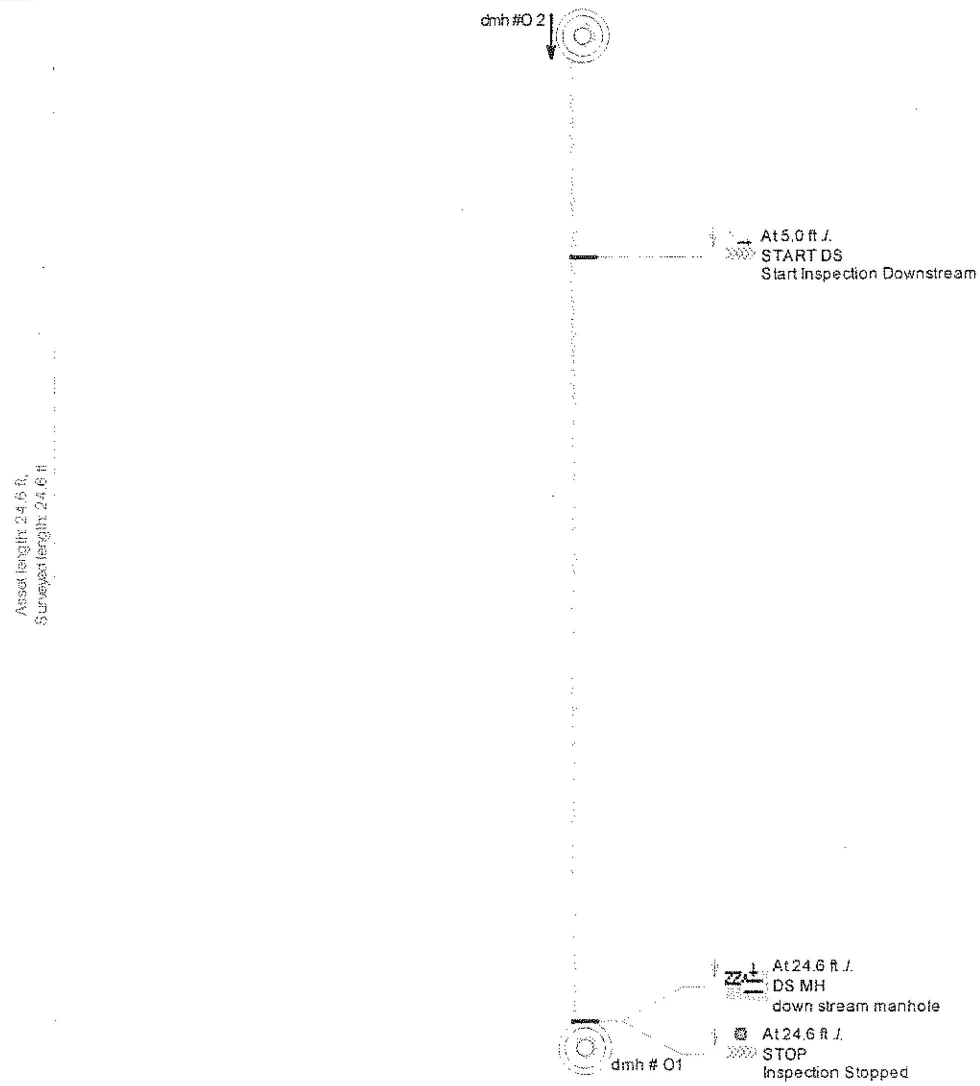
Fax: 407-425-1569

GRANITE XP
Pipeline Inspection and Integration Software

Project Name:	Asset ID:	City:	Address:
salem ma	ocean st dmh #1	salem ma	ocean st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	24.6	Dry	



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Fax: 407-425-1569

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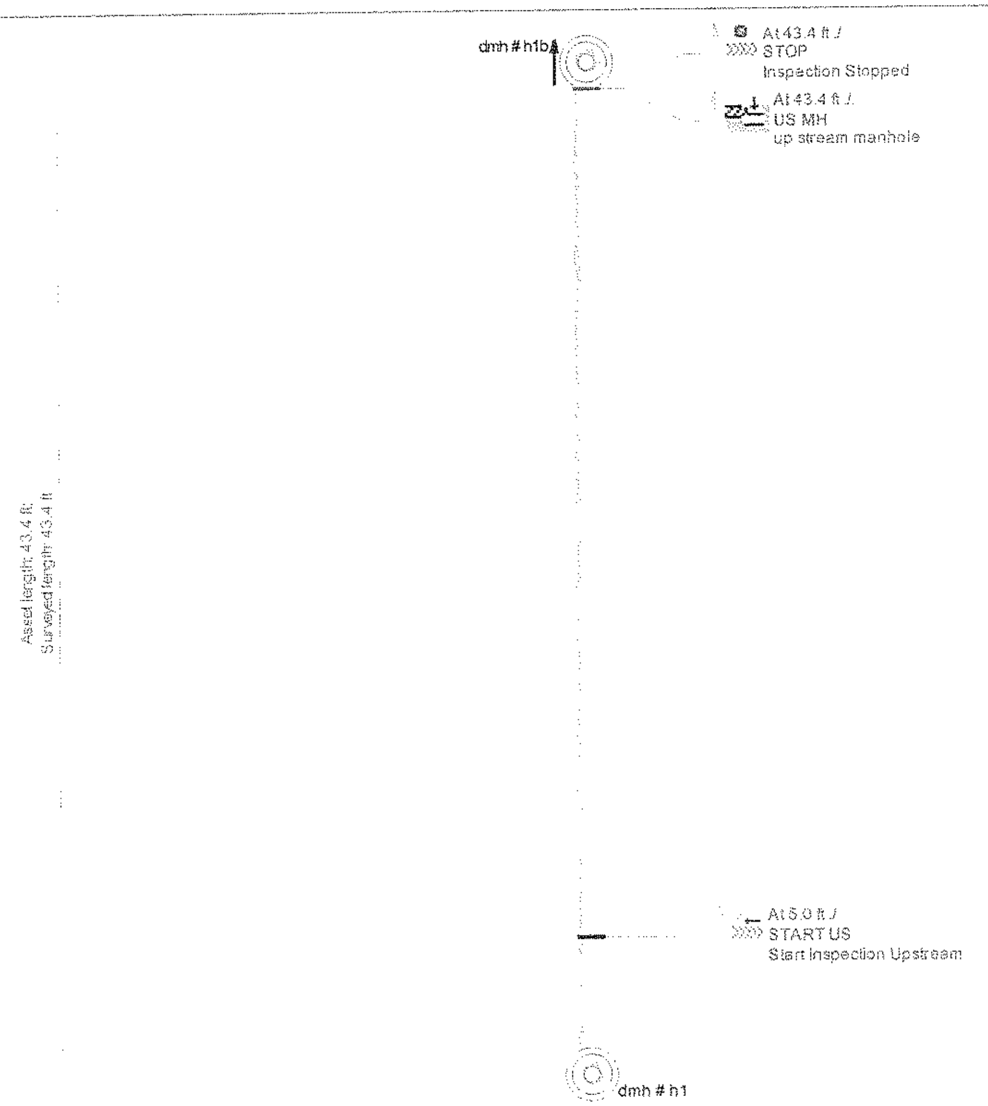
Project Name:	Asset ID:	City:	Address:
salem ma	hersey st #1	salem ma	hersey st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	36	36	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	43.4	Dry	



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GRANITE Xp
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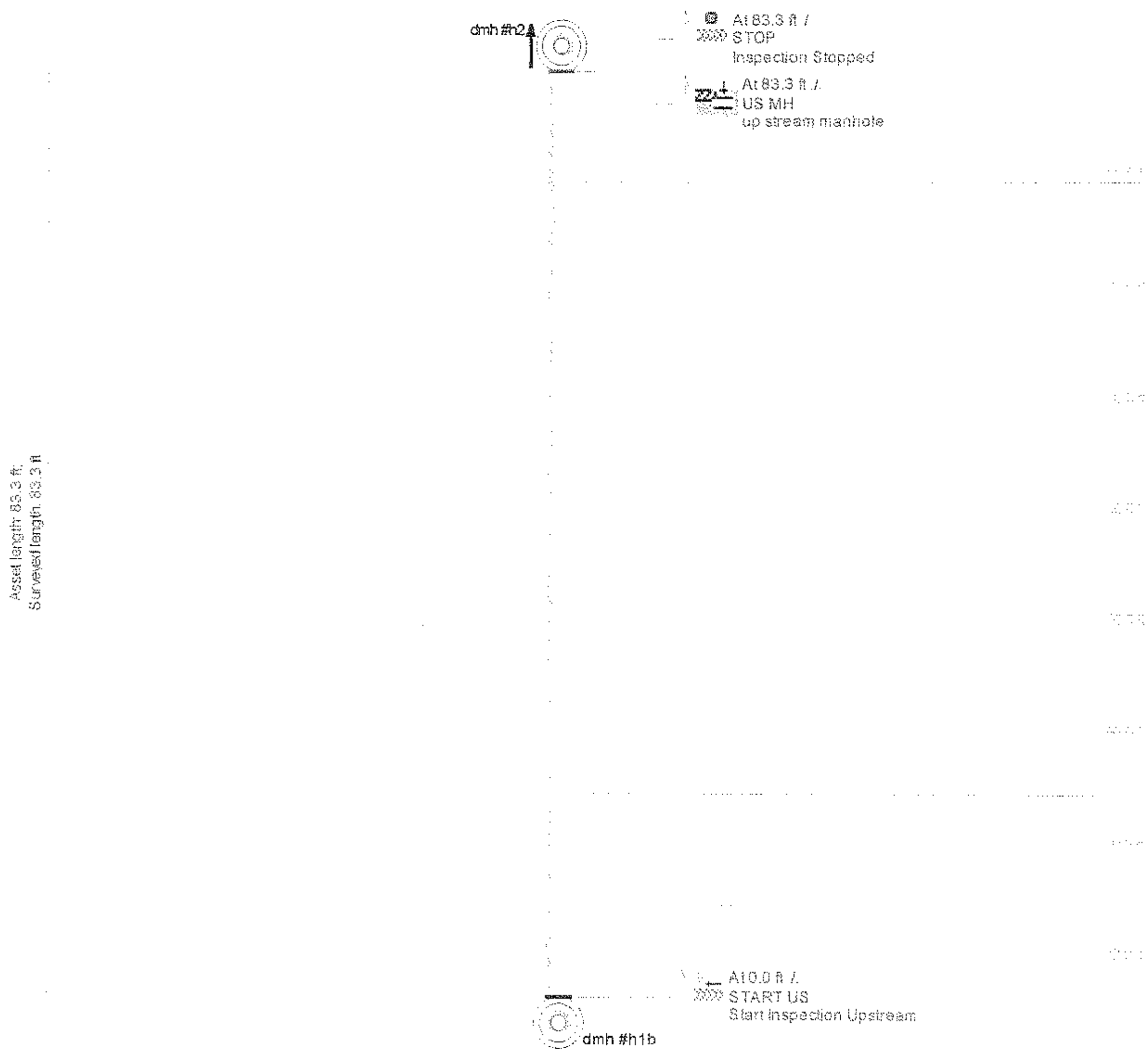
Project Name:	Asset ID:	City:	Address:
salem ma	hersey dmh #2	salem ma	hersey st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/13/2009	36	36	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	83.3	Dry	



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Fax: 407-425-1569

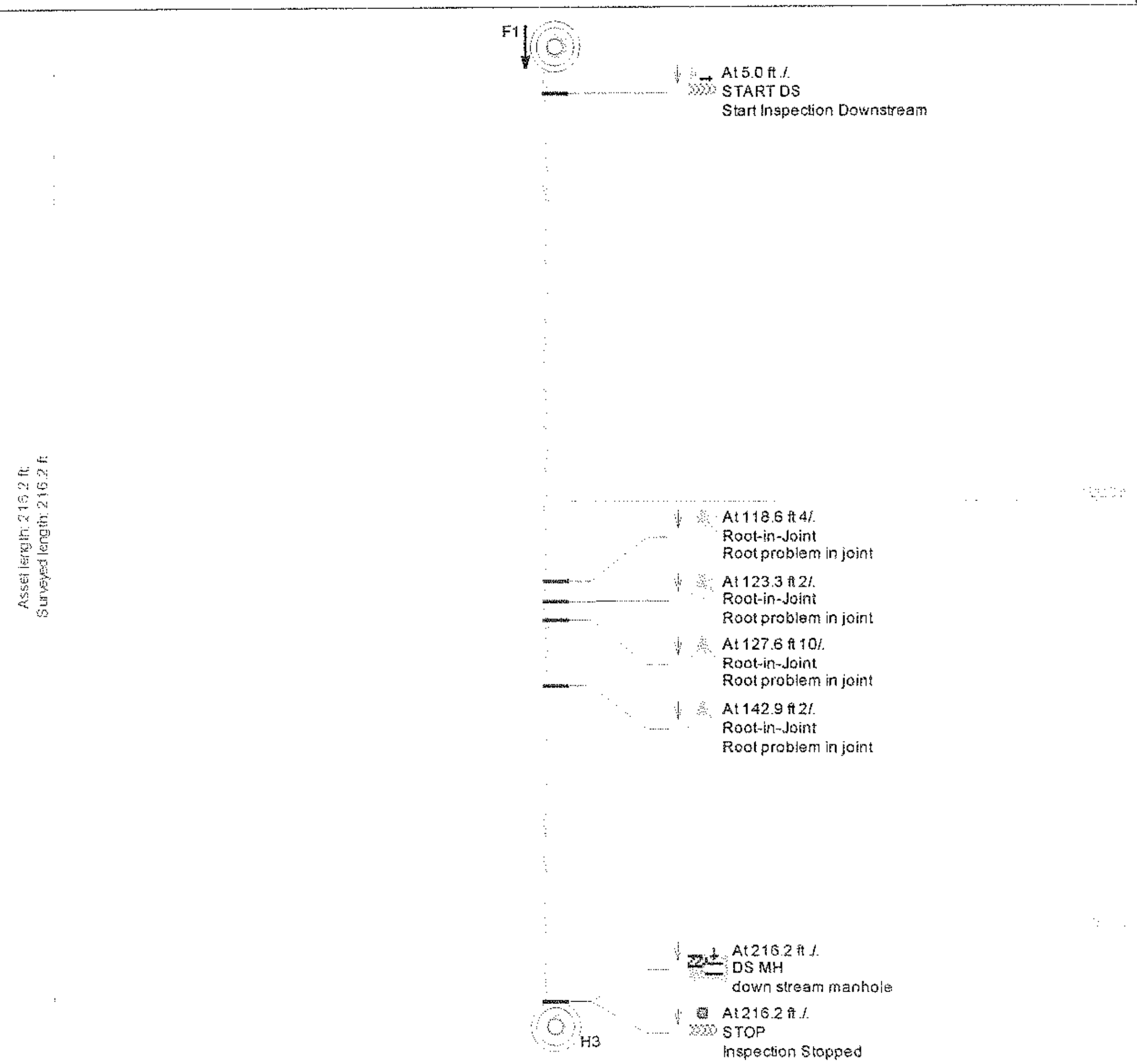
GRANITE XP
Pipeline Inspection and Integration Software

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	FOREST#1	salem ma	FOREST AVE

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	39	39	Concrete Reinforced	Other

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	216.2	Dry	



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Fax: 407-425-1569

GRANITE XP
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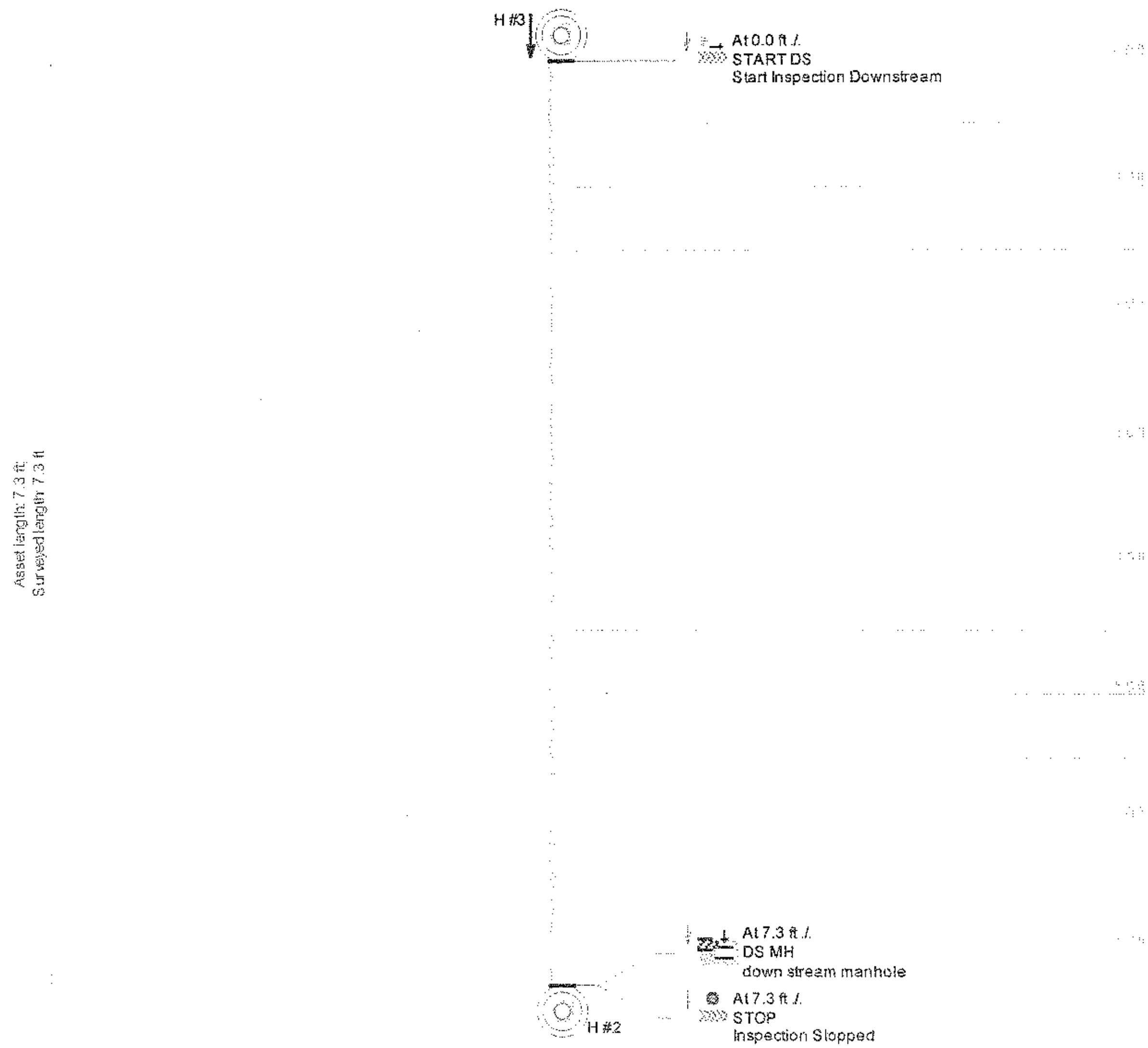
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	Forest #2	Salem, Ma.	Forest Ave

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	36	36	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	7.3	Dry	



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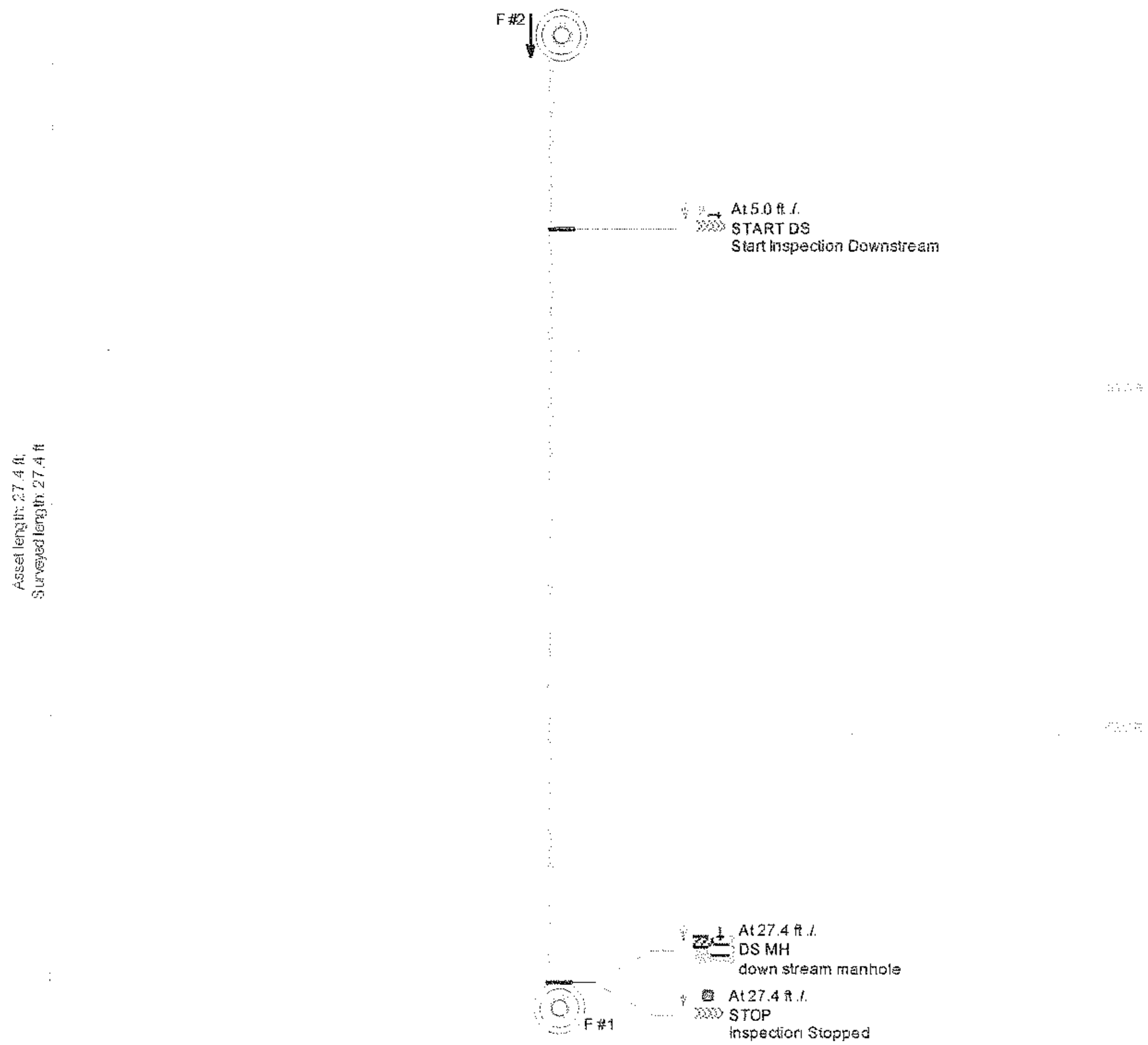
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	Forest #3	Salem, Ma.	Forest Ave.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	36	36	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	27.4	Dry	



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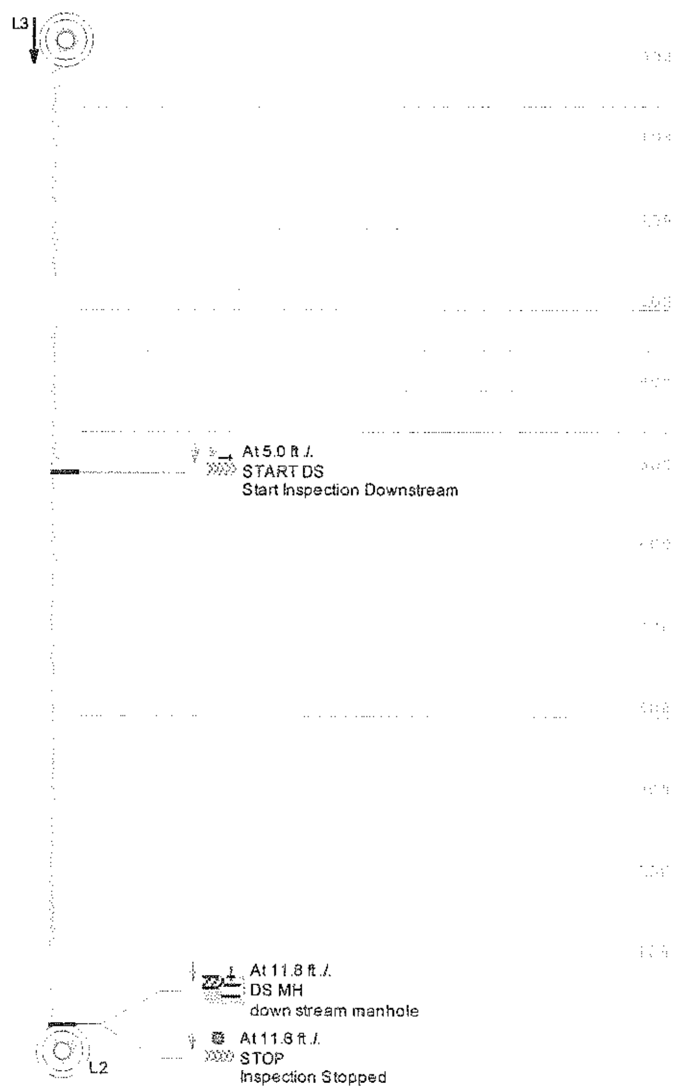
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	LAUREL#13	SALEM MA	LAUREL ST

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	39	39	Concrete Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	11.8	Light Rain	

Asset length: 11.8 ft,
Surveyed length: 11.8 ft



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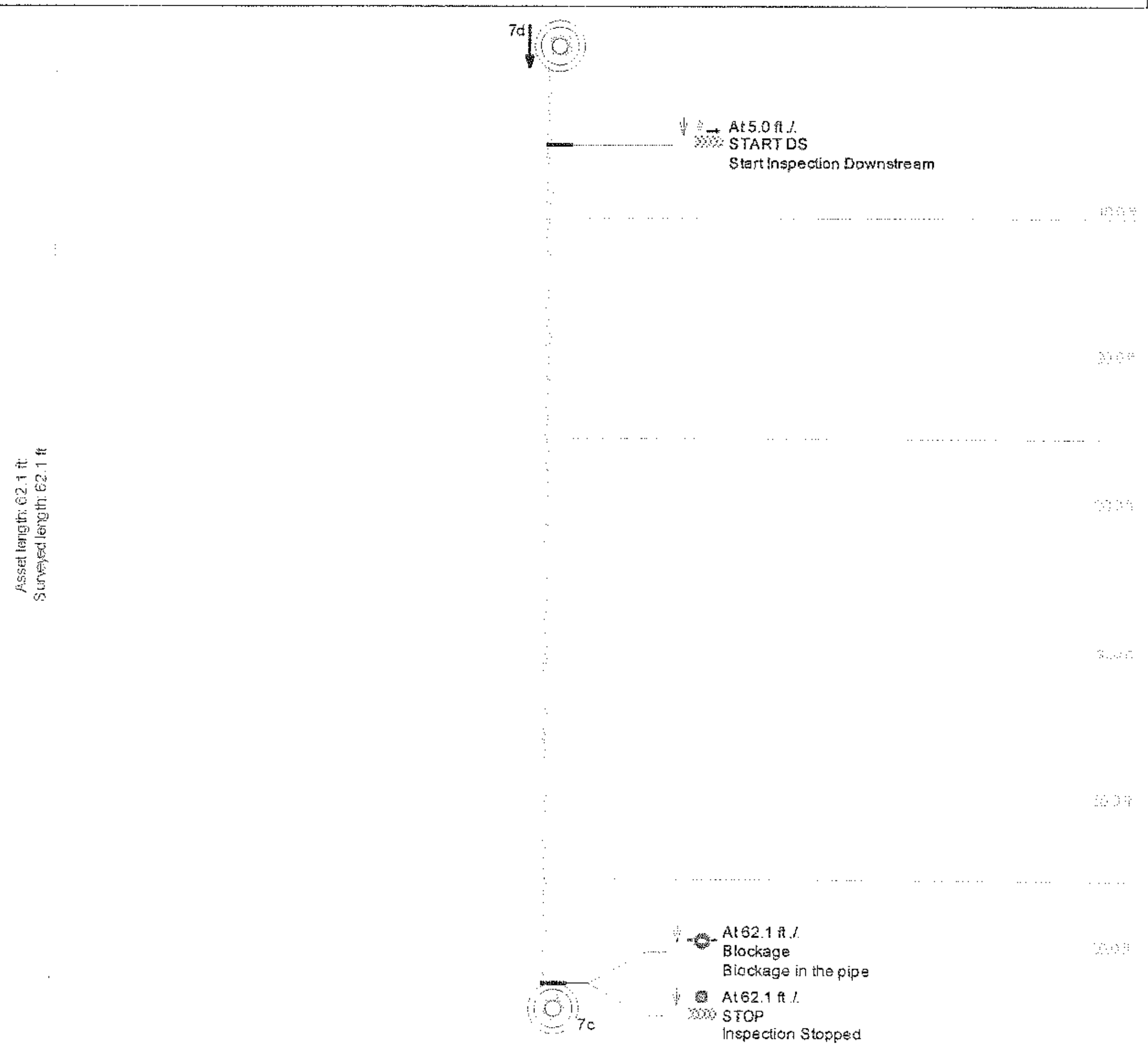
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	SSCCB7D7C	SALEM MA	CANAL ST

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	12	12	Ductile	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	62.1	Light Rain	



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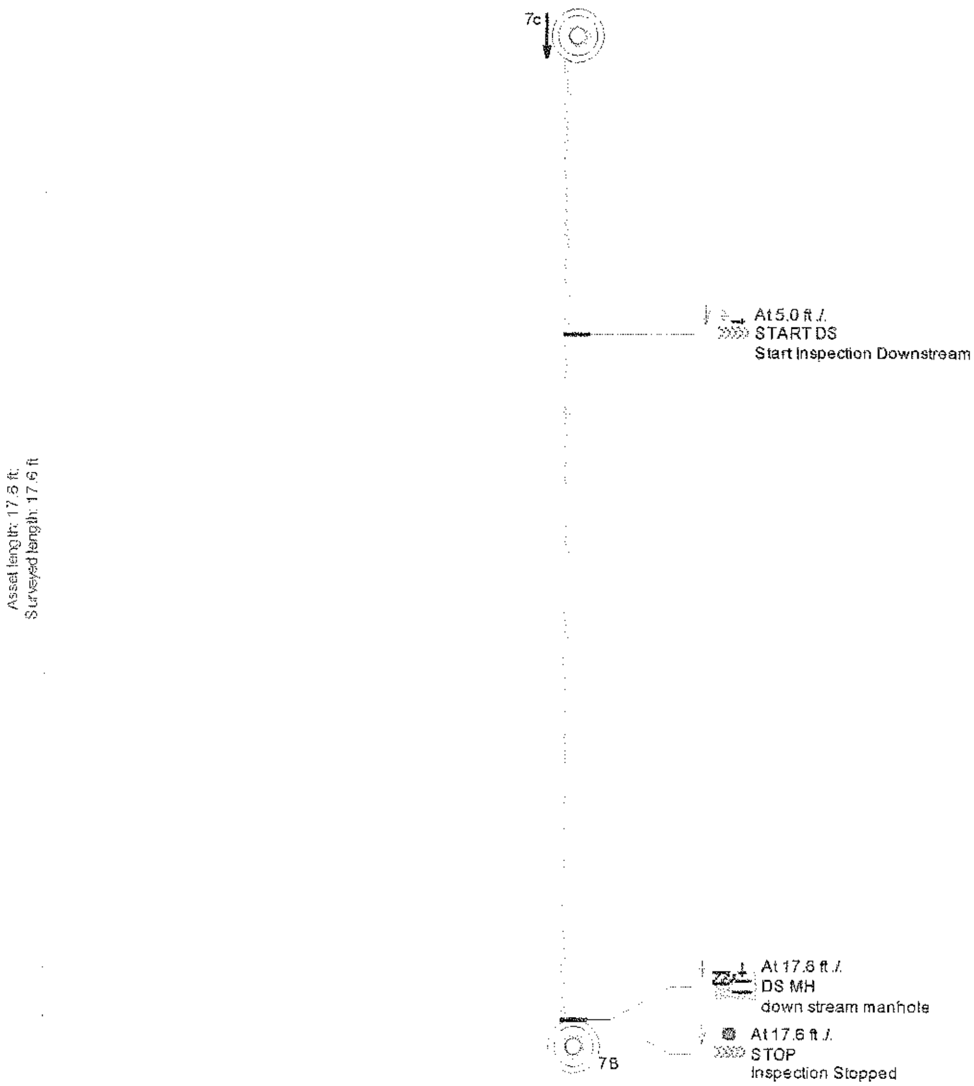
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	SSC CB 7C 7B	SALE, MA.	CANAL ST.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	12	12	Ductile	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	17.6	Light Rain	



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Fax: 407-425-1569

GRANITE Xp
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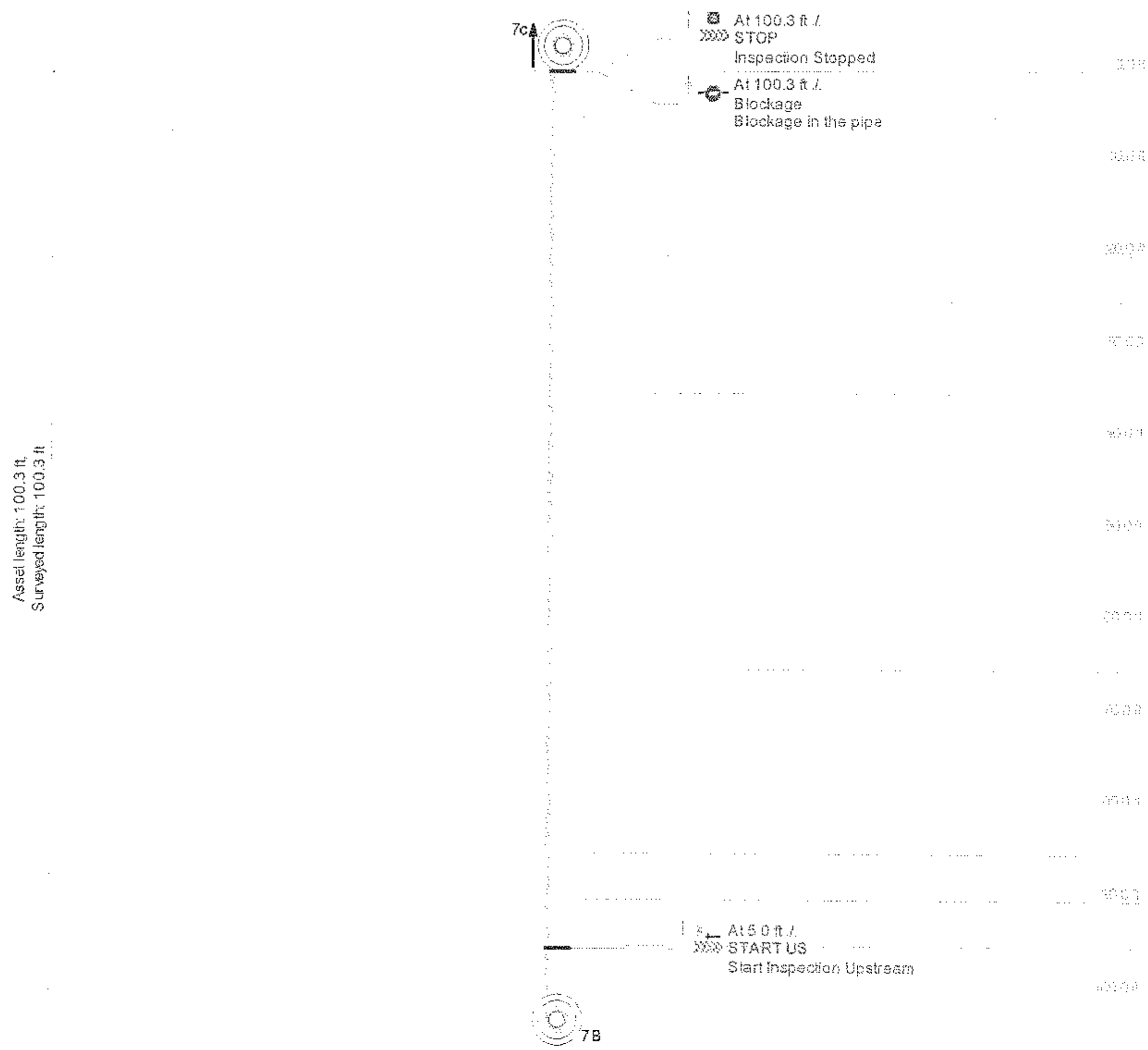
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:	
salem ma	SSC CB 000	SALEM, MA.	CANAL ST	
Date	**Pipe Width:**	**Pipe Height:**	**Pipe Type:**	**Surface Condition:**
5/14/2009	12	12	Ductile	Asphalt
Direction:	**Surveyed Footage:**	**Weather**	**Tape/Media #**	
Towards Upstream	100.3	Light Rain		



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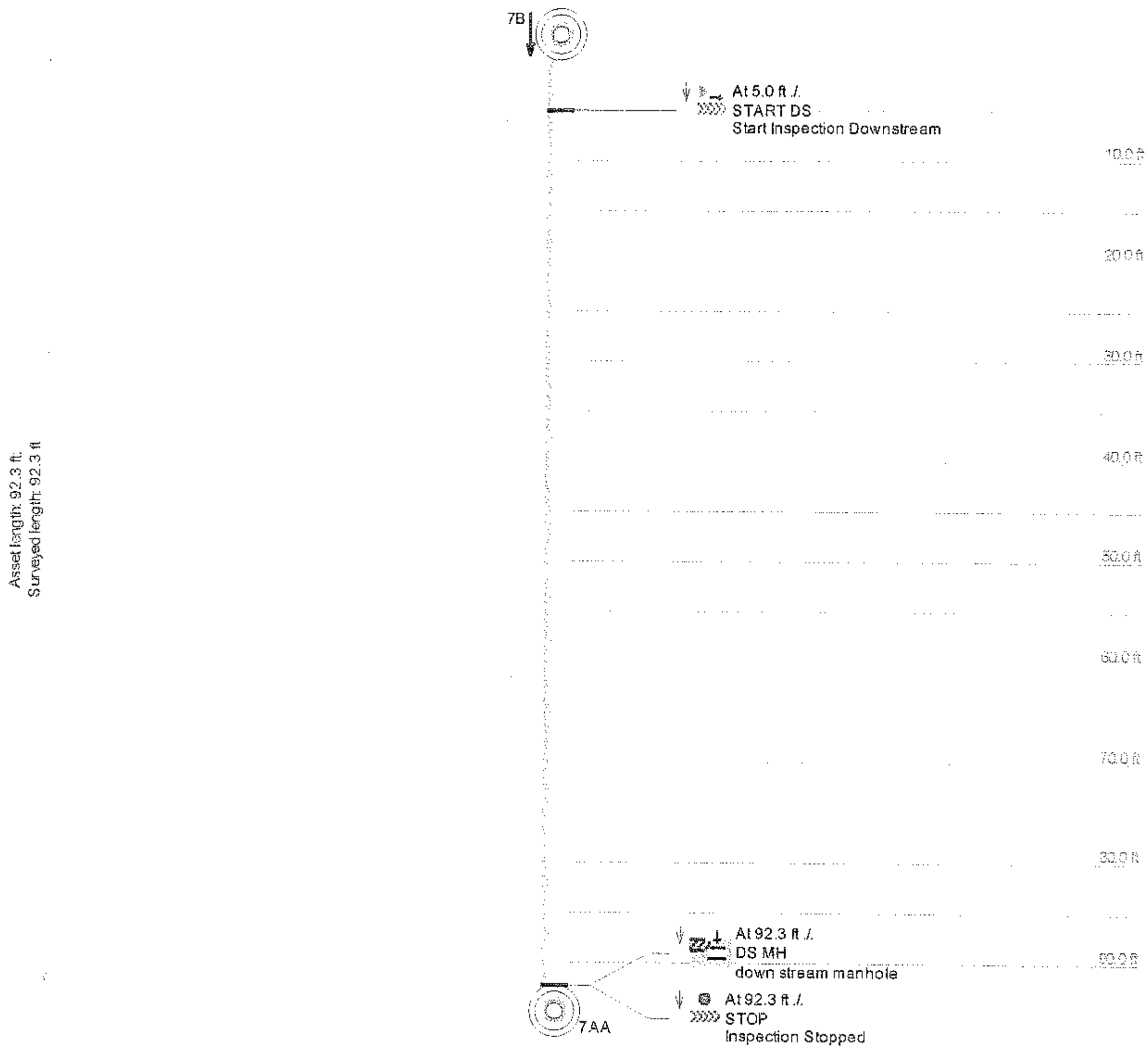
TV Inspection with Pipe-Run Graph

Project Name:		Asset ID:	City:	Address:
salem ma		SSCCB7B7AA	SALEM, MA.	CANAL ST.
Date	**Pipe Width:**	**Pipe Height:**	**Pipe Type:**	**Surface Condition:**
5/14/2009	12	12	Ductile	Asphalt
Direction:	**Surveyed Footage:**		**Weather**	**Tape/Media #**
Towards Downstream	92.3		Light Rain	



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Fax: 407-425-1569

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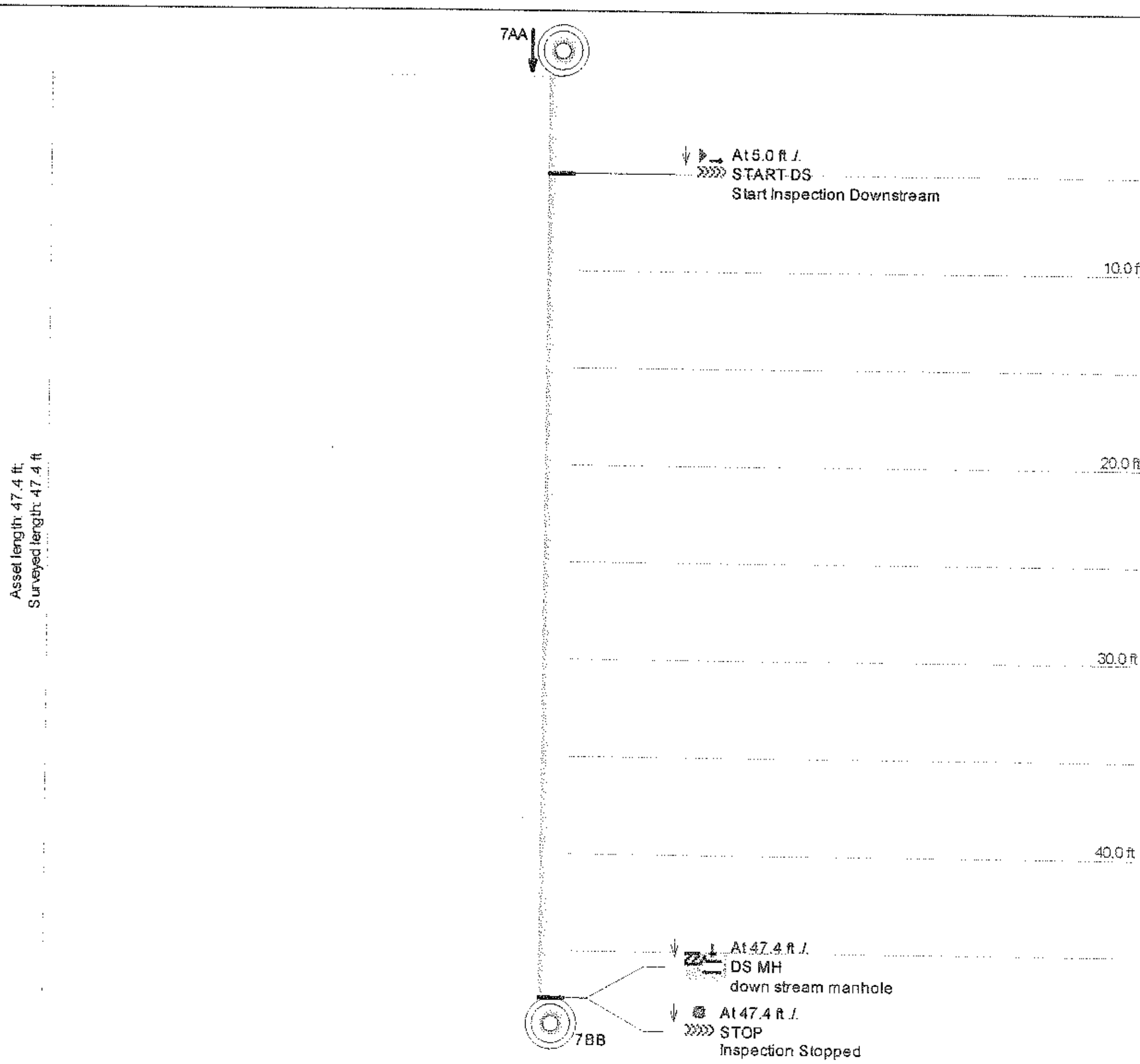
TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	SSCCB7AA7BB	SALEM, MA.	CANAL ST.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/14/2009	12	12	Ductile	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	47.4	Light Rain	



SPARTAN ENGINEERING, LLC
Structural Design, Analysis & Investigations

June 17, 2009

Ms. Jenn Turcotte
Green Environmental
120 Longwater Drive
Norwell, MA 02061

Subject: **Salem Tide Gate and Drainage System Review from New Derby Street to Canal Street, Salem, MA**
Regarding: **Existing Condition Summary**

Dear Ms. Turcotte:

As you requested I visited the subject drainage system and tide gate structures on Wednesday, April 29, 2009 in order to perform a visual review of the structure. The entire length of the system was walked and observed with the assistance of hand-held flashlights. The walls of the system are typically constructed from dry stacked granite stones and generally are in good condition. The composition of the roof structure varied along the length of the system. The following paragraphs summarize the findings of the visual survey.

The tide gate structure located at the east end of the system is composed of cast in place concrete. The walls and tide gates are heavily covered with barnacles, muscles and sea vegetation. Neither the north nor south gates appear to seal properly. It appears that there was a past attempt to seal the north tide gate with spray foam insulation. The existing climbing rungs leading from the hatch to the tide gates are deteriorated, damaged and not usable. The tide gate chambers had to be accessed using an extension ladder.

The concrete walls of the tide gate have areas where the fine aggregate and mortar of the concrete matrix had washed away leaving exposed course aggregate. The concrete walls were sounded with a hammer and found not to have any delaminating concrete. The washout of the fines was most likely a function of the original concrete mix and not a function of decay. One small area of spalled concrete was found along the northern edge of the south tide gate. The remaining concrete appeared to be sound. A horizontal crack was noted over the top of the north tide gate. Based upon the findings of the visual review it was not possible to determine the depth of the crack into the concrete however sounding the concrete did not yield any indication of delaminations and no spalling was noted. The overall condition of the tide gate concrete appears to be structurally sound.

An approximately 72" inside diameter concrete pipe leads from the tide gate structure back into a large chamber. The pipe appears to be structurally sound with only isolated areas of washed out fines within the concrete matrix. The chamber is constructed of dry stacked granite stone walls and a cast in place concrete roof slab. The roof slab had regularly spaced steel I beams contained within the concrete. Based upon the visual review it cannot be determined if the ceiling slab is positively connected to the granite walls.

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The granite walls appear to be sound however the ceiling slab is heavily spalled over approximately half of its area. The surface of the unspalled concrete is stained and the shadow of the embedded steel beams can be seen. This staining may indicated that the remaining embedded beams are actively corroding. The bottom surface of the ceiling could not be reached in order to be sounded therefore the exact extent of delamination could not be determined. Many of the lower flanges of the steel beams are exposed and severely corroded. It appears that the salt in the seawater vapor had penetrated the concrete cover and initiated corrosion in the embedded steel. As the steel corroded, it began to swell and it caused the concrete to spall. Many substantially sized pieces of concrete are loose and are hanging from the underside of the slab. No reinforcing bars were noted between the steel beams. Since record drawings of the ceiling slab were not available at the time of the visual survey, the depth of the slab and the size of the steel beams are not known. The ceiling slab supports a parking area and rear entrance of a bank, therefore the top surface of the slab is not visible and cannot be viewed without top surface excavation.

BANK STRUCTURE
0+58 TO 1+70

Based upon observations made during a visual review a complete evaluation of the ceiling slab cannot be made regarding its structural adequacy. However, given the level of corrosion that has occurred in the visible steel beams, the structural integrity of the slab is suspect.

The bulk of the drainage system is composed of dry stacked granite walls and the roof slab construction varies along the length of the system. Near the intersection of New Derby and Washington Streets heading back towards the tide gate structure, several large timber beams supported by both timber and granite posts span across the existing chamber. The exact purpose of the timbers is unknown. A few timbers support various utility pipes, but most do not nor do they appear to support the roof slabs or brace the granite walls. The timbers are exhibiting varying levels of decay and several pieces of timbers were found downstream. They are hindering flow within the pipe and are causing sediment to building in the drainage system.

6+80
TO
7+95
TRANSITION STRUCTURE

Beyond the timber beams the roof slab is framed with reinforced concrete beams which are cast integrally with the roof slab. Most of the concrete beams are in fair to good condition however several had exposed reinforcing bars which are actively corroding. Many of the exposed reinforcing bars did not appear to have adequate concrete cover when the beams were originally cast. The lack of concrete cover may be the reason for the corrosion of the bars. One of the concrete beams in particular contained a deep split along the bottom surface. This particular beam sounded hollow when knocked on with a hammer which indicates a failure within the concrete.

In the vicinity of the cast in place concrete beams, an area of granite wall had fallen into the drainage system most likely during the installation of a drain pipe at some point in the past. The remaining granite wall appears to be stable.

#4

Continuing toward the tide gate, the roof construction changes at several locations. The roof structure went from granite slabs spanning across the drainage system to closely spaced steel beams with red brick infill to steel sheet piling. (It is assumed that the steel sheet piling was used as a form during construction however the assumption could not be verified based upon the observations made during the visual review.) The granite slabs appeared to be stable. The steel beams supporting the brick appeared to be stable however moderate steel corrosion is evident. The corrosion level of the steel sheet piling varied however the sheeting appears to be stable.

Next the system between the intersection of New Derby and Washington Streets and Canal Street was observed. Upon reaching the point where the system splits to a double barrel section the contractor had marked stations along the granite wall. The stations started at approximately 16+40 at the split of the double barrel and decreased to 0+00 at the double siphon leading toward the pond. The following conditions were noted in this area of the system. The conditions are referenced to the contractor's stationing.

1. At station 16+40 the roof construction consisted of granite slabs clear spanning between the granite walls. One section of granite is cracked and is hanging below the ceiling. A cast in place slab was noted above the granite. No cracks or obvious signs of structural distress were noted on the visible bottom face of the concrete slab.

2. At station 14+60 the roof slab is composed of steel sections embedded in cast in place concrete. As part of the original construction the bottom of steel was set several inches below the bottom of concrete. The exposed steel section is severely deteriorated and pieces of the section including the bottom flanges are missing. Due to the absences of record drawings of the drainage system the exact details of the concrete slab is unknown however, in general, the concrete between the steel sections appears sound.

3. Between stations 12+00 and 9+00 there are several areas where what looks like the original timber formwork left in place. The timbers are hanging from the ceiling.

4. Near stations 3+00 and 1+10 the roof slabs are composed of a flat cast in place reinforced concrete. Areas of the concrete had spalled and several areas of the reinforcing bars are exposed. The reinforcing bars are corroding to varying degrees however the slabs appear to be structurally stable.

5. Near station 0+00 the system splits into a double barrel siphon which heads towards a pond. Due to water levels the siphon could not be accessed. The granite walls that could be seen from the end of the siphons appear to be stable and in good condition.

Structural Recommendations:

The following recommendations are offered with respect to the subject tide gate and associated drainage system:

investigation

1. Since the structural adequacy of the ceiling to the chamber behind the tide gates is suspect, it is recommended that the ceiling be temporarily shored until it can be fully investigated. Temporary shoring may consist of pressure treated timbers or other means. Prior to installing the shoring, any loose concrete should be removed from the ceiling in

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order to limit falling hazards. The design of the temporary shoring and evaluation of the ceiling is outside of the scope of this report.

INVESTIGATION

2. Further evaluation is recommended of the cast in place reinforced concrete beams near the intersection of New Derby and Washington Streets. In order to maintain the structural integrity of the roof slab in this area the concrete beams may require reinforcing and repair.

REPAIR

3. In order to maintain the flow within the drainage system it is recommended that timber beams not supporting utilities be removed. TRANSITION STRUCTURE

REPAIR

4. Near the concrete beams where the granite blocks have fallen into the drainage system, fill the void left in the wall with concrete prior to removing the fallen blocks. The concrete fill should be composed a low slump concrete mix or dry packed. TRANSITION STRUCTURE

REPAIR

5. In order to limit further decay of the ceiling area composed of steel beams and red brick infill it is recommended that the bottom flange of the steel beams be cleaned and coated. The coating may consist of an epoxy based coating, bitumen or other similar product. SOMEWHERE BETWEEN WASHINGTON & LAGRANGE

REPAIR

6. The hanging granite slab at station 16+40 should be removed so as to not hinder the flow within the system. CANAL ST

INVESTIGATION

7. Due to the level of corrosion of the steel sections, further investigation is recommended for the ceiling section near station 14+60. CANAL ST.

REPAIR

8. In order to limit debris falling into the drainage system, it is recommended that any hanging timber be removed between stations 12+00 and 9+00. CANAL ST.

REPAIR

9. In order to preserve the structural integrity of the cast in place roof slabs, the ceilings near stations 3+10 and 1+10 should be patched and repaired. Any deteriorated or damaged reinforcing bars should be repaired or supplemented.

The above recommendations are intended to serve as a guide and shall not be considered to server as a contract document. The design of temporary shoring and steel/concrete repairs is outside of the scope of this report however services may be provided under a separate agreement.

If you have any further questions regarding this matter, please call the undersigned at (508) 532-0876.

Sincerely,

Frank Lagodimos, PE, SECB

Photo Log

Photo 1 - South Tide Gate Elevation

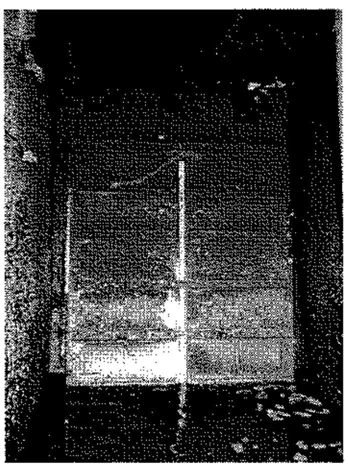


Photo 2 – South Tide Gate Elevation

Photo 3 – South Tide Gate Spall: A small concrete spall was present at the north edge of the south tide gate. The surrounding concrete appeared to be sound.

Photo 4 – Climbing Rungs at South Tide Gate: The climbing rungs from the upper hatch to the tide gates are damaged and unusable.

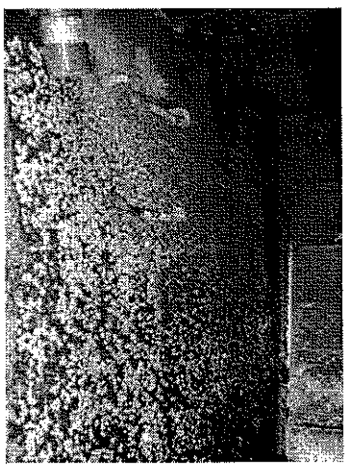


Photo 5 – Climbing Rungs at North Tide Gate

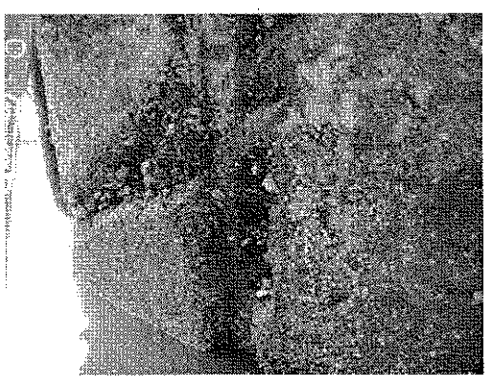


Photo 6 – Concrete Fines Washout at South Tide Gate: At several locations the fine aggregate and the mortar had been washed out of the concrete matrix leaving the course aggregate exposed.

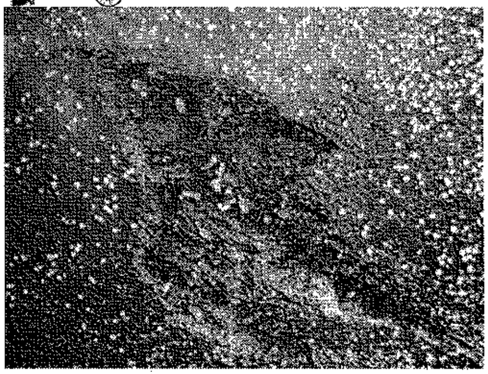


Photo 7 – Concrete Fines Washout at North Tide Gate

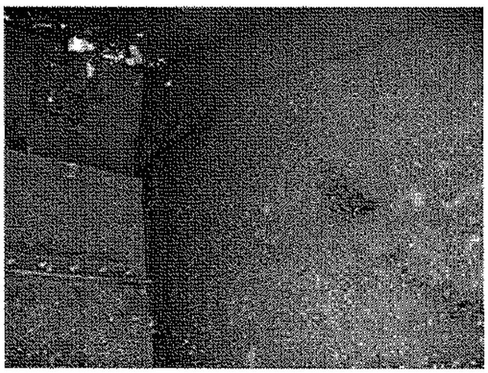


Photo 8 – Concrete Fines Washout at North Tide Gate

Photo 9 – Crack on Header Above North Tide Gate: A crack in the concrete starts at the upper left corner of the header and extends down and to the right looking at Photo #9.

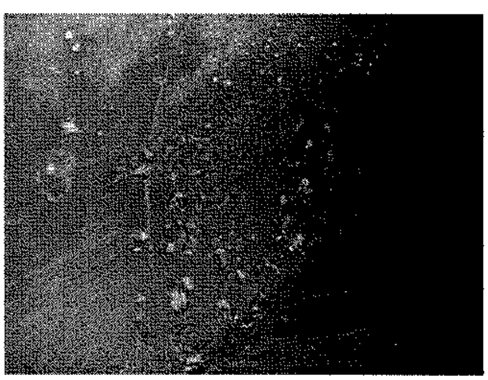


Photo 10 – Concrete Fines Washout at 72" Diameter Pipe Behind Tide Gates

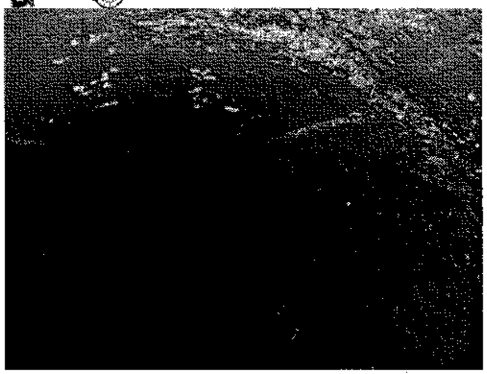


Photo 11 – Concrete Fines Washout at 72" Diameter Pipe Behind Tide Gates

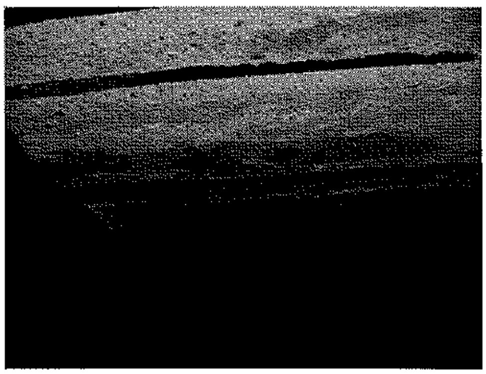


Photo 12 – Overall Photo of Chamber Roof Behind Tide Gates: Approximately half of the ceiling surface is spalled. The remaining surface exhibits staining and shadows of the embedded steel sections contained within the concrete. The staining could indicate active corrosion of the embedded steel sections.

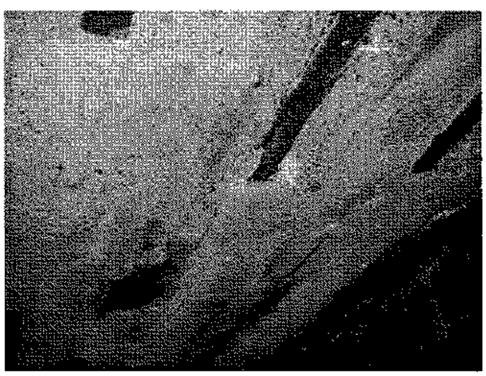


Photo 13 – Typical Condition of the Bottom Surface of the Chamber Ceiling: Heavy corrosion of the steel sections has occurred and substantial pieces of concrete hang from the ceiling.

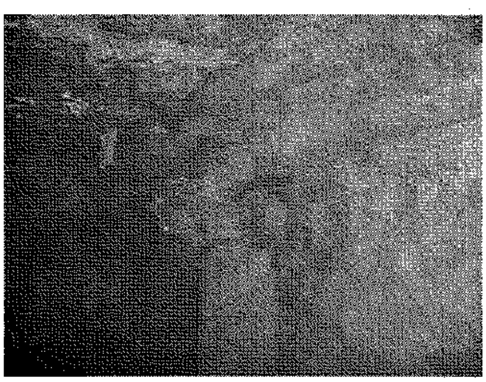


Photo 14 – Typical Timber Beam: The purpose of the existing timbers is unknown and the timbers are exhibiting varying levels of decay.

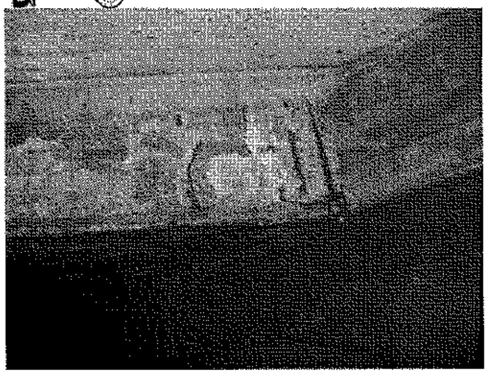


Photo 15 – Exposed Reinforcing Bars on Cast in Place Concrete Roof Beams: Inadequate concrete cover appears to be the cause of the initiated corrosion on the bars.

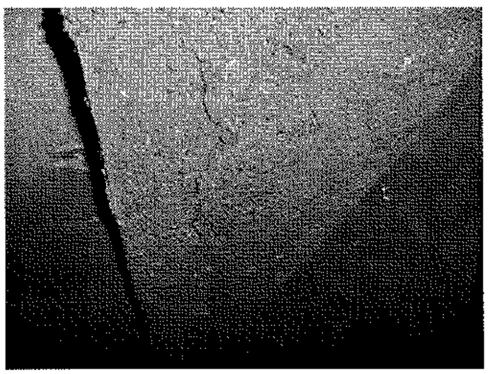


Photo 16 – Crack Along the Bottom of a Concrete Roof Beam: The bottom surface of this concrete beam displays a deep crack. The beams sounded hollow when knocked with a hammer.

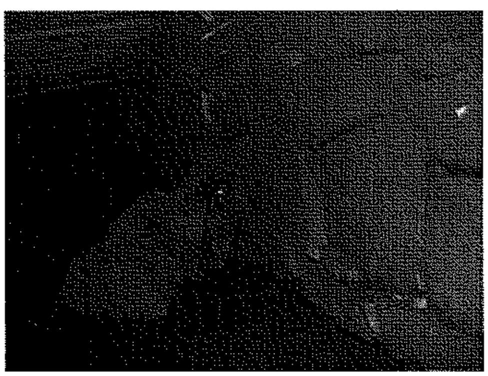


Photo 17 – Fallen Granite Stones

Photo 18 – Corroding Steel Roof Beams with Red Brick Infill

Photo 19 – Bottom Surface of Underside of Sheet Piling Forming Roof

Photo 20 – Falling Granite Slab at Station 16+40

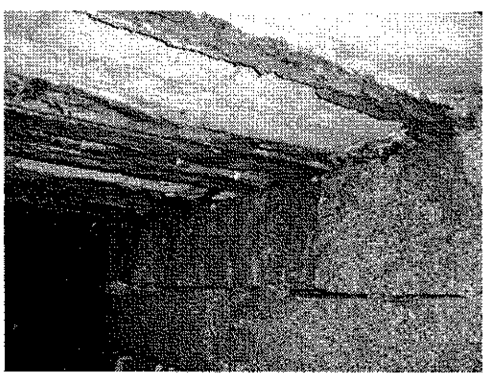


Photo 21 – Corroding Embedded Steel at Station 14+60: Although the steel sections have lost significant area due to corrosion the concrete infill appears to be sound.

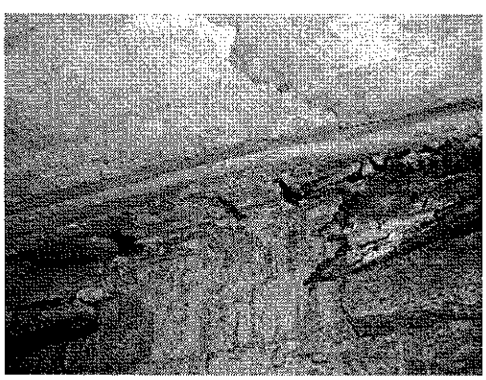


Photo 22 – Hanging Timber Forms: Several pieces of timber hang from the ceiling between Stations 12+00 and 9+00

SPARTAN ENGINEERING, LLC
Structural Design, Analysis & Investigations

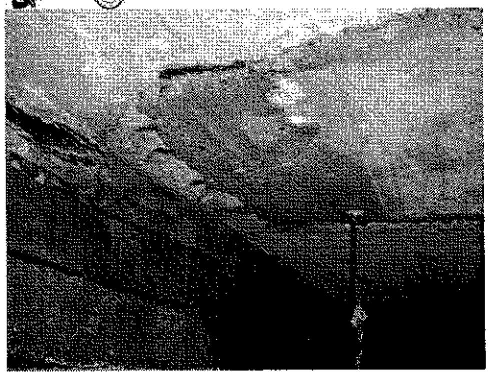


Photo 23 – Exposed Rebar at Station 3+10

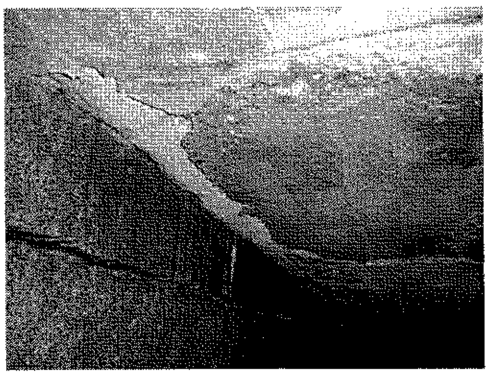


Photo 24 – Underside of Roof Slab at Station 1+10

CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

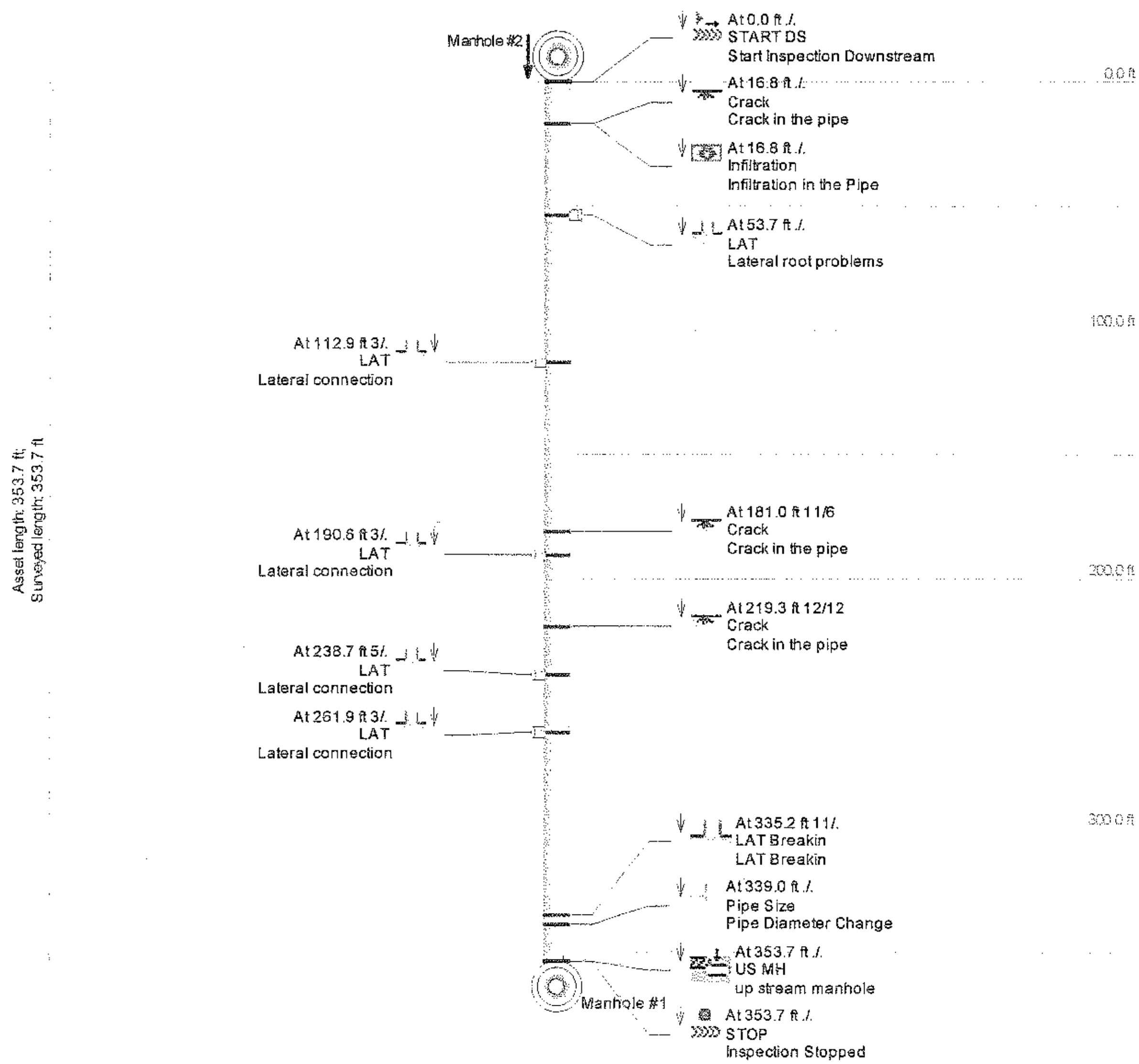
GRANITE XP
Pipeline Inspection and Integration Software

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	West 72"	Salem, Ma.	Canal St.

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/1/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream	353.7	Dry	



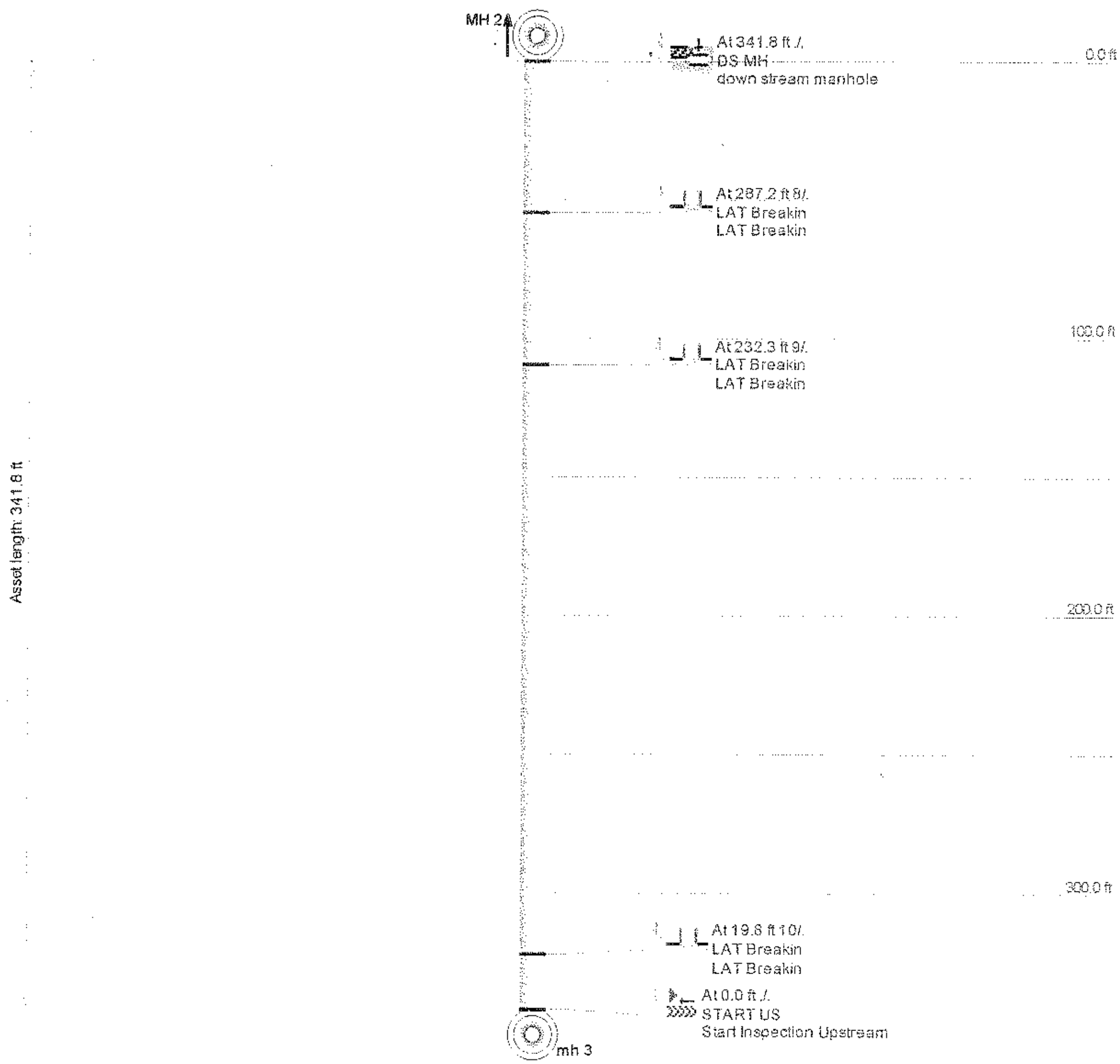
CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	west 72 " #2	salem	canal st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/1/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream		Dry	



CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

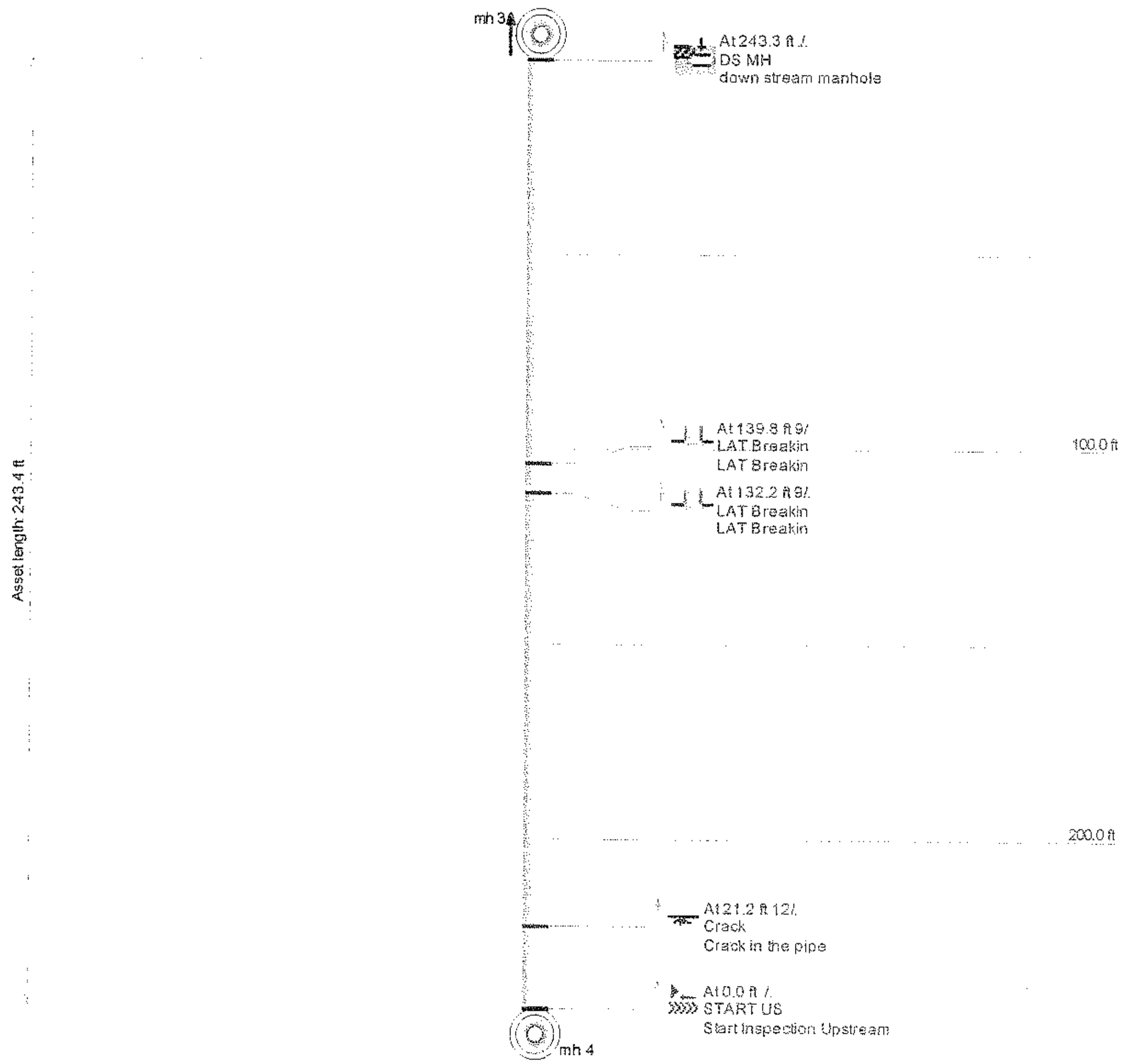
GRANITE XP
Pipeline Inspection and Integration Software

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	west 72" #3	salem	canal st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/1/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream		Dry	



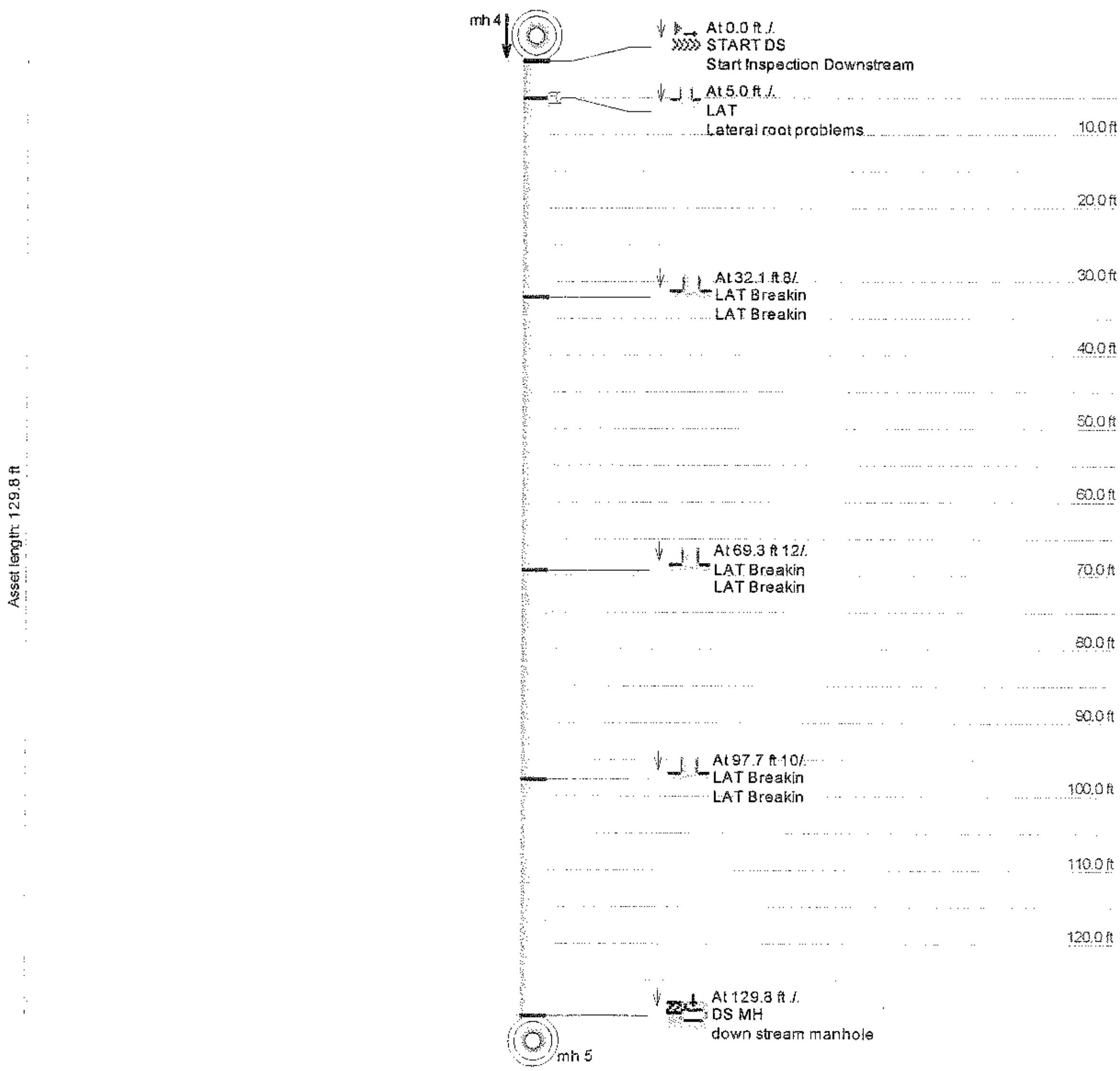
CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	west 72" #4	sale	canal st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/1/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Downstream		Dry	



CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

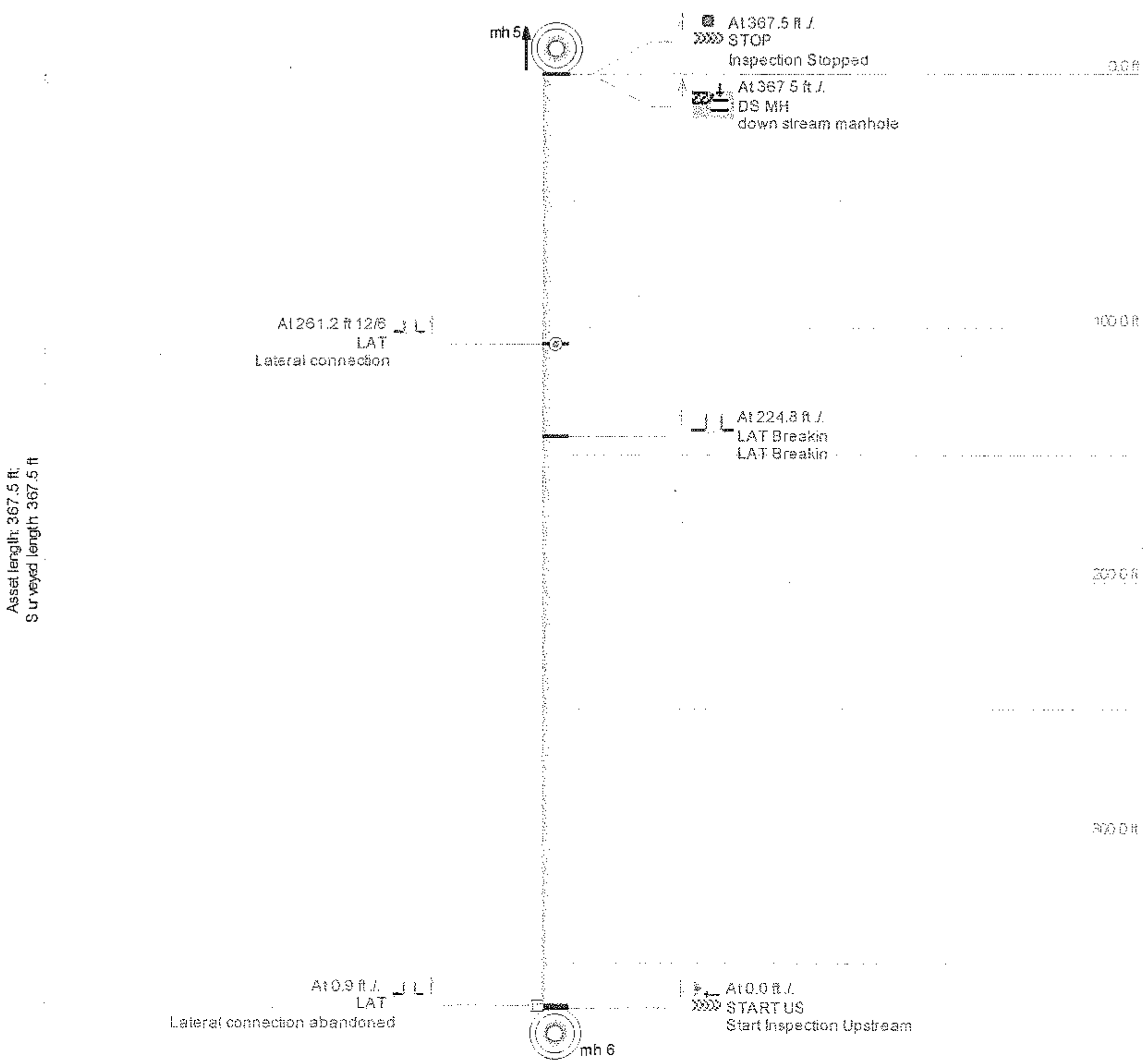
GRANITE XP
Pipeline Inspection and Integration Software

TV Inspection with Pipe-Run Graph

Project Name:	Asset ID:	City:	Address:
salem ma	west 72 " #5 b	salem	mill st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/4/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream	367.5	Dry	



CUES, Inc.
3600 Rio Vista Avenue
Orlando, FL 32805
Phone: 407-849-0190
Fax: 407-425-1569

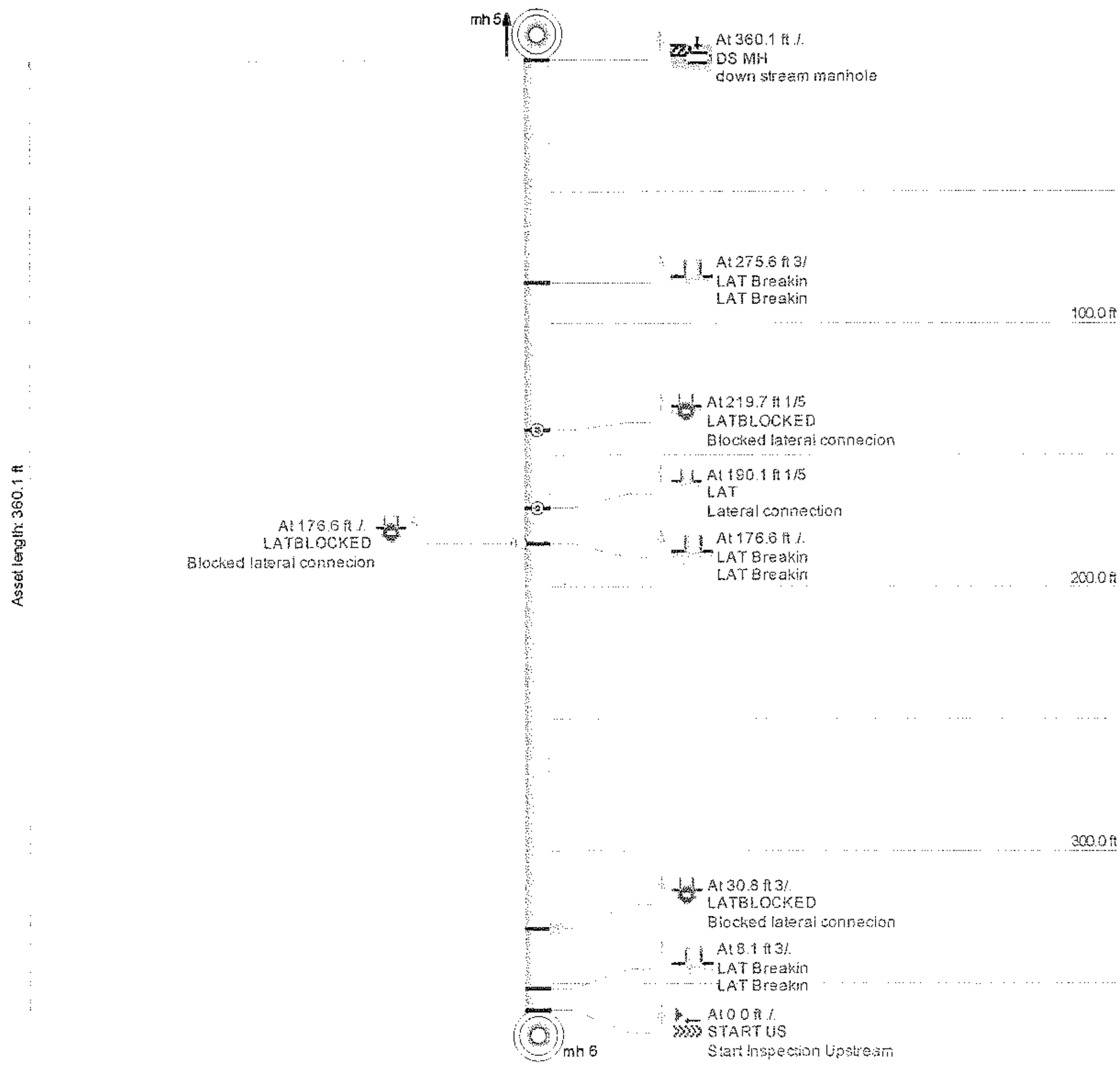
GRANITE XP
Pipeline Inspection and Integration Software

TV Inspection with Pipe-Run Graph

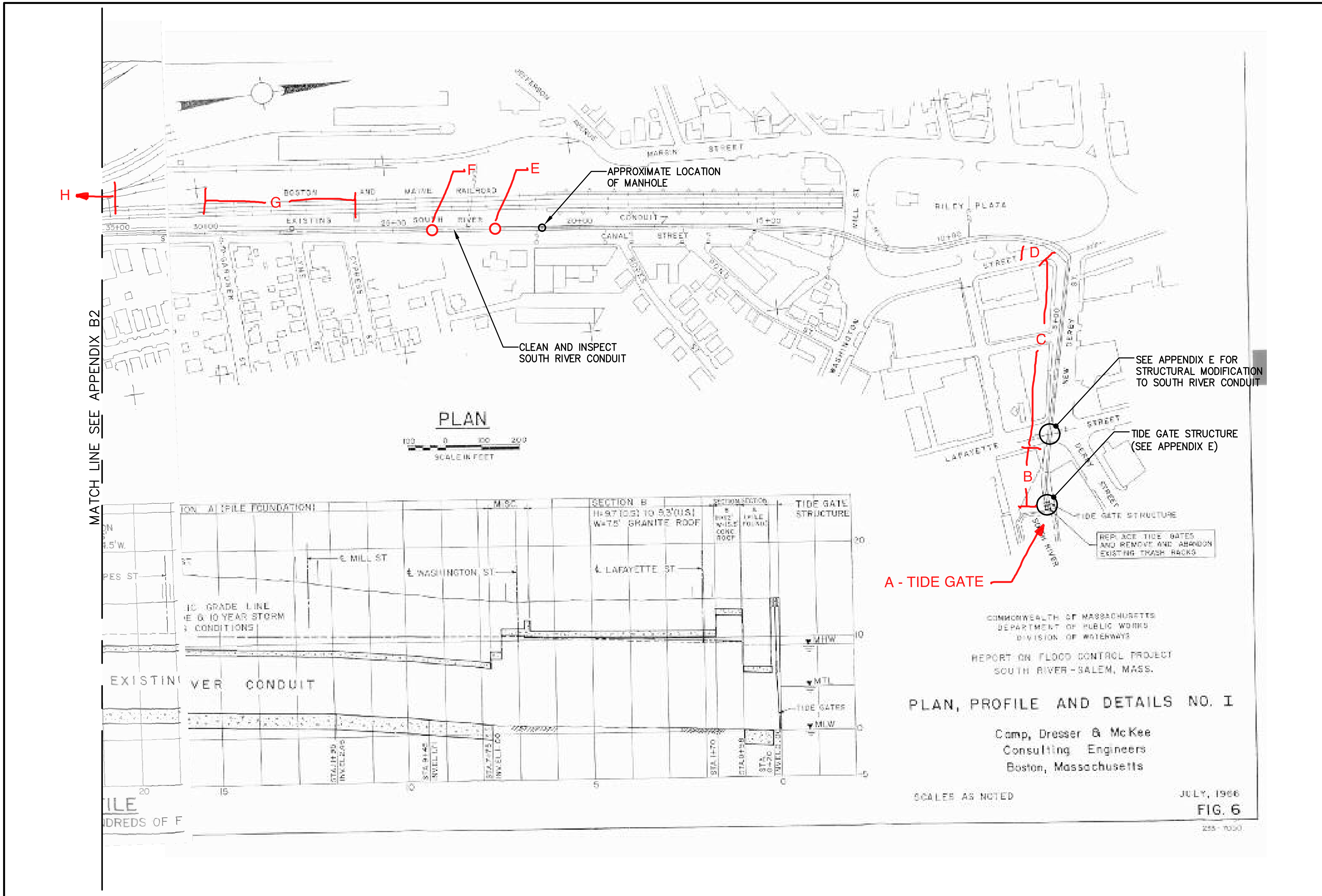
Project Name:	Asset ID:	City:	Address:
salem ma	east 72 " # 5 b	salem	mill st

Date	Pipe Width:	Pipe Height:	Pipe Type:	Surface Condition:
5/4/2009	72	72	Cement Reinforced	Asphalt

Direction:	Surveyed Footage:	Weather	Tape/Media #
Towards Upstream		Dry	



ATTACHMENT B – LOCATION OF SOUTH RIVER CONDUIT STATIONS



WOODARD & CURRAN
35 New England Business Center
Andover, Massachusetts 01810
866.702.6371 | www.woodardcurran.com

COMMITMENT & INTEGRITY DRIVE RESULTS

SOUTH RIVER CONDUIT FROM STA 0+00 TO STA 35+00

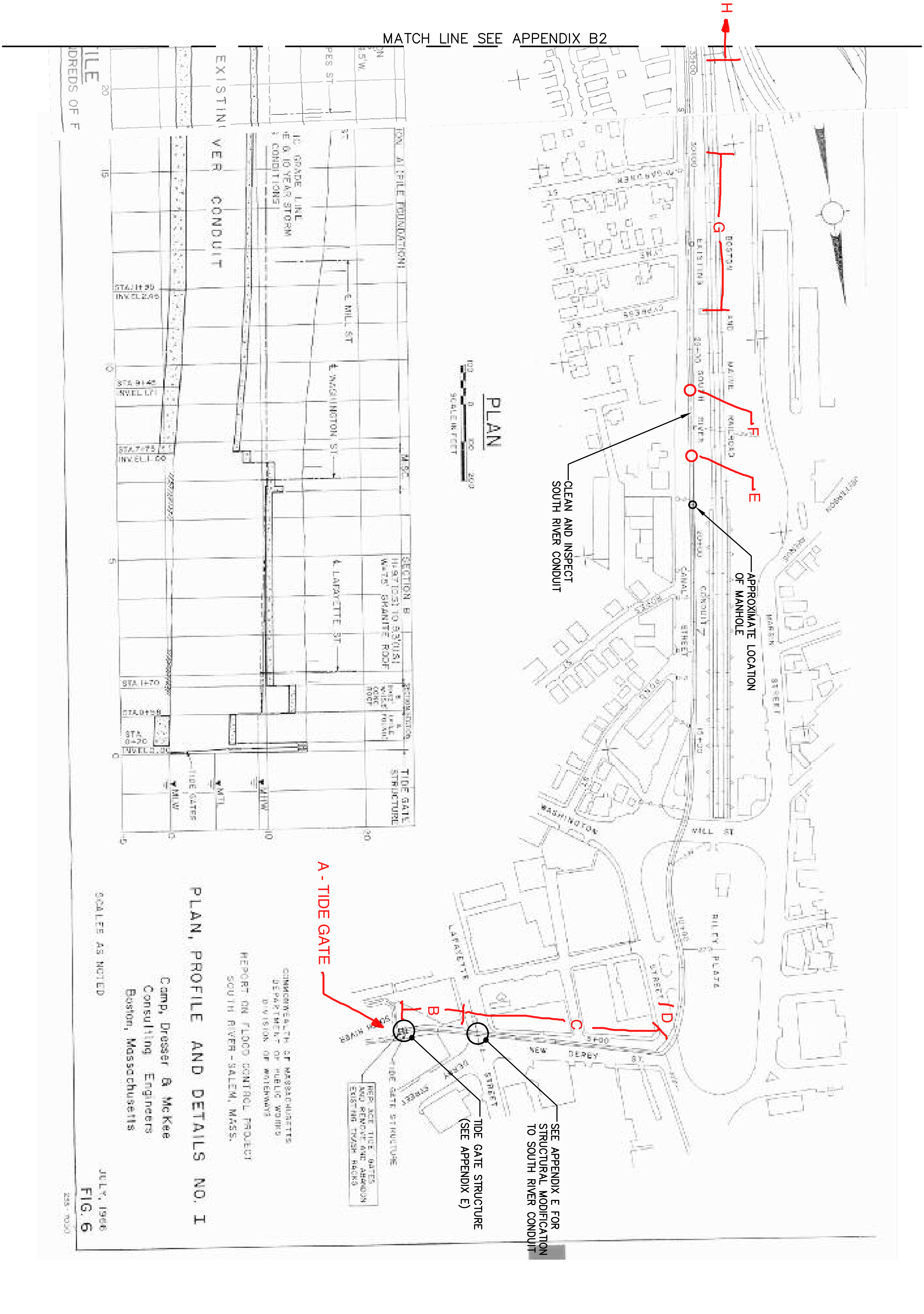
DESIGNED BY: HCP
DRAWN BY: HCP
CHECKED BY: DAW
Appendices.dwg

CITY OF SALEM, MA

SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT

JOB NO: 218953
DATE: December 2008
SCALE: AS NOTED

B1



JOB NO.: 218953	CITY OF SALEM, MA
DATE: December 2008	SOUTH RIVER DRAINAGE IMPROVEMENT PROJECT
SCALE: AS NOTED	
B1	

SOUTH RIVER CONDUIT
FROM STA 0+00 TO STA 35+00

DESIGNED BY:	HCP	CHECKED BY:	DAW
DRAWN BY:	HCP	Appendices.dwg	

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Andover, Massachusetts 01810
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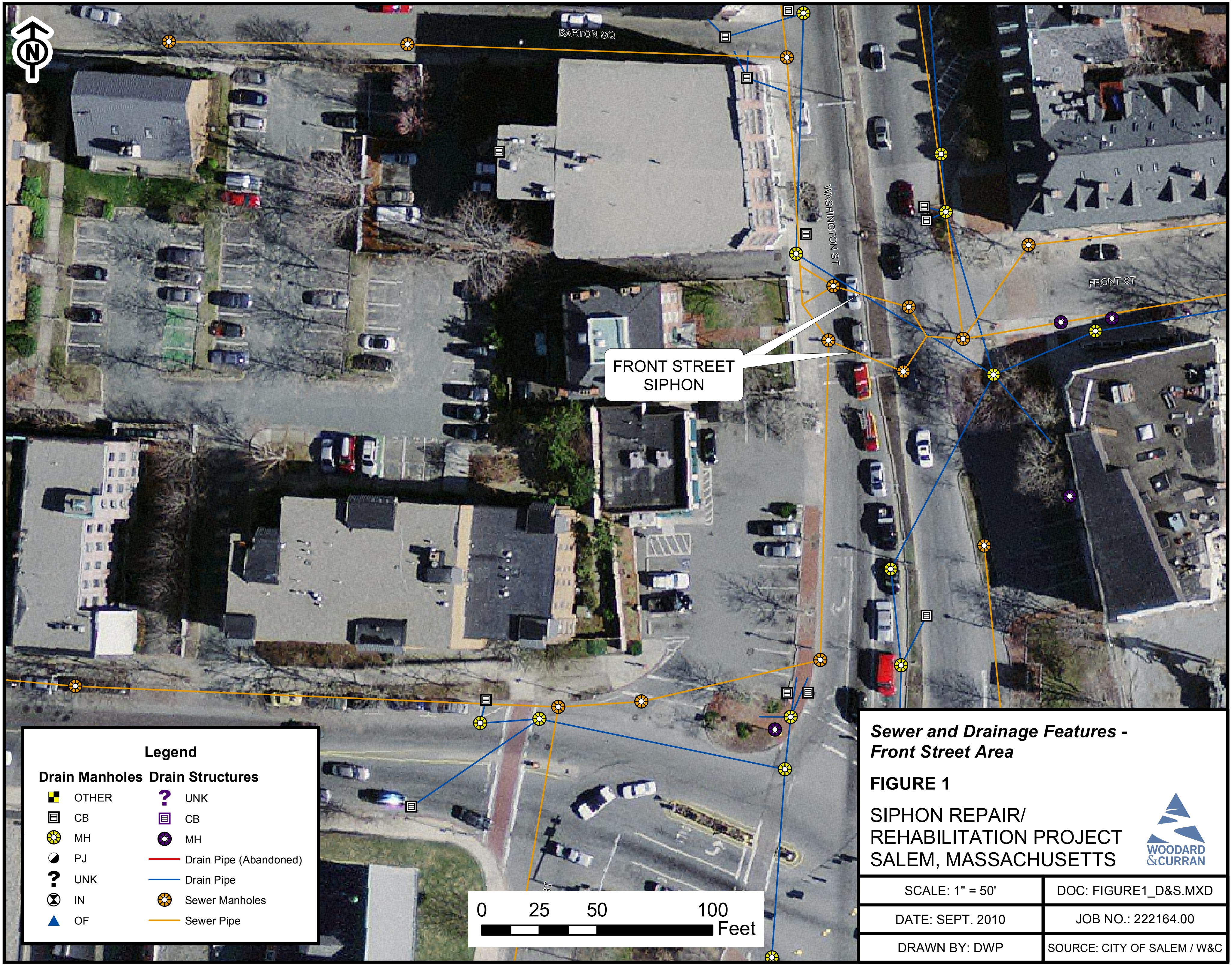
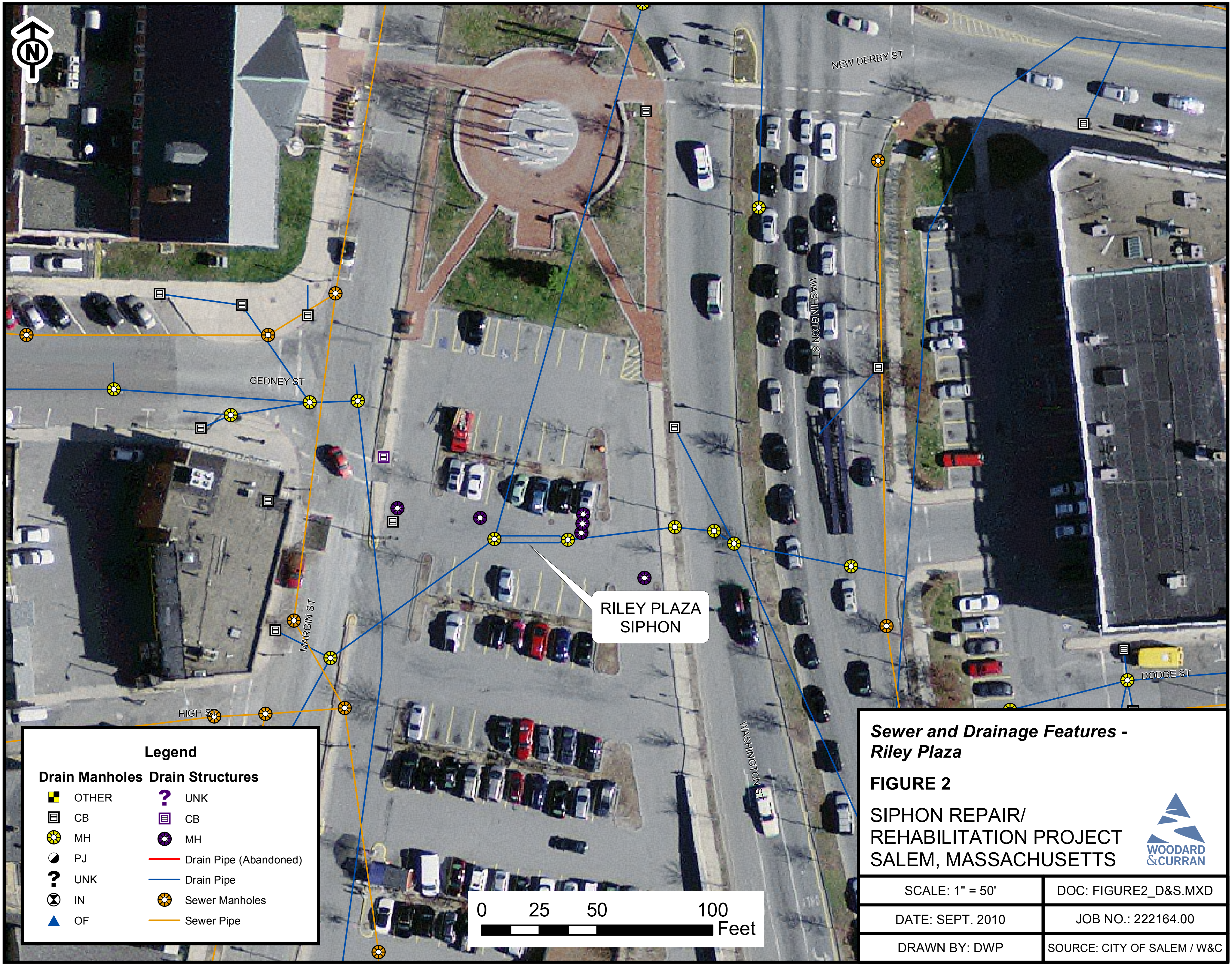
COMMITMENT & INTEGRITY DRIVE RESULTS

ATTACHMENT C – LOCATION OF SIPHONS



N
BARTON SQ
WASHINGTON ST
FRONT ST
FRONT STREET SIPHON
Legend
Drain Manholes
OTHER
CB
MH
PJ
UNK
IN
OF
Drain Structures
UNK
CB
MH
Drain Pipe (Abandoned)
Drain Pipe
Sewer Manholes
Sewer Pipe
0 25 50 100 Feet
Sewer and Drainage Features - Front Street Area
FIGURE 1
SIPHON REPAIR/ REHABILITATION PROJECT
SALEM, MASSACHUSETTS
WOODARD &CURRAN
SCALE: 1" = 50'
DOC: FIGURE1_D&S.MXD
DATE: SEPT. 2010
JOB NO.: 222164.00
DRAWN BY: DWP
SOURCE: CITY OF SALEM / W&C

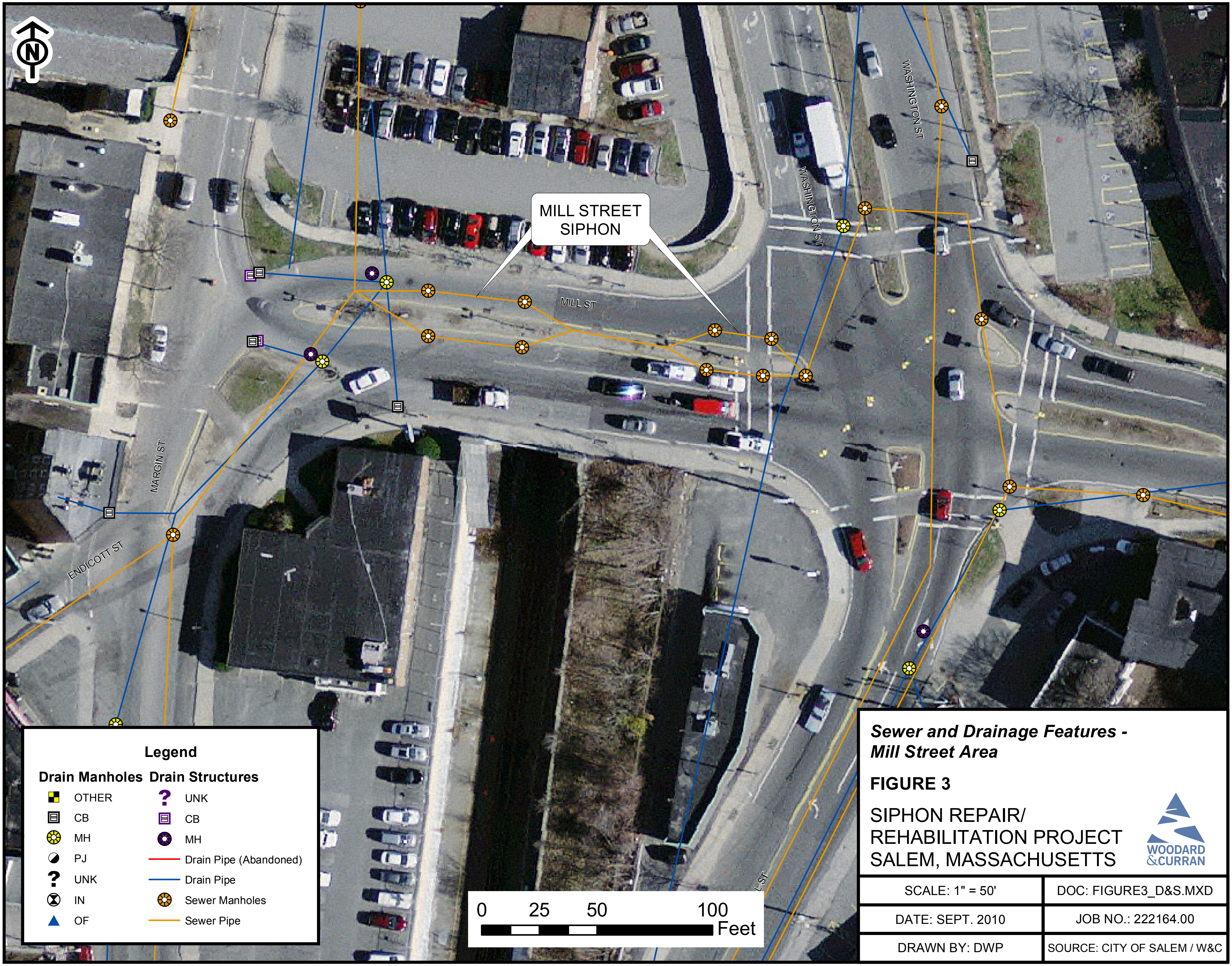


Sewer and Drainage Features - Riley Plaza

FIGURE 2

SIPHON REPAIR/
REHABILITATION PROJECT
SALEM, MASSACHUSETTS

SCALE: 1" = 50'	DOC: FIGURE2_D&S.MXD
DATE: SEPT. 2010	JOB NO.: 222164.00
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C



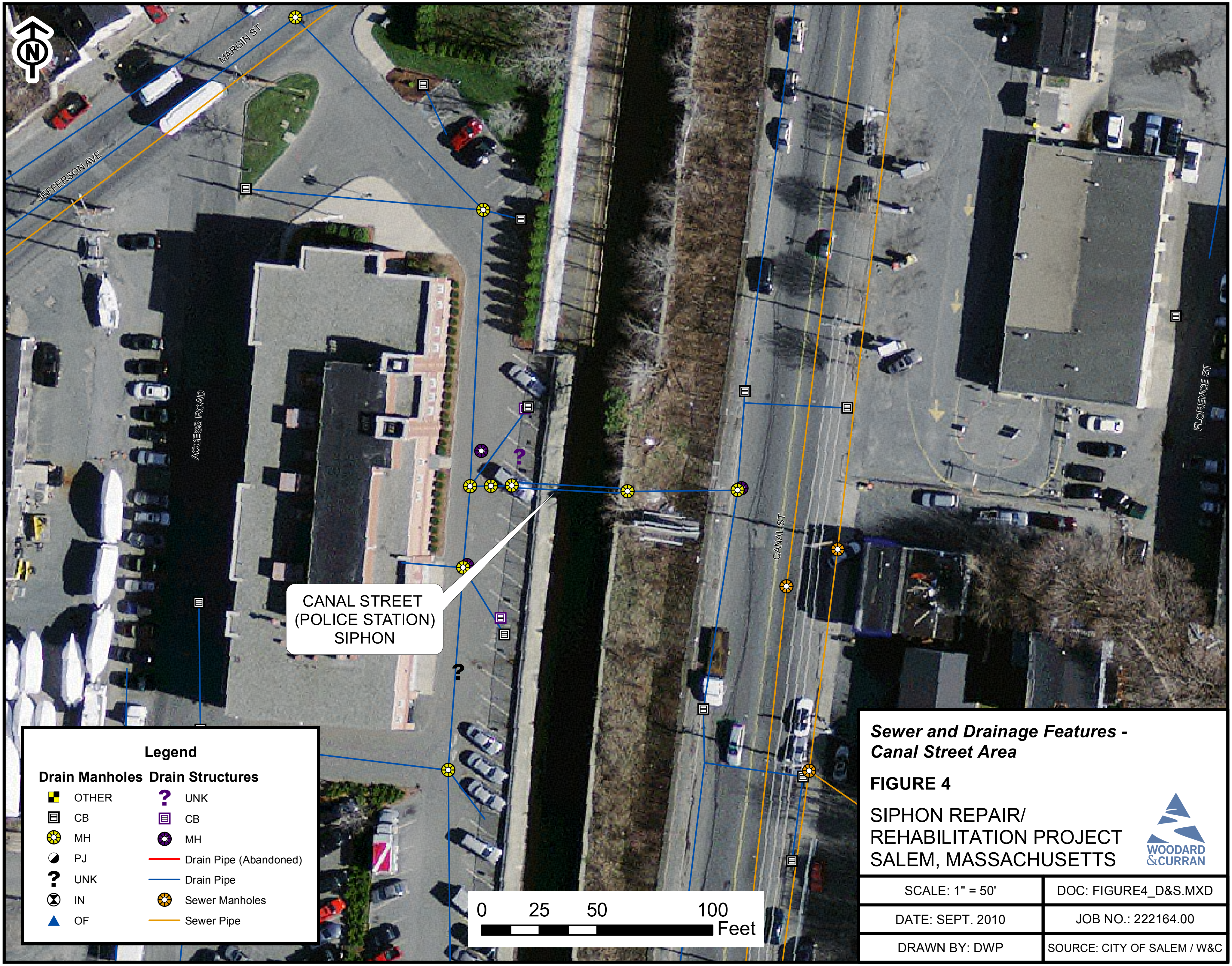
Sewer and Drainage Features - Mill Street Area

FIGURE 3

SIPHON REPAIR/
REHABILITATION PROJECT
SALEM, MASSACHUSETTS

WOODARD & CURRAN

SCALE: 1" = 50'	DOC: FIGURE3_D&S.MXD
DATE: SEPT. 2010	JOB NO.: 222164.00
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C



Sewer and Drainage Features - Canal Street Area

FIGURE 4

SIPHON REPAIR/
REHABILITATION PROJECT
SALEM, MASSACHUSETTS

SCALE: 1" = 50'	DOC: FIGURE4_D&S.MXD
DATE: SEPT. 2010	JOB NO.: 222164.00
DRAWN BY: DWP	SOURCE: CITY OF SALEM / W&C

ATTACHMENT D – COST ESTIMATES FOR SIPHONS

City of Salem, MA
Police Station Concept Design for Siphon Replacement

DRAFT

General Contractor Work:	
Equipment Capital and Direct Labor	$123,238
General Conditions (7.5%)	$9,243
Contractor's Overhead and Profit (15%)	$20,000
Specialty Contractor	$32,600
Subtotal Base Bid	$185,081
Plus 20% Contingency Base Bid	$37,000
Total General Contractor Construction Cost	**$222,000**
Engineering	
Detail Design (15% of total construction cost)	**$33,000**
Construction Admin (8%)	**$18,000**
Total Project Cost	**$273,000**

Cost Estimate Breakdown

Item Description	Quantity	Unit Cost	Total
Police Station (Canal Street)			
18" plain end by flanged pipe - Unit cost is per 10' section	2	$2,739	$5,478
18" flanged by flanged pipe - Unit cost is per 10' section	4	$3,222	$12,888
18" solid sleeve coupling	4	$1,010	$4,040
18" Wye/Tee	4	$2,900	$11,600
18" blind flange for wye or tee	4	$2,063	$8,252
Gasket kit with 304SS bolts	12	$315	$3,780
Pipe supports - 3 support per pipe assumed value	12	$1,000	$12,000
2-1/2" Drain assembly (nipple, valve)	4	$150	$600
Stop planks	2	$1,000	$2,000
Vacuum Truck, day	1	$1,500	$1,500
Excavator, days	5	$2,500	$12,500
Labor - assumes 3 man crew	5	$2,500	$12,500
Pipe Freight, LS	1	$3,500	$3,500
Specialty Contractor			
CIPP lining of 18-inch pipes, per LF	184	$150	$27,600
Internal Grouting of Entry/exit structure, ea	2	$2,500	$5,000

Assumes

No bypassing required

5 days total

City of Salem, MA
Riley Plaza Concept Design for Siphon Replacement

DRAFT

General Contractor Work:	
Equipment Capital and Direct Labor	$125,764
General Conditions (7.5%)	$9,432
Contractor's Overhead and Profit (15%)	$20,000
Specialty Contractor	$47,000
Subtotal Base Bid	$202,196
Plus 20% Contingency Base Bid	$40,000
Total General Contractor Construction Cost	**$242,196**
Engineering	
Detail Design (15% of total construction cost)	**$36,000**
Construction Admin (8%)	**$19,000**
Total Project Cost	**$297,000**

Cost Estimate Breakdown

Item Description	Quantity	Unit Cost	Total
Riley Plaza			
36" plain end by flanged pipe - Unit cost is per 10' section	3	$7,776	$23,328
36" solid sleeve coupling	4	$1,300	$5,200
36" Wye/Tee	4	$10,000	$40,000
36" blind flange for wye or tee	4	$2,459	$9,836
Gasket kit with 304SS bolts	8	$850	$6,800
Pipe supports - 2 support per pipe assumed value	8	$1,000	$8,000
2-1/2" Drain assembly (nipple, valve)	4	$150	$600
Stop planks	2	$1,000	$2,000
Vacuum Truck, day	1	$1,500	$1,500
Excavator, days	5	$2,500	$12,500
Labor - assumes 3 man crew	5	$2,500	$12,500
Pipe Freight, LS	1	$3,500	$3,500
Specialty Contractor			
CIPP lining of 36-inch pipes, per LF	140	$300	$42,000
Internal Grouting of Entry/exit structure, ea	2	$2,500	$5,000

Assumes

No bypassing required

5 days total

City of Salem, MA
Mill Street Concept Design for Siphon Replacement

DRAFT

General Contractor Work:		
Equipment Capital and Direct Labor		$157,712
General Conditions (7.5%)		$11,828
Contractor's Overhead and Profit (15%)		$25,000
Specialty Contractor		$92,800
	Subtotal Base Bid	$287,340
Plus 20% Contingency Base Bid		$57,000
	Total General Contractor Construction Cost	**$344,340**
Engineering		
Detail Design (15% of total construction cost)		**$52,000**
Construction Admin (8%)		**$28,000**
	Total Project Cost	**$424,000**

Cost Estimate Breakdown

Item Description	**Quantity**	**Unit Cost**	**Total**
Mill Street - railroad tunnel			
18" plain end by flanged pipe - Unit cost is per 10' section	2	$2,739	$5,478
18" flanged by flanged pipe - Unit cost is per 10' section	6	$3,222	$19,332
18" solid sleeve coupling	4	$1,010	$4,040
18" Wye/Tee	4	$2,900	$11,600
18" blind flange for wye or tee	4	$2,063	$8,252
Gasket kit with 304SS bolts	14	$315	$4,410
Pipe supports - 3 support per pipe assumed value	12	$1,000	$12,000
2-1/2" Drain assembly (nipple, valve)	4	$150	$600
Stop planks	2	$1,000	$2,000
Vacuum Truck, day	1	$1,500	$1,500
Excavator, days	10	$1,500	$15,000
Labor - assumes 3 man crew	10	$2,000	$20,000
Pipe Freight, LS	1	$3,500	$3,500
Bypass pumping allowance, LS	1	$50,000	$50,000
Specialty Contractor			
CIPP lining of 18-inch pipes, per LF (South River)	352	$150	$52,800
(RR)	200	$150	$30,000
Internal Grouting of Entry/exit structure, ea	4	$2,500	$10,000

Assumes

Maintain one way traffic

10 days total

City of Salem, MA
Front Street Concept Design for Siphon Replacement DRAFT

General Contractor Work:	
Equipment Capital and Direct Labor	$104,928
General Conditions (7.5%)	$7,870
Contractor's Overhead and Profit (15%)	$17,000
Specialty Contractor	$31,200
Subtotal Base Bid	$160,998
Plus 20% Contingency Base Bid	$32,000
Total General Contractor Construction Cost	**$193,000**
Engineering	
Detail Design (15% of total construction cost)	**$30,000**
Construction Admin (8%)	**$15,000**
Total Project Cost	**$238,000**

Cost Estimate Breakdown

Item Description	Quantity	Unit Cost	Total
Front Street			
General Contractor			
8" plain end by flanged pipe - Unit cost is per 10' section	4	$911	$3,644
8" flanged by flanged pipe - Unit cost is per 10' section	12	$1,072	$12,864
8" solid sleeve coupling	8	$225	$1,800
8" Wye/Tee	8	$872	$6,976
8" blind flange for wye or tee	8	$193	$1,544
Gasket kit with 304SS bolts	24	$38	$900
Pipe supports - 2 support per pipe assumed value	16	$750	$12,000
2-1/2" Drain assembly (nipple, valve)	8	$150	$1,200
Stop planks	4	$1,000	$4,000
Vacuum Truck, day	2	$1,500	$3,000
Excavator, days	10	$2,500	$25,000
Labor - assumes 3 man crew	10	$2,500	$25,000
Pipe Freight, LS	2	$3,500	$7,000
Specialty Contractor			
CIPP lining of 8-inch pipes, per LF	212	$100	$21,200
Internal Grouting of Entry/exit structure, ea	4	$2,500	$10,000

Assumes

Two each entry and exit structures
No bypassing required
Close street during work
Conduct work at night

APPENDIX B: ALTERNATIVES ANALYSIS RESULTS

WOODARD & CURRAN
35 New England Business Center
Andover, Massachusetts 01810
Tel: 866.702.6371 Fax: 978.557.7948

Table 1 of 3 - Summary of Preliminary Alternatives Analysis
April 2011
10-year Peak Water Surface Elevations - Mean High Water Tidal Conditions
South River Drainage Improvement Project - Salem, MA

General Notes
- Water Surface Elevations (WSE) are on City of Salem Datum and represent the peak water surface elevation.
- Cells shaded in gray denote the critical elevation was exceeded under baseline conditions. Cells with red text signify that the peak water surface elevation is equal to or has exceeded the critical elevation for the evaluated alternative.
- Δ implies the change in peak water surface elevations from baseline conditions and the evaluated alternative.
- Critical elevation denotes the elevation at which flooding becomes a concern. It represents the lowest elevation of a roadway crossing at a culvert, rim elevation at the lowest point on a drainage system, lowest point of a flood control levee, or ground surface elevation of adjacent structures.
- U/S = Upstream, D/S = Downstream

Description	Critical Elev.	Base	Alt. 1 Increase Capacity of South River Conduit		Alt. 2 Divert Flow from Golf Course		Alt. 3 PS at end of Canal St. & Salem State Systems		Alt. 4 PS at end of South River Conduit		Alt. 5 Enlarge Rosie's Pond		Alt. 6 PS at O'Keefe Center Parking Area		Alt. 7 Modify Rosie's Pond Bypass		Alt. 8 PS on Salem State System		Alt. 9 PS on Canal St. System		Alt. 10 Enlarge Salem State System		Alt. 11 Enlarge Canal St. System		Alt. 12 Enlarge Canal St. & Salem State Systems		Alt. 13 Storage at Golf Course	
		WSE	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ
SRC Outfall		9.5	9.3	-0.2	9.3	-0.2	9.4	0.0	3.8	-5.6	9.4	-0.1	9.4	0.0			9.5	0.0	9.5	0.0	9.5	0.0	9.5	0.0	9.5	0.0	9.3	-0.2
SRC at Canal Street	14.3	11.1	10.9	-0.2	10.9	-0.2	11.1	0.0	9.7	-1.4	11.0	-0.1	11.1	0.0			11.1	0.0	11.1	0.0	11.1	0.0	11.1	0.0	11.1	0.0	10.9	-0.2
SRC Inlet	11.0	11.3	11.1	-0.2	11.1	-0.2	11.2	0.0	9.8	-1.4	11.2	-0.1	11.2	0.0			11.3	0.0	11.3	0.0	11.3	0.0	11.3	0.0	11.3	0.0	11.1	-0.2
O'Keefe Parking Area	8.0	11.2	11.1	-0.2	11.1	-0.2	7.1	-4.2	9.8	-1.4	11.2	-0.1	11.2	-0.1			7.1	-4.2	11.2	0.0	11.3	0.0	11.3	0.0	11.3	0.0	11.1	-0.2
McDonald's Catch Basin	8.9	13.1	13.1	0.0	13.1	0.0	13.1	0.0	13.1	0.1	13.1	0.0	13.1	0.0			13.1	0.1	13.1	0.1	13.1	0.0	11.1	-2.0	11.1	-2.0	13.2	0.1
D/S Mill Pond	11.0	11.3	11.2	-0.2	11.2	-0.2	11.3	0.0	9.9	-1.4	11.3	-0.1	11.3	0.0			11.3	0.0	11.3	0.0	11.3	0.0	11.3	0.0	11.3	0.0	11.2	-0.2
U/S Mill Pond	11.0	11.9	11.7	-0.2	11.7	-0.2	11.9	0.0	10.5	-1.4	11.8	-0.1	11.9	0.0			11.9	0.0	11.9	0.0	11.9	0.0	11.9	0.0	11.9	0.0	11.7	-0.2
D/S Jefferson Ave. Culvert (3)[3]	14.6	12.0	11.8	-0.2	11.8	-0.2	11.9	0.0	10.5	-1.4	11.9	-0.1	11.9	0.0			12.0	0.0	12.0	0.0	12.0	0.0	12.0	0.0	12.0	0.0	11.8	-0.2
U/S Jefferson Ave. Culvert (3)[3]	14.6	12.0	11.8	-0.2	11.8	-0.2	12.0	0.0	10.6	-1.4	11.9	-0.1	12.0	0.0			12.0	0.0	12.0	0.0	12.0	0.0	12.0	0.0	12.0	0.0	11.8	-0.2
D/S Dove Ave. Culvert	13.7	12.1	11.9	-0.2	11.9	-0.2	12.0	0.0	10.6	-1.4	12.0	-0.1	12.0	0.0			12.1	0.0	12.1	0.0	12.1	0.0	12.1	0.0	12.1	0.0	11.9	-0.2
U/S Dove Ave. Culvert	13.7	12.1	11.9	-0.2	11.9	-0.2	12.1	0.0	10.9	-1.2	12.0	-0.1	12.1	0.0			12.1	0.0	12.1	0.0	12.1	0.0	12.1	0.0	12.1	0.0	11.9	-0.2
D/S Jefferson Ave. Berm	12.5	12.2	12.0	-0.2	12.0	-0.2	12.1	0.0	11.0	-1.2	12.1	-0.1	12.1	0.0			12.2	0.0	12.2	0.0	12.2	0.0	12.2	0.0	12.2	0.0	12.0	-0.2
U/S Jefferson Ave. Berm	12.5	12.3	12.1	-0.2	12.1	-0.3	12.3	0.0	11.2	-1.2	12.3	-0.1	12.3	0.0			12.3	0.0	12.3	0.0	12.3	0.0	12.3	0.0	12.3	0.0	12.1	-0.2
D/S Jefferson Ave. Culvert (2)[2]	15.1	12.4	12.2	-0.2	12.1	-0.3	12.4	0.0	11.2	-1.2	12.3	-0.1	12.4	0.0			12.4	0.0	12.4	0.0	12.4	0.0	12.4	0.0	12.4	0.0	12.2	-0.2
U/S Jefferson Ave. Culvert (2)[2]	15.1	12.4	12.2	-0.2	12.1	-0.3	12.4	0.0	12.1	-0.3	12.4	-0.1	12.4	0.0			12.4	0.0	12.4	0.0	12.4	0.0	12.4	0.0	12.4	0.0	12.2	-0.2
D/S Brook St. Berm	13.3	12.5	12.3	-0.2	12.2	-0.3	12.5	0.0	12.2	-0.3	12.4	-0.1	12.5	0.0	NOT MODELED		12.5	0.0	12.5	0.0	12.5	0.0	12.5	0.0	12.5	0.0	12.3	-0.2
U/S Brook St. Berm	13.3	13.1	13.0	-0.2	12.6	-0.5	13.1	0.0	12.8	-0.3	13.1	-0.1	13.1	0.0			13.1	0.0	13.1	0.0	13.1	0.0	13.1	0.0	13.1	0.0	13.0	-0.2
D/S Lawrence Ave. Culvert	16.0	13.2	13.0	-0.2	12.7	-0.5	13.2	0.0	12.9	-0.3	13.2	-0.1	13.2	0.0			13.2	0.0	13.2	0.0	13.2	0.0	13.2	0.0	13.2	0.0	13.0	-0.2
U/S Lawrence Ave. Culvert	16.0	13.5	13.3	-0.2	12.7	-0.8	13.3	-0.2	13.3	-0.2	13.2	-0.4	13.5	0.0			13.3	-0.2	13.3	-0.2	13.3	-0.2	13.3	-0.2	13.3	-0.2	13.0	-0.5
D/S Rosie's Pond Outlet	13.0	13.8	13.7	-0.2	12.9	-0.9	13.7	-0.2	13.7	-0.2	13.5	-0.4	13.9	0.0			13.7	-0.2	13.7	-0.2	13.7	-0.2	13.7	-0.2	13.7	-0.2	13.4	-0.5
U/S Rosie's Pond	13.0	14.8	14.8	0.0	12.9	-1.9	14.8	0.0	14.8	0.0	15.0	0.2	14.8	0.0			14.8	0.0	14.8	0.0	14.8	0.0	14.8	0.0	14.8	0.0	13.6	-1.2
D/S Jefferson Ave. Culvert (1)[2]	17.5	14.9	14.9	0.0	13.0	-1.9	14.9	0.0	14.9	0.0	15.1	0.2	14.9	0.0			14.9	0.0	14.9	0.0	14.9	0.0	14.9	0.0	14.9	0.0	13.7	-1.2
U/S Jefferson Ave. Culvert (1)[2]	17.5	15.5	15.5	0.0	13.0	-2.5	15.5	0.0	15.5	0.0	15.1	-0.4	15.5	0.0			15.5	0.0	15.5	0.0	15.5	0.0	15.5	0.0	15.5	0.0	13.7	-1.8
D/S Box Culverts	16.0	15.7	15.7	0.0	(N/A)[1]	(N/A)[1]	15.7	0.0	15.7	0.0	15.4	-0.4	15.7	0.0			15.7	0.0	15.7	0.0	15.7	0.0	16.1	0.4	15.7	0.0	13.8	-1.9
U/S Box Culverts	19.2	17.4	17.4	0.0	(N/A)[1]	(N/A)[1]	17.4	0.0	17.4	0.0	16.7	-0.7	17.4	0.0			17.4	0.0	17.4	0.0	17.4	0.0	17.4	0.0	17.4	0.0	14.1	-3.4
Golf Course Pond	25.0	19.3	19.3	0.0	13.6	-5.7	19.3	0.0	19.3	0.0	19.3	0.0	19.3	0.0			19.3	0.0	19.3	0.0	19.3	0.0	19.3	0.0	19.3	0.0	23.0	3.7
D/S Diversion Structure	25.0	21.1	21.1	0.0	21.1	0.0	21.1	0.0	21.1	0.0	21.1	0.0	21.1	0.0			21.1	0.0	21.1	0.0	21.1	0.0	21.1	0.0	21.1	0.0	23.1	2.0
D/S Diversion Pond		22.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0			22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	23.1	1.1
Diversion Structure Pond	30.0	23.7	23.7	0.0	23.7	0.0	23.7	0.0	23.7	0.0	23.7	0.0	23.7	0.0			23.7	0.0	23.7	0.0	23.7	0.0	23.7	0.0	23.7	0.0	23.7	0.0
D/S Highland Ave. Culvert	96.4	82.7	82.7	0.0	82.7	0.0	82.7	0.0	82.7	0.0	82.7	0.0	82.7	0.0			82.7	0.0	82.7	0.0	82.7	0.0	82.7	0.0	82.7	0.0	82.7	0.0
U/S Highland Ave. Culvert (Pond)	96.4	86.6	86.6	0.0	86.6	0.0	86.6	0.0	86.6	0.0	86.6	0.0	86.6	0.0			86.6	0.0	86.6	0.0	86.6	0.0	86.6	0.0	86.6	0.0	86.6	0.0

[1] Alternative diverts stormwater from the golf course resulting in no flow through the culverts from the golf course.

[2] Jefferson Avenue crosses South River at three locations. "1" represents the upstream most crossing, and "3" represents the downstream most crossing.

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Table 2 of 3 - Summary of Preliminary Alternatives Analysis
April 2011
50-year Peak Water Surface Elevations - Mean Water Tidal Conditions
South River Drainage Improvement Project - Salem, MA

General Notes
- Water Surface Elevations (WSE) are on City of Salem Datum and represent the peak water surface elevation.
- Cells shaded in gray denote the critical elevation was exceeded under baseline conditions. Cells with red text signify that the peak water surface elevation is equal to or has exceeded the critical elevation for the evaluated alternative.
- Δ implies the change in peak water surface elevations from baseline conditions and the evaluated alternative.
- Critical elevation denotes the elevation at which flooding becomes a concern. It represents the lowest elevation of a roadway crossing at a culvert, rim elevation at the lowest point on a drainage system, lowest point of a flood control levee, or ground surface elevation of adjacent structures.
- U/S = Upstream, D/S = Downstream

Description	Critical Elev.	Base	Alt. 1 Increase Capacity of South River Conduit		Alt. 2 Divert Flow from Golf Course		Alt. 3 PS at end of Canal St. & Salem State Systems		Alt. 4 PS at end of South River Conduit		Alt. 5 Enlarge Rosie's Pond		Alt. 6 PS at O'Keefe Center Parking Area		Alt. 7 Modify Rosie's Pond Bypass	
		WSE	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ
SRC Outfall		6.1	9.9	3.8	5.5	-0.6	6.1	0.0	5.2	-0.8	6.1	0.0	6.1	0.0		
SRC at Canal Street	14.3	11.4	10.8	-0.7	11.2	-0.2	10.7	-0.7	11.4	0.0	11.2	-0.2	11.5	0.0		
SRC Inlet	11.0	11.6	10.8	-0.8	11.4	-0.2	10.9	-0.7	11.6	0.0	11.4	-0.2	11.7	0.0		
O'Keefe Parking Area	8.0	11.8	11.0	-0.8	11.6	-0.2	11.0	-0.8	11.8	0.0	11.6	-0.2	11.9	0.1		
McDonald's Catch Basin	8.9	14.1	14.1	0.0	14.1	0.0	14.1	0.0	14.1	0.0	14.1	0.0	14.1	0.0		
D/S Mill Pond	11.0	11.7	10.8	-0.9	11.5	-0.2	11.0	-0.7	11.7	0.0	11.5	-0.2	11.7	0.0		
U/S Mill Pond	11.0	12.2	10.8	-1.5	12.0	-0.2	11.5	-0.7	12.2	0.0	12.0	-0.2	12.3	0.0		
D/S Jefferson Ave. Culvert (3)[3]	14.6	12.3	10.8	-1.5	12.1	-0.2	11.6	-0.7	12.3	0.0	12.1	-0.2	12.4	0.0		
U/S Jefferson Ave. Culvert (3)[3]	14.6	12.3	10.8	-1.5	12.1	-0.2	11.6	-0.7	12.3	0.0	12.1	-0.2	12.4	0.0		
D/S Dove Ave. Culvert	13.7	12.4	10.8	-1.6	12.2	-0.2	11.7	-0.7	12.4	0.0	12.2	-0.2	12.5	0.0		
U/S Dove Ave. Culvert	13.7	12.4	11.6	-0.8	12.2	-0.2	11.7	-0.7	12.4	0.0	12.2	-0.2	12.5	0.0		
D/S Jefferson Ave. Berm	12.5	12.5	11.7	-0.8	12.3	-0.2	11.8	-0.7	12.5	0.0	12.3	-0.2	12.6	0.0		
U/S Jefferson Ave. Berm	12.5	12.7	11.9	-0.8	12.5	-0.2	11.9	-0.7	12.7	0.0	12.5	-0.2	12.7	0.0		
D/S Jefferson Ave. Culvert (2)[2]	15.1	12.8	12.0	-0.8	12.5	-0.2	12.0	-0.7	12.7	0.0	12.5	-0.2	12.8	0.0		
U/S Jefferson Ave. Culvert (2)[2]	15.1	13.0	13.0	0.0	12.6	-0.4	13.0	0.0	13.0	0.0	12.7	-0.2	13.0	0.0		
D/S Brook St. Berm	13.3	13.0	13.0	0.0	12.6	-0.4	13.0	0.0	13.0	0.0	12.8	-0.2	13.0	0.0	NOT MODELED	
U/S Brook St. Berm	13.3	13.8	13.8	0.0	13.3	-0.5	13.8	0.0	13.8	0.0	13.5	-0.3	13.8	0.0		
D/S Lawrence Ave. Culvert	16.0	13.9	13.9	0.0	13.4	-0.5	13.9	0.0	13.9	0.0	13.6	-0.3	13.9	0.0		
U/S Lawrence Ave. Culvert	16.0	14.3	14.3	0.0	13.4	-0.9	14.3	0.0	14.3	0.0	14.1	-0.1	14.3	0.0		
D/S Rosie's Pond Outlet	13.0	14.6	14.6	0.0	13.6	-1.0	14.6	0.0	14.6	0.0	14.5	-0.2	14.6	0.0		
U/S Rosie's Pond	13.0	15.5	15.5	0.0	13.6	-2.0	15.5	0.0	15.5	0.0	15.8	0.2	15.5	0.0		
D/S Jefferson Ave. Culvert (1)[2]	17.5	15.6	15.6	0.0	13.7	-2.0	15.6	0.0	15.6	0.0	15.9	0.2	15.6	0.0		
U/S Jefferson Ave. Culvert (1)[2]	17.5	16.1	16.1	0.0	13.7	-2.4	16.1	0.0	16.1	0.0	16.0	-0.1	16.1	0.0		
D/S Box Culverts	16.0	16.4	16.4	0.0	(N/A)[1]	(N/A)[1]	16.4	0.0	16.4	0.0	16.3	-0.1	16.4	0.0		
U/S Box Culverts	19.2	18.9	18.9	0.0	(N/A)[1]	(N/A)[1]	18.9	0.0	18.9	0.0	18.7	-0.2	18.9	0.0		
Golf Course Pond	25.0	21.0	21.0	0.0	13.8	-7.2	21.0	0.0	21.0	0.0	21.0	0.0	21.0	0.0		
D/S Diversion Structure	25.0	21.6	21.6	0.0	21.6	0.0	21.6	0.0	21.6	0.0	21.6	0.0	21.6	0.0		
D/S Diversion Pond		22.7	22.7	0.0	22.7	0.0	22.7	0.0	22.7	0.0	22.7	0.0	22.7	0.0		
Diversion Structure Pond	30.0	25.3	25.3	0.0	25.3	0.0	25.3	0.0	25.3	0.0	25.3	0.0	25.3	0.0		
D/S Highland Ave. Culvert	96.4	82.8	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0		
U/S Highland Ave. Culvert (Pond)	96.4	88.1	88.1	0.0	88.1	0.0	88.1	0.0	88.1	0.0	88.1	0.0	88.1	0.0		

Description	Alt. 8 PS on Salem State System		Alt. 9 PS on Canal St. System		Alt. 10 Enlarge Salem State System		Alt. 11 Enlarge Canal St. System		Alt. 12 Enlarge Canal St. & Salem State Systems		Alt. 13 Storage at Golf Course	
	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ
SRC Outfall	6.1	0.0	6.1	0.0	6.1	0.0	6.3	0.3	5.7	-0.3	5.5	-0.6
SRC at Canal Street	10.8	-0.7	11.3	-0.1	12.1	0.6	11.9	0.5	12.5	1.1	11.2	-0.2
SRC Inlet	10.9	-0.7	11.5	-0.1	12.2	0.6	12.1	0.5	12.7	1.1	11.4	-0.2
O'Keefe Parking Area	11.0	-0.8	11.7	-0.1	12.6	0.8	12.3	0.5	13.1	1.3	11.9	0.0
McDonald's Catch Basin	14.1	0.0	14.1	0.0	14.1	0.0	13.8	-0.3	13.8	-0.3	14.1	0.0
D/S Mill Pond	11.0	-0.7	11.6	-0.1	12.3	0.6	12.2	0.5	12.8	1.1	11.5	-0.2
U/S Mill Pond	11.6	-0.7	12.1	-0.1	12.9	0.6	12.7	0.5	13.3	1.1	12.0	-0.2
D/S Jefferson Ave. Culvert (3)[3]	11.6	-0.7	12.2	-0.1	12.9	0.6	12.8	0.5	13.4	1.1	12.1	-0.2
U/S Jefferson Ave. Culvert (3)[3]	11.7	-0.7	12.2	-0.1	13.0	0.6	12.8	0.5	13.4	1.1	12.1	-0.2
D/S Dove Ave. Culvert	11.7	-0.7	12.3	-0.1	13.0	0.6	12.9	0.5	13.5	1.1	12.2	-0.2
U/S Dove Ave. Culvert	11.8	-0.7	12.3	-0.1	13.1	0.6	12.9	0.5	13.5	1.1	12.2	-0.2
D/S Jefferson Ave. Berm	11.8	-0.7	12.4	-0.1	13.1	0.6	13.0	0.5	13.6	1.1	12.3	-0.2
U/S Jefferson Ave. Berm	12.0	-0.7	12.5	-0.1	13.3	0.6	13.1	0.5	13.8	1.1	12.5	-0.2
D/S Jefferson Ave. Culvert (2)[2]	12.1	-0.7	12.6	-0.1	13.4	0.6	13.2	0.5	13.9	1.1	12.5	-0.2
U/S Jefferson Ave. Culvert (2)[2]	13.0	0.0	13.0	0.0	13.4	0.4	13.2	0.3	13.9	0.9	12.6	-0.4
D/S Brook St. Berm	13.0	0.0	13.0	0.0	13.5	0.4	13.3	0.3	14.0	0.9	12.6	-0.4
U/S Brook St. Berm	13.8	0.0	13.8	0.0	14.1	0.3	14.0	0.2	14.6	0.8	13.3	-0.5
D/S Lawrence Ave. Culvert	13.9	0.0	13.9	0.0	14.2	0.3	14.0	0.2	14.7	0.8	13.4	-0.5
U/S Lawrence Ave. Culvert	14.3	0.0	14.3	0.0	14.3	0.0	14.3	0.0	14.7	0.4	13.4	-0.9
D/S Rosie's Pond Outlet	14.6	0.0	14.6	0.0	14.6	0.0	14.6	0.0	15.0	0.4	13.6	-1.0
U/S Rosie's Pond	15.5	0.0	15.5	0.0	15.5	0.0	15.5	0.0	15.5	0.0	14.3	-1.3
D/S Jefferson Ave. Culvert (1)[2]	15.6	0.0	15.6	0.0	15.6	0.0	15.6	0.0	15.6	0.0	14.4	-1.3
U/S Jefferson Ave. Culvert (1)[2]	16.1	0.0	16.1	0.0	16.1	0.0	16.1	0.0	16.1	0.0	14.7	-1.4
D/S Box Culverts	16.4	0.0	16.4	0.0	16.4	0.0	16.4	0.0	16.4	0.0	15.0	-1.4
U/S Box Culverts	18.9	0.0	18.9	0.0	18.9	0.0	18.9	0.0	18.9	0.0	16.1	-2.8
Golf Course Pond	21.0	0.0	21.0	0.0	21.0	0.0	21.0	0.0	21.0	0.0	23.5	2.4
D/S Diversion Structure	21.6	0.0	21.6	0.0	21.6	0.0	21.6	0.0	21.6	0.0	23.6	2.0
D/S Diversion Pond	22.7	0.0	22.7	0.0	22.7	0.0	22.7	0.0	22.7	0.0	23.6	0.9
Diversion Structure Pond	25.3	0.0	25.3	0.0	25.3	0.0	25.3	0.0	25.3	0.0	25.3	0.0
D/S Highland Ave. Culvert	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0
U/S Highland Ave. Culvert (Pond)	88.1	0.0	88.1	0.0	88.1	0.0	88.1	0.0	88.1	0.0	88.1	0.0

[1] Alternative diverts stormwater from the golf course resulting in no flow through the culverts from the golf course.

[2] Jefferson Avenue crosses South River at three locations. "1" represents the upstream most crossing, and "3" represents the downstream most crossing.

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Table 3 of 3 - Summary of Preliminary Alternatives Analysis
April 2011
100-year Peak Water Surface Elevations - Mean Water Tidal Conditions
South River Drainage Improvement Project - Salem, MA

General Notes
- Water Surface Elevations (WSE) are on City of Salem Datum and represent the peak water surface elevation.
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- Δ implies the change in peak water surface elevations from baseline conditions and the evaluated alternative.
- Critical elevation denotes the elevation at which flooding becomes a concern. It represents the lowest elevation of a roadway crossing at a culvert, rim elevation at the lowest point on a drainage system, lowest point of a flood control levee, or ground surface elevation of adjacent structures.
- U/S = Upstream, D/S = Downstream

Description	Critical Elev.	Base	Alt. 1 Increase Capacity of South River Conduit		Alt. 2 Divert Flow from Golf Course		Alt. 3 PS at end of Canal St. & Salem State Systems		Alt. 4 PS at end of South River Conduit		Alt. 5 Enlarge Rosie's Pond		Alt. 6 PS at O'Keefe Center Parking Area		Alt. 7 Modify Rosie's Pond Bypass		Alt. 8 PS on Salem State System		Alt. 9 PS on Canal St. System		Alt. 10 Enlarge Salem State System		Alt. 11 Enlarge Canal St. System		Alt. 12 Enlarge Canal St. & Salem State Systems		Alt. 13 Storage at Golf Course	
		WSE	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ	WSE	Δ
SRC Outfall		6.1	9.9	3.8	5.7	-0.4	6.1	0.0	5.7	-0.3	6.1	0.0	6.1	0.0			6.1	0.0	6.1	0.0	6.1	0.0	6.1	0.0	6.3	0.2	5.7	-0.4
SRC at Canal Street	14.3	13.1	10.8	-2.3	12.4	-0.7	11.4	-1.6	13.1	0.0	12.4	-0.7	13.1	0.0			11.5	-1.5	12.9	-0.1	13.8	0.7	13.6	0.5	14.4	1.3	12.4	-0.6
SRC Inlet	11.0	13.2	10.8	-2.5	12.6	-0.7	11.6	-1.6	13.2	0.0	12.5	-0.7	13.2	0.0			11.7	-1.5	13.1	-0.1	14.0	0.7	13.8	0.5	14.5	1.3	12.6	-0.6
O'Keefe Parking Area	8.0	13.5	11.2	-2.3	12.8	-0.7	11.2	-2.3	13.5	0.0	12.8	-0.7	13.5	0.0			11.4	-2.1	13.3	-0.1	14.3	0.9	14.0	0.5	14.9	1.4	12.8	-0.6
McDonald's Catch Basin	8.9	14.1	14.1	0.0	14.1	0.0	14.1	0.0	14.1	0.0	14.1	0.0	14.1	0.0			14.1	0.0	14.1	0.0	14.1	0.0	13.9	-0.3	14.6	0.5	14.1	0.0
D/S Mill Pond	11.0	13.3	10.8	-2.5	12.7	-0.7	11.7	-1.6	13.3	0.0	12.6	-0.7	13.3	0.0			11.8	-1.5	13.2	-0.1	14.1	0.7	13.8	0.5	14.6	1.3	12.7	-0.6
U/S Mill Pond	11.0	13.9	10.8	-3.1	13.2	-0.6	12.2	-1.6	13.9	0.0	13.2	-0.7	13.9	0.0			12.3	-1.5	13.7	-0.1	14.6	0.7	14.4	0.5	15.2	1.3	13.2	-0.6
D/S Jefferson Ave. Culvert (3)[3]	14.6	13.9	10.8	-3.2	13.3	-0.7	12.3	-1.6	13.9	0.0	13.2	-0.7	13.9	0.0			12.4	-1.5	13.8	-0.1	14.7	0.7	14.5	0.5	15.2	1.3	13.3	-0.6
U/S Jefferson Ave. Culvert (3)[3]	14.6	14.0	10.8	-3.2	13.3	-0.7	12.3	-1.6	14.0	0.0	13.3	-0.7	14.0	0.0			12.4	-1.5	13.8	-0.1	14.7	0.7	14.5	0.5	15.3	1.3	13.3	-0.6
D/S Dove Ave. Culvert	13.7	14.0	10.8	-3.3	13.4	-0.6	12.4	-1.6	14.0	0.0	13.3	-0.7	14.0	0.0			12.5	-1.5	13.9	-0.1	14.8	0.7	14.6	0.5	15.3	1.3	13.4	-0.6
U/S Dove Ave. Culvert	13.7	14.1	11.9	-2.2	13.4	-0.7	12.4	-1.6	14.1	0.0	13.4	-0.7	14.1	0.0			12.5	-1.5	13.9	-0.1	14.8	0.7	14.6	0.5	15.4	1.3	13.4	-0.6
D/S Jefferson Ave. Berm	12.5	14.1	12.0	-2.2	13.5	-0.7	12.5	-1.6	14.1	0.0	13.4	-0.7	14.1	0.0			12.6	-1.5	14.0	-0.1	14.9	0.7	14.7	0.5	15.4	1.3	13.5	-0.6
U/S Jefferson Ave. Berm	12.5	14.3	12.1	-2.2	13.7	-0.7	12.7	-1.6	14.3	0.0	13.6	-0.7	14.3	0.0			12.8	-1.5	14.2	-0.1	15.0	0.7	14.8	0.5	15.6	1.3	13.7	-0.6
D/S Jefferson Ave. Culvert (2)[2]	15.1	14.4	12.2	-2.2	13.7	-0.7	12.8	-1.6	14.4	0.0	13.7	-0.7	14.4	0.0			12.9	-1.5	14.3	-0.1	15.1	0.7	14.9	0.5	15.7	1.3	13.7	-0.6
U/S Jefferson Ave. Culvert (2)[2]	15.1	14.4	13.1	-1.3	13.8	-0.7	13.1	-1.3	14.4	0.0	13.7	-0.7	14.4	0.0			13.1	-1.3	14.3	-0.1	15.1	0.7	14.9	0.5	15.7	1.3	13.8	-0.6
D/S Brook St. Berm	13.3	14.5	13.2	-1.3	13.8	-0.7	13.2	-1.3	14.5	0.0	13.8	-0.7	14.5	0.0	NOT MODELED		13.2	-1.3	14.4	-0.1	15.2	0.7	15.0	0.5	15.8	1.3	13.8	-0.6
U/S Brook St. Berm	13.3	15.1	14.0	-1.2	14.5	-0.6	14.0	-1.2	15.1	0.0	14.4	-0.7	15.1	0.0			14.0	-1.2	15.0	-0.1	15.9	0.7	15.6	0.5	16.4	1.3	14.5	-0.6
D/S Lawrence Ave. Culvert	16.0	15.2	14.1	-1.2	14.6	-0.6	14.1	-1.2	15.2	0.0	14.5	-0.7	15.2	0.0			14.1	-1.2	15.1	-0.1	15.9	0.7	15.7	0.5	16.5	1.3	14.6	-0.6
U/S Lawrence Ave. Culvert	16.0	15.2	14.4	-0.8	14.6	-0.6	14.4	-0.8	15.2	0.0	14.5	-0.7	15.2	0.0			14.4	-0.8	15.1	-0.1	15.9	0.7	15.7	0.5	16.5	1.3	14.6	-0.6
D/S Rosie's Pond Outlet	13.0	15.5	14.7	-0.8	14.8	-0.7	14.7	-0.8	15.5	0.0	14.7	-0.8	15.5	0.0			14.7	-0.8	15.4	-0.1	16.3	0.7	16.0	0.5	16.8	1.3	14.8	-0.7
U/S Rosie's Pond	13.0	15.8	15.8	0.0	14.9	-0.9	15.8	0.0	15.8	0.0	16.1	0.3	15.8	0.0			15.8	0.0	15.8	0.0	16.3	0.5	16.1	0.3	16.9	1.1	14.9	-0.9
D/S Jefferson Ave. Culvert (1)[2]	17.5	15.9	15.9	0.0	15.0	-0.9	15.9	0.0	15.9	0.0	16.2	0.3	15.9	0.0			15.9	0.0	15.9	0.0	16.4	0.5	16.2	0.3	17.0	1.1	15.0	-0.9
U/S Jefferson Ave. Culvert (1)[2]	17.5	16.4	16.4	0.0	15.0	-1.4	16.4	0.0	16.4	0.0	16.3	-0.1	16.4	0.0			16.4	0.0	16.4	0.0	16.4	0.1	16.4	0.0	17.0	0.6	15.7	-0.7
D/S Box Culverts	16.0	16.6	16.6	0.0	(N/A)[1]	(N/A)[1]	16.6	0.0	16.6	0.0	16.6	-0.1	16.6	0.0			16.6	0.0	16.6	0.0	16.7	0.1	16.6	0.0	17.3	0.6	15.9	-0.7
U/S Box Culverts	19.2	19.2	19.2	0.0	(N/A)[1]	(N/A)[1]	19.2	0.0	19.2	0.0	19.2	-0.1	19.2	0.0			19.2	0.0	19.2	0.0	19.2	0.0	19.2	0.0	19.2	0.0	18.2	-1.0
Golf Course Pond	25.0	21.8	21.8	0.0	13.9	-7.9	21.8	0.0	21.8	0.0	21.8	0.0	21.8	0.0			21.8	0.0	21.8	0.0	21.8	0.0	21.8	0.0	21.8	0.0	23.8	2.0
D/S Diversion Structure	25.0	22.0	22.0	0.0	21.9	-0.1	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0			22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0	24.0	1.9
D/S Diversion Pond		23.1	23.1	0.0	23.1	0.0	23.1	0.0	**23.1**	0.0	23.1	0.0	23.1	0.0			23.1	0.0	23.1	0.0	23.1	0.0	23.1	0.0	23.1	0.0	24.0	0.9
Diversion Structure Pond	30.0	26.0	26.0	0.0	26.0	0.0	26.0	0.0	26.0	0.0	26.0	0.0	26.0	0.0			26.0	0.0	26.0	0.0	26.0	0.0	26.0	0.0	26.0	0.0	26.0	0.0
D/S Highland Ave. Culvert	96.4	82.8	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0			82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0	82.8	0.0
U/S Highland Ave. Culvert (Pond)	96.4	88.7	88.7	0.0	88.7	0.0	88.7	0.0	88.7	0.0	88.7	0.0	88.7	0.0			88.7	0.0	88.7	0.0	88.7	0.0	88.7	0.0	88.7	0.0	88.7	0.0

[1] Alternative diverts stormwater from the golf course resulting in no flow through the culverts from the golf course.

[2] Jefferson Avenue crosses South River at three locations. "1" represents the upstream most crossing, and "3" represents the downstream most crossing.

APPENDIX C: COST ESTIMATE FOR CANAL STREET/SALEM STATE UNIVERSITY AREA IMPROVEMENTS

COMMITMENT & INTEGRITY DRIVE RESULTS
WOODARD & CURRAN
35 New England Business Center
Andover, Massachusetts 01810
Tel: 866.702.6371 Fax: 978.557.7948

Client: City of Salem, Massachusetts
Project: South River Drainage Improvement Project
Designed By: MAP Date: April 2011
Checked By: DAW Date: April 2011
Project No. 218953.02

COST ESTIMATE
Canal Street/Salem State University Area Improvements

		Centrifugal Pump - Located at Upstream Location of Route											
		Flow Rate: 10 c.f.s. **Storage:** 3,000,000 gal.			**Flow Rate:** 20 c.f.s. **Storage:** 2,200,000 gal.			**Flow Rate:** 40 c.f.s. **Storage:** 1,600,000 gal.			**Flow Rate:** 175 c.f.s. **Storage:** None		
		Feet	**$ / Foot**	**Cost**	**Feet**	**$ / Foot**	**Cost**	**Feet**	**$ / Foot**	**Cost**	**Feet**	**$ / Foot**	**Cost**
Alternative 1	**O'Keefe Parking to Forest River via Rail Trail**												
	Pump system												
	- Storage under O'Keefe Parking Lot	20,319	$550	$11,180,000	15,024	$550	$8,260,000	10,514	$550	$5,780,000			
	- Pump station			$1,500,000			$2,250,000			$2,775,000			$5,392,550
	- Discharge system												
	- Force main	1,450	$350	$507,500	1,450	$450	$652,500	1,450	$500	$725,000	1,450	$1,000	$1,450,000
	- Gravity	3,200	$300	$960,000	3,200	$350	$1,120,000	3,200	$400	$1,280,000	3,200	$1,000	$3,200,000
	- Gravity w/ Deep Cut												
	- Utility Relocation										4,650	$500	$2,325,000
	Improvements to local drainage	6,500	$300	$1,950,000	6,500	$300	$1,950,000	6,500	$300	$1,950,000	6,500	$300	$1,950,000
	Total:			**$16,097,500**			**$14,232,500**			**$12,510,000**			**$14,317,550**
Alternative 2	**Canal Street to Bay via Ocean Avenue**												
	Pump System												
	- Storage under O'Keefe Parking Lot	20,319	$550	$11,180,000	15,024	$550	$8,260,000	10,514	$550	$5,780,000			
	- Pump station			$1,500,000			$2,250,000			$2,775,000			
	- Discharge												
	- Force main	1,100	$400	$440,000	1,100	$500	$550,000	1,100	$550	$605,000			
	- Gravity	1,700	$350	$595,000	1,700	$400	$680,000	1,700	$450	$765,000			
	- Gravity w/ Deep Cut												
	Improvements to local drainage	5,800	$300	$1,740,000	5,800	$300	$1,740,000	5,800	$300	$1,740,000			
	- Utility Relocation												
	Total:			**$15,455,000**			**$13,480,000**			**$11,665,000**			
Alternative 3	**Canal Street to Forest River via Rail Trail**												
	Pump System												
	- Storage under O'Keefe Parking Lot	20,319	$550	$11,180,000	15,024	$550	$8,260,000	10,514	$550	$5,780,000			
	- Pump station			$1,500,000			$2,250,000			$2,775,000			$5,392,550
	- Discharge												
	- Force main	1,750	$350	$612,500	1,750	$450	$787,500	1,750	$500	$875,000	1,750	$1,000	$1,750,000
	- Gravity	4,000	$300	$1,200,000	4,000	$350	$1,400,000	4,000	$400	$1,600,000	4,000	$1,000	$4,000,000
	- Gravity w/ Deep Cut												
	- Utility Relocation										5,750	$500	$2,875,000
	Improvements to local drainage	5,800	$300	$1,740,000	5,800	$300	$1,740,000	5,800	$300	$1,740,000	5,800	$300	$1,740,000
	Total:			**$16,232,500**			**$14,437,500**			**$12,770,000**			**$15,757,550**

	Alternative 4		
	Screw Pump @ Outfall **Flow Rate:** 175 c.f.s. **Storage: None**		
	Feet	**$ / Foot**	**Cost**
O'Keefe Parking to Forest River via Rail Trail			
Pump system			$3,000,000
- Discharge system			
- Gravity	3,200	$1,000	$3,200,000
- Gravity w/ Deep Cut	1,450	$1,200	$1,740,000
- Utility Relocation	4,650	$500	$2,325,000
Improvements to local drainage	6,500	$300	$1,950,000
Total:			**$12,215,000**
Canal Street to Forest River via Rail Trail			
Pump System			$3,000,000
- Discharge			
- Gravity	5,750	$1,000	$5,750,000
- Utility Relocation	5,750	$500	$2,875,000
Improvements to local drainage	5,800	$300	$1,740,000
Total:			**$13,365,000**

APPENDIX D: COST ESTIMATE FOR ROSIES POND/BROOKS STREET/JEFFERSON AVENUE AREA IMPROVEMENTS

COMMITMENT & INTEGRITY DRIVE RESULTS
WOODARD & CURRAN
35 New England Business Center
Andover, Massachusetts 01810
Tel: 866.702.6371 Fax: 978.557.7948

CLIENT	City of Salem, Massachusetts		
PROJECT	South River Flood Mitigation		
DESIGNED BY	Mark A. Pereira	DATE	April 2011
CHECKED BY	David A. White	DATE	April 2011
PROJECT NO.	218953.02	SHEET NO.	1 OF 1

COST ESTIMATE

Rosies Pond, Brooks Street, & Jefferson Avenue Improvements - No Unsuitable Material

ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST	NOTES
Site Preparation					
Mobilization/Demobilization	LS	1.0	$10,000.00	$10,000.00	
Site Preparation - Clear & Grub	AC	1.2	$9,000.00	$10,800.00	
Site Preparation - Erosion & Sedimentation Control	LS	1.0	$10,000.00	$10,000.00	
Earthwork					
Strip & Stockpile Loam	CY	956.0	$10.00	$9,560.00	
Place & Compact Berm Material	CY	1,581.0	$40.00	$63,240.00	
Construct Wall					
Rosies Pond[1]	LF	775.0	$250.00	$193,750.00	
Upstream Lawrence Avenue[1]	LF	235.0	$250.00	$58,750.00	
Downstream Lawrence Avenue[1]	LF	200.0	$250.00	$50,000.00	
Upstream Jefferson Avenue[1]	LF	350.0	$250.00	$87,500.00	
Construct Stormwater Infrastructure					
Collection System w/ Flap Gate at Rosies Pond[2]	LS	2.0	$5,500.00	$11,000.00	
Collection System w/ Flap Gate at Wheatland Street[2]	LS	1.0	$5,500.00	$5,500.00	
Collection System w/ Flap Gate at Lawrence Street[2]	LS	1.0	$5,500.00	$5,500.00	
Flap gate at Brooks Street[3]	LS	1.0	$1,000.00	$1,000.00	
Restoration					
Respread Stockpiled Loam	CY	956	$4.00	$3,824.00	
Restoration - Seeding	SY	5,733.0	$0.75	$4,299.75	
Construction Subtotal	-	-	-	**$524,723.75**	
Engineering & Construction Admin. (25%)	-	-	-	**$131,181.00**	
Survey	-	-	-	**$10,000.00**	
Environmental Studies	-	-	-	**$15,000.00**	
Geotechnical Study	-	-	-	**$15,000.00**	
Regulatory Permitting	-	-	-	**$20,000.00**	
Subtotal	-	-	-	**$715,904.75**	
Contingencies (30%)				**$214,771.43**	
Total	-	-	-	**$930,676.18**	

[1] Cast-in-Place retaining wall, reinforced gravity (2007 means 32 32.13.10, 2900)
[2] One catch basin ($2,500), 20' of 12" diameter pipe ($2,000), and one flap gate through wall ($1,000)
[3] One flap gate (12" diameter assumed) lump sum including installation

WOODARD & CURRAN
COMMITMENT & INTEGRITY DRIVE RESULTS
35 New England Business Center
Andover, Massachusetts 01810
Tel: 866.702.6371 Fax: 978.557.7948

CLIENT	City of Salem, Massachusetts		
PROJECT	South River Flood Mitigation		
DESIGNED BY	Mark A. Pereira	DATE	April 2011
CHECKED BY	David A. White	DATE	April 2011
PROJECT NO.	218953.02	SHEET NO.	1 OF 1

COST ESTIMATE

Rosies Pond, Brooks Street, & Jefferson Avenue Improvements - Unsuitable Material

ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST	NOTES
Site Preparation					
Mobilization/Demobilization	LS	1.0	$10,000.00	$10,000.00	
Site Preparation - Clear & Grub	AC	1.7	$9,000.00	$15,300.00	
Site Preparation - Erosion & Sedimentation Control	LS	1.0	$5,000.00	$5,000.00	
Earthwork					
Strip & Stockpile Loam	CY	1,330.0	$10.00	$13,300.00	
Excavation of Unsuitable Material	CY	5,495.0	$10.00	$54,950.00	
Place & Compact Berm Material	CY	7,450.0	$40.00	$298,000.00	
Construct Wall					
Rosies Pond[1]	LF	775.0	$250.00	$193,750.00	
Upstream Lawrence Avenue[1]	LF	235.0	$250.00	$58,750.00	
Downstream Lawrence Avenue[1]	LF	200.0	$250.00	$50,000.00	
Upstream Jefferson Avenue[1]	LF	75.0	$250.00	$18,750.00	
Construct Stormwater Infrastructure					
Collection System w/ Flap Gate at Rosies Pond[2]	LS	2.0	$5,500.00	$11,000.00	
Collection System w/ Flap Gate at Wheatland Street[2]	LS	1.0	$5,500.00	$5,500.00	
Collection System w/ Flap Gate at Lawrence Street[2]	LS	1.0	$5,500.00	$5,500.00	
Flap gate at Brooks Street[3]	LS	1.0	$1,000.00	$1,000.00	
Restoration					
Respread Stockpiled Loam	CY	1,330.0	$4.00	$5,320.00	
Restoration - Seeding	SY	7,981.0	$0.75	$5,985.75	
Excess Soil Disposal	CY	5,495.0	$4.00	$21,980.00	
Construction Subtotal	-	-	-	**$774,085.75**	
Engineering & Construction Admin. (15%)	-	-	-	**$116,112.86**	
Survey	-	-	-	**$10,000.00** `	
Environmental Studies	-	-	-	**$15,000.00**	
Geotechnical Study				**$20,000.00**	
Regulatory Permitting	-	-	-	**$30,000.00**	
Subtotal	-	-	-	**$965,198.61**	
Contingencies (30%)	-	-	-	**$289,559.58**	
Total	-	-	-	**$1,254,758.20**	

[1] Cast-in-Place retaining wall, reinforced gravity (2007 means 32 32.13.10, 2900)
[2] One catch basin ($2,500), 20' of 12" diameter pipe ($2,000), and one flap gate through wall ($1,000)
[3] One flap gate (12" diameter assumed) lump sum including installation

COMMITMENT & INTEGRITY DRIVE RESULTS
WOODARD & CURRAN
35 New England Business Center
Andover, Massachusetts 01810
Tel: 866.702.6371 Fax: 978.557.7948

CLIENT	City of Salem, Massachusetts				
PROJECT	South River Flood Mitigation				
DESIGNED BY	Mark A. Pereira		DATE	April 2011	
CHECKED BY	David A. White		DATE	April 2011	
PROJECT NO.	218953.02	SHEET NO.	1	OF	1

COST ESTIMATE

Storage on Ocean Avenue West

ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST	NOTES
Site Preparation					
Mobilization/Demobilization	LS	1.0	$5,000.00	$5,000.00	
Site Preparation - Clear & Grub	AC	0.2	$4,500.00	$900.00	
Site Preparation - Erosion Control	LS	1.0	$2,000.00	$2,000.00	
Excavation					
Class A Trench Excavation	CY	1,689.0	$25.00	$42,225.00	
Installation of Storage Units					
Storage Tanks (including delivery)	LS	1.0		$330,000.00	Includes oversight by vendor
Equipment & Labor	DAY	10.0	$5,000.00	$50,000.00	RSMeans B-69 Crew
Crushed Stone Bedding and Backfill	CY	279.0	$35.00	$9,765.00	Assumes 1' around and below tanks
Restoration					
Restoration - Pavement	TON	95.7	$100.00	$9,570.00	3,100 sq. ft., 5" of Asphalt, 2 ton/cy
Restoration - Roadway Base	CY	114.8	$25.00	$2,870.00	3,100 sq. ft., 12" of Base
Restoration - Seeding	SY	333.3	$0.75	$250.00	
Restoration - Loam	CY	55.6	$25.00	$1,388.89	Assumes 6" loam
Excess Soil Disposal	CY	1,604.0	$4.00	$6,416.00	
Construction Subtotal	-	-	-	**$460,384.89**	
Engineering & Construction Admin. (15%)	-	-	-	**$69,057.73**	
Survey	-	-	-	**$10,000.00**	
Regulatory Permitting	-	-	-	**$10,000.00**	
Subtotal	-	-	-	**$549,442.62**	
Contingencies (30%)	-	-	-	**$164,832.79**	
Total	-	-	-	**$714,275.41**	

WOODARD & CURRAN
COMMITMENT & INTEGRITY DRIVE RESULTS
35 New England Business Center
Andover, Massachusetts 01810
Tel: 866.702.6371 Fax: 978.557.7948

CLIENT	City of Salem, Massachusetts				
PROJECT	South River Flood Mitigation				
DESIGNED BY	Mark A. Pereira		DATE	April 2011	
CHECKED BY	David A. White		DATE	April 2011	
PROJECT NO.	218953.02	SHEET NO.	1	OF	1

COST ESTIMATE

Rosies Pond Outlet Structure Improvements

ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST	NOTES
Site Preparation					
Mobilization/Demobilization	LS	1.0	$5,000.00	$5,000.00	
Site Preparation - Clear & Grub	AC	0.1	$4,500.00	$450.00	
Site Preparation - Erosion Control	LS	1.0	$2,000.00	$2,000.00	
Flow Diversion	WEEK	2.0	$7,500.00	$15,000.00	
Structure Reconstruction					
Earthwork	SY	148.0	$25.00	$3,700.00	50'Lx20'Wx4'H assumed
Flow Control Structure	LS	1.0	$15,000.00	$15,000.00	
Riprap	TON	100.0	$28.00	$2,800.00	50'Lx20'Wx1.5'H assumed, 1.8 ton/cy
Restoration					
Restoration - Seeding	SY	112.0	$0.75	$84.00	100'Lx10'W Accessway
Restoration - Loam	CY	19.0	$25.00	$475.00	100'Lx10'W Accessway / Assumes 6" loam
Construction Subtotal	-	-	-	**$44,509.00**	
Engineering & Construction Admin. (15%)	-	-	-	**$6,676.35**	
Survey	-	-	-	**$5,000.00**	
Geotechnical Investigation	-	-	-	**$5,000.00**	
Regulatory Permitting	-	-	-	**$10,000.00**	
Subtotal	-	-	-	**$71,185.35**	
Contingencies (30%)	-	-	-	**$21,355.61**	
Total	-	-	-	**$92,540.96**	

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DESIGNED BY	Mark A. Pereira	DATE	April 2011
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COST ESTIMATE
Improvements to Drainage Structure along Jefferson Avenue

	ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST	NOTES
Site Preparation						
Site Preparation						
1	Mobilization/Demobilization	LS	1.0	$5,000.00	$5,000.00	
2	Site Preparation - Erosion Control	LS	1.0	$2,000.00	$2,000.00	
Drainage Structures and Piping						
3	Catch Basin - 0'-9'	EA	5.0	$3,800.00	$19,000.00	
4	Catch Basin - Frame & Grate	EA	5.0	$650.00	$3,250.00	
5	Manhole - 5' I.D. - 0'-9'	EA	5.0	$4,000.00	$20,000.00	
6	Manhole - Frame & Grate	EA	5.0	$550.00	$2,750.00	
7	Pipe - 12" RCP	LF	178.0	$50.00	$8,900.00	
8	Pipe - 36" RCP	LF	514.0	$120.00	$61,680.00	
9	Retrofit Pipe into Exisiting Manhole	EA	5.0	$500.00	$2,500.00	
Excavation						
10	Class A Trench Excavation[1]	CY	1,846.0	$25.00	$46,150.00	692', 8'W trench, 9' Deep
11	Remove Existing Manhole	LS	5.0	$500.00	$2,500.00	Will be replaced
12	Remove Existing Catch Basin	LS	5.0	$500.00	$2,500.00	Will be replaced
Restoration						
13	Restoration - Pavement	TON	206.0	$100.00	$20,600.00	692', 8'W trench, 6" Depth of Asphalt, 2 ton/cy
14	Restoration - Roadway Base	CY	206.0	$25.00	$5,150.00	692', 8'W trench, 12" Depth of Base
15	Excess Soil Disposal	CY	331.0	$4.00	$1,324.00	Total volume of pipe and bedding (6"bedding)
	Construction Subtotal	-	-	-	**$203,304.00**	
	Engineering & Construction Admin. (15%)	-	-	-	**$30,495.60**	
	Survey	-	-	-	**$5,000.00**	
	Subtotal	-	-	-	**$238,799.60**	
	Contingencies (30%)	-	-	-	**$71,639.88**	
	Total	-	-	-	**$310,439.48**	

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PROJECT NO.	218953.02	SHEET NO.	1	OF	1

COST ESTIMATE
Physical Rehabilitation of Ocean Avenue West Pump Station

ITEM	UNIT	QUANTITY	UNIT COST	EXTENDED COST	NOTES
Site Preparation					
Mobilization/Demobilization	LS	1.0	$5,000.00	$5,000.00	
Pump Station					
Improvements[1,2]	LS	1.0	$569,000.00	$569,000.00	
Construction Subtotal	-	-	-	**$574,000.00**	
Engineering & Construction Admin. (15%)	-	-	-	**$86,100.00**	
Regulatory Permitting	-	-	-	**$5,000.00**	
Subtotal	-	-	-	**$665,100.00**	
Contingencies (25%)	-	-	-	**$166,275.00**	
Total	-	-	-	**$831,375.00**	

[1] Cost obtained from "Ocean Avenue West Pump Station Assessment Report" dated March 9, 2009 and projected to 2011 costs following RSMeans Cost Data Methodology.

[2] Specific improvements are outlined in "Ocean Avenue West Pump Station Assessment Report" dated March 9, 2009.