FEMA Accreditation Report
Chicopee Falls Flood Control System
Chicopee, Massachusetts

November, 2010

Submitted by:
City of Chicopee
Department of Public Works
115 Baskin Drive
Chicopee, MA 01020

Submitted to:
Federal Emergency
Management Agency
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FEMA ACCREDITATION REPORT
CHICOPEE FALLS FLOOD CONTROL SYSTEM
CHICOPEE, MASSACHUSETTS

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SECTION 1

INTRODUCTION

1.1 PURPOSE AND STANDARD OF CARE

The purpose of this report is to compile and present engineering opinions, survey documentation and analyses of the Chicopee Falls Flood Control System in Chicopee, Massachusetts to the Federal Emergency Management Agency (FEMA) for their sole use in establishing risk zones for the National Flood Insurance Program (NFIP) maps. Use of this report or the opinions and findings in the report in whole or in part by any other party, or for any other project or purpose is not intended nor authorized and may lead to inappropriate conclusions. Reliance upon the information presented in this report by any other party other than FEMA, without Baystate Environmental Consultants, Inc. (BEC) prior written permission shall be at that other party's sole risk and without any liability to BEC.

The findings, opinions and conclusions contained herein are based on the work conducted as part of the contracted scope of services undertaken pursuant to contractual terms with the City and reflect professional judgment. These findings and conclusions must be considered not as scientific or engineering certainties, but rather as professional opinions and judgments built upon the limited data gathered during the course of the work. To understand how these opinions were developed, and to understand the intended use of the report, the report must be read in its entirety including the stated limitations.

The Code of Federal Regulations, Title 44 Part 65 addresses "Identification and Mapping of Special Hazard Areas" within which is Paragraph 65.10, "Mapping of areas protected by levee systems". This report is intended to document compliance with the minimum design, operation, and maintenance standards for levee systems established in 44 CFR 65.10, a copy of which is appended to this report.

This report opines that the Chicopee Falls Flood Control System meets the minimum criteria for design, operation and maintenance as established in 44 CFR 65.10 during a one-percent annual chance flood as determined by FEMA and issued in April, 2009, within the preliminary Flood Insurance Study and Flood Insurance Rate Maps for Hampden County, Massachusetts which includes all of the City of Chicopee. It must be noted that the one-percent annual chance flood is used by FEMA only as a flood insurance criterion.

1.2 LOCATION AND DESCRIPTION OF FLOOD CONTROL SYSTEM

The Flood Control Works in the City of Chicopee, Hampden County, Massachusetts was constructed by the United States Army Corps of Engineers (USACE) in four separate systems, namely the Plainfield Street Flood Control System, the South Bank Chicopee River Flood Control System, the Willimansett Flood Control System, and the Chicopee Falls Flood Control System. In total, the Flood Control Works within the City consists of 25,820 linear feet of earthen levee, 7,500 linear feet of flood control walls, eight pumping stations, three cast-in-place concrete closure structures, and various appurtenant drainage features. Figure 1 is a locus plan of the four systems in Chicopee. Although all four systems do share a common Operation and Maintenance Manual, each system is physically independent from one another. As such, individual Accreditation Reports have been prepared for each system.

The Chicopee Falls Flood Control System consists of two segments of cast-in-place concrete flood walls and two segments of earthen levee, extending along the southern bank of the Chicopee River from the Deady Memorial Bridge to higher ground at a railroad, for a total length of 5,002 linear feet. USACE plans for this section are dated 1963. In addition, two stormwater pumping stations were constructed: the Main Street Pumping Station and the Oak Street Pumping Station. Following is a description of the system based upon the USACE plans and other available information.

From the Deady Bridge at Station 4+13, a segment of cast-in-place cantilever concrete wall extends westerly (downstream) for 557 linear feet to Station 9+70. The first 400± feet of wall is founded directly on ledge with rock anchors, while the last 157 feet is founded on earth. The exposed wall height is approximately 20 feet on both the landside and riverside. A perforated pipe toe drain surrounded by stone and filter sand was installed adjacent to the wall footing on the landward side from Station 6+80 to the downstream end of the wall. Stone slope protection was installed on the riverside of the wall starting at Station 5+90 and continues to the earthen levee slope protection, which begins at Station 9+70.

An earthen levee was constructed from Station 9+70 to Station 16+82 for a length of 712 feet, including riprap slope protection on the riverside and a perforated pipe toe drain surrounded with stone and filter sand along the bottom of the levee slope on the landside. The typical levee cross section consists of compacted random fill on the landside and compacted impervious soil on the riverside, including an impervious foundation cutoff. The top of levee is approximately 17 feet higher than the landside grading.

A second segment of cast-in-place cantilever concrete floodwall extends from Station 16+82 to Station 25+45 for a length of 863 feet. This wall segment is located on the inside of a bend of the Chicopee River where flow direction turns approximately 90 degrees from westerly to southerly. This entire segment of wall is founded directly on ledge, and a perforated pipe toe drain surrounded by stone and filter sand was installed adjacent to the wall footing on the landside. Riprap slope protection was installed on the riverside. The wall stem has an exposure of approximately 16 feet on the landside and 20 feet facing the river. The Main Street Pumping Station was constructed into the wall at Station 24+20.

A second segment of earthen levee extends 2,870 linear feet from Station 25+45 to Station 54+15. Riprap slope protection on the riverside and a toe drain on the landside were also constructed. The typical cross section consists of compacted random fill on the landside with compacted impervious soil on the riverside with an impervious foundation cutoff. The Oak Street Pumping Station was built into the levee at Station 49+15. Two gate valves with catwalk access are located in this segment in close proximity to the pumping station. One was an intake for the now defunct U.S. Rubber Company facility with associated improvements, while the other is an outlet from the Oak Street Pumping Station. A new downstream pressure drain is also shown on the USACE plans downstream from the pumping station near Station 52+50.

A collector drain line was constructed on the landside of the system from Station 7+00 to the Main Street Pumping Station and also from Station 34+70 to the Main Street Pumping Station. A second drainage line that discharges to the Oak Street Pumping Station was also built adjacent to the levee toe on the landside from Station 39+00 to Station 51+20. The USACE constructed a pressure drain with an inlet upstream of the Deady Bridge at the Chicopee River Falls gatehouse to an outlet through the levee at Station 36+10. The pressure line was controlled by various sluice gates and appears to have provided process water to various manufacturing facilities within the area protected by the Chicopee Falls system. The USACE plans indicate that the section of the drain from the gatehouse to the manhole at Station 3+00 was only temporary and was to be removed when the process water line was no longer needed. A bypass was also constructed that tied the pressure drain into the collector drain at Station 39+00.

The Chicopee Falls Flood Control System also included the relocation and/or widening of a 3,700± ft segment of the Chicopee River. From approximately Sta. 30+17 to 52+00±, the river was relocated from east to west by excavation of the western (right) bank to an elevation of 75.0 ft (Mean Sea Level Datum) with a newly constructed bank rising on a 1 on 2 slope to a 15-ft wide shelf at elevation 81.0. The eastern (left) bank was filled in association with construction of the earthen levee. Three storm drain outfalls discharging at the right bank were modified to accommodate the relocated riverbank. From Sta. 52+00± to a point approximately 1,330 ft downstream of the end of the Chicopee Falls Flood Control Works, the channel was widened by excavation of the western (right) bank to an elevation of 75.0 ft (Mean Sea Level Datum) with a newly constructed bank rising on a 1 on 2 slope to a 15-ft wide shelf at elevation 81.0. The elevation increases from the shelf at a 1 on 2.5 slope until meeting natural high ground. No alterations were made to the eastern (left) bank downstream of the end of the levee.

During a visual inspection of current conditions along this system and based upon a comparison to prior documents, a number of changes were noted to have taken place since the original construction by the Corps of Engineers. Although not intended to be a complete listing, identified changes include:

1) The Oak Street and Main Street Pumping Stations were upgraded in a contract by the City in approximately 1999. All work was approved by USACE according to the City. Under that contract the roofs were replaced. New fuel tanks were installed to meet standards for spill prevention.

2) The Deady Memorial Bridge over the Chicopee River was rebuilt and the last concrete floodwall panel adjacent to and connecting with the bridge abutment appears to have been reconstructed.

3) The USACE plans indicate that the section of the former industrial water intake (leading to the pressure flow process water line) in the Deady Bridge area from the gatehouse to the manhole at Station 3+00 was only temporary and was to be removed when the process water line was no longer needed. According to the City, the line has reportedly been abandoned and is understood to be closed.

4) Storm drainage has been installed at the rebuilt Deady Memorial Bridge with manholes at the corners of the southern abutment connected to a pipe installed along the riverside face of the flood control wall. A small concrete wall was constructed in front of the floodwall and the storm drain pipe installed between the two walls at a shallow depth with the pipe partially exposed. The pipe is corrugated metal approximately 30 inches in diameter and visually terminates at a concrete (thrust) block cast against the floodwall on the riverside near Station 6+50. It is surmised that the drain line turns perpendicular to the wall at this concrete block and discharges to the river.

5) A power line was installed with a vertical riser on the riverside face of the floodwall near Station 6+75.

6) A hydropower generating facility was built on the riverside of the floodwall with an intake at the Chicopee Falls.

7) A gravel vehicle access drive to the power generating facility was installed near Station 10+00. An access way on the landside from Main Street ramps up to the top of the levee, crosses over to the riverside, turns parallel to the river and slopes downward in front of the upstream floodwall. The drive has a locked gate on the landside of the levee.

8) Access to the Oak Street Pumping Station is no longer possible through the closed U.S. Rubber Company plant site. A gravel vehicle access drive has been constructed from the right of way near Station 10+00 along the landward toe of slope to the Main Street Pumping Station. The gravel drive continues toward the Oak Street Pumping Station including a paved ramp from the landside toe at Station 35+50 to Station 36+25. Thereafter, the access drive is along the top of levee to a turnaround at the downstream limit of the levee.

9) The industrial water intake for the former U.S. Rubber Company plant near the Oak Street Pumping Station has been closed since the factory stopped operation and is exercised annually by the City.

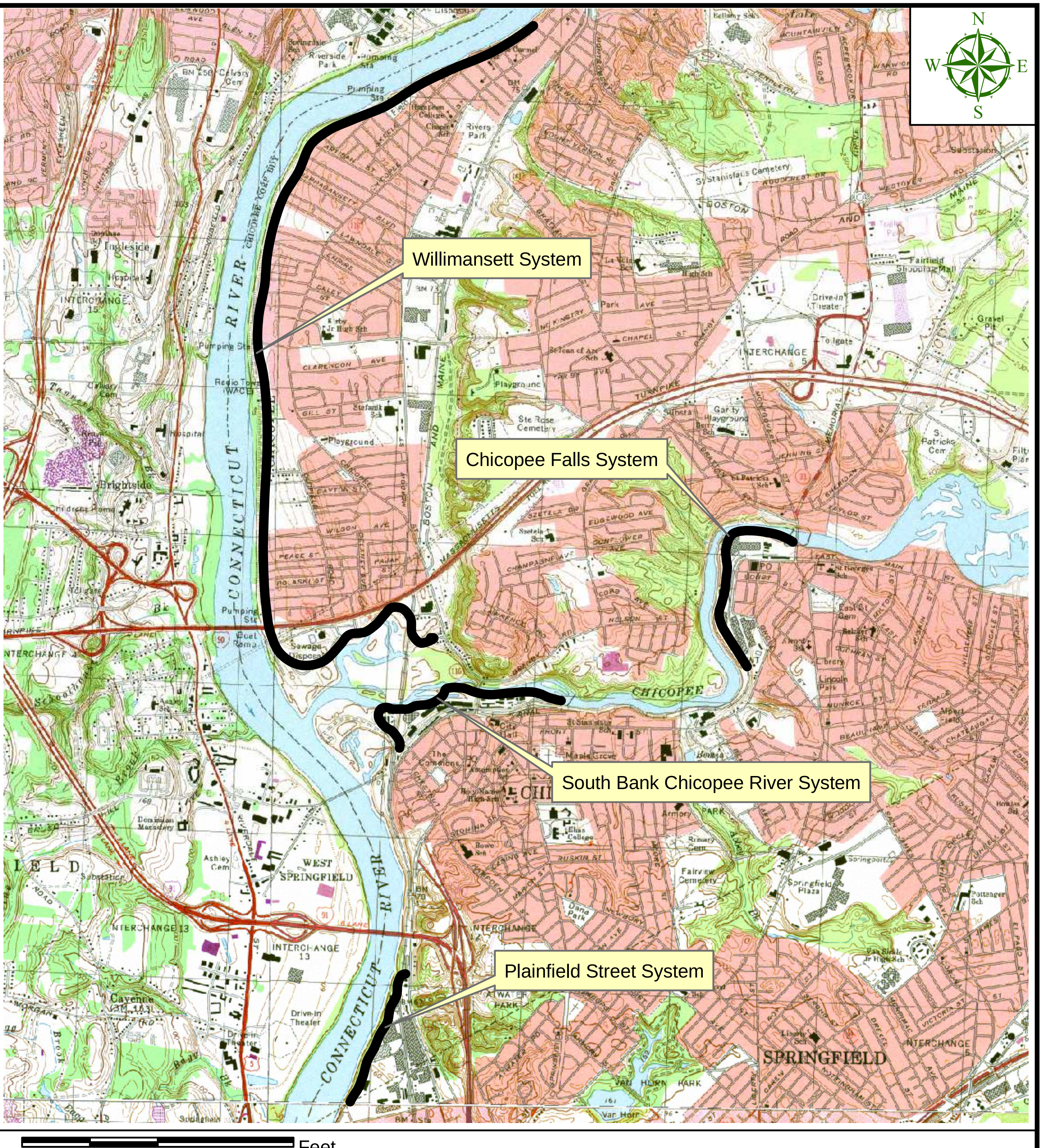

Figure 1: Locus Map

FEMA Accreditation Report
City of Chicopee
Flood Control Works

Chicopee, Massachusetts

USGS TOPOGRAPHIC QUADRANGLE MAP
SPRINGFIELD NORTH, MA, 1979

Baystate Environmental Consultants, Inc.
296 North Main Street, East Longmeadow, MA

Data obtained from MASS GIS, Commowealth of Massachusetts
Executive Office of Environmental Affairs (EOEA)

Figure 2: Chicopee Falls System

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Legend

Flood Wall

Flood Levee

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MassGIS Orthophoto (2005) obtained from MASS GIS,
Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA).

1.3 REPORT LIMITATIONS

1. This Report has been prepared for the exclusive use by FEMA for specific application to the accreditation of these flood control works for their sole purpose of establishing risk zones for the National Flood Insurance Program, in accordance with generally accepted engineering practices. No other warranty, express or implied, is made.

2. This Report has been prepared for the purpose of allowing the City of Chicopee, MA to fulfill its responsibility to provide data and documentation to FEMA demonstrating that the flood control system meets the criteria within 44 CFR 65.10. This Report is a compliance determination by Baystate Environmental Consultants, Inc. (BEC) and is not a determination of how the flood control works will perform in an actual flood event.

3. The observations described in this Report were made under the conditions stated. The opinions, conclusions and results presented in the Report were based solely on the services described, and not on scientific tasks or procedures beyond the scope of described services or the time constraints of the project.

4. In preparing this Report, BEC has relied on certain information provided by the City of Chicopee as well as Federal, state, and local officials and other parties referenced. BEC has also relied on certain information contained in the files of the City as well as Federal, state, and local officials and other parties which were available to BEC at the time of the analysis. Although there may have been some degree of overlap in the information provided by these various sources, BEC did not attempt to independently verify the accuracy or completeness of all information reviewed or received during the course of this work.

5. In reviewing this Report, it should be realized that the reported existing conditions of the various components of the flood control system are based on observations of field conditions during the course of the evaluation along with data made available to BEC. The observations of conditions in the field reflect only the situation present at the specific moment in time the observations were made, under the specific conditions present.

6. It is important to note that the condition of any flood control system depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the flood control system will continue to represent the condition of the flood control system at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions or increased risk may be detected.

7. BEC based any hydraulic analyses on existing conditions, site plans made available to BEC as of the date of this Report, prior hydraulic studies completed by others and made available, or upon field reconnaissance. In the event that any changes in the nature,

design or location of the flood control system, its appurtenant structures, or drainage areas contributing to the pumping stations are planned, the conclusions and recommendations contained in this Report shall not be considered valid unless the changes are reviewed and conclusions of this Report are modified or verified by BEC. Any BEC hydrologic analyses presented herein are for the rainfall volumes and distributions stated herein. For storm or riverine flood conditions other than those analyzed, the response of the flood control works and pumping stations has not been evaluated.

8. Relative to subsurface conditions, the generalized soil profiles provided in this Report and on our subsurface exploration logs are intended only to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized, and were based on our assessment of subsurface conditions. The composition of strata, and the transitions between strata, may be more variable and more complex than indicated. For more specific information on soil conditions at a specific location, refer to the exploration logs. Actual subsurface conditions are likely more complex than indicated in the Report. Mathematical modeling is, by its very nature, a simplification of actual conditions. In constructing the model, point specific data was generalized and extrapolated across the study area. In addition, in areas where field data was not available, professional judgment, based on experiences and regional information, was relied upon to construct the model.

9. Water level readings have been made in test holes and monitoring wells at the specified times and under the stated conditions. These data have been reviewed and interpretations have been made in this Report. However, fluctuations in the level of the groundwater occur due to temporal or spatial variations in areal recharge rates, soil heterogeneities, the presence of subsurface utilities, and/or natural or artificially induced perturbations. The observed water table may be other than indicated in the Report.

10. Our services did not include an assessment of the presence of oil or hazardous materials at the property. Consequently we did not consider the potential impacts (if any) that contaminants in soil or groundwater may have on construction activities, or the use of structures on the property.

11. Observations or opinions regarding foundation drainage, waterproofing, and moisture control address the conventional geotechnical aspects of seepage control. These recommendations may not preclude an environment that allows the infestation of mold or other biological pollutants.

1.4 AUTHORIZATION

On May 23, 2007 the City of Chicopee entered into a contract for professional services with BEC relative to the City's Flood Control Works. This contract was subsequently amended on September 9, 2009, to include the work task to, "conduct an engineering evaluation of the flood control works and prepare data and documentation for the City to submit to FEMA for accreditation to demonstrate the flood control works meets the requirement of the National Flood Insurance Program as per current Code of Federal Regulations, (44 CFR Section 65.10)". A copy of the original contract with terms and conditions as well as a copy of the September 9, 2009 amendment are appended to this report. This report concludes this work task as related to the Chicopee Falls Flood Control System and is subject to the terms and conditions of the amended contract.

SECTION 2

LEVEE SYSTEM EVALUATION

2.1 STATEMENT OF LEVEE SYSTEM EVALUATION
Date of Statement: November 12, 2010

This Statement of Levee System Evaluation is made solely to the U.S. Federal Emergency Management Agency (FEMA) for the purpose of obtaining accreditation of the Chicopee Falls Flood Control System in the City of Chicopee, Hampden County, Massachusetts, one of four separate systems owned, operated and maintained by the City. Reliance upon this Statement by any other party without written authorization from the signatory is at such other party's sole risk and without any liability to BEC or the signatory.

This Statement is made in accordance with the requirements stated in the Code of Federal Regulations, Title 44 – Emergency Management and Assistance, Part 65 – Identification and Mapping of Special Hazard Areas (10-1-07 Edition). The meaning and context of the term "certification", is derived from the definition provided in 44 CFR 65.2 (b), which states:

> *For the purpose of this part, a certification by a registered professional engineer or other party does not constitute a warranty or guarantee of performance, expressed, or implied. Certification of data is a statement that the data is accurate to the best of certifier's knowledge. Certification of analyses is a statement that the analyses have been performed correctly and in accordance with sound engineering practices. Certification of structural works is a statement that the works are designed in accordance with sound engineering. Certification of "as-built" conditions is a statement that the structure(s) has been built according to the plans being certified, is in place, and is fully functioning.*

"Sound engineering practices" are defined by the signatory as performed in a manner consistent with the degree of skill and care ordinarily exercised by members of the engineering profession currently practicing in the same locality under similar conditions.

Analyses have been limited to the "Base flood" test condition only, to be utilized by FEMA to establish risk zone determinations under the NFIP. For the purposes of this Statement, the "Base flood" is defined by FEMA as the one-percent annual chance flood, documented in the Flood Insurance Study, Hampden County, Massachusetts and Incorporated Areas, Volume 1, 2 and 3 and dated "Preliminary, April 30, 2009".

"As-built" is defined as and limited by the signatory to those visual attributes which could be observed, mapped and documented on the enclosed topographic survey and the field investigations documented in this report. BEC did not observe nor document the original construction of the Chicopee Falls Flood Control System or subsequent construction activities and use of the "As-built" plans other than for general informational purposes is at the user's sole risk.

"Fully functional" is defined by the signatory as the physical conditions as of the Date of Statement.

This Statement applies solely to the development of National Flood Insurance Program insurance rates and is not a representation that any accredited levee will provide for the safety, health, and welfare of the public.

In accordance with 44 CFR 65.2 (b) and as supported by the information contained within this report, this is to state that:

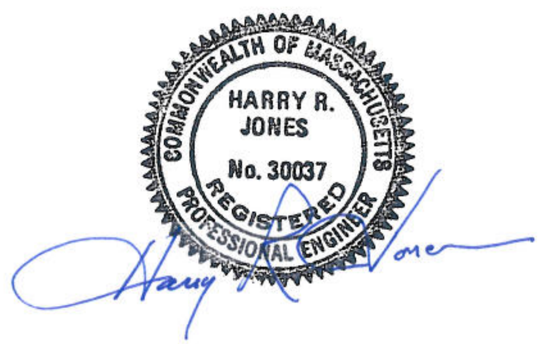
- DATA – The data presented within this submission is accurate to the best of the signatory's knowledge.

- ANALYSES – The analyses have been performed correctly and in accordance with sound engineering practices.

- STRUCTURAL WORKS – The works are designed in accordance with sound engineering practices to provide protection from the base flood.

- "AS-BUILT" CONDITION – The structure(s) has been built according to the plans, is in place, and is fully functional to the best of the signatory's knowledge.

This Statement is provided in accordance and consistent with the definitions provided in 44 CFR 65.2(b) and further per the definitions and limitations described within this report and the subsequent Engineer's Opinions, mapping and documentation.



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East Longmeadow, MA 01028

Date: Nov. 12, 2010

2.2 RESIDUAL RISK AND PUBLIC SAFETY

Under the NFIP, levee certification is a prerequisite for receiving levee accreditation from FEMA. With an accredited levee, areas which would otherwise be subject to flooding by the one-percent annual chance flood event will be designated as Zone X or moderate risk zone, as opposed to Zone A or high risk zone. The single and only purpose for this report is a determination of compliance with 44 CFR 65.10, and as such, a distinction must be emphasized between this report's purpose and the issue of public safety.

Risk is the product of the probability of an event's occurrence and the consequences or damages related thereof. FEMA has established a uniform probability factor of one-percent for the annual chance flood event as the means of determining flood insurance rates on a national basis. Since FEMA applies this same probability to a site with nominal or low consequences as well as to those sites with a severe or high consequence, the degree of risk varies and is not uniformly applied to all flood control systems. At the Chicopee Falls system, significant loss of lives and property could result. Thus, a significant public safety risk remains associated with the Chicopee Falls Flood Control System regardless of any designation under the NFIP. The Chicopee Falls system may reduce the probability of flooding but it does not eliminate the risk.

The Chicopee River has a long history of severe flooding events that have impacted the vicinity of the Chicopee Falls Flood Control System. The flooding events of September, 1938 and August, 1955 directly led to the USACE's construction of the Chicopee Falls system. According to the December, 1962 Chicopee Falls Local Protection Project Design Memorandum No. 2 by the USACE, the maximum flood of record on the Chicopee River had a peak discharge of 45,200 CFS in September, 1938, as recorded in Springfield. The report also noted that the Chicopee Falls Local Protection Project was designed for a flood discharge of 70,000 CFS at Chicopee Falls. The current FEMA Flood Insurance Study documents the estimated flood discharge for the one-percent annual chance flood (100-year) event as 32,000 CFS whereas that of the 0.2-percent annual chance flood (500-year) event to be 62,000 CFS. From a numerical perspective, this accreditation documents the performance of this system when subjected to an annual chance flood peak flow rate which is just over 70% of the documented flood of record flow rate and only 45% of that in the original USACE design.

SECTION 3

ENGINEER'S OPINIONS OF DESIGN CRITERIA

3.1 EVALUATION OF FREEBOARD - 44 CFR 65.10(b)(1)

This minimum design standard as stated in 44 CFR 65.10(b)(1) specifies the following:

1.) *Riverine levees must provide a minimum freeboard of three feet above the water-surface level of the base flood* (one-percent annual chance flood).

2.) *An additional one foot above the minimum is required within 100 feet in either side of structures (such as bridges) riverward of the levee or wherever the flow is constricted.*

3.) *An additional one-half foot above the minimum at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee, is also required.*

To verify this design standard, a system profile was prepared and is reproduced in the attached Appendix A-4.1. The system extends from the Deady Bridge downstream 5,002 feet to higher ground at a railroad embankment. Actual field spot elevations along the top of the system were obtained by Heritage Surveys, Inc. in October-November, 2009 taken at an approximate five hundred foot interval and are reproduced on the "As-Built" drawings, dated December, 2009. The top of system is illustrated on the profile as a solid black line with spot elevations indicated. The base flood profile information was obtained from the Preliminary Flood Insurance Study, Hampden County, Massachusetts, FIS #25013CV001, April, 2009 and is represented as a blue line on the system profile.

The freeboard criteria are also illustrated on the profile in red shading, Criteria One being a uniform three feet above the base flood elevation. Criteria Two applies at the Deady Bridge site. Criteria Three is additive to Criteria One and Two and is also illustrated in red. At all locations along the Chicopee Falls system, the top of wall or top of levee elevations are higher than the base flood elevations plus the applicable freeboard criteria.

It is the opinion of this professional engineer that the Chicopee Falls Flood Control System in Chicopee, Massachusetts meets the 44 CFR 65.10(b)(1) freeboard requirements for the base (one-percent annual chance) flood.

Opinion offered by:

COMMONWEALTH OF MASSACHUSETTS
THOMAS E. JENKINS, JR.
CIVIL
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REGISTERED PROFESSIONAL ENGINEER

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(Seal and Date)

11/12/10

3.2 EVALUATION OF CLOSURES - 44 CFR 65.10(b)(2)

This minimum design standard as stated in 44 CFR 65.10(b)(2) specifies the following:

All openings must be provided with closure devices that are structural parts of the system during operation and design according to sound engineering practice.

To verify this design standard, a closures report was prepared including a matrix of Flood System Penetrations Summary which is reproduced in Appendix A-4.2. All documented openings passing through the Chicopee Falls system outlet to the Chicopee River. In addition to the discharge lines from the Main Street and Oak Street Pumping Stations, four penetrations identified in the USACE plans were field verified. One is a pressure drain controlled by a sluice gate located upstream near West Main Street that is operated and maintained by the City. Another is the discharge pipe from a single grated basin located at the crest of the levee, well above the one-percent chance flood elevation. The third opening is a prior industrial intake line closed by a gate valve that is now operated and maintained by the City. Last is a pressure drain pipe from a storm drain system located well above the one-percent chance annual flood elevation.

Both pumping stations have outfalls that discharge by gravity flow during normal river flow events. During high flow conditions, gates are closed on the gravity discharge lines and interior flows are diverted to the pumping stations which then pump drainage flows to the river. Each pump is protected against backflow in the event that it may not be in operation at any time during river flooding. All gates and valves are maintained and operated by the City.

It is the opinion of this professional engineer that the Chicopee Falls Flood Control System in Chicopee, Massachusetts meets the 44 CFR 65.10(b)(2) closures requirements for the base flood (one-percent annual chance flood).

Opinion offered by:

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3.3 EVALUATION OF EMBANKMENT PROTECTION - 44CFR65.10(b)(3)

This minimum design standard as stated in 44 CFR 65.10(b)(3) specifies the following:

Engineering analyses must be submitted that demonstrate that no appreciable erosion of the levee embankment can be expected during the base flood, as a result of either currents or waves, and that anticipated erosion will not result in failure of the levee embankment or foundation directly or indirectly through reduction of the seepage path and subsequent instability. The factors to be addressed in such analyses include, but are not limited to: Expected flow velocities (especially in constricted areas); expected wind and wave action; ice loading; impact of debris; slope protection techniques; duration of flooding at various stages and velocities; embankment and foundation materials; levee alignment, bends, and transitions; and levee side slopes.

To verify this design standard, an Embankment Protection Analysis, Chicopee Falls Flood Control System was prepared, dated October 2010. A copy of this analysis is reproduced in the attached Appendix A-4.3. The analysis was performed in accordance with applicable methods and guidelines in the USACE Engineering Manual on Hydraulic Design of Flood Control Channels (EM 1110-2-1601, Change 1, 30 Jun 94), USACE Coastal Engineering Manual, Part II (EM 1110-2-1100, Change 2, 1 August 2008), and the United States Department of Agriculture, Soil Conservation Service (USDA SCS) Handbook of Channel Design for Soil and Water Conservation (TP-61, 1954).

The side slope flow velocities at various cross sections of the Chicopee River along the reach of the Chicopee Falls Flood Control System were below the acceptable velocities for riprap slope protection as present and thus the riprap protection is adequate. In the area where riprap is not present, the floodwall is founded directly on ledge with rock anchors, thus any erosion of the embankment in this area is unlikely to cause failure of the floodwall. Wind and wave action was based upon wave height determined at this site to be 1.6 feet. The available freeboard for the base flood is approximately 7.1 feet thus indicating that overtopping and related erosion and failure is not expected to occur. Average channel velocities are such that it is not expected that any impacts of ice or debris will cause significant damage to the system.

It is the opinion of this professional engineer that the Chicopee Falls Flood Control System in Chicopee, Massachusetts meets the 44 CFR 65.10(b)(3) embankment protection requirements for the base (one-percent annual chance) flood.

Opinion offered by:

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COMMONWEALTH OF MASSACHUSETTS
ROSALIE T STARVISH
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(Seal and Date)

3.4 EVALUATION OF EMBANKMENT AND FOUNDATION STABILITY – 44 CFR 65.10(b)(4)

This minimum design standard as stated in 44 CFR 65.10(b)(4) specifies the following:

Engineering analyses that evaluate levee embankment stability must be submitted. The analyses provided shall evaluate expected seepage during loading conditions associated with the base flood and shall demonstrate that seepage into or through the levee foundation and embankment will not jeopardize embankment or foundation stability. An alternative analysis demonstrating that the levee is designed and constructed for stability against loading conditions for Case IV as defined in the U.S. Army Corps of Engineers (COE) manual, "Design and Construction of Levees" (EM 1110-2-1913, Chapter 6, Section II), may be used. The factors that shall be addressed in the analyses include: Depth of flooding, duration of flooding, embankment geometry and length of seepage path at critical location, embankment and foundation materials, embankment compaction, penetration, other design factors affecting seepage (such as drainage layers), and other design factors affecting embankment and foundation stability (such as berms).

To verify this design standard, seepage was evaluated by creating typical levee cross-sections based upon recent topographic survey information, recent boring logs, historical boring logs (USACE pre-construction borings), laboratory data, empirical correlations from SPT N-value data and engineering literature. These parameters were input into SEEP/W 2007, a two-dimensional finite element seepage modeling software created by GEO-SLOPE International, Ltd. Models were analyzed with and without the toe-drain to analyze additional load cases that could impact seepage through the levee. Flow and exit gradients were computed within the toe drain and at the landside toe of the levee and were all below the limiting gradient of 0.5 per US Army Corps Technical Letter ETL 110-2-569 *Design Guidance for Levee Underseepage* for Normal and 100 Year Flood elevations.

The parent SEEP/W model was incorporated into SLOPE/W, a two-dimensional finite element slope stability modeling software created by GEO-SLOPE International, Ltd. with additional parameters including unit weight, strength and internal friction angle based upon laboratory data and empirical correlations from SPT N-value data and engineering literature. Factors of Safety against slope failure on the landside and riverside were analyzed under normal and 100 flood (steady-state and sudden drawdown conditions).

Based upon our slope stability evaluation of the Chicopee Falls levee, it is our opinion that the levee is in compliance with 44 CFR 65.10 (4). Summary sheets showing computed factors of safety for the various loading conditions and for each cross-section can be found in Appendix A-4.4.

A qualitative liquefaction analysis was performed on the Chicopee Falls Levee to evaluate whether the levee exhibited certain characteristics that would make it more susceptible to liquefaction (i.e. soil samples with high N-values and high fines contents are generally not as susceptible to liquefaction as loose, clean sands with low fines contents). It is our opinion that based upon the qualitative liquefaction analysis, a more in-depth quantitative analysis was not required.

It is the opinion of this professional engineer that the Chicopee Falls Flood Control System in Chicopee, Massachusetts meets the 44 CFR 65.10(b)(4) embankment and foundation requirements for the base flood (one-percent annual chance flood).

Opinion offered by:

Anders B. Bjarngard, P.E.
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COMMONWEALTH OF MASSACHUSETTS
ANDERS B.
BJARNGARD
CIVIL
No. 39766
REGISTERED
PROFESSIONAL ENGINEER

(Seal and Date)

3.5 EVALUATION OF SETTLEMENT - 44 CFR 65.10(b)(5)

This minimum design standard as stated in 44 CFR 65.10(b)(5) specifies the following:

Engineering analyses must be submitted that assess the potential and magnitude of future losses of freeboard as a result of levee settlement and demonstrate that freeboard will be maintained within the minimum standards set forth in paragraph (b)(1) of this section. This analysis must address embankment loads, compressibility of embankment soils, compressibility of foundation soils, age of the levee system, and construction compaction methods. In addition detailed settlement analysis using procedures such as those described in the COE manual, "Soil Mechanics Design-Settlement Analysis" (EM 1100-2-1904) must be submitted.

To verify this design standard, primary and secondary settlement of the varved foundation soils were estimated using one-dimensional consolidation theory, empirical correlations and published literature, as well as GZA's recent boring and survey information. Consolidation of granular soils was considered to occur immediately and to have been accounted for during the construction of the levee. Settlement analysis was conducted in general accordance with EM 1110-1-1904 *Settlement Analysis*, published by the USACE, dated September 30, 1990.

Primary settlement was estimated at approximately 3 inches, 90% of which was estimated to have been completed by 1964. Since end of primary consolidation, an estimated one-half inch of secondary settlement has occurred, resulting in a total of about 3.5 inches since construction. Approximately ¼ to ½ inch of secondary settlement (also known as creep) is expected to occur over the next 50-100 years.

Based upon our settlement evaluation of the Chicopee Falls Levee, it is our opinion that the levee is in compliance with 44 CFR 65.10(b)(5) and that freeboard has not sufficiently been affected by resulting post-construction settlement. Any increase in fill or loading above the USACE record drawings and recent survey by Heritage Survey renders this opinion null and void.

It is the opinion of this professional engineer that the Chicopee Falls Flood Control System in Chicopee, Massachusetts meets the 44 CFR 65.10(b)(5) settlement requirements for the base flood (one-percent annual chance flood).

COMMONWEALTH OF MASSACHUSETTS
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3.6 EVALUATION OF INTERIOR FLOODING - 44CFR65.10(b)(6)

This minimum design standard as stated in 44 CFR 65.10(b)(6) specifies the following:

An analysis must be submitted that identifies the source(s) of such flooding, the extent of the flooded area, and, if the average depth is greater than one foot, the water-surface elevation(s) of the base flood. This analysis must be based on the joint probability of interior and exterior flooding and the capacity of facilities (such as drainage lines and pumps) for evacuating interior floodwaters.

To verify this design standard, an Interior Flooding Analysis, Chicopee Falls Flood Control System was prepared, dated May, 2010 and submitted to FEMA for review and acceptance under the technical appeal process. A copy of this analysis along with the appeal resolution letter from FEMA dated July 19, 2010 are reproduced in the attached Appendix A-4.6. The analysis was conducted in accordance with the USACE's Engineering Circular on Certification of Levee Systems (EC 1110-2-6067) and their Engineer Manual, Hydrologic Analysis of Interior Areas (EM 1110-2-1413). The Coincident Frequency Method was utilized for this analysis due to the relative independence of the exterior (i.e., river flooding) event to the interior (localized flooding) event.

A total area of 16 acres drains to the Main Street Pumping Station and 15 acres drains to the Oak Street Pumping Station based upon information provided by the City and existing topographic mapping from the digital elevation model provided by FEMA which in turn was based upon a Light Detection and Ranging(LiDAR) survey. The discharge rates of the pumping stations were based upon the original pump test curves provided by the manufacturer of the installed pumps. The Chicopee River Stage Frequency curves were developed from USGS gage data at Indian Orchard, Springfield which had a record period of 82 years.

The Coincident Frequency Analysis concluded that the one-percent chance interior flooding elevation was lower than the lowest ground surface elevation within the Main Street and the Oak Street Pumping Station drainage areas and therefore there is no interior flooding associated with the base flood at the Chicopee Falls Flood Control System.

It is the opinion of this professional engineer that the Chicopee Falls Flood Control System in Chicopee, Massachusetts meets the 44 CFR 65.10(b)(6) interior drainage requirements for the base flood.

Opinion offered by:

Rosalie T. Starvish, P.E.
BEC, Inc.
296 North Main Street
East Longmeadow, MA 01028

(Seal and Date)

3.7 EVALUATION OF OTHER DESIGN CRITERIA (STRUCTURAL) - 44CFR65.10(b)(7)

This minimum design standard as stated in 44CFR65.10(b)(7) specifies the following:

In unique situations, such as those where the levee system has relatively high vulnerability, FEMA may require that other design criteria and analyses be submitted to show that the levees provide adequate protection. In such situations, sound engineering practice will be the standard on which FEMA will base its determinations. FEMA will also provide the rationale for requiring this additional information.

To the best of our knowledge FEMA has not identified other design criteria in need of evaluation for the Chicopee Falls Flood Control System. However it is the signatory's opinion that a structural evaluation of the flood protection walls was warranted. The objectives of our structural evaluation were to determine, with reasonable certainty, that the structures meet current design standards and are in a suitable condition to perform as intended and therefore meet the requirements of 44CFR65.10(b)(7). This evaluation of the Chicopee Falls Flood Control System floodwalls was accomplished by visiting the site and viewing the structures; reviewing available original design drawings, Construction Drawings, calculations, and previous inspection reports; evaluating recently collected site data; and performing structural calculations in accordance with current design standards.

Guidance in the performance of our structural evaluation was taken from the U. S. Army Corps of Engineers Draft Technical Letter No. 1110-570, *Certification of Levee Systems for the National Flood Insurance Program (NFIP)*, 12 September 2007. Parameters used in our calculations included the existing available design and construction documentation and data obtained from recently completed topographic surveys, subsurface exploration programs, laboratory testing and hydraulic analyses.

Our structural engineers visited the subject site on December 17, 2009. They walked the length of the system to visually observe the condition of the exposed portions of the flood wall.
Our structural engineers reviewed the original design documents in order to determine the assumed loading conditions and to review how the structural elements were designed. The result of the original analysis was compared to the current USACE guidance to verify that the structures meet current design requirements specified in the following documents:

1. USACE Manual EM 1110-2-2100 *Stability Analysis of Concrete Structures.*
2. USACE Manual EM 1110-2-2104 *Strength Design for Reinforced Concrete Hydraulic Structures.*
3. USACE Manual EM 1110-2-2502 *Retaining and Flood Walls.*

A total of 11 different wall sections have been evaluated using methods prescribed in USACE Manual EM 1110-2-2502 *Retaining and Flood Walls.* Our engineers evaluated each section for the load condition resulting from the one-percent-annual chance flood as required by FEMA Regulations 44 CFR 65.10. The floodwalls were evaluated for sliding stability, overturning stability, foundation soil bearing capacity and strength and serviceability of the structural members. A presentation of our analyses, methods and results can be found in Appendix A-4.7.

Based on our observations, the floodwalls appear to be constructed as indicated in the Record Drawings and to be structurally sound. The results of our analyses indicate that, as originally designed, the structures meet current design standards for the base flood event.

It is the opinion of this professional engineer that the Chicopee Falls Flood Control System floodwalls meet the requirements of 44CFR65.10(b)(7) for the base flood (one-percent annual chance flood).

Opinion offered by
Dino D. Fiscaletti, P.E.
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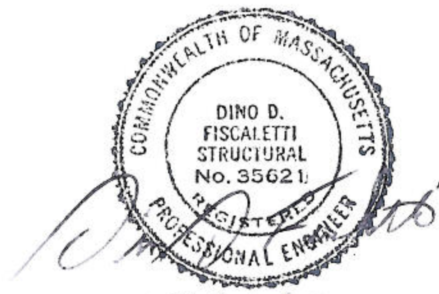
530 Broadway
Providence, RI 02909



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SECTION 4

ENGINEER'S OPINION OF OPERATION PLANS AND CRITERIA

4. ENGINEER'S OPINION OF OPERATION PLANS AND CRITERIA

Operation of the Chicopee Falls Flood Protection System levee embankment, floodwalls, pump stations, and penetrations is the responsibility of the Chicopee Department of Public Works as detailed in the appended Operation and Maintenance (O&M) Manual, Chicopee and Chicopee Falls, Massachusetts, Local Protection Projects, Connecticut and Chicopee Rivers, October, 2010. This document was officially adopted by the City Council as the Operations and Maintenance Manual for all flood protection systems in the City of Chicopee, MA.

In BEC's opinion, this operation plan as detailed in the O&M Manual:

- Establishes all operation activities are under the jurisdiction of the City of Chicopee Department of Public Works;

- For Closures: Documents the flood warning system used to trigger emergency operation activities and demonstrates that sufficient flood warning time exists for the completed operation of all closure structures, including necessary sealing, before flood waters reach the base of the closure; a formal plan of operation including specific actions and assignments of responsibility by individual name or title, and provisions for periodic operation, at not less than one-year intervals, of the closure structure for testing and training purposes;

- For Interior Drainage Systems: Documents the flood warning system used to trigger emergency operation activities and demonstrates that sufficient flood warning time exists to permit activation of mechanized portions of the drainage system, a formal plan of operation including specific actions and assignments of responsibility by individual name or title; provision for manual backup for the activation of automatic systems, and provisions for periodic inspection of interior drainage systems and periodic operation of any mechanized portions for testing and training purposes with no more than one year lapse between either the inspections or the operations.

Other operating plans and criteria to ensure that adequate protection is provided in specific situations have not been identified by FEMA to the knowledge of BEC.

In accordance with the definitions and limitations set forth in 44 CFR 65.2(b), it is the opinion of this professional engineer that this O&M Manual meets the minimum operation requirements specified in 44 CFR 65.10(c).

Opinion offered by:

Rosalie T. Starvish, P.E.
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(Seal and Date)

SECTION 5

ENGINEER'S OPINION OF MAINTENANCE PLANS AND CRITERIA

5. ENGINEER'S OPINION OF MAINTENANCE PLANS AND CRITERIA

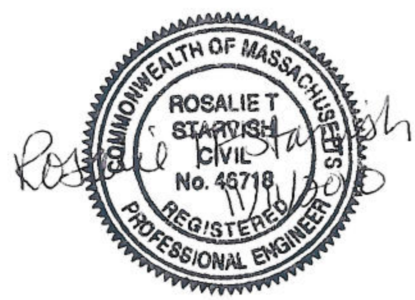
Maintenance of the Chicopee Falls Flood Protection System levee embankment, floodwalls, pump stations, and penetrations is the responsibility of the Chicopee Department of Public Works as detailed in the appended Operations and Maintenance (O&M) Manual, Chicopee and Chicopee Falls, Massachusetts Local Protection Projects, Connecticut and Chicopee Rivers, October, 2010. This document was officially adopted by the City Council as the Operations and Maintenance Manual for all flood protection systems in the City of Chicopee, MA.

In BEC's opinion, this maintenance plan as detailed in the O&M Manual:

- Establishes that all maintenance activities are under the jurisdiction of the City of Chicopee Department of Public Works;
- Documents the formal procedures that ensures that the stability, height, and overall integrity of the levee and its associated structures and system are maintained;
- Specifies the maintenance activities to be performed, the frequency of their performance, and the person by name or title responsible for their performance.

In accordance with the definitions and limitations set forth in 44 CFR 65.2(b), it is the opinion of this professional engineer that this O&M Manual meets the minimum maintenance requirements specified in 44 CFR 65.10(d).

Opinion offered by:



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(Seal and Date)

SECTION 6

AS BUILT PLANS

SECTION 6. AS BUILT PLANS

44CFR65.10(e), titled "Certification requirements" includes the statement, "Also, certified as-built plans of the levee must be submitted." Also within 44CFR65.2, titled "Definitions" is the statement, "Certification of "as-built" conditions is a statement that the structure(s) has been built according to the plans being certified, is in place, and is fully functioning." In response to these requirements a topographic survey of the Chicopee Falls Flood Control System was prepared based upon aerial photography and supplemented with ground surveys performed from May, 2008 through September, 2009. "As-built" is defined as and limited to those visual attributes which could be observed and documented. BEC did not observe nor document the original construction of the Chicopee Falls Flood Control System or that of subsequent construction activities and use of the "As-built" plans other than for general informational purposes is at the user's sole risk.

The five sheet plan set of topographic mapping is enclosed within this report in Appendix A-5. Plans are titled "Chicopee Falls System, Chicopee Flood Control Works, Chicopee, MA", dated December 12, 2009 and stamped by a MA Licensed Land Surveyor.

APPENDIX A-3

GEOTECHNICAL DATA
AND
LABORATORY ANALYSES

GEOTECHNICAL DATA

CHICOPEE FALLS FLOOD CONTROL SYSTEM

CHICOPEE FLOOD CONTROL WORKS

CITY OF CHICOPEE

HAMPDEN COUNTY, MASSACHUSETTS

November, 2010

GZA GeoEnvironmental, Inc.

TABLE OF CONTENTS

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August 19, 2010
File No. 15.0702100.50

INTRODUCTION:

GZA GeoEnvironmental, Inc. (GZA) is pleased to submit this geotechnical data report for the Chicopee Falls Levee of the Chicopee Flood Control Works in Chicopee, Massachusetts. This report presents the results of field and laboratory programs completed as part of our geotechnical study. Conclusions and recommendations relative to levee seepage and stability analysis will be provided separately. Please note that this report is subject to the limitations provided in Section 1.3. Elevations included in this report are referenced to the North American Vertical Datum of 1988 (NAVD 88). Please note that many original U.S. Army Corps. of Engineers project plans and documentation are in the Means Sea Level datum, approximately 0.7 feet above the NAVD 88 datum in the Chicopee local area. (MSL-0.7'=NAVD 88)

BACKGROUND

GZA's understanding of the project is based on our work at the site, discussions with the City of Chicopee Department of Public Works, and the following project documents:

- A drawing set entitled "Chicopee Falls, Chicopee River, Massachusetts," prepared by Green Engineering Affiliates, Inc., Boston, MA for the U.S Army Engineer Division, Waltham, MA, dated April 1963, sheets 1-63;

- A design memorandum entitled, "Chicopee Falls, Local Protection Project, Chicopee River, Massachusetts, Design Memorandum No. 5, Embankments and Foundations," prepared by the U.S Army Engineer Division, New England Waltham, MA, dated March 1963, 16 pp;

- A five sheet plan set of topographic mapping prepared by Heritage Surveys, Inc. dated December 12, 2009 and entitled "Topographic Plan of Land in Chicopee, Massachusetts, Surveyed for the City of Chicopee.

EXISTING CONDITIONS

In response to significant flooding events in the 1930s and 1950s, flood control works were designed and constructed by the United States Army Corps of Engineers (USACE) for locations along the Chicopee and Connecticut Rivers in the City of Chicopee (City). Construction along the Connecticut River and the North and South Banks of the Chicopee River was conducted in a series of construction contracts initiated in 1938 and completed in 1942, collectively known as the Chicopee Local Protection Project (CLPP).

In total, the Chicopee Flood Control Works (CFCW) consists of 25,820 linear feet of earthen levee, 7,500 linear feet of flood control walls, eight pump stations, three cast-in-place concrete closure structures, and various appurtenant drainage features. The CFCW was constructed in four separate systems, namely the Plainfield Street system, the South Bank Chicopee River system, the Willimansett system, and the Chicopee Falls system. The Chicopee Falls system is shown on Figure 1, consisting of improved embankment and concrete floodwall from Station 0+00 at the Deady Memorial Bridge to high ground near Front Street at Station 54+15.

As a cooperative Federal/City effort, the USACE was responsible for the design and construction, while the City provided all of the lands, easements, and rights-of-way necessary for the construction. The City also agreed to maintain and operate the flood control works after completion, in accordance with federally prescribed regulations. These requirements are detailed in the Code of Federal Regulations, 33 CFR 208.10 which is entitled, "Local flood protection works; maintenance and operation of structures and facilities".

SUBSURFACE EXPLORATIONS

The subsurface explorations presented herein include borings from previous subsurface investigations by the USACE (designated by "BH") prior to construction, as well as the program of recent subsurface explorations performed for this project. The previous and recent subsurface explorations are described below.

Previous Explorations

In addition to the recent explorations, our study included the review of subsurface explorations and data from previous subsurface evaluations performed prior to the levee's construction.

Subsurface conditions from record drawings were used to supplement the current geotechnical evaluation and provide confirmation on levee and flood wall foundation soils. These test boring locations and exploration logs from the previous study are included in Section A-3.1. Soil samples were classified using the USACE Providence District Soil Classification System which corresponds to a soil unit number and grain size distribution. The previous borings generally encountered fill over fluvial sands, silts and gravels (often noted as till) underlain by red shale (and occasionally conglomerate and sandstone). Varved soils were identified on previous USACE boring logs in the vicinity of Station 50+00 and further south.

Recent Explorations

The subsurface exploration program performed for this project consisted of 11 borings which are described below. Borings were completed using the rotary (drive and wash) method with cased techniques in general accordance with our Comprehensive Work Plan dated December 29, 2009 and accepted by the USACE in a letter dated January 7, 2010, applicable ASTM and USACE standards and observed fulltime by GZA personnel. Standard Penetration Tests (SPTs) and split spoon sampling were generally performed continuously in the upper 8 feet of the borings, and at 5-foot intervals thereafter. Representative soil samples were collected from the split spoon samples and stored in jars for later review and laboratory testing. Boreholes were tremie-grouted with a bentonite/cement grout upon completion. Logs of the recently performed borings are included in Section A-3.2 and the approximate boring locations are shown on Figures 2 through 5.

Borings

Eleven test borings were performed between January 6, 2009 and February 4, 2010 at the Chicopee Falls levee section (CF-1 through CF-11) by A&A Test Boring of South Windsor, CT using a Diedrich D-120 all-terrain drill rig, and were observed by GZA personnel. Borings were generally spaced 500 linear feet apart along the top of the levee and at transitions between earth embankment and flood wall sections. Completed boring depths ranged between 20 and 80 feet below ground surface.

LABORATORY ANALYSES

GZA performed thirteen laboratory gradation analyses and one percent organics test from recovered soil samples along the Chicopee Falls Levee in accordance with applicable ASTM Standards D422 and D2974. The geotechnical laboratory test results are included in Section A-3.3, and summarized on Table 1.

SUBSURFACE CONDITIONS

Ground surface elevations on the landside of the Chicopee Falls were generally between 89 and 92 feet (NAVD 88), slightly higher west of Station 10 (rising up to El. 95) and slightly lower alongside the former Facemate property (sloping down to El. 84). River-side toe elevations range from approximately El. 82 at the east end to approximately El. 78 at the west end. Top of levee/floodwall elevations of the Chicopee Falls system ranged between El. 110 and El. 99, decreasing in elevation with increasing Station (NAVD 88).

Soils

Brief soil descriptions are provided below. Detailed information about subsurface conditions based on recent and historical borings, as well as assumed parameters for unit weight, hydraulic conductivity and internal friction angle can be found in the attached summary sheets and analysis profiles located in Appendix A-4.4 of the FEMA Accreditation report.

> Fill – Four to thirty-seven feet of fill, consisting of dense to very dense, fine to coarse SAND, with little to some fine to coarse gravel and trace to some Silt and trace amounts of loose to medium fine to coarse sand and Silt, with occasional

trace amounts of brick, ash, wood, plastic and organics. Average fill thickness was around 25 feet, with the smallest amount of fill occurring near the Deady Memorial Bridge where rock elevation is closest to the ground surface. Bottom of fill elevations generally seemed to correspond to the river elevation, where loose blow counts and losses of washwater were occasionally observed.

USACE drawings identify multiple fill zones consisting of compacted impervious fill and compacted random fill in the typical levee sections. These two soil types are also specified in the Chicopee Falls Design Memo. Compacted impervious fill "is a well graded gravelly, silty, clayey sand (SM-SC) with at least 20% passing the No. 200 sieve" (USACE, 9). Compacted random fill can consist of "any granular materials which contain no organic or decaying matter, are essentially non-plastic in nature, and contain no gravel sizes larger than 2/3 the allowable life thickness will be usable" (USACE, 10). No distinction between these soil types was observed in the borings as would be expected based on the geometry shown on the USACE drawings. Laboratory gradations were performed on both sample types and plotted against USACE Design Memo gradations. Sample gradations from the zones classified as either random or impervious were found to satisfy both gradation curves. It is GZA's opinion that the levee was likely constructed of the more conservative compacted impervious fill to simplify construction, or based on availability, while satisfying design requirements.

Sand and Gravel/Till – A very dense brown to red-brown, fine to coarse SAND, some fine to coarse Gravel, little Silt was observed beneath the fill except in boring CF-9. Top of Sand and Gravel/Till elevations ranged between 82 and 86 at Stations 10+00 and 16+70 (dipping briefly to El. 74 at Station 13+30) decreasing to El. 60 at Station 60.5 and 65 at Stations 44+60 and 50+00, respectively.

Varved Silt/Clay – Hard, brown, varved soils were encountered in boring CF-11 at Station 50+00, approximately 22.5 feet in thickness (also noted in the design memo). Field torvane measurements of shear strength on recovered split-spoon samples ranged from 0.65 to 1.45 tons per square foot. Pocket penetrometer readings ranged from 3.25 to over 4 tons per square foot.

Weathered Rock/Sandstone Bedrock – Red-brown Sandstone with occasional Shale zones was encountered below the Fill in borings CF-1 and CF-9, the Varved Silt/Clay in boring CF-11 and below the Sand and Gravel/Till in the remaining borings (except for CF-7 which was terminated prior to encountering bedrock). In general the top of rock decreases in elevation from upstream (El. 89 in CF-1) to downstream (El. 20 in CF-11). The bedrock generally increased in quality with depth, ranging from completely weathered to slightly weathered with RQD values (defined as the sum of lengths over 4" divided by the total run length) as high as 72 percent.

Groundwater

Groundwater levels were measured during performance of the test borings and generally seemed to correspond with the approximate river elevation at the test boring location, with average elevation ranging between Elevation 82 and 83 NAVD88. This data is similar to data collected prior to construction (varying date). No observation wells or piezometers were installed. River elevation data for both the Chicopee and Connecticut Rivers are recorded daily by City Flood Control. In conversations with the Flood Control Foreman, Ernest Laflamme, an electronic database of river levels is also maintained and updated yearly.

Note that fluctuations in the groundwater levels will occur due to variations in season, precipitation, temperature, river level, impacts from existing utilities, and other factors different than those existing at the time of the explorations.

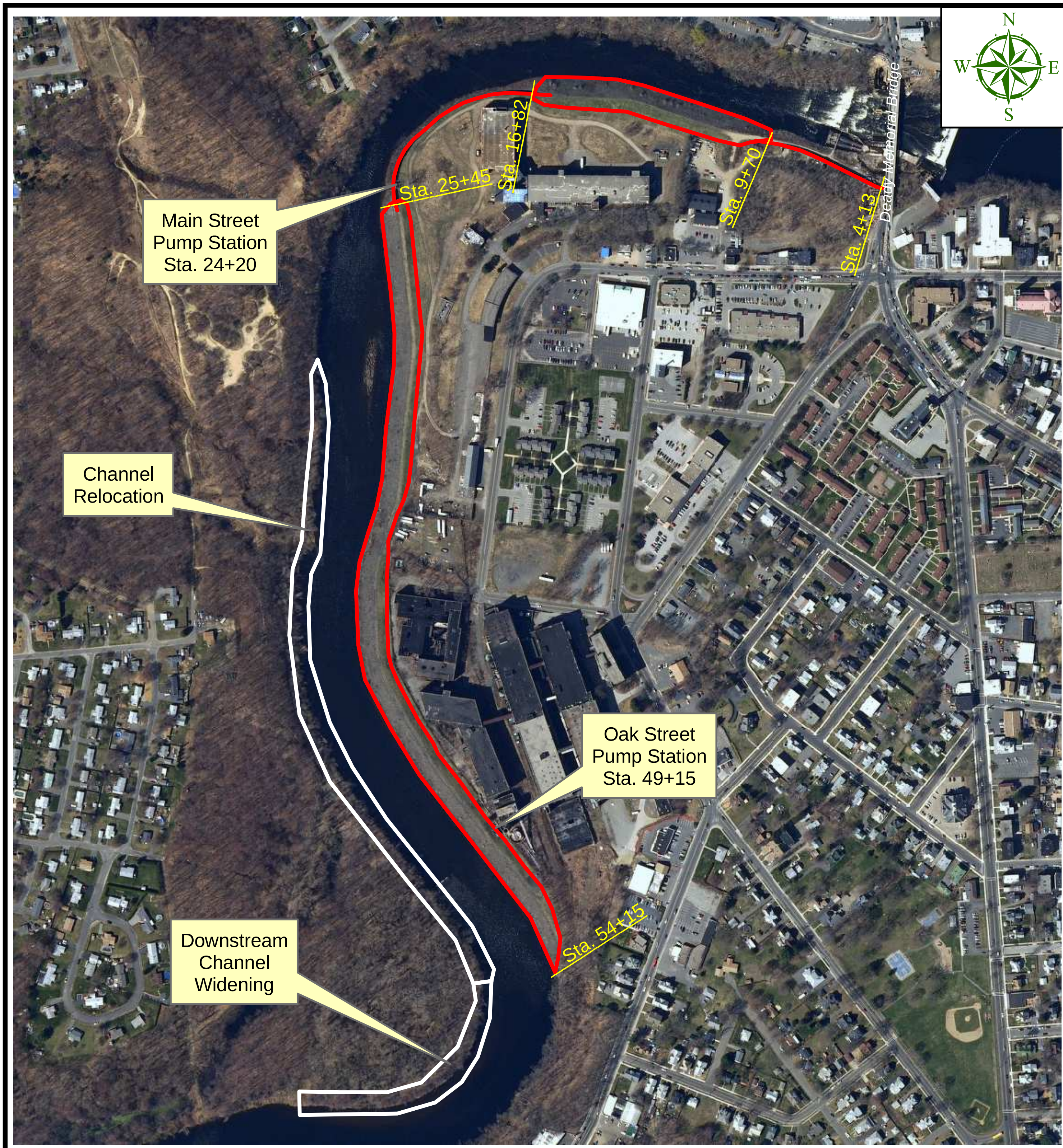
TABLE

Chicopee Flood Control Works
GZA Project No. 15.0702100.50
Chicopee Falls Levee - Geotechnical Laboratory Testing Summary

							Percent By Weight:								
									Fines						
Boring	Sample	Station [(1)]	Depth (ft.)	Elevation [(2)]	USACE [(3)]	Stratum [(4)]	Gravel	Sand	Silt	Clay	WC [(5)]	LL	PL	PI	Comments
CF-3	S-2	13+30 LC	3	104	Cpt. Imp. Fill	Fill	15	54	31		--	--	--	--	
CF-3	S-5	13+30 LC	11	96	Cpt. Rdm. Fill	Fill	27	54	19		--	--	--	--	
CF-3	S-7	13+30 LC	21	86	Cpt. Rdm. Fill	Fill	25	60	15		--	--	--	--	
CF-3	S-9	13+30 LC	28	79	-	Fill	13	72	15		--	--	--	--	5.4% Organic
CF-5	S-2	13+30 RC	3	104	Cpt. Imp. Fill	Fill	21	51	28		--	--	--	--	
CF-5	S-5	13+30 RC	11	96	Cpt. Rdm. Fill	Fill	32	45	22		--	--	--	--	
CF-5	S-11	13+30 RC	29	78	Cpt. Rdm. Fill	Fill	11	74	15		--	--	--	--	
CF-6	S-5	25+50 RC	11	93	Cpt. Imp. Fill	Fill	15	60	25		--	--	--	--	
CF-7	S-5	30+00 RC	11	91			19	53	28		--	--	--	--	
CF-7	S-12	30+00 RC	36	66	Till	S+G	53	37	10		--	--	--	--	
CF-11	S-3	50+00 RC	5	94	Cpt. Imp. Fill	Fill	11	63	26		--	--	--	--	
CF-11	S-5	50+00 RC	11	88	Cpt. Rdm. Fill	Fill	18	59	24		--	--	--	--	
CF-11	S-13	50+00 RC	32	67	Cpt. Imp. Fill	Fill	10	62	28		--	--	--	--	

1. Stationing is approximate. "RC" = Riverside Crest, "LC" = Landside Crest
2. Elevations referenced to the NAVD88 datum and are in the text.
3. "USACE" refers to stratum description from typical levee sections in record drawings or Design Memo by U.S. Army Engineers.
"Imp. Blkt." = Impervious Blanket, "Perv. Mat." = Pervious Material
4. "S+G" = Sand and Gravel, "Varved" = Varved Silt and Clay, N/A = Not Analyzed
5. WC = Water Content, LL = Liquid Limit, PL = Plastic Limit, PI = Plasticity Index, Tv = Torvane, readings in tons/square foot.
6. All tests conducted in general accordance with applicable ASTM Standards D2216, D4318, 2974, and D422.

FIGURES



Feet
500 250 0 500

Figure 1: Chicopee Falls System

Comprehensive Work Plan
for Drilling Services and Geotechnical Testing
of the Flood Control Works

Chicopee, Massachusetts

Legend

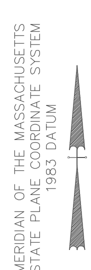
Flood Wall

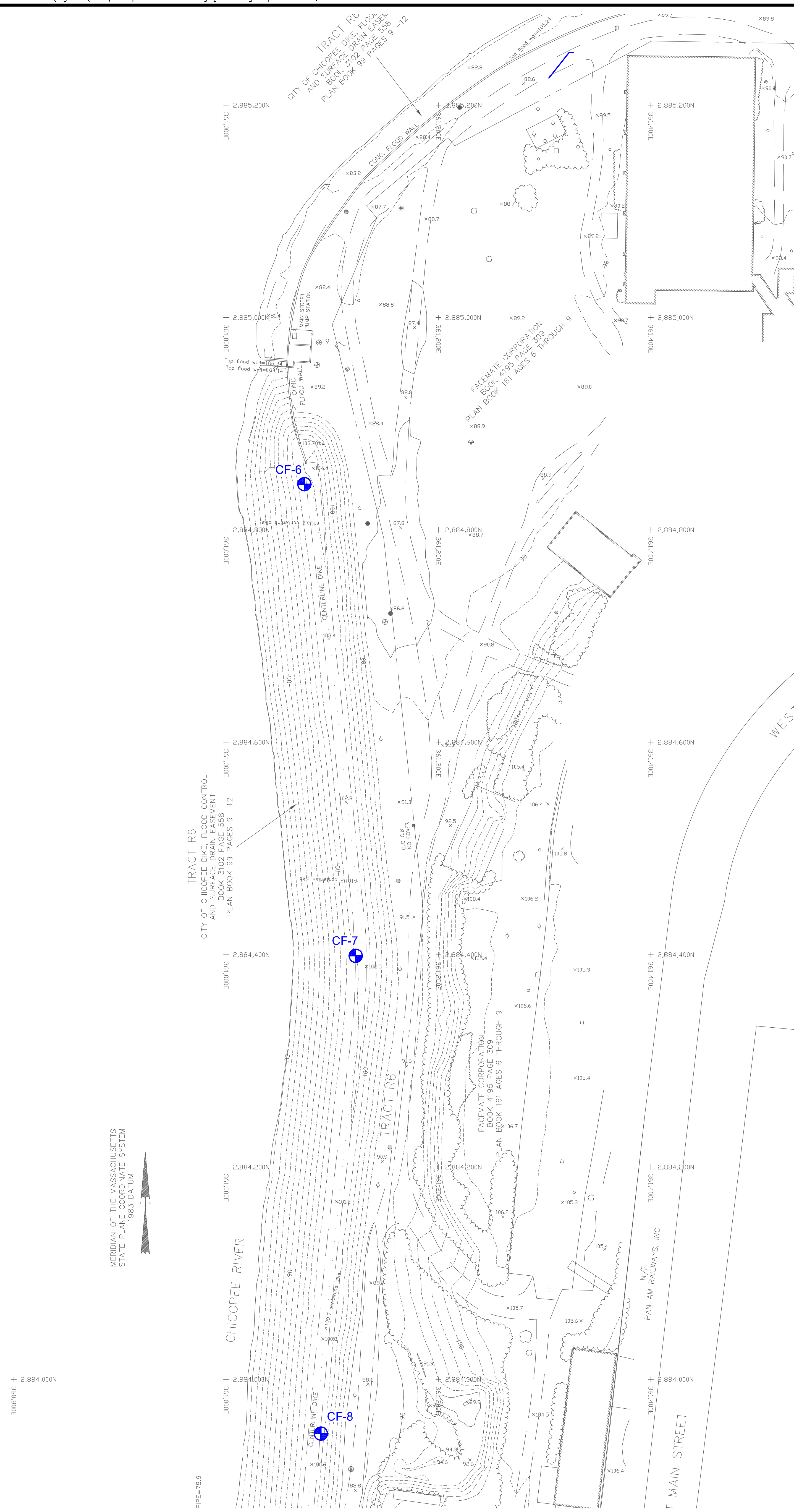
Flood Levee

Baystate Environmental Consultants, Inc.
296 North Main Street, East Longmeadow, MA

MassGIS Orthophoto (2005) obtained from MASS GIS,
Commonwealth of Massachusetts Executive Office of Environmental Affairs (EOEA).

©2009- GZA GeoEnvironmental, Inc. GZA-J:\Branch\NORWOOD\CHICOPEE-LEVEE\Figures\CAD\Chicopee-Falls XLP.dwg [Sheet 3] September 24, 2010 - 10:33am robert.house





SURVEYOR'S NOTES:

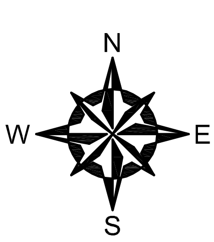
1. TOPOGRAPHIC DATA SHOWN HEREON IS BASED UPON AERIAL PHOTOGRAPHY TAKEN DURING APRIL, 2008. PHOTOGRAPHY AND MAPPING WERE PERFORMED BY COL-EAST, INC. OF NORTH ADAMS, MA AND SUPPLEMENTED WITH GROUND SURVEYS PERFORMED BY HERITAGE SURVEYS, INC. FROM MAY, 2008 THROUGH SEPTEMBER, 2009.

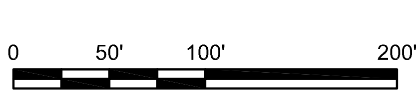
2. FOR REFERENCE TO BOUNDARY LINE AND EASEMENTS SEE A PLAN PREPARED BY HERITAGE SURVEYS, INC. TITLED "PLAN OF FLOOD CONTROL AND DIKE EASEMENT IN CHICOPEE, MASSACHUSETTS SURVEYED FOR THE CITY OF CHICOPEE", DATED JUNE 15, 2009, SHEETS 1 THROUGH 4.

3. UNDERGROUND UTILITY LOCATIONS SHOWN HEREON ARE BASED UPON SURFACE FEATURES AS LOCATED BY SURVEY AND AVAILABLE RECORD DATA, AND ARE APPROXIMATE. ACTUAL LOCATIONS SHOULD BE VERIFIED WITH THE APPROPRIATE UTILITY COMPANY AND/OR MUNICIPAL DEPARTMENT PRIOR TO FINAL DESIGN AND/OR CONSTRUCTION.

4. LOCATION OF FLOOD WALL AND DIKE BASELINES SHOWN ARE APPROXIMATE AND ARE BASED UPON PLANS PREPARED BY THE U.S. ARMY CORPS OF ENGINEERS FOR CHICOPEE RIVER FLOOD CONTROL DATED APRIL, 1963. NO MONUMENTATION OF BASELINES WAS FOUND AND IS HISTORICAL ONLY.

5. TOP OF CONCRETE FLOOD WALL AND CENTERLINE DIKE GRADES IN BOLD TYPE ARE FIELD LOCATED BY SURVEY AND ARE NOT THE RESULT OF AERIAL MAPPING.



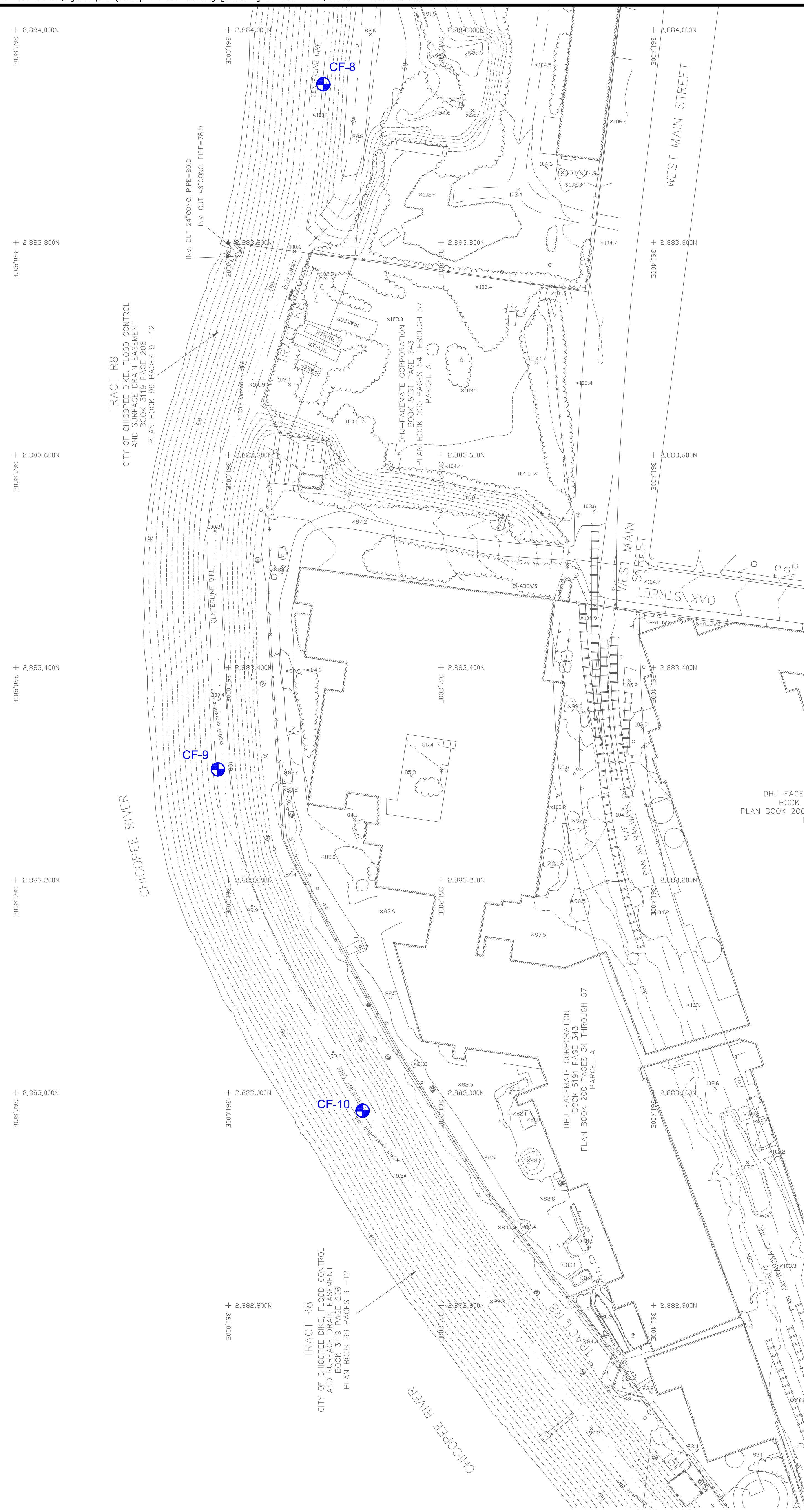


BORING COMPLETED BY A&A TEST BORING OF SOUTH WINDSOR, CT AND OBSERVED BY GZA PERSONNEL BETWEEN JANUARY 6, 2010 AND FEBRUARY 4, 2010

CHICOPEE FALLS
CHICOPEE, MASSACHUSETTS

CHICOPEE FALLS FLOOD PROTECTION SYSTEM
EXPLORATION LOCATION PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists, ONE EDGEWATER DRIVE, NORWOOD, MA 02062, 781-278-3700		PREPARED FOR: CITY OF CHICOPEE DEPT. OF PUBLIC WORKS	
PROJ MGR: NA	REVIEWED BY: ABB	CHECKED BY: CT	FIGURE
DESIGNED BY: DF/ABB	DRAWN BY: GAS	SCALE: 1 INCH = 100 FEET	3
DATE: 6-30-2010	PROJECT NO. 15.0702100	REVISION NO.	



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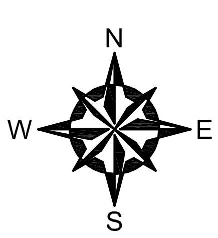

0 50' 100' 200'

SCALE IN FEET

BORING COMPLETED BY A&A TEST BORING OF SOUTH WINDSOR, CT AND OBSERVED BY GZA PERSONNEL BETWEEN JANUARY 6, 2010 AND FEBRUARY 4, 2010

CHICOPEE FALLS
CHICOPEE, MASSACHUSETTS

CHICOPEE FALLS FLOOD PROTECTION SYSTEM EXPLORATION LOCATION PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists, ONE EDGEWATER DRIVE, NORWOOD, MA 02062, 781-278-3700		PREPARED FOR: CITY OF CHICOPEE DEPT. OF PUBLIC WORKS	
PROJ MGR: NA	REVIEWED BY: ABB	CHECKED BY: CT	FIGURE 4
DESIGNED BY: DF/ABB	DRAWN BY: GAS	SCALE: 1 INCH = 100 FEET	
DATE: 6-30-2010	PROJECT NO. 15.0702100	REVISION NO.	

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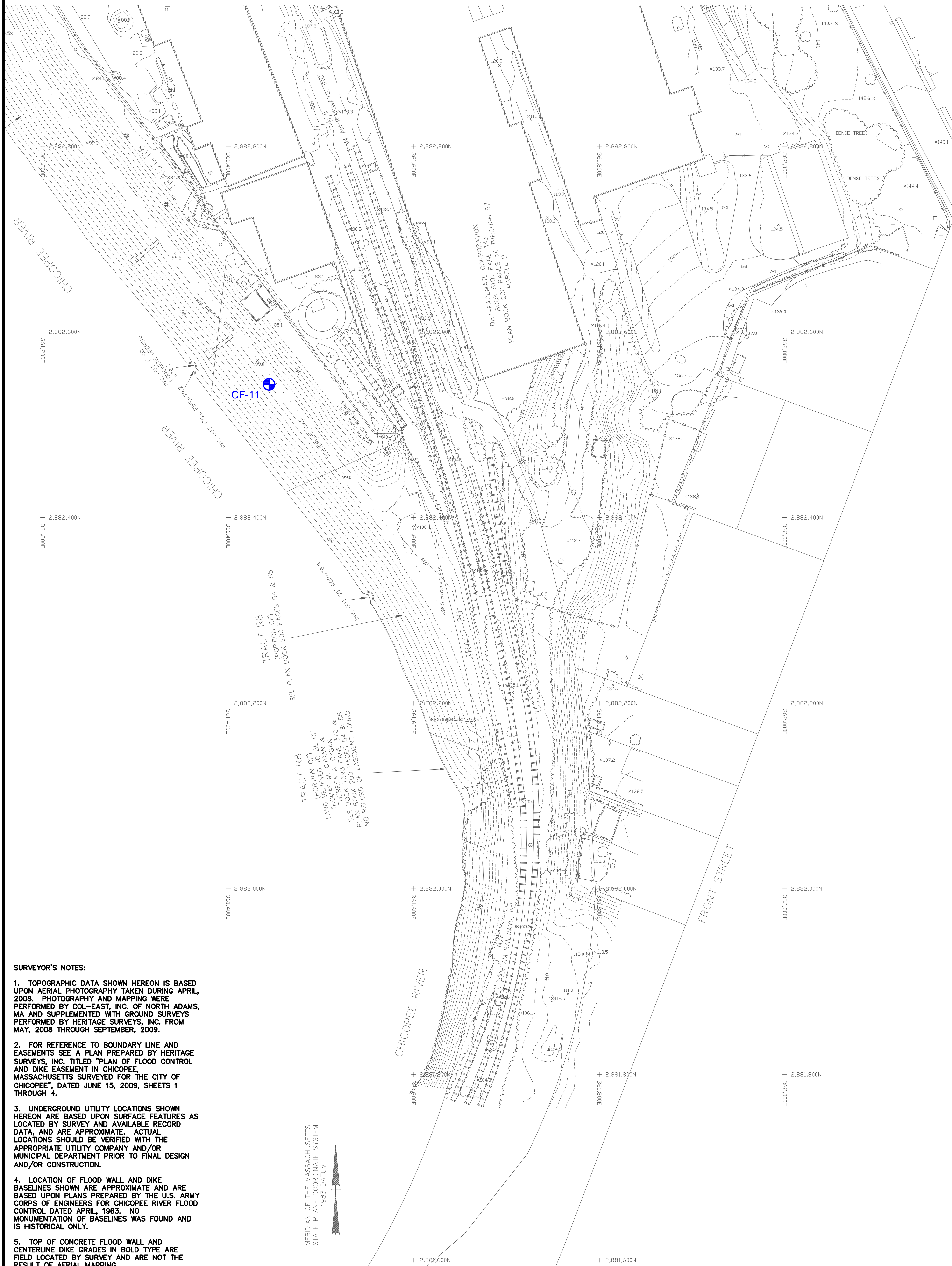

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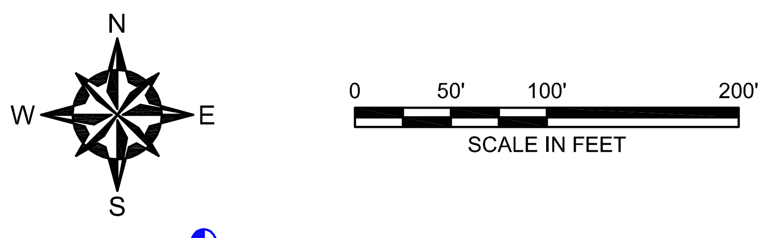


BORING COMPLETED BY A&A TEST BORING OF SOUTH WINDSOR, CT AND OBSERVED BY GZA PERSONNEL BETWEEN JANUARY 6, 2010 AND FEBRUARY 4, 2010

CHICOPEE FALLS
CHICOPEE, MASSACHUSETTS

CHICOPEE FALLS FLOOD PROTECTION SYSTEM
EXPLORATION LOCATION PLAN

PREPARED BY: GZA GeoEnvironmental, Inc. Engineers and Scientists, ONE EDGEWATER DRIVE, NORWOOD, MA 02062, 781-278-3700

PREPARED FOR: CITY OF CHICOPEE DEPT. OF PUBLIC WORKS

PROJ MGR: NA	REVIEWED BY: ABB	CHECKED BY: CT	FIGURE
DESIGNED BY: DF/ABB	DRAWN BY: GAS	SCALE: 1 INCH = 100 FEET	5
DATE: 6-30-2010	PROJECT NO. 15.0702100	REVISION NO.	

SECTION A-3.2

RECENT BORING LOGS
(CF-1 THROUGH CF-11)

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-6
Page: 1 **of** 2
File No.: 15.0702100.50
Check: DMB

Contractor: A&A Drilling, LLC
Foreman: A. Augustine
Logged by: R. House
Date Start/Finish: 1-18-10 / 1-19-10
Boring Location: See Plan
GS Elev.: 103'± **Datum:** NAVD88

	Auger/Casing	Sampler
Type:	HSA/Steel	S.S.
I.D.:	2-1/4"/4"	2" O.D.
Hammer Wt.:	300 lbs.	140 lb.
Hammer Fall:	24"	30"
Other:		NX Core

GROUNDWATER READINGS

Date	Time	Depth	Casing	Stab
See	Note 3.			
1/18/10	1545	17'	40'	45 min.
1/19/10	0715	23'	40'	15.5 hours

Depth	No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
	S-1	24/4	0-2	31-22 18-11		S-1: Dense, brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt, trace Organics Piece of Gravel observed in spoon tip.	FILL	1 2	None
2	S-2	24/12	2-4	11-21 22-18		S-2: Dense, brown, fine to coarse SAND, some fine Gravel, trace Silt		3	
4	S-3	24/16	4-6	17-22 20-23	33 54	S-3: Dense, brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt			
6	S-4	24/18	6-8	19-22 25-25	59 87 125 60	S-4: Dense, brown, fine to coarse SAND, some fine to coarse Gravel, trace Silt, trace Ash			
10	S-5	24/13	10-12	22-15 15-23	43 87 72 65 63	S-5: Brown, fine to coarse SAND, some Silt, little fine Gravel			
15	S-6	24/12	15-17	22-23 31-25	67 260 272 119 65	S-6: Very dense, brown, fine to coarse SAND, some fine to coarse Gravel, some Silt, trace Brick	19' SAND AND GRAVEL		
20	S-7	24/11	20-22	22-28 26-48	53 61 64 70 60	S-7: Very dense, brown, fine to coarse SAND, some fine to coarse Gravel, little Silt		4	
25	S-8	24/13	25-27	31-42 30-27	49 57 62 70	S-8: Very dense, brown, fine to coarse SAND, little fine to coarse Gravel, little Silt	30'		

REMARKS

1. SPT conducted using "safety" hammer and 2" diameter split spoon sampler.
2. Borehole advanced from 0 to 4 feet below grade using 2 1/4" I.D. hollow stem augers. Borehole advanced 4 to 40 feet below grade with 4" flush joint casing and rotary wash methods. Drilling wash water introduced to borehole at 8 feet below grade to completion of boring.
3. No groundwater encountered prior to drilling wash water being introduced to borehole at 8 feet below grade. Groundwater reading performed after introduction of drilling wash water to borehole and may represent perched drilling fluid and may not be representative of actual groundwater conditions.
4. Driller roller bitted ahead prior to driving casing from 20 to 40 feet.
5. Shale fragments present in samples S-9 and S-10.

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-6

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-6
Page: 2 **of** 2
File No.: 15.0702100.50
Check: DMB

Depth	Sample Information: No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/ Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
	S-9	24/13	30-32	51-33 35-32	63	S-9: Very dense, brown, fine to coarse SAND, little fine to coarse Gravel, little Silt	TILL	5	
31					49				
32					62				
33					61				
34					121				
35	S-10	17/14	35-36.5	31-57 100/5"	68	S-10: Brown, fine to coarse SAND, little fine to coarse Gravel, little Silt			
36					71				
37					57				
38					51				
39					80				
40	S-11	4/4	40-40.3	100/4"		S-11: Brown, completely weathered SHALE	40' SANDSTONE		
41	CR-1	60/48	41-46	min/ft 5:00		CR-1: Soft to moderately hard, moderate to very severely weathered, fine grained, red-brown SANDSTONE with very close to closely spaced, horizontal joints/fractures RQD = 20%		6	
42				6:00					
43				5:30					
44				8:15					
45				8:00					
46	CR-2	60/60	46-51	7:00		CR-2: Soft to moderately hard, moderate to severely weathered, fine grained, red-brown SANDSTONE with very close to closely spaced, horizontal to sub-horizontal joints/fractures RQD = 41%			
47				10:00					
48				4:30				7	
49				5:00					
50				5:15					
51	CR-3	60/60	51-56	3:15		CR-3: Soft to moderately hard, moderately severe to slight weathering, medium grained, red-brown to brown SANDSTONE with very close to closely spaced, horizontal to vertical joints/fractures RQD = 33% Last 21": Dark brown in color			
52				2:30					
53				3:00					
54				3:15					
55				3:00					
56						End of Exploration at 56'	56'	8	
57									
58									
59									
60									
61									
62									
63									
64									

REMARKS

6. Times represent penetration in minutes/foot. RQD = Rock Quality Deesignation.
7. Driller increased penetration rate between 48 and 49 feet.
8. Borehole tremie grouted to ground surface with 2/3 tub (~30 gallons/tub) bentonite/cement grout upon completion. (Approximately 20 gallons actual vs 28 gallons theoretical.)

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-6

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-7
Page: 1 **of** 2
File No.: 15.0702100.50
Check: DMB

Contractor: A&A Drilling, LLC
Foreman: A. Augustine
Logged by: R. House
Date Start/Finish: 1-19-10 / 1-20-10
Boring Location: See Plan
GS Elev.: 102'± **Datum:** NAVD88

	Auger/ Casing	Sampler
Type:	HSA/Steel	S.S.
I.D.:	2-1/4"/4"	2" O.D.
Hammer Wt.:	300 lbs.	140 lb.
Hammer Fall:	24"	30"
Other:		NX Core

GROUNDWATER READINGS

Date	Time	Depth	Casing	Stab
See	Note 4.			
1/19/10	1555	18'	38.5'	5 min.
1/20/10	0715	21.5'	38.5'	15.3 hours

No.	Pen./ Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/ Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
S-1	24/12	0-2	37-23 11-14		S-1: Dense, brown, fine to coarse SAND and fine to coarse GRAVEL, little Silt, trace Organics	0.2' TOPSOIL FILL	1 2	None
S-2 S-2A	24/0 24/18	2-4 2-4	39-39 30-13		S-2: No sample recovered S-2A: Brown, fine to coarse SAND, little fine Gravel, little Silt		3 4	
S-3	24/12	4-6	8-17 14-39	35 43	S-3: Dense, brown to red-brown, fine to coarse SAND, some fine to coarse Gravel, little Silt			
S-4	24/17	6-8	49-22 15-8	49 69 78 64	S-4: Dense, red-brown to dark brown, fine to coarse SAND, some fine to coarse Gravel, trace Silt, trace Brick			
S-5	24/12	10-12	22-23 27-28	27 37 52 62 52	S-5: Brown, fine to coarse SAND, some Silt, little fine to coarse Gravel		5	
S-6	24/2	15-17	17-18 17-34	34 29	S-6: Dense, red BRICK, some fine to coarse Sand, trace Silt			
S-7	24/11	17-19	14-9 12-17	39 55	S-7: Medium dense, red-brown to dark brown, fine to coarse SAND and BRICK, little Silt, little Ash			
S-8	24/7	19-21	16-14 19-26	36 61	S-8: Dense, brown, fine to coarse SAND, little fine to coarse Gravel, trace Silt (possible wash) (Piece of Gravel observed in spoon tip.)			
S-9	24/6	21-23	51-71 40-29	68 90 195 155	S-9: Very dense, brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt	21' SAND AND GRAVEL (TILL)		
S-10	24/8	25-27	35-47 43-69	39 43 68 117 160	S-10: Very dense, red-brown, fine to coarse SAND and fine to coarse GRAVEL, little Silt Piece of Gravel observed in spoon tip.		6	

REMARKS

1. SPT conducting using "safety" hammer and 2" diameter split spoon sampler. 7"x5" cobble removed from top 1 foot.
2. Borehole advanced from 0 to 4 feet below grade using 2 1/4" I.D. hollow stem augers. Borehole advanced from 4 to 38.5 feet below grade with 4" flush joint casing and rotary wash methods. Drilling wash water introduced to borehole at 8 feet below grade to completion of boring.
3. No recovery in sample S-2. Therefore sample S-2A redrove into side of borehole.
4. No groundwater encountered prior to drilling wash water being introduced to borehole at 8 feet below grade. Groundwater reading performed after introduction of drilling wash water to borehole and may represent perched drilling fluid and may not be representative of actual groundwater conditions.
5. Driller noted change in wash color from brown to black at 14.5 feet. Loss of casing fluid at 15 feet.
6. Driller roller bitted ahead prior to driving casing from 25 to 38.5 feet. Shale fragments observed in S-10 and S-12.

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-7

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-7
Page: 2 **of** 2
File No.: 15.0702100.50
Check: DMB

Depth	No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
31	S-11	9/1	30-30.8	73-100/3"	50 / 42	S-11: Brown, fine to coarse GRAVEL and fine to coarse SAND, little Silt (Piece of Gravel observed in spoon tip.)	SAND AND GRAVEL (TILL)	7	
32					69				
33					80				
34					117				
35	S-12	24/11	35-37	42-40 40-66	40	S-12: Brown, fine to coarse GRAVEL and fine to coarse SAND, little Silt			
36					60				
37					95				
38					300/6"		38.5'		
39							SANDSTONE		
40	S-13 / CR-1	1/1 / 54/50	39.9-40 / 40-44.5	100/1" / 7:30 / 4:30 / 5:30 / 9:00 / 5:45/6"		S-13: Very dense, brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt CR-1: Soft to moderately hard, moderately to very severe weathering, fine grained, red-brown SANDSTONE with very close to close, horizontal to vertical joints/fractures Extremely weathered from 43.5 to 44 feet RQD = 0%			
44							44.5'		
45						End of Exploration at 44.5'		8	
46									
47									
48									
49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									

REMARKS

7. Moderate to heavy drill chatter from 30 to 40 feet. Driller noted change in drilling effort at 38.5 feet.
8. Borehole tremie grouted to ground surface with 2/3 tub (~30 gallons) bentonite/cement grout (approximately 23 gallons actual vs 23 gallons theoretical).

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-7

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-8
Page: 1 of 2
File No.: 15.0702100.50
Check: DMB

Contractor: A&A Drilling, LLC
Foreman: A. Augustine
Logged by: R. House
Date Start/Finish: 1-20-10 / 1-21-10
Boring Location: See Plan
GS Elev.: 101'± Datum: NAVD88

	Auger/ Casing	Sampler
Type:	HSA/Steel	S.S.
I.D.:	2-1/4"/3"	2" O.D.
Hammer Wt.:	300 lbs.	140 lb.
Hammer Fall:	24"	30"
Other:		

GROUNDWATER READINGS

Date	Time	Depth	Casing	Stab
See	Note 3.			
1/20/10	1540	13.5'	16'	10 min.
1/21/10	0730	15'	16'	16 hours
1/21/10	1140	14'	37'	10 min.

Depth	No.	Pen./ Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/ Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
0-1	S-1	24/17	0-2	9-19 20-32		S-1: Top 6": Dark brown, fine to coarse SAND, some fine to coarse Gravel, little Silt, trace Organics	0.5' TOPSOIL / FILL	1	None
1-2								2	
2-3	S-2	9/7	2-2.8	47-100/3"		S-2: Brown, fine to coarse SAND, little fine to coarse Gravel, trace Silt Piece of Gravel in spoon tip.		3	
3-4	S-3	24/16	3-5	23-30 41-62		S-3: Very dense, brown to red-brown, fine to coarse SAND, little fine to coarse Gravel, little Silt			
5-6	S-4	9/5	5-5.8	31-100/3"	38	S-4: Brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt			
7-8	S-5	24/16	7-9	24-52 42-45	52	S-5: Very dense, dark brown to gray, fine to coarse SAND, some Silt, little fine to coarse Gravel, trace Brick			
8-9					130				
9-10					138				
10-11	S-6	24/6	10-12	35-34 37-80	37	S-6: Very dense, brown, fine to coarse SAND, some fine to coarse Gravel, little Silt (Piece of Gravel observed in spoon tip.)			
11-12					20				
12-13	S-7	24/6	12-14	18-28 17-15	32	S-7: Dense, brown to yellow, fine to coarse SAND and fine to coarse GRAVEL, trace Silt, trace Brick			
13-14					48				
14-15	S-8	24/16	14-16	20-19 19-32	22	S-8: Dense, brown, fine to coarse SAND, some Silt, little fine Gravel, trace Brick			
15-16					53				
16-17	S-9	24/4	16-18	10-11 5-3	13	S-9: Medium dense, brown, fine to coarse SAND, little Silt, little fine Gravel, trace Brick, trace Ceramic			
17-18					20				
18-19	S-10	24/6	18-20	4-2 4-5	22	S-10: Top 3" Gray ASH Bottom 3": Tan-brown, fine SAND, some Silt			
19-20					24				
20-21	S-11	24/8	20-22	6-7 9-13	14	S-11: Medium dense, tan, fine to medium SAND, little Silt			
21-22					20				
22-23	S-12	24/16	22-24	8-22 51-39	33	S-12: Top 9": Tan, fine to medium SAND, little Silt Bottom 7": Brown to red-brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt	23' SAND AND GRAVEL (TILL)		
23-24					73				
24-25					110				
25-26	S-13	24/13	25-27	44-43 54-78	37	S-13: Very dense, brown to red-brown, fine to coarse SAND, some fine to coarse Gravel, little Silt		4	
26-27					37				
27-28					51				
28-29					64				

REMARKS

1. SPT conducted using "safety" hammer and 2" diameter split spoon sampler.
2. Borehole advanced from 0 to 5 feet below grade using 2 1/4" I.D. hollow stem augers. Borehole advanced from 5 to 37 feet below grade with 3" flush joint casing and rotary wash methods. Drilling wash water introduced to borehole at 5 feet below grade to completion of boring.
3. No groundwater encountered prior to drilling wash water being introduced to borehole at 5 feet below grade. Groundwater reading performed after introduction of drilling wash water to borehole and may represent perched drilling fluid and may not be representative of actual groundwater conditions.
4. Driller roller bitted ahead prior to driving casing from 25 to 37 feet.

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-8

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-8
Page: 2 **of** 2
File No.: 15.0702100.50
Check: DMB

Depth	No.	Pen./ Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/ Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
	S-14	14.5/9	30-31.2	38-129 100/2.5"	20	S-14: Brown, fine to coarse GRAVEL, some fine to coarse Sand, little Silt	SAND AND GRAVEL (TILL)		
31					25				
32					46				
33					117				
34					145				
35	S-15	3/1	35-35.3	100/3"	58	S-15: Brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt			
36					191		36' WEATHERED BEDROCK		
37									
38	S-16	1/1	38-38.1	100/1"		S-16: Red-brown, fine to coarse SAND and fine to coarse GRAVEL (Weathered Rock)	38.1'	5 6	
39						End of Exploration at 38.1'			
40									
41									
42									
43									
44									
45									
46									
47									
48									
49									
50									
51									
52									
53									
54									
55									
56									
57									
58									
59									
60									
61									
62									
63									
64									

REMARKS

5. Driller noted change in wash water color from brown to red-brown at 38 feet possibly indicating change in material.
6. Borehole tremie grouted to ground surface with 2/3 tub bentonite/cement grout (~30 gallons/tub) upon completion. (Approximately 20 gallons actual vs 19 gallons theoretical.)

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-8

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

File No.: 15.0702100.50
Check: DMB

Contractor: A&A Drilling, LLC
Foreman: A. Augustine
Logged by: R. House
Date Start/Finish: 1-21-10 / 1-26-10
Boring Location: See Plan
GS Elev.: 99'± **Datum:** NAVD88

	Auger/Casing	Sampler
Type:	HSA	S.S.
I.D.:	2-1/4"/3"	2" O.D.
Hammer Wt.:	300 lbs.	140 lb.
Hammer Fall:	24"	30"
Other:		

GROUNDWATER READINGS

Date	Time	Depth	Casing	Stab
1/22/10	0715	2.5'	14'	15 hours
1/22/10	1510	19.5'	50'	10 min.
1/26/10	0720	21'	50'	3.5 days
1/26/10	1015	17.5'	60'	5 min.

Depth	No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
0	S-1	24/8	0-2	19-25 8-8		S-1: Top 1": Dark brown, fine to coarse SAND, little fine to coarse Gravel, trace Silt, trace Organics Bottom 7": Brown, fine to coarse SAND, some fine to coarse Gravel, trace Silt	0.5' ROADWAY MATERIAL FILL	1	None
1								2	
2	S-2	24/12	2-4	12-18 21-25		S-2: Dense, brown, fine to coarse SAND, some fine to coarse Gravel, little Silt		3	
3									
4	S-3	24/7	4-6	16-22 9-11	13	S-3: Dense, brown, fine to coarse SAND, some fine to coarse Gravel, little Silt Piece of gravel observed in spoon tip.			
5					13				
6	S-4	24/20	6-8	16-26 20-18	47	S-4: Top 13": Brown, fine to coarse SAND, little Silt, little fine to coarse Gravel Bottom 7": Tan to brown, fine SAND, some Silt			
7					60				
8					71				
9					103				
10	S-5	16/4	10-11.3	69-105 100/4"	14	S-5: Top 3": Tan to brown, fine SAND, some Silt Bottom 1": Brown, fine to coarse SAND and fine to coarse GRAVEL, little Silt Piece of Gravel observed in spoon tip.		4	
11					14				
12					27				
13					52				
14	S-6	17/8	14-15.4	33-61 100/5"	27	S-6: Brown, fine to coarse SAND, some fine to coarse Gravel, little Silt, trace Brick			
15					44				
16					39				
17					30				
18					37				
19					40				
20	S-7	24/13	20-22	27-50 96-80	38	S-7: Very dense, brown to dark brown, fine to coarse SAND, little fine to coarse Gravel, little Silt, trace Brick, trace Glass, trace Fiber (Piece of Gravel observed in spoon tip)			
21					30				
22					28				
23					21				
24					42				
25	S-8	24/10	25-27	35-32 29-28	60	S-8: Very dense, brown, fine to coarse SAND, little fine to coarse Gravel, little Silt			
26					57				
27	S-9	24/11	27-29	32-31 23-24	96	S-9: Very dense, brown, fine to coarse SAND, little fine to coarse Gravel, little Silt			
28					63				
29	S-10	24/9	29-31	21-24	59	S-10: Dense, brown, fine to coarse SAND,			

REMARKS

1. SPT conducted using "safety" hammer and 2" diameter split spoon sampler. Cobbles 4"x4" 6x4" (2), and 8"x14" removed from top 6 inches.
2. Borehole advanced from 0 to 4 feet below grade using 2 1/4" I.D. hollow stem augers. Borehole advanced from 4 to 61 feet below grade with 3" flush joint casing and rotary wash methods. Drilling wash water introduced to borehole at 8 feet below grade to completion of boring.
3. No groundwater encountered prior to drilling wash water being introduced to borehole at 8 feet below grade. Groundwater reading performed after introduction of drilling wash water to borehole and may represent perched drilling fluid and may not be representative of actual groundwater conditions.
4. Driller roller bitted ahead prior to driving casing from 10 to 25 feet.

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-9
Page: 2 of 2
File No.: 15.0702100.50
Check: DMB

Depth	Sample Information: No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
				17-8		some fine to coarse Gravel, little Silt	FILL		
31	S-11	24/6	31-33	44-31 16-11	34	S-11: Dense, brown, fine to coarse SAND, some fine to coarse Gravel, some Silt			
32					67				
33	S-12	24/3	33-35	11-10 6-5	48	S-12: Medium dense, brown, fine to coarse SAND, some Silt, little fine to coarse Gravel			
34					37				
35	S-13	24/6	35-37	3-7 19-37	30	S-13: Top 2": Brown, fine to coarse SAND and SILT, little fine to coarse Gravel Bottom 4": Brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt		5	
36					41				
37	S-14	6/6	37-37.5	100/6"	34	S-14: Brown, fine to coarse SAND, little Gravel, trace Silt (Piece of Gravel observed in spoon tip.)	37' TILL		
38					189				
39					310				
40	S-15	4/1	40-40.3	100/4"	450	S-15: Brown, fine to coarse SAND and fine to coarse GRAVEL, little Silt			
41					77				
42					111				
43					74				
44					112				
45	S-16	10/4	45-45.8	105-100/4"	82	S-16: Brown, fine to coarse SAND, some Silt, little fine Gravel			
46					64				
47					44				
48					50				
49					79				
50	S-17	10/8	50-50.8	99-100/4"	83	S-17: Brown, fine to coarse SAND, some Silt, little fine Gravel			
51					83				
52					107				
53					69				
54					82				
55	S-18	24/16	55-57	60-67 72-39	82	S-18: Very dense, brown, fine SAND and SILT, trace fine Gravel			
56					54				
57					42				
58					67			6	
59					262		59' WEATHERED BEDROCK		
60	S-20	2/1	61-61.2	100/2"	309/1"	S-20: Red-brown WEATHERED ROCK			
	S-19	2/1	60-60.2	100/2"		S-19: Red-brown WEATHERED ROCK			
61						End of Exploration at 61.2'	61.2'	7	
62									
63									
64									

REMARKS

5. Driller roller bitted ahead prior to driving casing from 35 to 61 feet. Possible obstructions 37 to 40 feet.
6. Driller noted change in drilling effort at 58.5 to 59 feet.
7. Borehole tremie grouted to ground surface with 1 tub bentonite/cement grout (~30 gallons/tub) upon completion. (Approximately 30 gallons actual vs 30 gallons theoretical.)

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-9

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-10
Page: 1 **of** 3
File No.: 15.0702100.50
Check: DMB

Contractor: A&A Drilling, LLC
Foreman: A. Augustine
Logged by: R. House
Date Start/Finish: 1-26-10 / 2-1-10
Boring Location: See Plan
GS Elev.: 99'± **Datum:** NAVD88

	Auger/ Casing	Sampler
Type:	HSA/Steel	S.S.
I.D.:	2-1/4"/3"	2" O.D.
Hammer Wt.:	300 lbs.	140 lb.
Hammer Fall:	24"	30"
Other:		NX Core

GROUNDWATER READINGS

Date	Time	Depth	Casing	Stab
1/27/10	0735	11'	15'	16 hours
1/28/10	0740	18.5'	55'	16.5 hours
2/1/10	0725	18'	35'	2.5 days
2/1/10	1235	14.5'	55'	45 min.

Depth	Sample No.	Pen./ Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/ Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
	S-1	24/2	0-2	6-13 16-16		S-1: Medium dense, dark brown, fine to coarse GRAVEL, little fine to coarse Sand, trace Organics, trace Silt	ROADWAY MATERIAL 0.9' FILL	1	None
1								2	
2	S-2	24/8	2-4	5-7 12-15		S-2: Medium dense, brown, fine to coarse SAND, some Silt, little fine to coarse Gravel, trace Organics		3	
3									
4	S-3	24/10	4-6	8-15 10-20	11	S-3: Medium dense, brown, fine to coarse SAND and fine to coarse GRAVEL, little Silt			
5					33				
6	S-4	24/17	6-8	23-23 28-19	46	S-4: Top 14": Brown to red-brown, fine to coarse SAND and fine to coarse GRAVEL, some Silt			
7					90	Bottom 3": Gray, fine SAND, some Silt			
8	S-5	24/10	8-10	34-33 38-42	39	S-5: Very dense, gray-brown, fine SAND, some Silt, trace fine Gravel			
9					147				
10					21			4	
11					28			5	
12					44				
13					61				
14					200				
15	S-6	24/10	15-17	73-68 50-57	32	S-6: Very dense, gray-brown, fine to coarse SAND, some Silt, little fine Gravel, trace Brick			
16					34				
17					39				
18					40				
19					64				
20	S-7	24/12	20-22	41-46 36-21	72	S-7: Very dense, gray-brown to red-brown, fine to coarse SAND and fine to coarse GRAVEL, little Silt (Piece of gravel observed in spoon tip.)			
21					46				
22					64				
23					48				
24					48				
25	S-8	24/8	25-27	13-9 9-8	38	S-8: Medium dense, brown, fine to coarse SAND, some Silt, little fine Gravel			
26					46				
27	S-9	24/10	27-29	3-5 7-6	46	S-9: Medium dense, brown, fine to coarse SAND, some Silt, little fine Gravel			
28					49				
29	S-10	24/6	29-31	7-22	60	S-10: Dense, brown to red-brown, fine to			

REMARKS

1. SPT conducted using "safety" hammer and 2" diameter split spoon sampler.
2. Borehole advanced from 0 to 4 feet below grade using 2-1/4 I.D. hollow stem augers. Borehole advanced from 4 to 57 feet below grade with 3" flush joint casing and rotary wash methods. Drilling wash water introduced to borehole at 8 feet below grade to completion of boring.
3. No groundwater encountered prior to introduction of drilling wash water at 8 feet below grade. Groundwater readings above 18 feet likely perched drill fluid and not indicative of actual groundwater. Groundwater reading performed after introduction of drilling wash water to borehole and may represent perched drilling fluid and may not be representative of actual groundwater conditions.
4. Driller roller bitted ahead, prior to driving casing from 10 to 25 feet.
5. Additional groundwater readings were taken on 1/26/10 and 1/27/10 with minimal stablization periods. Groundwater was measured 6 feet below ground surface on 1/26/10 (casing 15 feet below ground surface). Groundwater measured 18 feet below ground surface on 1/27/10 (casing 55 feet below ground surface).

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-10

Depth	No.	Pen./ Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/ Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
				17-17	61	coarse SAND and fine to coarse Gravel, trace Silt (Piece of gravel observed in spoon tip.)	FILL		
31	S-11	10.5/5	31-31.9	14-100/4.5"	56	S-11: Brown, fine to coarse SAND, some fine to coarse Gravel, trace Silt (Piece of gravel observed in spoon tip.)		6	
32					37				
33					40				
34					76				
35	S-12	24/8	35-37	30-42 55-49	61	S-12: Very dense, brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt (Piece of gravel observed in spoon tip.)			
36					40				
37					59				
38					127		38.5' SAND AND GRAVEL (TILL)		
39					193				
40	S-13	10/7	40-41.8	96-100/4"	120	S-13: Brown, fine to coarse SAND, some fine to coarse Gravel, trace Silt			
41					260				
42					275				
43					350				
44					440				
45	S-14	10/7	45-45.8	73-100/4"	75	S-14: Brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt			
46					50				
47					184				
48					95				
49					500				
50	S-15	6/2	50-50.5	125/6"	140	S-15: Brown, fine to coarse SAND, little fine to coarse Gravel, little Silt			
51					67			7	
52					68				
53					63				
54					134				
55	S-16	6/5	55-55.5	110/6"	170	S-16: Brown, fine to coarse SAND, little fine to coarse Gravel, little Silt			
56					500		56' WEATHERED SHALE		
57								8	
58								9	
59	S-17	1/0	59.9-60	100/1"		S-17: No sample obtained. Shale fragments in spoon tip.			
60	CR-1	60/54	60-65	10:00		CR-1: Top 9": Soft, moderately severe to very severe weathering, medium grained, gray SANDSTONE with horizontal to sub-horizontal, iron-oxide stained joints/fractures		10	
61				6:15		Bottom 45": Medium, moderate to slightly weathered, fine-grained, red-brown SANDSTONE with horizontal to	61' SANDSTONE	11	
62				12:00					
63				9:45					
64				13:00					

REMARKS

6. Shale fragments observed in samples S-10, S-12 and S-13.
7. Driller roller bitted ahead, prior to driving casing from 51 to 57 feet.
8. Casing refusal at 57 feet.
9. Driller noted brief change in washwater color from brown to orange-brown around 58 feet.
10. Washwater briefly changed color to milky-gray at 60.8 feet, turned to red-brown around 61.5 feet.
11. Times represent penetration in min/foot. RQD = Rock Quality Designation.

Depth	Sample Information: No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
66–70	CR-2	60/60	65-70	11:30 13:00 8:45 7:00 5:00		sub-horizontal joints/fractures RQD = 40% CR-2: Soft to moderately hard, moderate weathering, fine grained, red-brown SANDSTONE with horizontal to sub-horizontal, iron-oxide stained joints/fractures with gray Shale transition zones from 66 to 66.7 feet and 67.5 to 68.3 feet RQD = 21%	SANDSTONE 70'	12	
70–99						End of Exploration at 70'		13	

REMARKS

12. Driller increased penetration rate around 66.8 feet. No significant fluid loss during coring.
13. Borehole grouted to ground surface with 1 tub bentonite/cement grout (~30 gallons/tub) upon completion.

GZA GeoEnvironmental, Inc.
Engineers and Scientists

CHICOPEE FALLS LEVEE
CHICOPEE, MASSACHUSETTS

Boring No.: CF-11

File No.: 15.0702100.50
Check: DMB

Contractor: A&A Drilling, LLC
Foreman: A. Augustine
Logged by: R. House
Date Start/Finish: 2-1-10 / 2-4-10
Boring Location: See Plan
GS Elev.: 98'± **Datum:** NAVD88

	Auger/Casing	Sampler
Type:	HSA/Steel	S.S.
I.D.:	2-1/4"/4"	2" O.D.
Hammer Wt.:	300 lbs.	140 lb.
Hammer Fall:	24"	30"
Other:		

GROUNDWATER READINGS

Date	Time	Depth	Casing	Stab
2/2/10	1250	6'	25'	40 min.
2/3/10	0736	14'	31'	16.5 hours
2/3/10	1545	10'	60'	10 min.
2/4/10	0725	10'	60'	15.5 hours
2/4/10	1256	12.5'	75'	45 min.

Depth	No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
	S-1	24/12	0-2	24-30 13-13		S-1: Top 1": Dark brown, fine SAND and SILT, trace Organics Middle 6": Brown, fine to coarse SAND, little fine to coarse Gravel, little Silt Bottom 5": Light brown, fine to medium SAND, some fine to coarse Gravel, little Silt	0.1' TOPSOIL FILL	1 2 3	None
1									
2	S-2	24/11	2-4	27-27 26-16		S-2: Very dense, brown, fine to medium SAND, some Silt, little fine to coarse Gravel, trace Brick			
3									
4	S-3	24/16	4-6	13-33 28-32	59	S-3: Brown, fine to medium SAND, little Silt, little fine Gravel			
5					75				
6	S-4	24/12	6-8	24-25 32-30	97	S-4: Very dense, brown, fine to medium SAND, some fine to coarse Gravel, little Silt			
7					172				
8					193				
9					120				
10	S-5	24/12	10-12	63-66 42-22	41	S-5: Brown, fine to coarse SAND, some Silt, little fine to coarse Gravel		4	
11					31				
12					30				
13					89				
14					200				
15	S-6	24/7	15-17	82-88 63-34	83	S-6: Very dense, brown, fine to coarse SAND and fine to coarse GRAVEL, some Silt		5	
16					47				
17					36				
18					46				
19					90				
20	S-7	24/0	20-22	47-46 54-53	44	S-7: No sample recovered		6	
21					37				
22	S-8	24/0	22-24	41-53 23-22	34	S-8: No sample recovered			
23					50				
24					60				
25	S-9	24/7	25-27	24-37 28-32	44	S-9: Very dense, brown, fine to coarse SAND and fine to coarse GRAVEL, some Silt			
26					41				
27	S-10	24/7	27-29	32-26 19-15	79	S-10: Very dense, brown, fine to coarse SAND, some fine to coarse Gravel, little Silt			
28					49				
29	S-11	24/0	29-31	13-8	40	S-11: No sample recovered			

REMARKS

1. SPT conducted using "safety" hammer and 2" diameter split spoon sampler. Cobbles 3"x4" and 5"x4" removed from top foot.
2. Borehole advanced from 0 to 4 feet below grade using 2-1/4" I.D. hollow stem augers. Borehole advanced from 4 to 75 feet below grade with 4" flush joint casing and rotary wash methods. Drilling wash water introduced to borehole at 8 feet below grade to completion of boring.
3. Groundwater readings taken after introduction of drilling fluid and measured groundwater readings likely perched drilling fluid and not indicative of actual groundwater.
4. Driller roller bitted ahead, prior to driving casing from 10 to 29 feet.
5. Shale fragments observed in sample S-6.
6. Driller noted little to no resistance when removing spoon S-7 from sampling depth. Possible that cobble was encountered and advanced down by spoon based on blows and lack of recoveries.

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Boring No.: CF-11

Depth	Sample Information: No.	Pen./ Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/ Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
				6-5	30		FILL		
31	S-12	24/0	31-33		71	S-12: No sample recovered		7	
32	S-13	10/18	31-31.8		73	S-13: Brown, fine to coarse SAND, some Silt, little fine Gravel		8 9	
33	S-14	24/6	33-35	31-15 10-16	75	S-14: Medium dense, brown, fine to coarse SAND and fine to coarse GRAVEL, trace Silt	33' SAND AND GRAVEL		
34					60				
35	S-15	24/0	35-37	19-22 22-29	99	S-15: No sampled recovered			
36					120				
37	S-16	24/3	37-39	32-20 15-13	123	S-16: Dense, brown, fine to coarse GRAVEL, some fine to coarse Sand, little Silt			
38					91				
39					350/6"				
40	S-17	24/12	40-42	28-31 28-24	88	S-17: Very dense, brown, fine to coarse SAND, some fine to coarse Gravel, little Silt (Piece of gravel observed in spoon tip.)			
41					68				
42					76				
43					77				
44					143				
45	S-18	24/16	45-47	31-31 51-69	74	S-18: Very dense, brown, fine to coarse SAND, some Silt, little fine Gravel			
46					69				
47					75				
48					91				
49					300				
50	S-19	3/1	50-50.3	100/3"	251	S-19: Brown, fine to coarse SAND and fine to coarse GRAVEL, little Silt		10	
51					187				
52					135				
53					75			11	
54					87				
55	S-20	24/9	55-57	21-25 26-30	100	S-20: Top 6": Brown, fine to coarse SAND, some fine to coarse Gravel, little Silt Bottom 3": Brown, CLAY and SILT, little coarse Gravel	56' SILT AND CLAY		
56					103				
57					100				
58					81				
59					116				
60	S-21	24/24	60-62	12-17 20-21	89	S-21: Hard, brown, SILT and CLAY, trace fine Sand Tv = 0.65 tsf		12	
61					72				
62					72				
63					76				
64					93				

REMARKS

7. No recovery of sample S-12. Therefore sample S-13 redrove into other side of borehole. Sample S-12 not conducted in accordance with ASTM D1586. Hammer dropped greater than 30" in attempt to obtain recovery. Upon retrieval, playtex liner, inserted in spoon and resampled. Recovery successful. Liner also used in sample S-14.
8. Falling head test conducted over zone between 31 to 35 feet, following sampling.
9. Driller roller bitted ahead, prior to driving casing from 31 to 35 feet and 39.5 to 75 feet. S-17 sampled open hole.
10. Shale fragments observed in sample S-19.
11. Driller noted heavy roller bit resistance at 53 feet.
12. Tv = Field Torvane Shear Strength in tons per square feet (tsf).
13. PP = Pocket penetrometer compressive strength readings in tons per square foot (tsf).

Stratification lines represent approximate boundary between soil types, transitions may be gradual. Water level readings have been made at times and under conditions stated. Fluctuations of groundwater may occur due to other factors than those present at the time measurements were made.

Depth	Sample No.	Pen./Rec. (in.)	Depth (Ft.)	Blows (/6")	Casing Blows/Ft.	Sample Description & Classification	Stratum Desc.	Remarks	Equipment Installed
65	S-22	24/24	65-67	19-37 39-82	97	S-22: Hard, brown, Clayey SILT, little fine Sand PP = >4 tsf (Silt)	SILT AND CLAY	13	
66					70				
67					52				
68					66			14	
69					86				
70	S-23	24/24	70-72	22-20 17-21	63	S-23: Hard, brown, SILT and CLAY, trace fine Gravel, trace fine Sand PP = 3.25 tsf Tv = 1 tsf			
71					55				
72					65				
73					69				
74					81				
75	S-24	24/24	75-77	22-14 20-24		S-24: Hard, brown, CLAY and SILT PP = 3.5 tsf Tv = 1.45 tsf			
78							78.5' WEATHERED BEDROCK	15	
80	S-25	1/0.5	80-80.1	100/1"		S-25: Red-brown, fine to coarse GRAVEL (WEATHERED ROCK), little fine to coarse Sand, little Silt End of Exploration at 80.1'	80'	16	

Depth scale: 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99

REMARKS

14. Driller noted rod chatter at 68 feet.
15. Driller noted heavy roller bit resistance at 78 feet. Roller bitted additional two feet and sampled S-25.
16. Borehole tremie grouted to ground surface with 1 1/2 tubs bentonite/cement grout (~30 gallons/tub) upon completion.

SECTION A-3.3

GEOTECHNICAL LABORATORY RESULTS

LABORATORY TESTING DATA SHEET

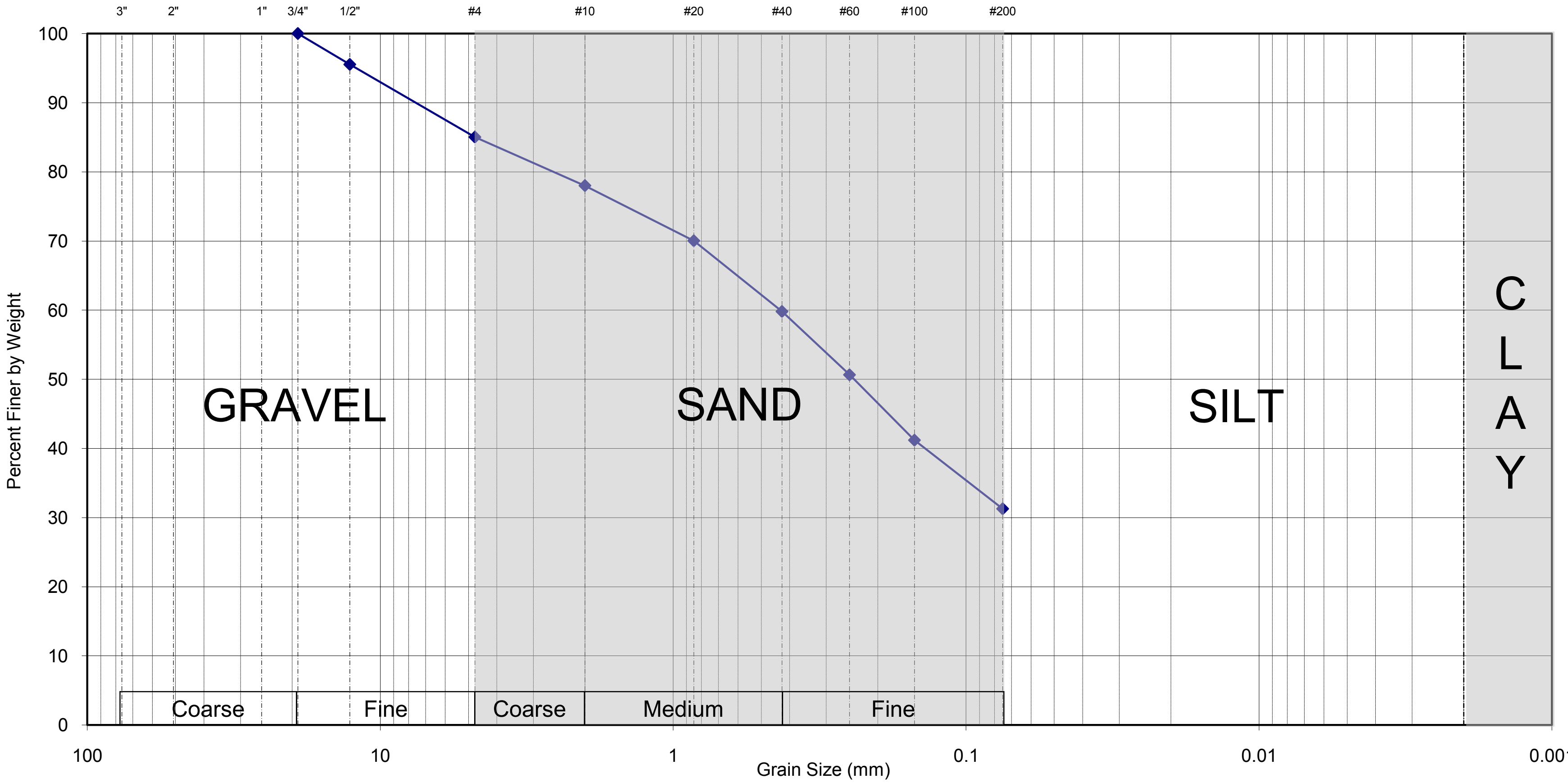
Project Name: Chicopee Flood Control Works
Location: Chicopee, MA
Reviewed By:

Project No.: 15.0702100.50
Assigned By: R. House

Project Engineer: M. Taylor/A. Bjarngard
Report Date: 3/24/2010
Date Reviewed: 3/24/2010

				Identification Tests							Strength Tests						
Boring No.	Sample No.	Depth ft.	Lab No.	Water Content %	LL %	PL %	Sieve -200 %	Hyd -2μ %	ORG %	Dry unit wt. pcf	Perme-ability cm/sec	Torvane or Type Test	$\bar{\sigma}_c$ psf	Failure Criteria	$\sigma_1 - \sigma_3$ or τ psf	Strain %	Laboratory Log and Soil Description
CF-3	S-2	2-4	25				31										Brown f-c SAND some Silt, little fine Gravel (SM)
CF-3	S-5	10-12	26				19										Brown f-c SAND some f-c Gravel, little Silt (SM)
CF-3	S-7	20-22	27				15										Brown f-c SAND some fine Gravel, little Silt (SM)
CF-3	S-9	27-29	28				15		5.4								Brown f-c SAND, little Silt little fine Gravel (trace Org.) (SM)
CF-5	S-2	2-4	29				28										Brown f-c SAND some Silt, some f-c Gravel (SM)
CF-5	S-5	10-12	30				22										Brown f-c SAND some f-c Gravel, some Silt (SM)
CF-5	S-11	28-30	31				15										Brown f-c SAND little Silt, little fine Gravel (SM)
CF-6	S-5	10-12	32				25										Brown f-c SAND some Silt, little fine Gravel (SM)
CF-7	S-5	10-12	33				28										Brown f-c SAND some Silt, little f-c Gravel (SM)
CF-7	S-12	35-37	34				10										Brown f-c GRAVEL and f-c SAND, little Silt (GW-GM)
CF-11	S-3	4-6	35				26										Brown f-m SAND little Silt, little fine Gravel (SM)
CF-11	S-5	10-12	36				24										Brown f-c SAND some Silt, little f-c Gravel (SM)
CF-11	S-13	31-33	37				28										Brown f-c SAND some Silt, little fine Gravel (SM)

U.S. STANDARD SIEVE AND HYDROMETER

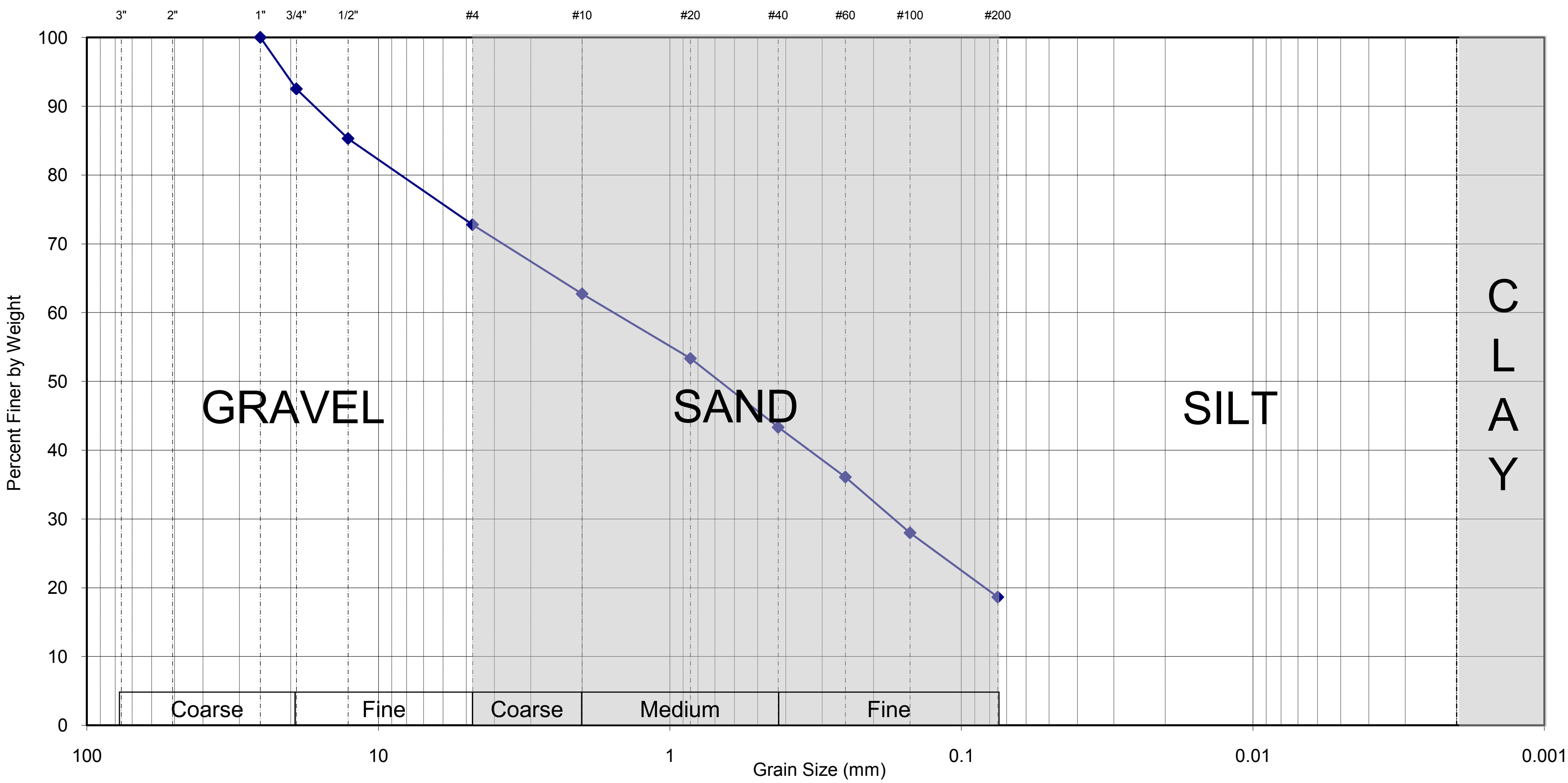


Gravel	Sand	Fines
15.0%	53.7%	31.3%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
25	CF-3	S-2	2-4'	Brown f-c SAND, some Silt, little fine Gravel (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50
Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

U.S. STANDARD SIEVE AND HYDROMETER

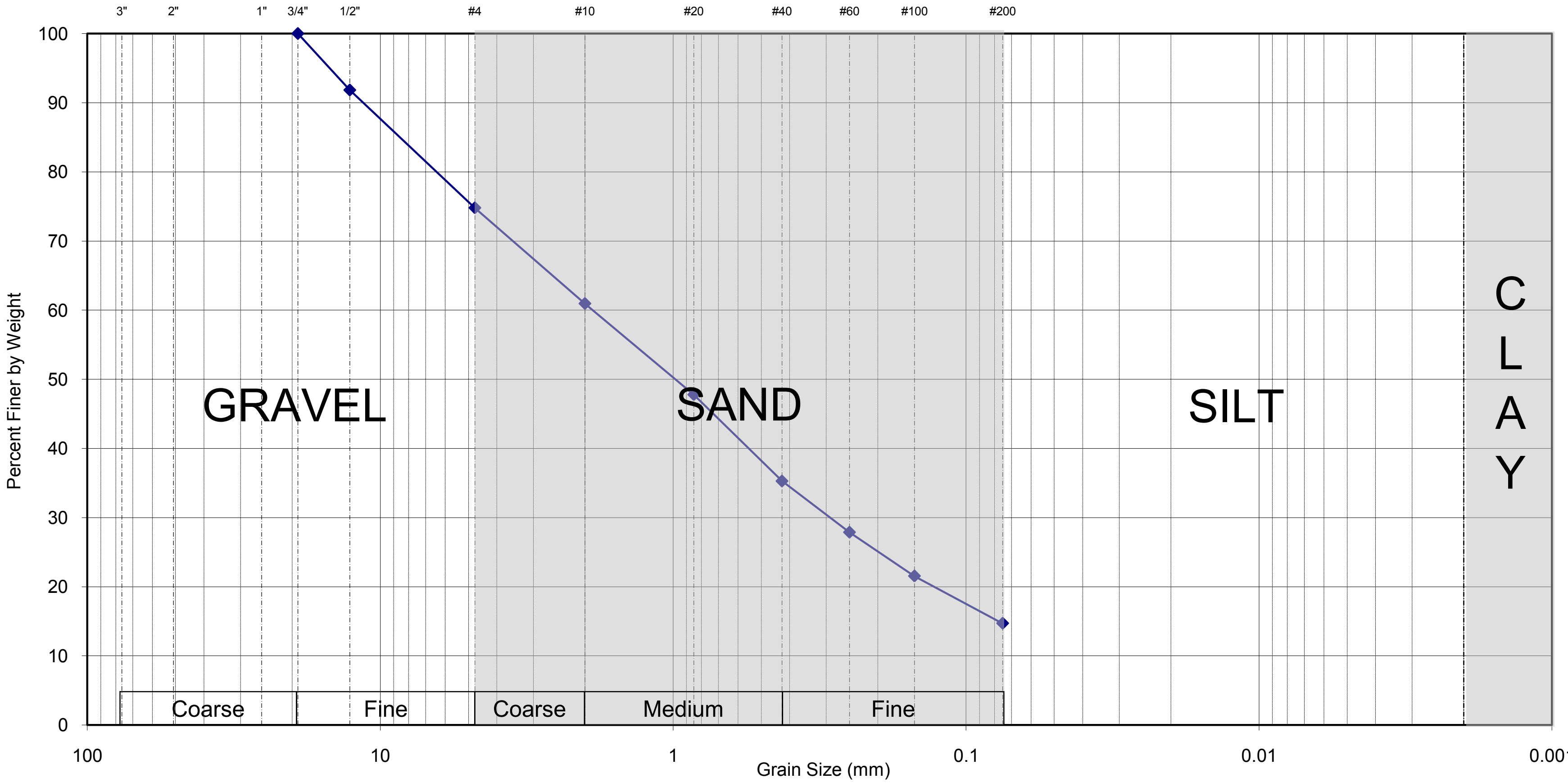


Gravel	Sand	Fines
27.2%	54.1%	18.6%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
26	CF-3	S-5	10-12'	Brown f-c SAND, some f-c Gravel, little Silt (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50
Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

U.S. STANDARD SIEVE AND HYDROMETER

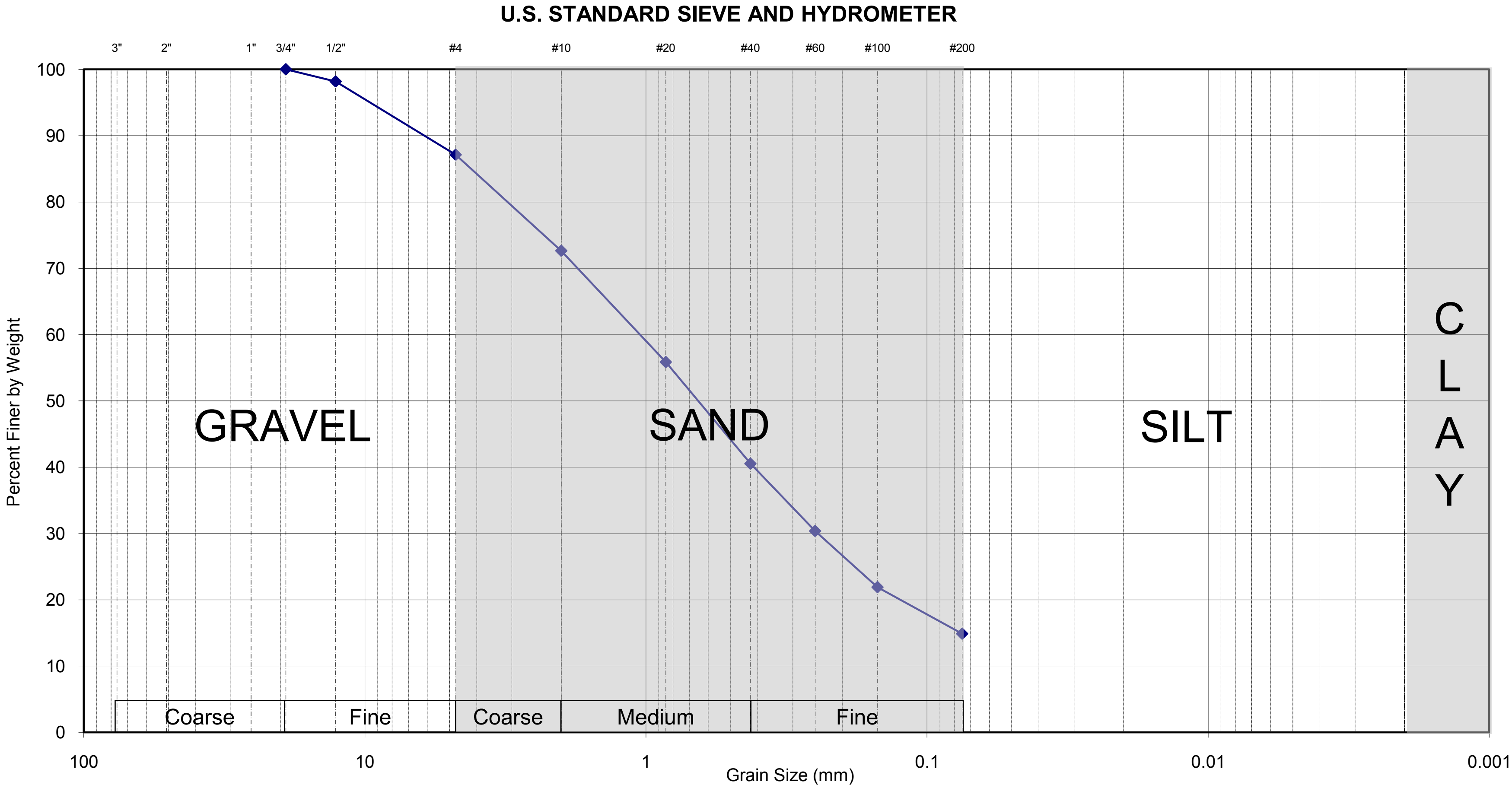


Gravel	Sand	Fines
25.2%	60.1%	14.7%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
27	CF-3	S-7	20-22'	Brown f-c SAND, some fine Gravel, little Silt (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by:	MST/PEC	Date:	3/18/10
Reviewed by:	MBP	Date:	3/24/10



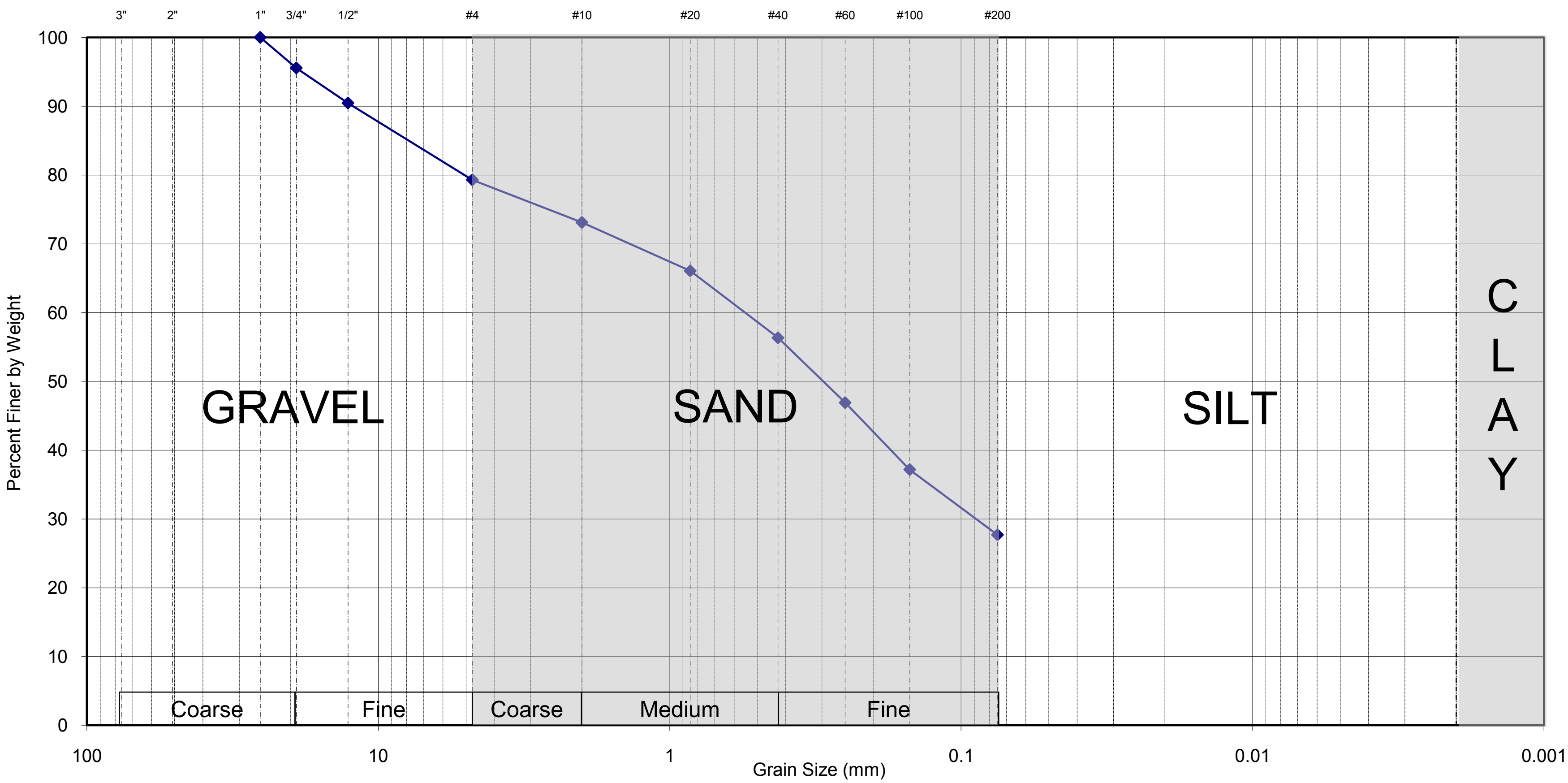
Gravel	Sand	Fines
12.9%	72.2%	14.9%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
28	CF-3	S-9	27-29'	Brown f-c SAND, little Silt, little fine Gravel (tr. Organics) (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by:	MST/PEC	Date:	3/18/10
Reviewed by:	MBP	Date:	3/24/10

U.S. STANDARD SIEVE AND HYDROMETER

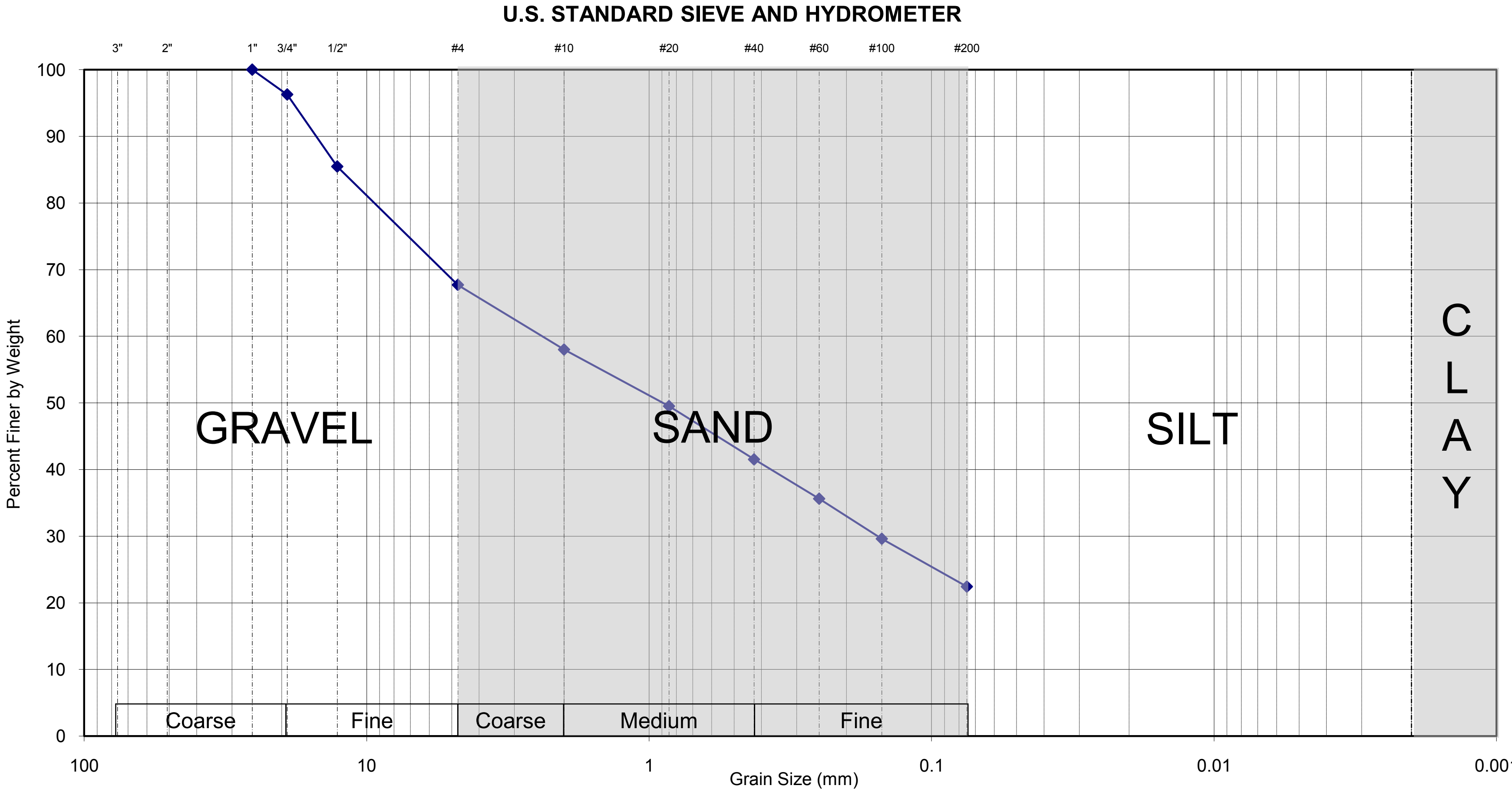


Gravel	Sand	Fines
20.7%	51.6%	27.7%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
29	CF-5	S-2	2-4'	Brown f-c SAND, some Silt, some f-c Gravel (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

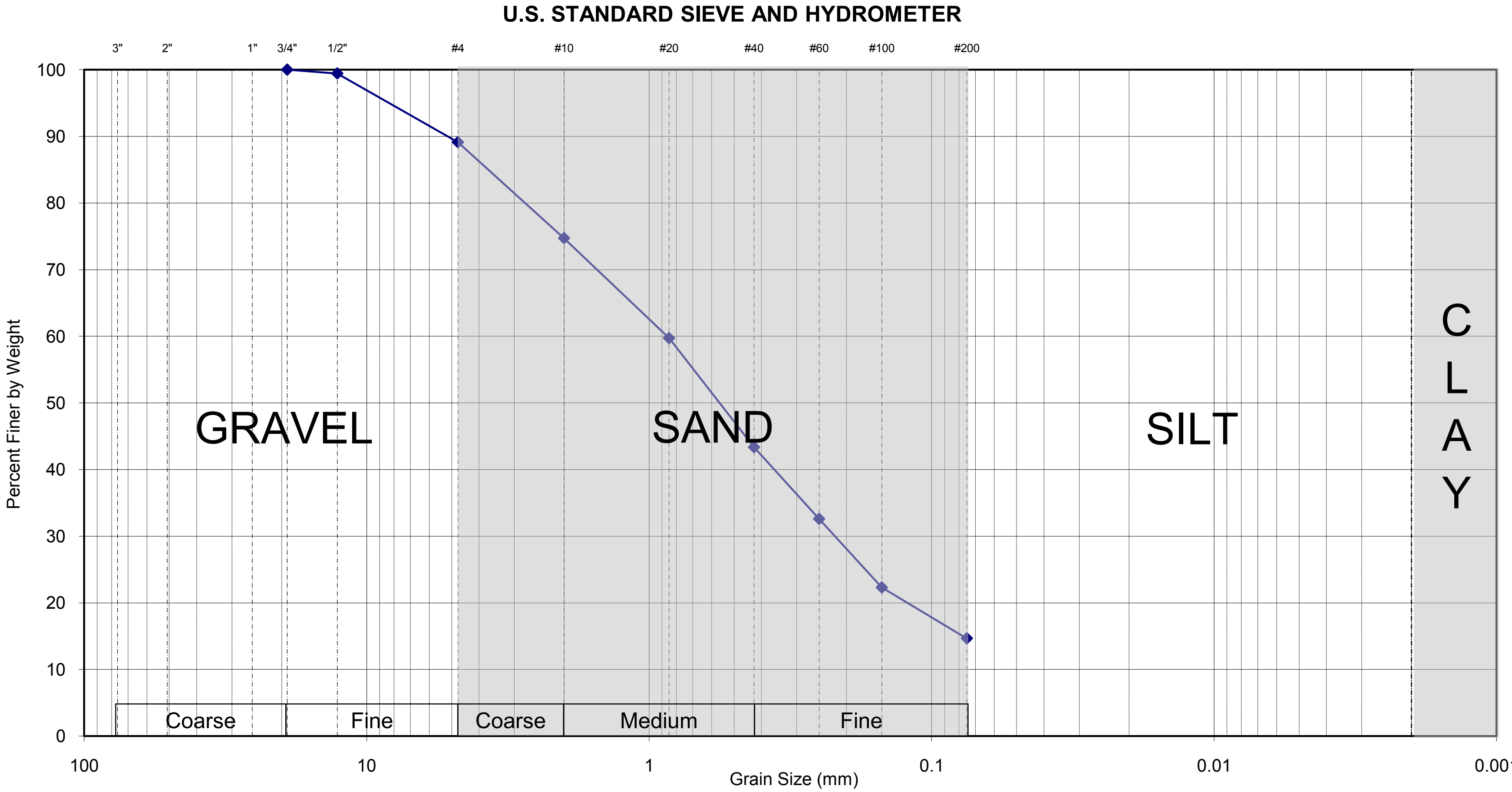


Gravel	Sand	Fines
32.3%	45.3%	22.4%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
30	CF-5	S-5	10-12'	Brown f-c SAND, some f-c Gravel, some Silt (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

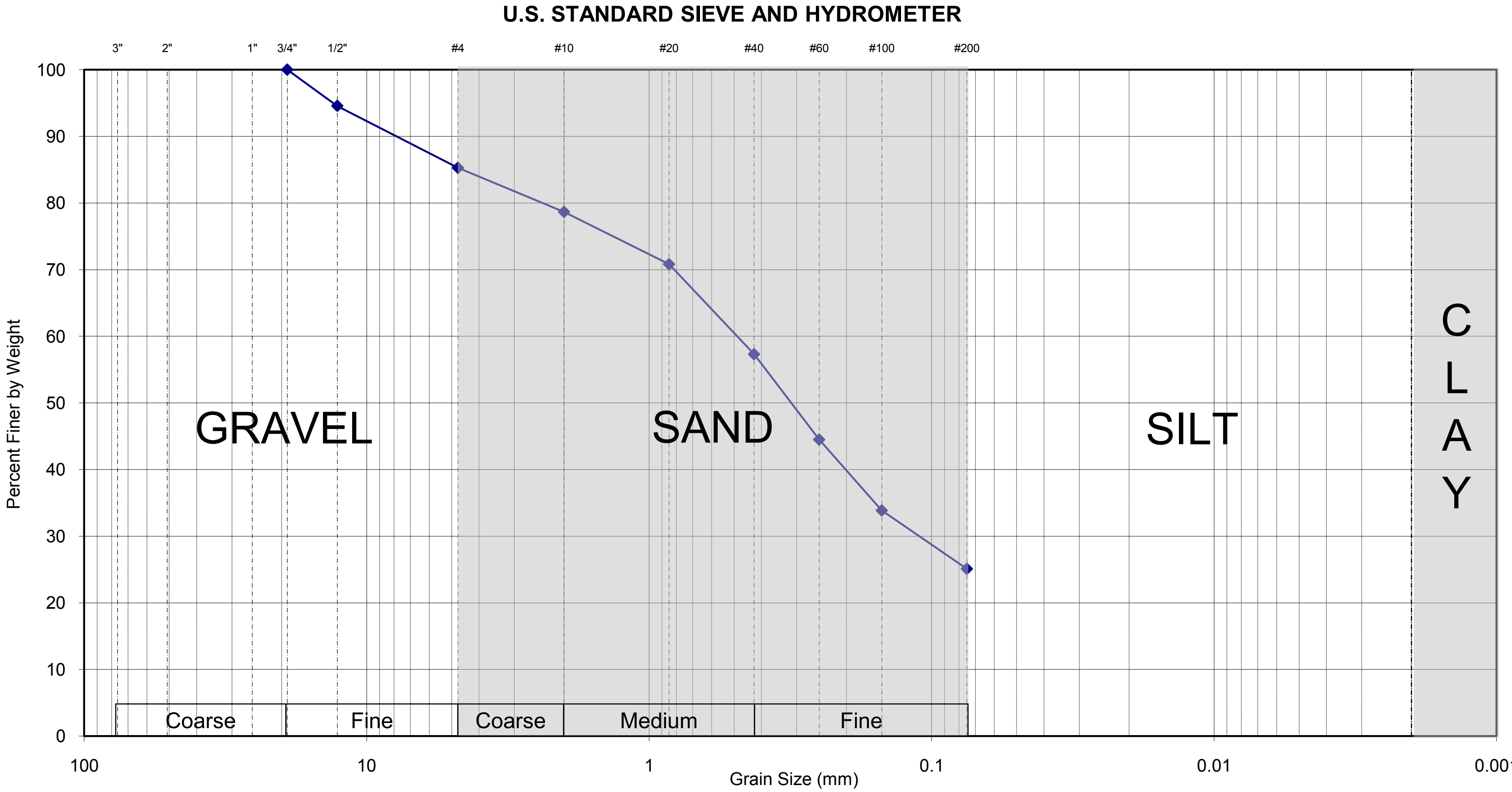


Gravel	Sand	Fines
10.9%	74.5%	14.7%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
31	CF-5	S-11	28-30'	Brown f-c SAND, little Silt, little fine Gravel (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10



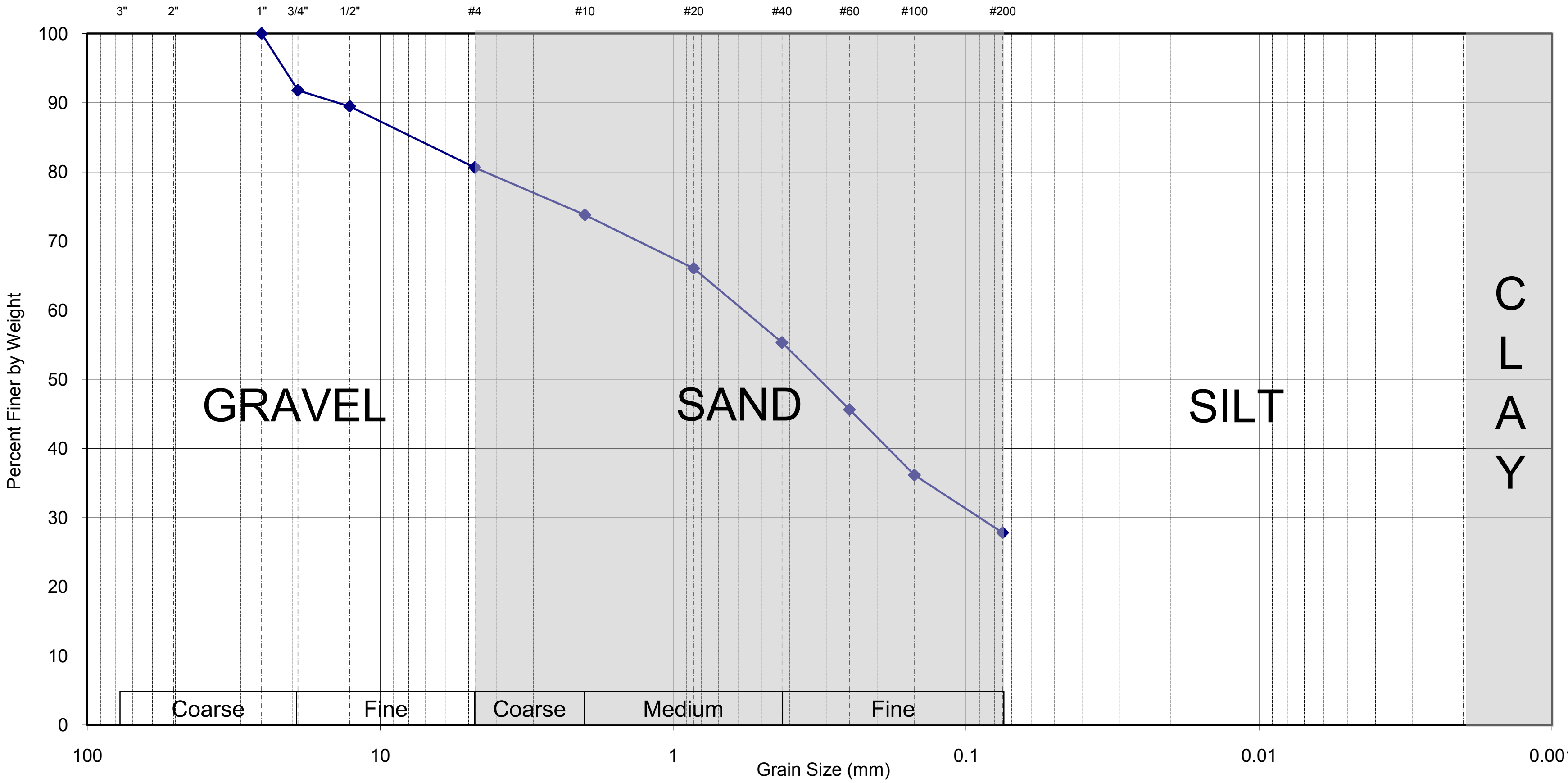
Gravel	Sand	Fines
14.7%	60.2%	25.1%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
32	CF-6	S-5	10-12'	Brown f-c SAND, some Silt, little fine Gravel (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

U.S. STANDARD SIEVE AND HYDROMETER



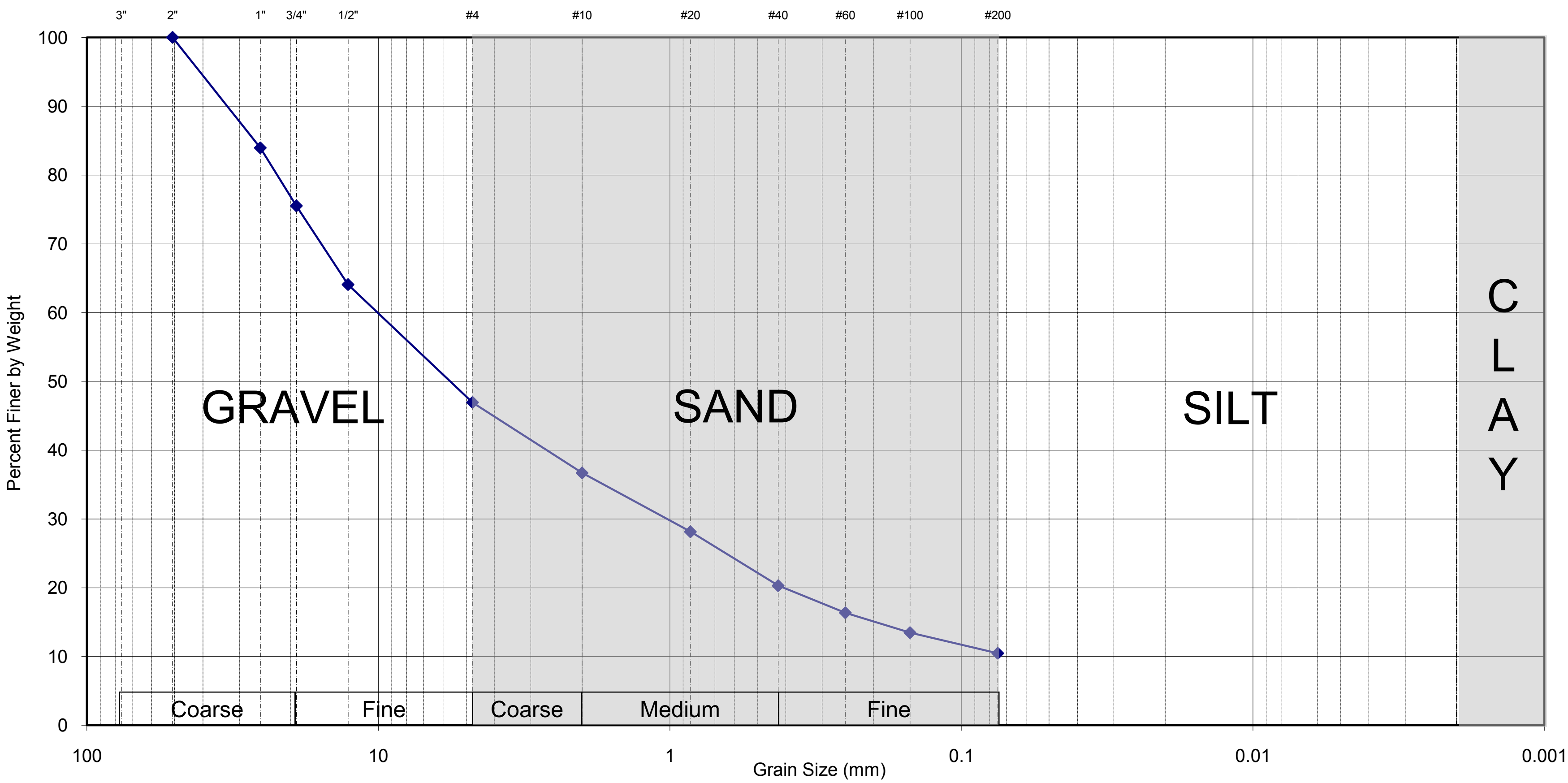
Gravel	Sand	Fines
19.4%	52.8%	27.8%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
33	CF-7	S-5	10-12'	Brown f-c SAND, some Silt, little f-c Gravel (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

U.S. STANDARD SIEVE AND HYDROMETER

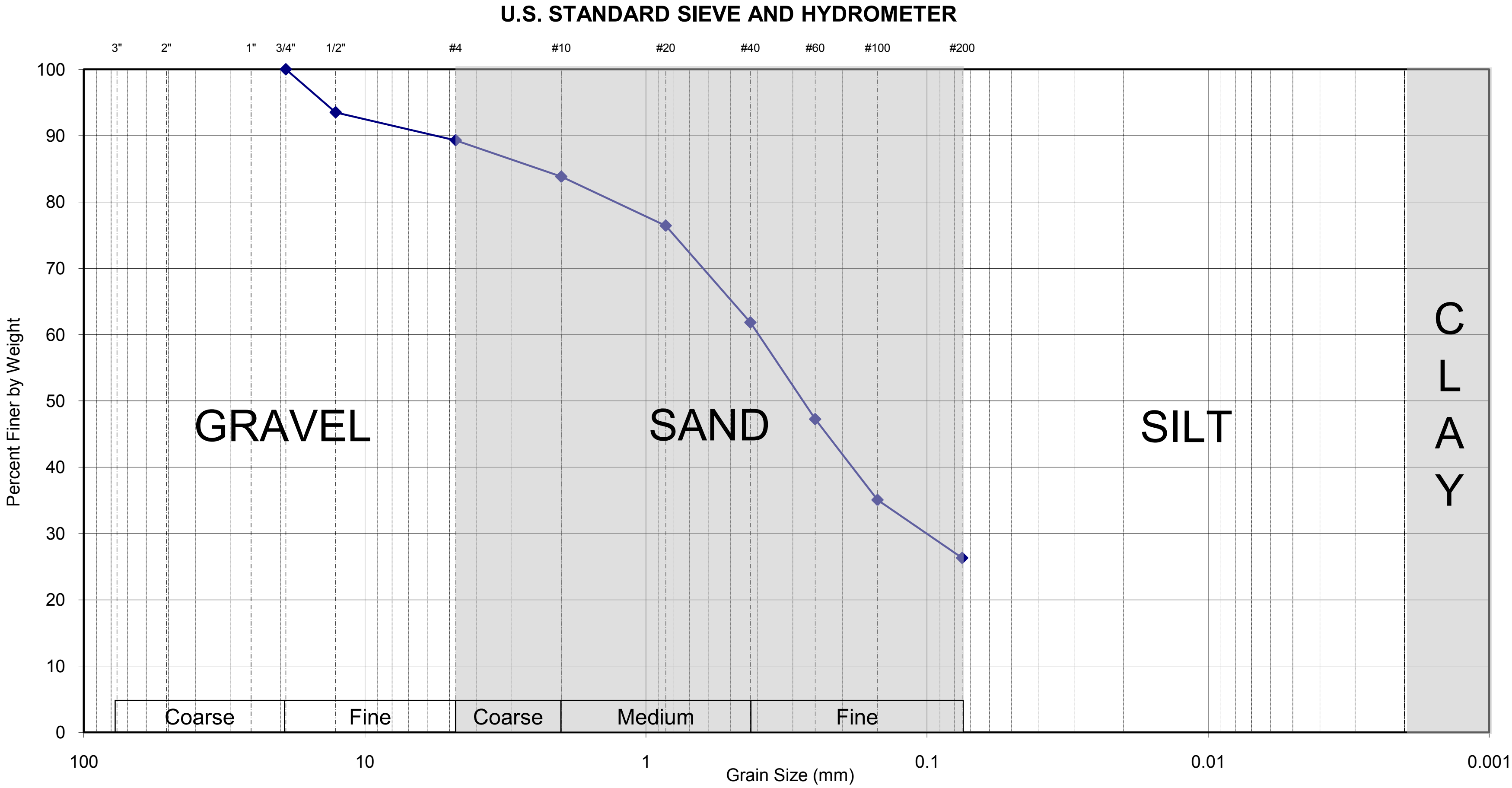


Gravel	Sand	Fines
53.1%	36.5%	10.5%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
34	CF-7	S-12	35-37'	Brown f-c GRAVEL and f-c SAND, little Silt (GW-GM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

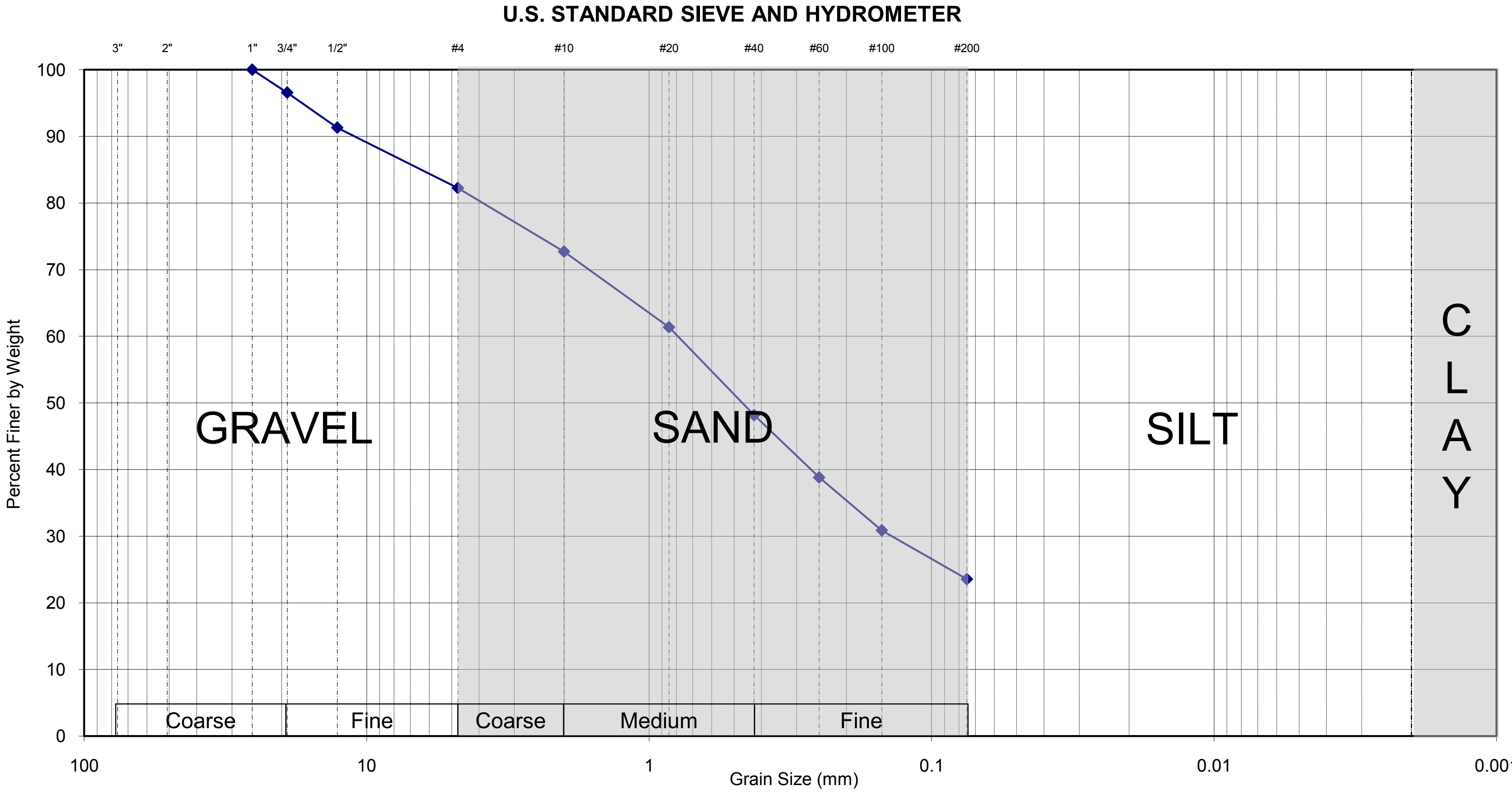


Gravel	Sand	Fines
10.7%	63.0%	26.3%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
35	CF-11	S-3	4-6'	Brown f-m SAND, some Silt, little fine Gravel (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by:	MST/PEC	Date:	3/18/10
Reviewed by:	MBP	Date:	3/24/10

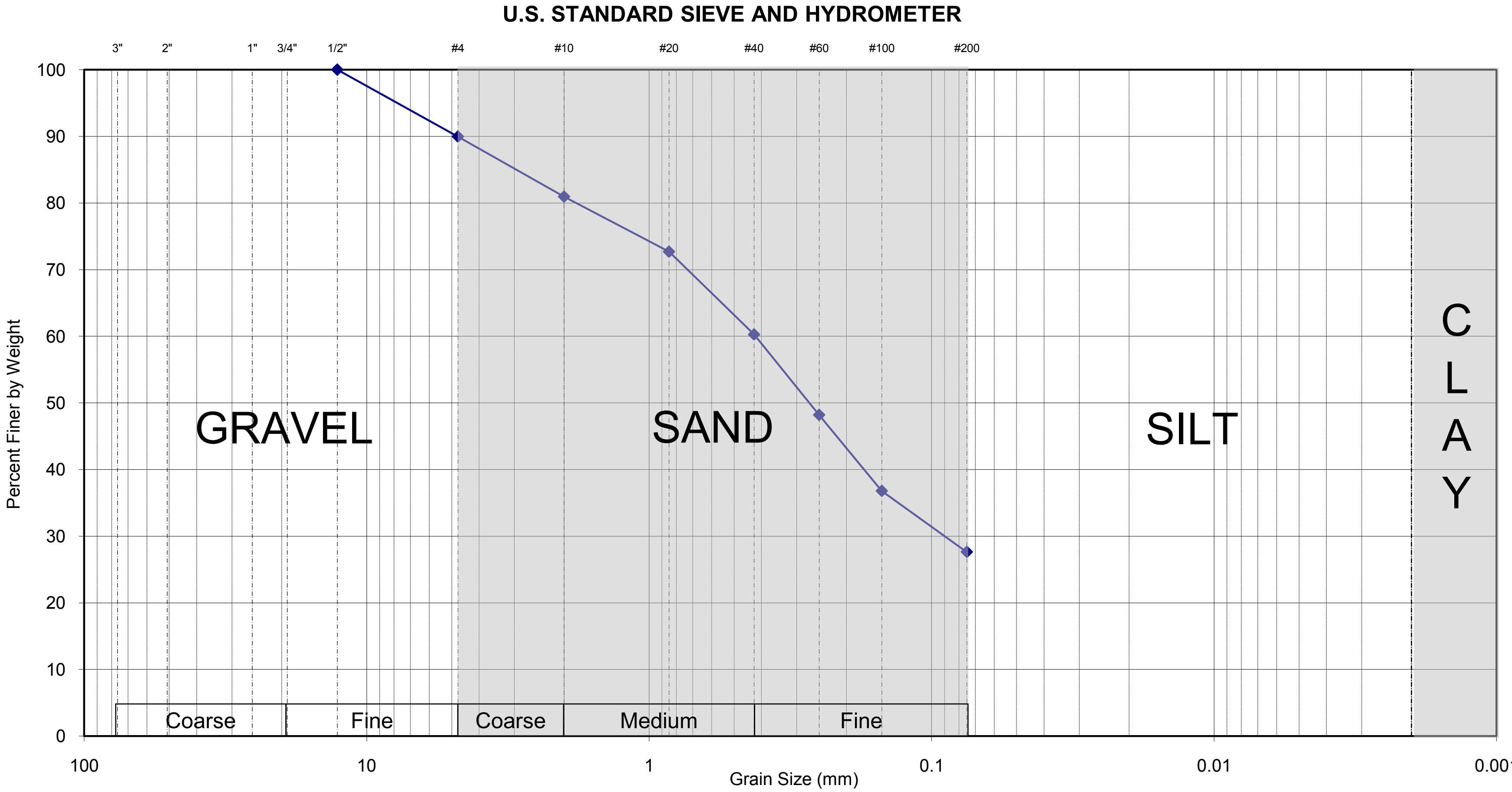


Gravel	Sand	Fines
17.8%	58.7%	23.6%

Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
36	CF-11	S-5	10-12'	Brown f-c SAND, some Silt, little f-c Gravel (SM)				

Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10



Gravel	Sand	Fines
10.0%	62.3%	27.6%

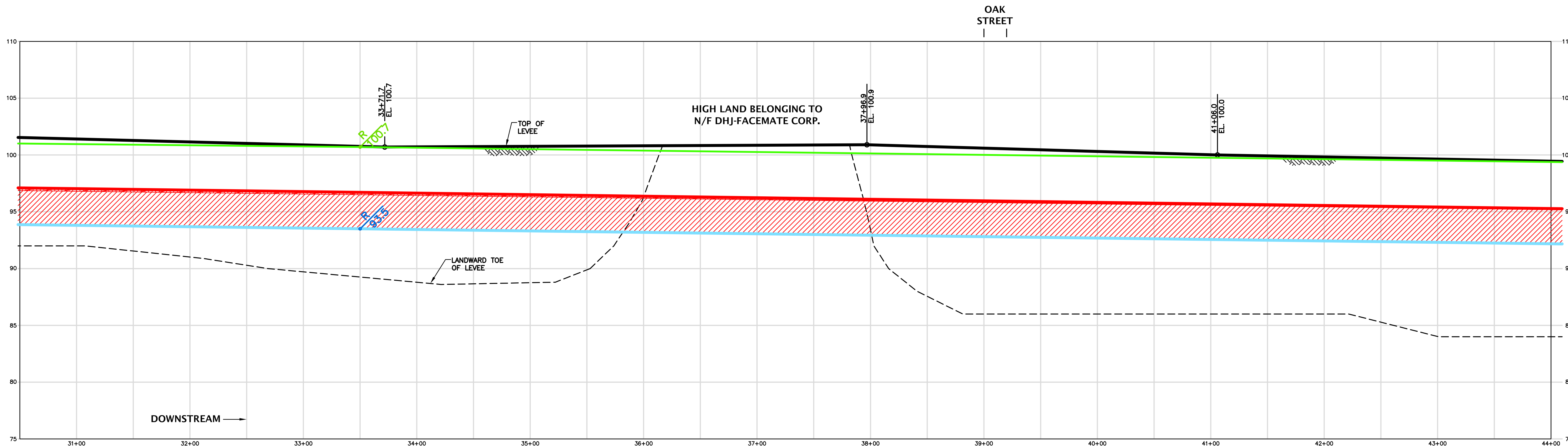
Lab #	Exploration	Sample	Depth (ft)	Description	WC	LL	PL	PI
37	CF-11	S-13	31-33'	Brown f-c SAND, some Silt, little fine Gravel (SM)				

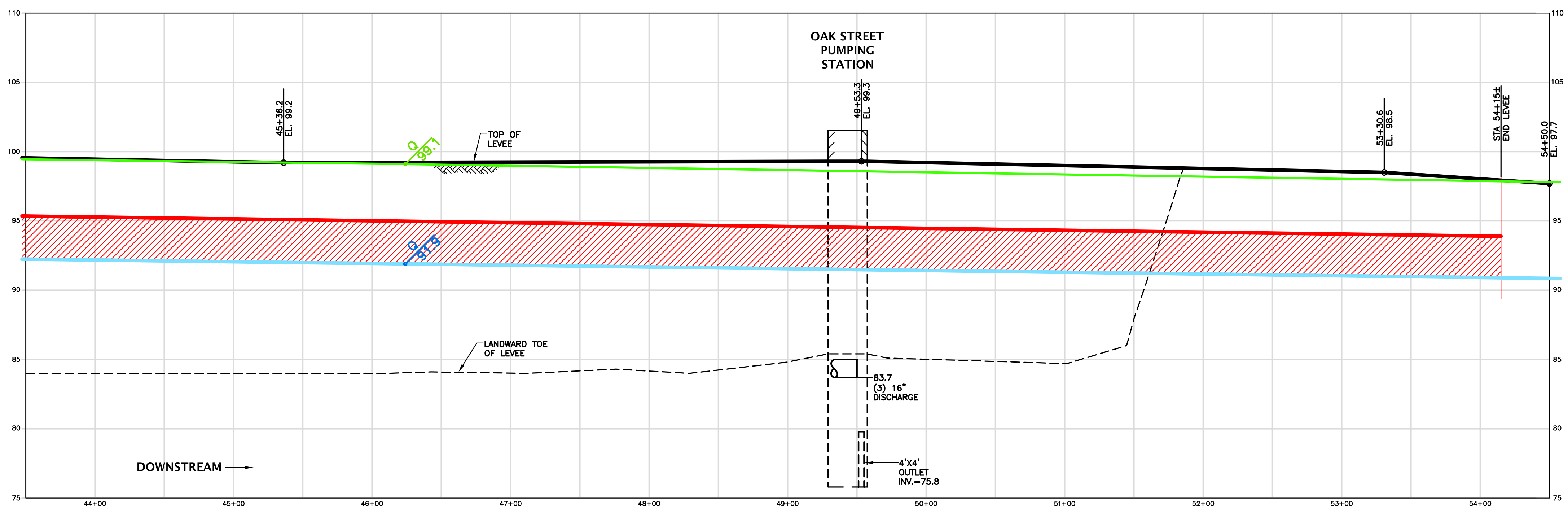
Chicopee Flood Control Works
Chicopee, MA
GZA File # 15.0702100.50

Tested by: MST/PEC Date: 3/18/10
Reviewed by: MBP Date: 3/24/10

APPENDIX A-4.1

FREEBOARD



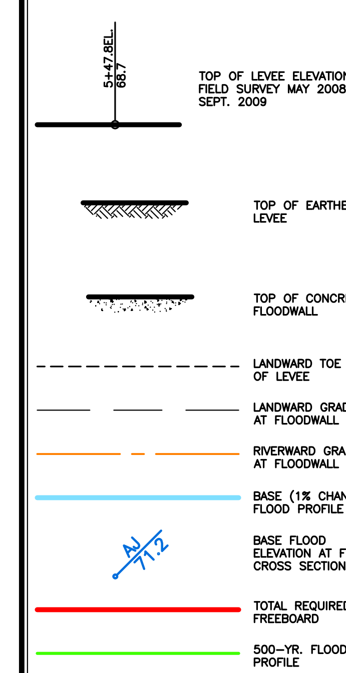


GENERAL NOTES:

1. ALL ELEVATIONS SHOWN ARE REFERENCED TO NORTH AMERICAN VERTICAL DATUM OF 1988 (NAVD88).
2. TOP OF LEVEE INFORMATION OBTAINED BY HERITAGE SURVEYS, INC., OCTOBER-DECEMBER, 2009, AND AS SHOWN ON THE FLOOD CONTROL SYSTEM "AS-BUILT" DRAWINGS, DECEMBER, 2009.
3. STATIONING REFERS TO THE FLOOD CONTROL SYSTEM LEVEE CENTERLINE AS DEPICTED ON THE ORIGINAL U.S. ARMY CORPS OF ENGINEERS CONSTRUCTION DRAWINGS OR RECORD DRAWINGS, AS AVAILABLE.
4. BASE FLOOD (1-PERCENT-ANNUAL CHANCE) AND 500-YEAR FLOOD PROFILE INFORMATION WAS OBTAINED FROM THE PRELIMINARY FLOOD INSURANCE STUDY, HAMPDEN COUNTY, MASSACHUSETTS, FIS # 25013CV001, FEDERAL EMERGENCY MANAGEMENT AGENCY, APRIL 30, 2009.

No.	DATE	REVISION	BY

LEGEND



FREEBOARD CRITERIA:

[AS PER 44 CFR 65.10(b)(1)(i)]

CRITERION #1: PROVIDE MINIMUM FREEBOARD OF THREE FEET ABOVE THE WATER-SURFACE LEVEL OF THE BASE (1% CHANCE) FLOOD

CRITERION #2: AN ADDITIONAL ONE FOOT ABOVE THE MINIMUM IS REQUIRED WITHIN 100 FEET IN EITHER SIDE OF STRUCTURES (SUCH AS BRIDGES) RIVERWARD OF THE LEVEE OR WHEREVER THE FLOW IS CONSTRICTED.

CRITERION #3: AN ADDITIONAL ONE-HALF FOOT ABOVE THE MINIMUM AT THE UPSTREAM END OF THE LEVEE, TAPERING TO NOT LESS THAN THE MINIMUM AT THE DOWNSTREAM OF THE LEVEE, IS ALSO REQUIRED.

SHEET TITLE:

CHICOPEE FALLS SYSTEM STA 31+00 TO STA 54+15± (HIGH GROUND)

PROJECT AND LOCATION:

FREEBOARD EVALUATIONS CITY OF CHICOPEE, MA FLOOD CONTROL WORKS

PREPARED FOR:

CITY OF CHICOPEE DEPARTMENT OF PUBLIC WORKS CHICOPEE MA

BAYSTATE ENVIRONMENTAL CONSULTANTS INC.
A GZA Company

Civil Engineers – Planners – Environmental Scientists

296 North Main Street
East Longmeadow, MA 01028

120 Mountain Avenue
Bloomfield, CT 06002

BEC PROJECT No.	15.0702100.40
SCALE	VERT. 1"=10' HOR. 1"=100'
DATE	JUNE, 2010
DRAWN BY	EDM
CHECKED BY	TEJ
SHEET No.	2 OF 2 SHTS

APPENDIX A-4.2

CLOSURES

Item	Location	Station	Description	Shown on USACE	Observed in field?	Comments	O&M MANUAL INFO.
1	Chicopee Falls	36+10	48" diam. RCP pressure drain with gate structure	YES	YES	Previously utilized by US Rubber Co. Gate located near Main Street in chamber operated and maintained by CIty	Sluice gates formerly operated for flushing lower level drainage system of former U.S. Rubber Co. consist of 48" diam. gravity discharge conduit, 24" sluice gate and a 48" sluice gate; under both normal & flood conditions, the 48" gate should remain wide open & the 24" tightly closed. During a localized storm causing local runoff not accompanied by a rise in the river level above el. 90.0, the 24" gate should be opened completely and slowly closing the 48" gate to flush 24" diam. bypass pipe.
2	Chicopee Falls	36+10	24" diam. RCP storm drain connected to drop inlet	YES	YES	Outfall shares same headwall as 48" diam. RCP. Pipe outlets slotted drain near top of levee which is higer than the one percent chance flood elevation.	
3	Chicopee Falls	48+00	30"x30" intake with gate structures on both sides	YES	YES	Previously utilized by U.S. Rubber Co. and no longer in use. Gate closed and pumps not operating.	See below * U.S. Rubber Co. no longer in operation. Gate is to be maintained in the CLOSED position.
4	Chicopee Falls	52+50	30" diam. RCP pressure drain	YES	YES	Outfall is from an area higher than the one percent chance flood elevation.	

* From Section VI of *Operation and Maintenance Manual,* USACE, 1984: "6-01. DESCRIPTION - Located at Sta. 48+00 are process water intake (30x30 sluice gate) and intake cooling water structure (30" wafer butterfly valve and 30" gate valve). Wafer butterfly maintains water levels between el. 77 and 79 in existing intake structure. 30" gate valve is, normally open but should be closed with cooling water pumps stopped. 6-03. OPERTION - When the river level is rising and reaches El. 79, the 30" wafer butterfly valve in the gate structure behind the dike should be throttled and constantly controlled to maintain the water level in the pit between El. 77 & 79. The elev. of the top of the gate structure is 84.5. Therefore, the water must be so controlled that the level at all times is between 5.5 and 7.5 ft below the top of the structure. This must be constantly watched as the level will change as the river level changes and also as the demand from the pumps change. The 30" gate valve also located in the gate structure should be closed if the cooling water pumps are stopped and the pressure through the wafer butterfly valve causes the water level in the pit to exceed El. 79. The sluice gate located on the river side of the dike should be kept open at all times. It should be closed only in the event of a rupture in the conduit between the 30" gate valve and the river."

APPENDIX A-4.3

EMBANKMENT PROTECTION

ANALYSIS OF EMBANKMENT PROTECTION

CHICOPEE FALLS FLOOD CONTROL SYSTEM

CHICOPEE FLOOD CONTROL WORKS

CITY OF CHICOPEE

HAMPDEN COUNTY, MASSACHUSETTS

October 2010

Baystate Environmental Consultants, Inc.

A GZA Company

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Tables

Figures

Appendices

1 INTRODUCTION

The federal regulations pertaining to mapping of areas protected by levee systems require an analysis of embankment protection which demonstrates "*that no appreciable erosion of the levee embankment can be expected during the base flood, as a result of either currents or waves, and that anticipated erosion will not result in failure of the levee embankment or foundation directly or indirectly through reduction of the seepage path and subsequent instability. The factors to be addressed in such analyses include, but are not limited to: Expected flow velocities (especially in constricted areas); expected wind and wave action; ice loading; impact of debris; slope protection techniques; duration of flooding at various stages and velocities; embankment and foundation materials; levee alignment, bends, and transitions; and levee side slopes*" (44 CFR 65.10(b)(3)).

The analysis of embankment protection was performed in accordance with 44 CFR 65.10(b)(3) and by the application of methods and guidelines found in the United States Army Corps of Engineers (USACE) Engineering Manual on Hydraulic Design of Flood Control Channels (EM 1110-2-1601, Change 1, 30 Jun 94), USACE Coastal Engineering Manual, Part II (EM 1110-2-1100, Change 2, 1 August 2008), and United States Department of Agriculture, Soil Conservation Service (USDA SCS) Handbook of Channel Design for Soil and Water Conservation (TP-61, 1954).

The following sources were consulted for information supporting the analysis of embankment protection:

- Federal Emergency Management Agency (FEMA), *Preliminary Flood Insurance Study Number 25013CV001* (April 30, 2009).
- Heritage Surveys, Inc. *Topographic Plan of Land in Chicopee, MA,* (December, 2009).
- National Climatic Data Center, "Climatic Wind Data for the United States" (November 1998).

1.1 Chicopee Falls Flood Control System Description

The Chicopee River is described by lettered cross-sections in the Preliminary Flood Insurance Study (FIS) for Hampden County, MA (April 30, 2009). The segment of the Chicopee River along which the Chicopee Falls Flood Control System is located extends from approximately Cross-Section "U" (upstream) to Cross-Section "Q" (downstream). The Chicopee Falls Flood Control System consists of two segments of cast-in-place concrete floodwall and two segments of earthen levee, for a total length of 5,002 linear feet. From the Deady Bridge upstream extending for 557 linear feet downstream, the system consists of cast-in-place cantilever concrete floodwall. The upstream 400± feet of wall is founded directly on ledge with rock anchors, while the last 157± feet is founded on earth. The exposed wall height is approximately 20 feet on both the landside and the riverside. The next downstream segment of the system consists of 712± feet of earthen levee. The top of levee is approximately 17 feet higher than the landside grading. The second segment of cast-in-place cantilever concrete floodwall extends for another 863± feet downstream. This wall section is located on the inside of a bend in the Chicopee River where flow direction turns approximately 90 degrees from westerly to southerly. This entire segment of wall is founded directly on ledge, and the exposed wall height is approximately 16 feet on the landside and 20 feet on the riverside. The second segment of earthen levee extends 2,870± linear feet downstream to complete the system.

Approximately eleven soil borings were recently performed along the Chicopee Falls Flood Control System and observed by GZA, and were advanced to depths ranging from approximately 20 to 80 feet below the ground surface (January/February, 2010). Seven (7) of the borings were performed either at the top of the levee near the riverside edge, or on the riverside slope. The borings indicated that soils near the surface of the levee consist primarily of sand with some gravel and silt.

Almost the entire length of the Chicopee Falls Flood Control System is protected on the riverside with hand- or machine-placed stone riprap. The riprap is angular rock, 1± ft in diameter, on average, and placed to provide a reasonably smooth surface approximately 18 inches thick. The USACE Specifications for construction of the Chicopee Falls Flood Control System indicate that "The material for stone slope protection shall consist of a well graded, angular quarry run stone which can be placed in an 18-inch layer. The maximum size stone shall weigh more than 200 pounds. The minimum size stone shall weigh less than 40 pounds. Material shall contain not more than 10 percent by weight of fragments that pass a two inch screen." Along the upstream section of floodwall, between the Deady Bridge and the beginning of the earthen levee section, the embankment riverward of the floodwall is covered mostly by grassy vegetation.

The City of Chicopee maintains the levees with regular mowing of the grass turf, repair of animal burrows, removal of drift and debris, repair of displaced riprap, and repair of erosion. Grass is generally maintained at a height between 4 and 8 inches.

2 EMBANKMENT PROTECTION ANALYSIS

2.1 Flow Velocity Impacts

Equation 3-3 of EM 1110-2-1601 computes the allowable characteristic side slope velocity of a channel based on the minimum riprap size of which 30% is finer by weight (D_{30}) and the local depth of flow. Based on the USACE's material specifications for stone slope protection described above in Section 1.1, the minimum size stone shall weigh less than 40 pounds. Assuming a unit weight of 100 pounds per cubic foot, a stone of 40 pounds is approximately 0.4 cubic foot in volume. A stone of 0.4 cubic foot in volume equates approximately to a rock of 0.91 feet in diameter. As most of the stone, as specified, must be greater than this size, it was assumed that the D_{30} for existing riprap along the Chicopee Falls Flood Control System is at least 0.91 ft, or 11± inches. Field inspections confirmed that the existing riprap generally conforms to the specifications. Therefore, as a check on slope protection along the Chicopee Falls Flood Control System, Equation 3-3 of EM 1110-2-1601 was used to estimate the characteristic side slope velocity for a D_{30} of 11 inches, under the consideration that existing riprap has a D_{30} of greater than 11 inches. The characteristic side slope velocity may be considered the allowable velocity for areas with riprap.

Equation 3-3 computes the characteristic side slope velocity based on the local depth of flow, both of which are typically taken at the subsection adjacent to the bank in the cross-section modeled in a water-surface profile computation. However, FEMA did not perform a new detailed study of the Chicopee River as part of the *Preliminary Flood Insurance Study* (FIS) *Number 25013CV001* (April 30, 2009). Therefore, a hydraulic model from which characteristic side slope velocities and local depths of flow along the Chicopee River could be estimated was unavailable. The best available source for velocity and depth data was the tabulated mean floodway velocities and flood profiles for the Chicopee River published in the Preliminary FIS. Cross-sections 'Q' through 'U' from the Preliminary FIS overlap the Chicopee Falls Flood Control System along the Chicopee River. The mean floodway velocities and levee surface cover at the locations of these cross-sections are listed in the following table.

Based on the maximum depth of flow at the applicable cross-sections for the 1% annual chance event, as shown on the Flood Profiles for the Chicopee River in the FEMA FIS, the computed characteristic side slope (allowable) velocity as computed by Equation 3-3 for a D_{30} of 11 inches ranged from approximately 12.9 to 13.6 feet per second (fps). Calculations are attached in Appendix A.

Table 1. Flow Velocities for Chicopee Falls Flood Control System along the Chicopee River.

Cross-section*	Distance in feet above confluence with Connecticut River*	Floodway Width (feet)*	Mean Floodway Velocity (feet per second)*	Levee Surface Cover
Q	12,100	339	6.1	Riprap
R	13,470	283	6.5	Riprap
S	15,040	201	10.5	Riprap
T	16,090	282	6.8	Riprap
U	16,360	351	7.4	Vegetation

*From Federal Emergency Management Agency (FEMA), *Preliminary Flood Insurance Study Number 25013CV001* (April 30, 2009).

The mean floodway velocities indicated in the FEMA Preliminary FIS are under 12.9 fps at all of the cross-sections. At cross-sections 'Q', 'R', 'S', and 'T', the existing cover at the levee is adequate to protect against erosion, even conservatively assuming that the characteristic side slope velocities are equal to the mean floodway velocities from the 1% annual chance flood. In open channel flow, velocity is not uniform across the area in flow, due to the adhesion between the wetted surface of the channel and the water. Generally, the velocity is at a maximum towards the center of the channel cross-section, and decreases towards the edges of the channel cross-section. Thus, it is concluded that the existing riprap protection is more than adequate to protect the embankment against erosion from the 1% annual chance flood.

The embankment riverward of the floodwall at cross-section 'U' is vegetated, rather than surfaced with riprap. Table 2-5 of EM 1110-2-1601 provides suggested maximum permissible mean channel velocities for design of non-scouring flood control channels based on channel material. For a channel material of sandy silt with Kentucky bluegrass, the maximum permissible mean channel velocity is 5.0 feet per second (fps), provided that the grass cover is good and maintained properly. This is equal to the recommended permissible velocity for "easily eroded soil" covered with Kentucky bluegrass indicated in Table 3 of the Handbook of Channel Design for Soil and Water Conservation, TP-61 (USDA SCS, 1954).

The mean floodway velocity at cross-section ‘U’ of 7.4 fps exceeds the suggested maximum permissible mean channel velocity of 5.0 fps. However, it is likely that the velocity adjacent to the earthen slope is significantly less than 7.4 fps, due to the typical variations in velocity across an open channel. Furthermore, the section of the floodwall in the vicinity of cross-section ‘U’ is founded directly on ledge with rock anchors; thus, erosion of the embankment riverward of the floodwall in this area is unlikely to cause failure of the floodwall.

In summary, the majority of the riverside embankment along the Chicopee Falls Flood Control System is adequately protected against erosion from the 1% annual chance flood due to cover of riprap. Within the upstream section where the embankment riverward of the floodwall is covered by vegetation, the characteristic side slope velocity is likely such that the vegetation provides adequate protection against erosion from the 1% annual chance flood. Even if the vegetation did not provide adequate protection against erosion, the floodwall in this area is founded on ledge with rock anchors, and erosion of the embankment would be unlikely to cause failure of the floodwall.

2.2 Wind and Wave Action

The effects of wind and wave action were evaluated by estimating the maximum wave height using the simplified procedures in EM 1110-2-1100, Coastal Engineering Manual (Part II), 1 August 2008 (Change 2).

Wave prediction was based on an assumed sustained wind equivalent to the peak recorded wind gust at the Chicopee Falls/Westover Air Force Base recording station, located 75.0 meters above sea level. The peak gust of 79 miles per hour had a prevailing wind direction of west-northwest (WNW). Data were obtained from “Climatic Wind Data for the United States” (National Climatic Data Center, November 1998).

Using the “Step-by-step procedure for simplified estimate of winds for wave prediction” outlined in EM 1110-2-1100, the wind speed of 79 miles per hour (35 meters/second) was adjusted to represent overwater wind speed. The resulting wind speed used in subsequent analyses was 42 meters/second. Calculations are shown in Appendix B.

Wave height was estimated using the equations in EM 1110-2-1100 applicable to wave growth with fetch, in which the wave height depends on straight line fetch distance and wind speed. The straight line fetch distance was approximated by determining the location along the flood control system at which the longest fetch could occur over water in a WNW direction and during the base flood as indicated by FEMA floodplain mapping.

The longest fetch along the Chicopee Falls Flood Control System is 292± meters, located at the downstream end of the levee, as shown in Figure 1. At this location, available base flood freeboard is approximately 7.1 feet, which is representative of the lowest available freeboard along the system.

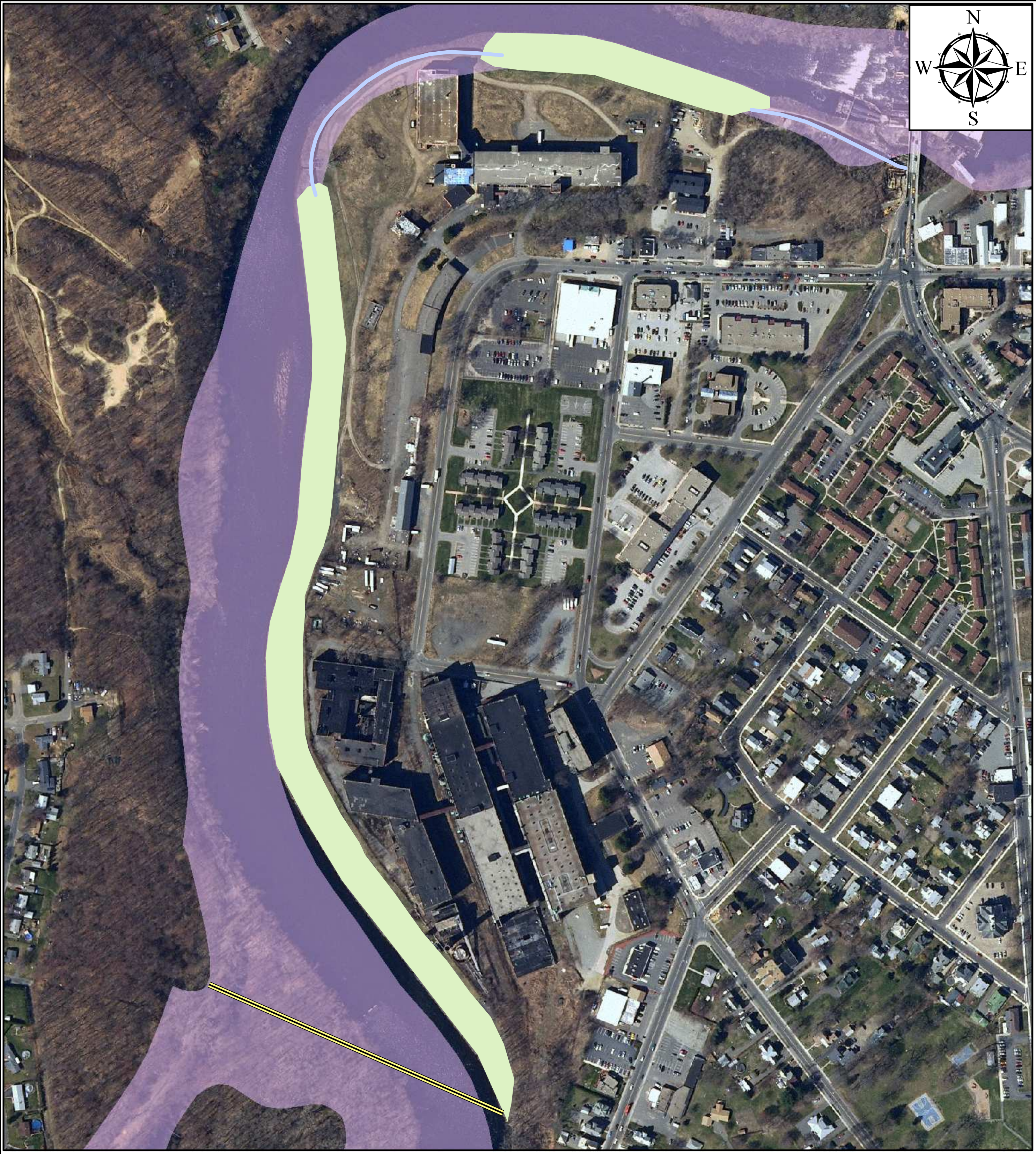
The estimated wave height was checked for shallow water limitations in accordance with the procedures in EM 1110-2-1100. Calculations are shown in Appendix B.

The input parameters and results are summarized in the following Table 2.

As the predicted wave height is less than the available freeboard for the base flood, overtopping is not expected to occur. Therefore, appreciable erosion and failure of the flood control system due to wave action is unlikely.

Table 2. Wave Height Computation Input and Results

Flood Control System	Chicopee Falls
Peak Gust Wind Speed (mph)	79
Peak Gust Wind Speed (m/s)	35
Peak Gust Prevailing Wind Direction	WNW
Wind Speed Adjusted for Overwater (m/s)	42
Fetch (m)	292
Wave Height (m)	0.48
Wave Height (ft)	1.6
Available Freeboard for Base Flood (ft)	7.1



Feet

400 200 0 400

LONGEST FETCH

Project No: 15.0702100.40

Legend

- FEMA Flood Zone A
- Floodwall
- Fetch
- Earthen Dike

Embankment Protection Analysis
Chicopee Falls Flood Control System
Chicopee, Massachusetts

Drawn by: RTS

Checked by: TEJ

Date: August 2010

MassGIS Orthophoto (2005)

Figure No: 1

FEMA Flood Zone A from Q3 Flood Data produced by FEMA, July 1997.

BEC A GZA Company
Baystate Environmental Consultants, Inc.
296 North Main Street, East Longmeadow, MA

2.3 Ice and Debris Impacts

There are no areas of the Chicopee Falls Flood Control System along the Chicopee River that are likely to experience direct impacts of ice or debris. The hydroelectric dam located upstream of the Deady Bridge will contain some of the ice and debris during the 1% annual chance flood. Ice formation on the Chicopee River through Chicopee is rare, and does not coincide with the typical timing of flood events during the spring months when the temperatures are above freezing. Average channel velocities of about 6 to 10 feet per second are such that it is not expected that any impacts of ice or debris will cause significant damage to the system.

3 CONCLUSION

No appreciable erosion of the levee embankment is expected during the base flood due to currents, waves, or ice and debris impacts which would result in failure of the levee embankment. The Chicopee Falls Flood Control System levee meets the requirements of 44 CFR 65.10 for embankment protection.

APPENDIX A-4.4

EMBANKMENT
AND
FOUNDATION
SEEPAGE & STABILITY

EMBANKMENT AND FOUNDATION SEEPAGE AND STABILITY ANALYSIS
CHICOPEE FALLS FLOOD CONTROL SYSTEM

CHICOPEE FLOOD CONTROL WORKS
CITY OF CHICOPEE
HAMPDEN COUNTY, MASSACHUSETTS

November, 2010
GZA GeoEnvironmental, Inc.

1 SEEPAGE

Seepage was evaluated for the Chicopee Falls Levee using SEEP/W 2007 a two-dimensional finite element seepage modeling software created by GEO-SLOPE International, Ltd, and analyzed in general accordance with USACE Technical Letter ETL 110-2-569 *Design Guidance for Levee Underseepage*. Seepage was evaluated for Normal and 100 Year Flood per FEMA regulations 44 CRF 65.2 and 65.10, assuming steady-state seepage conditions. Flow and exit gradients were estimated in the vicinity of the drain from SEEP/W results and compared to the limiting gradient criteria of 0.5. The seepage analyses were also performed with an assumed non-functional toe drain in order to determine if the required criteria would be met even with a compromised or non-functioning drain.

2 STABILITY

Slope Stability simulations were performed using guidance from USACE *Design and Construction of Levees*, EM 1110-2-1913 under normal and 100 year flood (steady-state seepage and sudden drawdown), for the landside and riverside slopes. Models were evaluated using SLOPE/W, a two-dimensional finite element slope stability modeling software created by GEO-SLOPE International, Ltd. utilizing the Spencer method and incorporating the parent SEEP/W model's seepage forces and phreatic surfaces. Staged Rapid Drawdown was modeled using the USACE 3-stage method.

3 TYPICAL SECTIONS

Station 13+30 (typical of Station 9+50 to 16+82 and 25+25 to 39+25) was selected as a representative cross-section to analyze the Chicopee Falls Levee system, as Station 13+30 had the loosest fill and loss of washwater was noted during boring (indicative of high permeability). Station 13+30 appears to represent the "worst case" along the Chicopee Falls Levee. An additional cross section was analyzed at Station 41+00 (typical of Station 39+25 to Station 50+00) that did not incorporate the gravelly sand layer. Two final cross sections were analyzed for seepage only at Station 9+00 (typical of Station 0+00 to 9+50) and 20+00 (typical of Station 16+82 to 25+50), as representative "worst-case" wall sections, where the difference between flood elevation and landside grade and/or difference between bottom of footing and top of bedrock were greatest.

4 SEEPAGE ANALYSES AND RESULTS

Hydraulic conductivities were estimated from grain-size distribution correlations and from published literature. Material properties and a typical cross-section can be found at the end of Appendix A-4.4. Boundary conditions were applied along the landside ground and wall surface. The toe drain was modeled as a point element with zero pressure head, surrounded by a flux section to estimate drain flow. An additional load case was modeled without the toe drain to check whether seepage would present an issue if the toe-drain was not functioning as designed. Elevations for normal and flood pools can be found in the Calculation Summary Sheets and the Freeboard Evaluation Plans at the end of Appendix A-4.4.

The computed exit gradients for the Chicopee Falls Levee system were found to be less than the limiting gradient criteria of 0.5, per ETL 110-2-569 *Design Guidance for Levee Underseepage.* The evaluated sections of the Chicopee Falls Levee had acceptable gradients for the 100-year flood with and without a functioning toe drain. Estimates of gradients and unit flow rates through the toe drain can be found in the Calculation Summary Sheet at the end of Appendix A-4.4.

5 STABILITY ANALYSES AND RESULTS

Minimum factors of safety against normal and flood conditions were conservatively assumed to be 1.4 using USACE guidance from EM 1110-2-1913. A specific factor of safety for sudden drawdown is not given in EM 1110-2-1913, but rather a range from 1.0 to 1.2 based upon the period of sustained flood level is recommended. GZA used a value of 1.0 for factor of safety against sudden drawdown in our analyses, which we consider appropriate based upon our assumption of steady-state seepage and instantaneous flood elevations. Material unit weights, strength and internal friction angle values were estimated using SPT N-value correlations and values from published engineering literature.

All computed factors of safety against sliding were greater than the minimums specified above.

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Engineers and Scientists

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SHEET NO.	1	**OF**	2
CALCULATED BY	RDH/JGD	**DATE**	5/13/2010
CHECKED BY	JGD	**DATE**	5/13/2010
SCALE	N/A		

Objective: To assess seepage and stability of the **Chicopee Falls Section** of the Chicopee Flood Control Works

Method:

1) Develop typical cross section of levee at **Station 13+30, typical from Station 9+50 to 16+82 and 25+25 to 39+25** (See attached figure).
2) Determine material parameters from test borings and typical values of similar materials.
3) Calculate location of phreatic surface within levee for normal and flood conditions, using SEEP/W. Calculate factor of safety against piping failure (where applicable).
4) Using pore water data from SEEP/W, calculate factors of safety against slope failure for the following load cases defined by requirements of EM 1110-2-1913, Section 6-7302. Steady-state factors of safety calculated for both riverside and landside slopes using Spencer method. Rapid drawdown factor of safety calculated using USACE 3-stage method.

<u>Case #1 -</u> Steady-state seepage at normal pool
<u>Case #2 -</u> Steady-state seepage at 100yr Flood
<u>Case #3 -</u> Rapid Drawdown from 100 yr Flood (Riverside only)

5) Where applicable, the above load cases were also checked for non-functioning drains and/or cutoffs

Subsurface Information:

- Test borings CF-1 through CF-11 and Exploration Location Plan by GZA (2009)
- "Chicopee River Flood Control - Chicopee Falls, Chicopee River, Massachusetts" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated April 1963
- "Chicopee Falls Local Protection Project - Design Memorandum No. 5 - Embankments and Foundations" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated March 1963

Assumptions:

- Soil strata interpreted from available test boring data and design drawings, actual configuration may vary.

Material Properties:

Strata	Total Unit Weight, γ_t	Effective Strength Cohesion,	Effective Strength Friction	Total Strength Cohesion, c	Total Strength Friction	K Ratio (k_v/k_h)	Saturated Horizontal Permeability, k_{sat}		Notes
Impervious Fill	118	0	35	0	35	1	4.6E-06	1.4E-04	(2),(3)
Existing Fill	120	0	30	0	30	1	3.3E-05	1.0E-03	(4),(5)
Silty Sand	110	0	30	0	27	1	4.6E-06	1.4E-04	(2),(4)
Gravelly Sand	130	0	35	0	35	1	6.6E-05	2.0E-03	(2),(4)
Riprap	140	0	42	0	42	1	8.0E-03	2.4E-01	(1)
Sandstone	-	-	-	-	-	1	1.6E-06	5.0E-05	(1),(6)

(1) - Unit weight and permeability values based on typical values for similar materials
(2) - Permeability values estimated from correlations with grain size distribution
(3) - Drained strength values based on correlations from SPT-N testing, total strength values are estimated
(4) - Drained strength based on values in USACE design
(5) - Permeability values based values used in USACE report
(6) - Strength of sandstone not included in slope stability analysis (assumed impenetrable)

Analysis Results:

SEEPAGE ANALYSIS RESULTS - EXISTING CONDITIONS

Case	River Elevation	Unit Flowrate, Q (1) (through slope into drain)	Exit Gradient, i_e (1)	Limiting Gradient(2)	OK?
1	Normal (El. ±83)	0 $ft^3/s/ft$	N/A	0.5	Y
2	100yr Flood (El. 97.9)	3.3E-05 $ft^3/s/ft$	0.04	0.5	Y
2a	100yr Flood (No Drain)	0 $ft^3/s/ft$	0.14	0.5	Y

- Note: Factor of safety values less than recommended values are shown in italics
(1) - Flow and exit gradient estimated from results of SEEP/W analysis at toe drain or landside face of the levee
(2) - Limiting gradient per requirements of US Army Corps Technical Letter ETL 1110-2-569 "DESIGN GUIDANCE FOR LEVEE UNDERSEEPAGE"

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SHEET NO.	2	**OF**	2
CALCULATED BY	RDH/JGD	**DATE**	5/13/2010
CHECKED BY	JGD	**DATE**	5/13/2010
SCALE	N/A		

SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	1.61	
		Landside		1.64	
2	100-year Flood (Steady State)	Riverside	1.4	1.73	
		Landside		1.62	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2(1)	1.27	

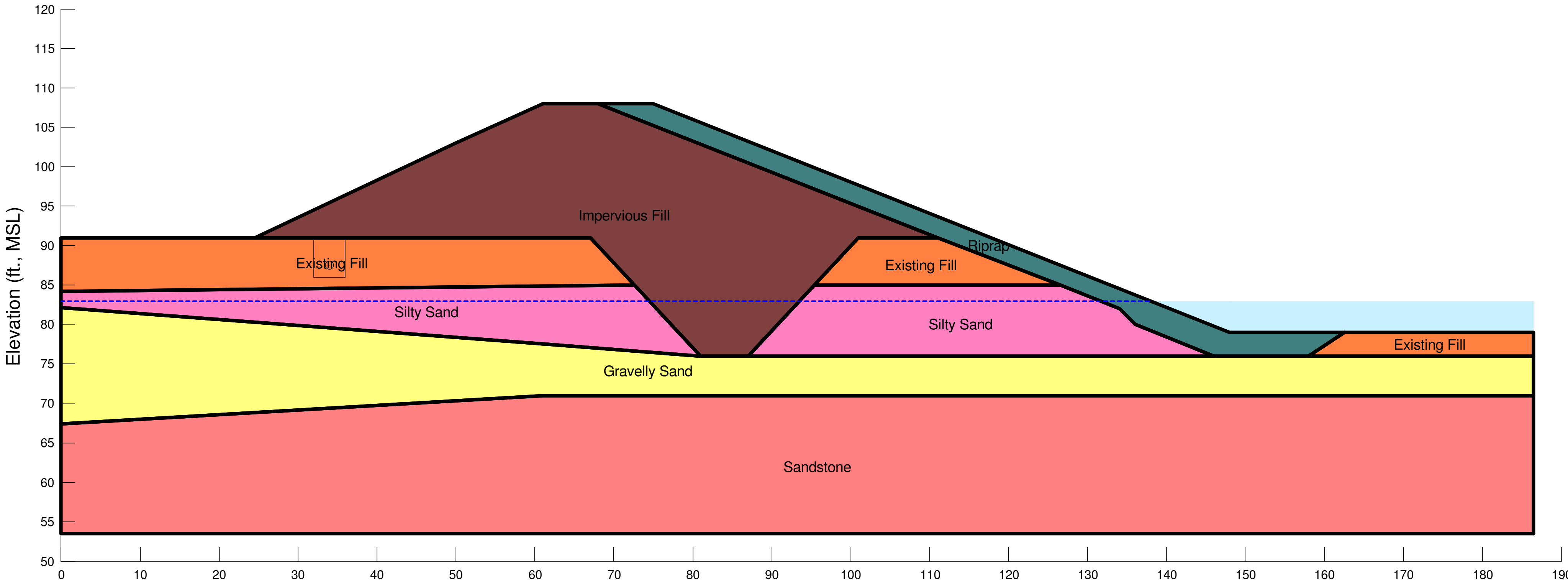
SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS - NON-FUNCTIONING DRAINS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	-	Same as Previous
		Landside		-	Same as Previous
2	100-year Flood (Steady State)	Riverside	1.4	1.70	
		Landside		1.47	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2(1)	1.27	

- Note: Factor of safety values less than recommended values are shown in italics
(1) - FS = 1.0 applies to flood levels unlikely to persist for long periods prior to drawdown, FS = 1.2 applies to levels likely to persist for long periods prior to drawdown.

- Refer to Attached SLOPE/W slope stability analysis graphical results

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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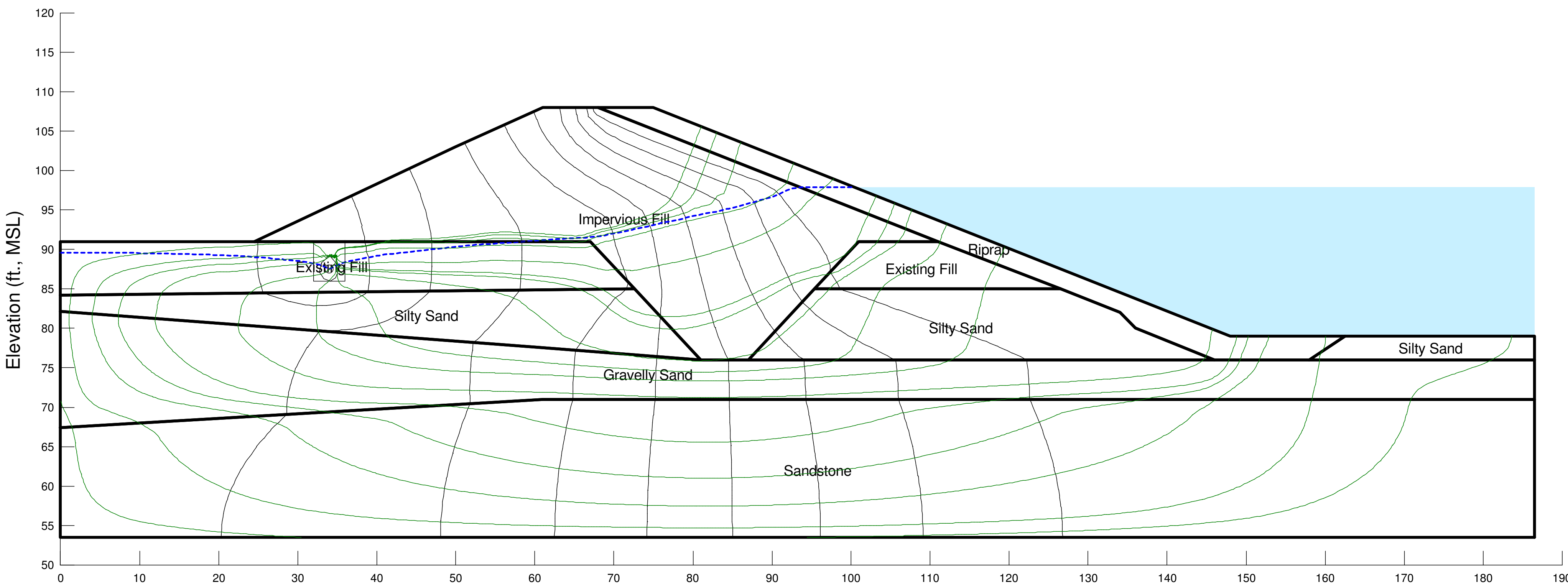
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Chicopee Flood Control - Chicopee Falls Section
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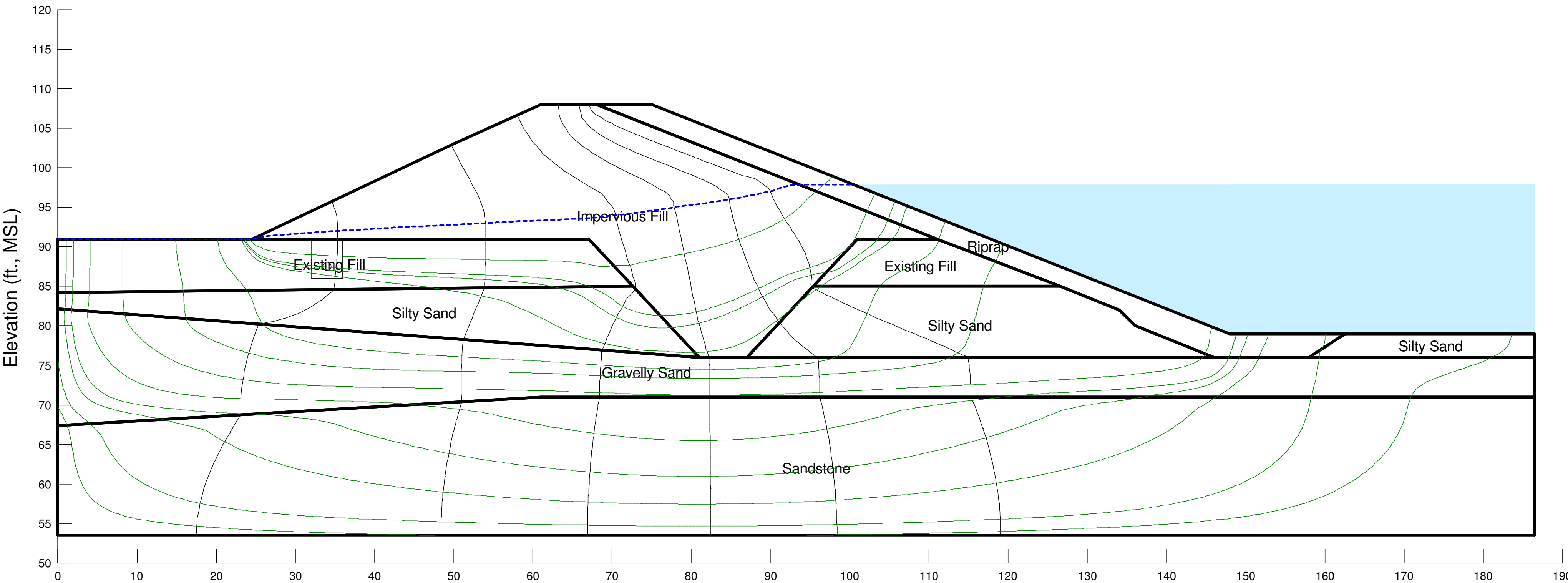

Station 13+30 - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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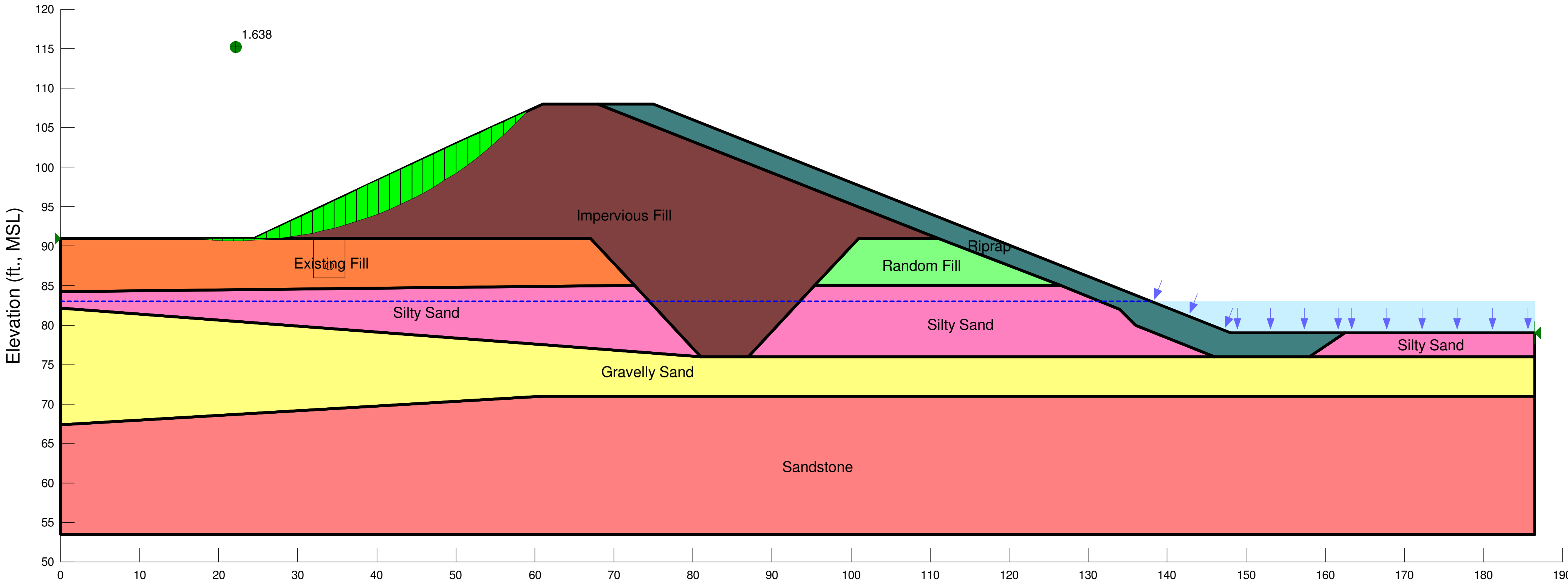
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 13+30 Landside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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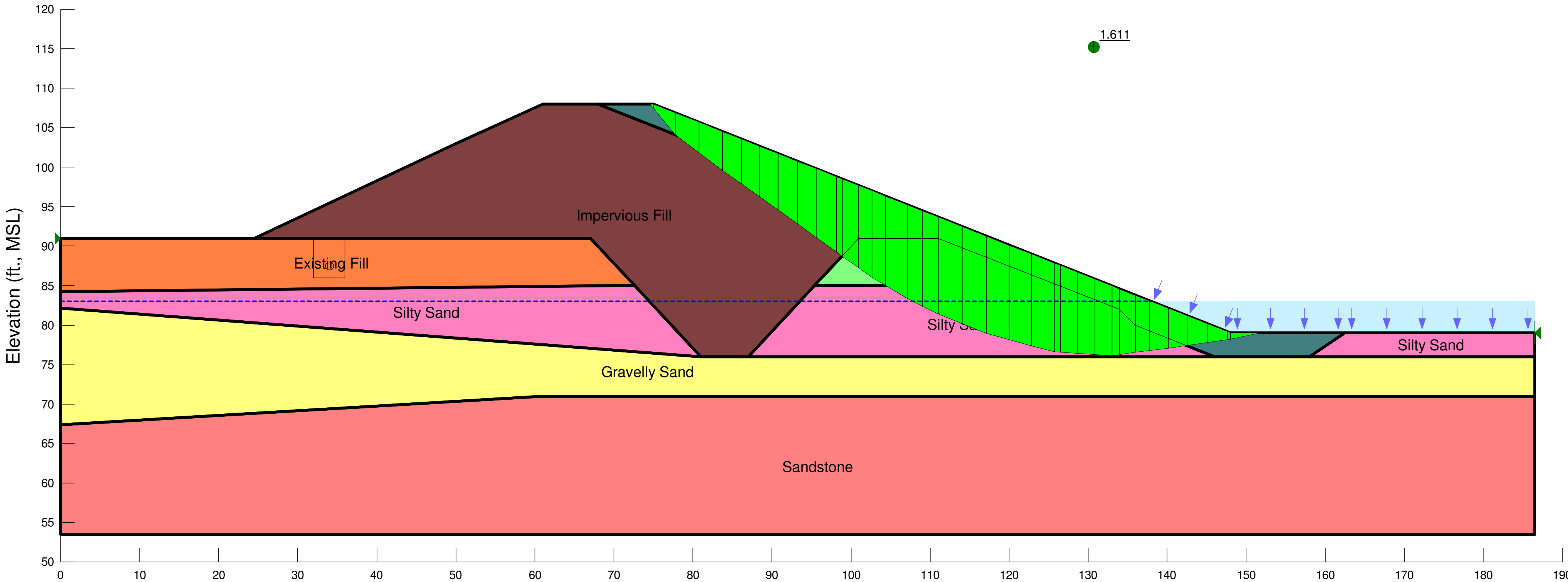

Station 13+30 Riverside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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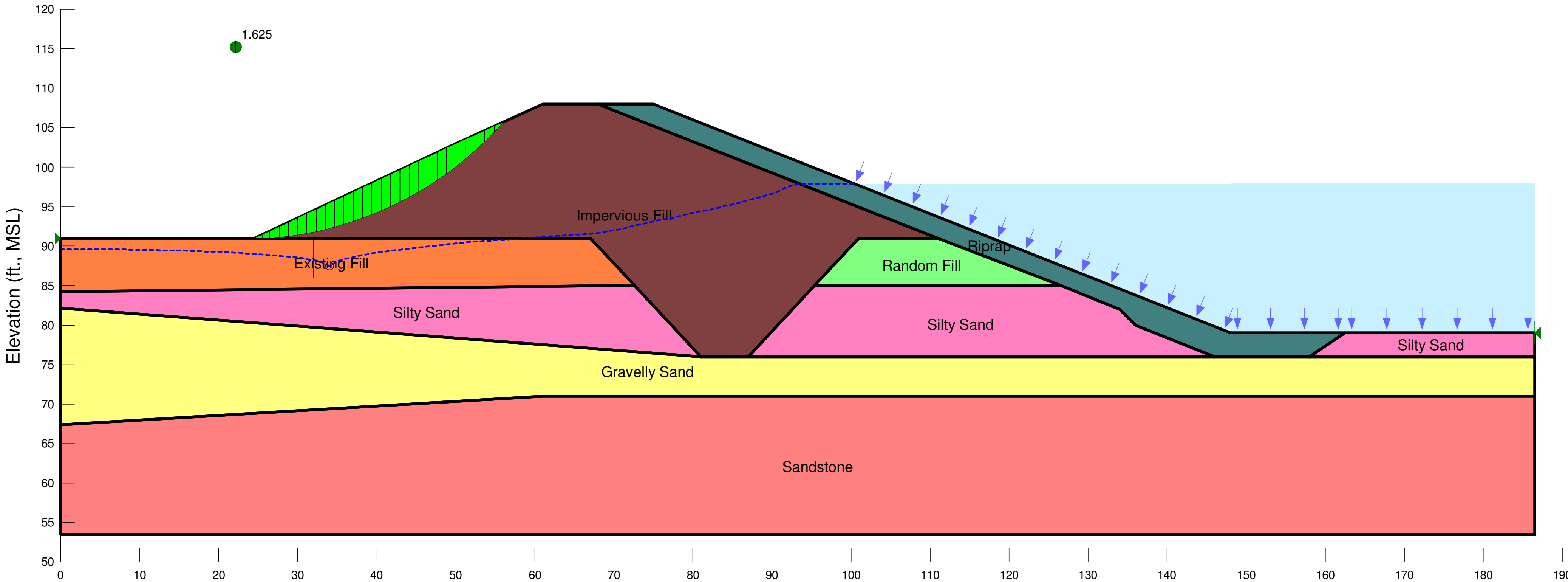

Station 13+30 Landside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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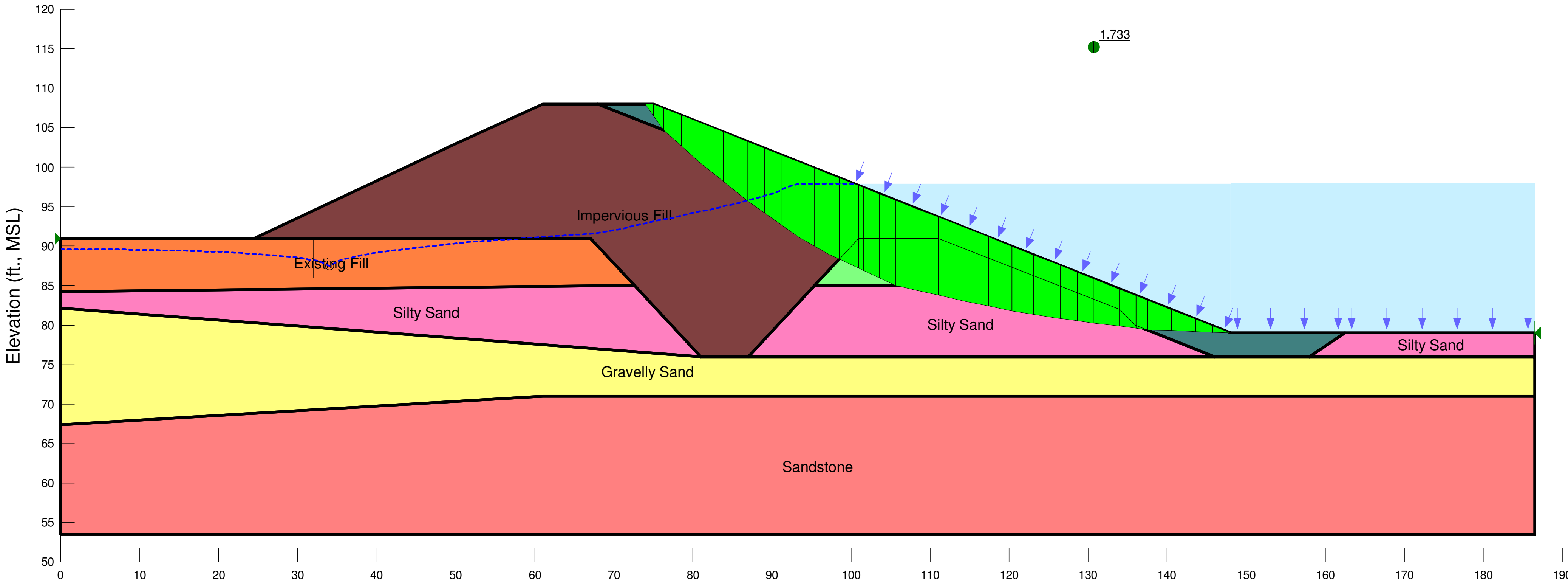

Station 13+30 Riverside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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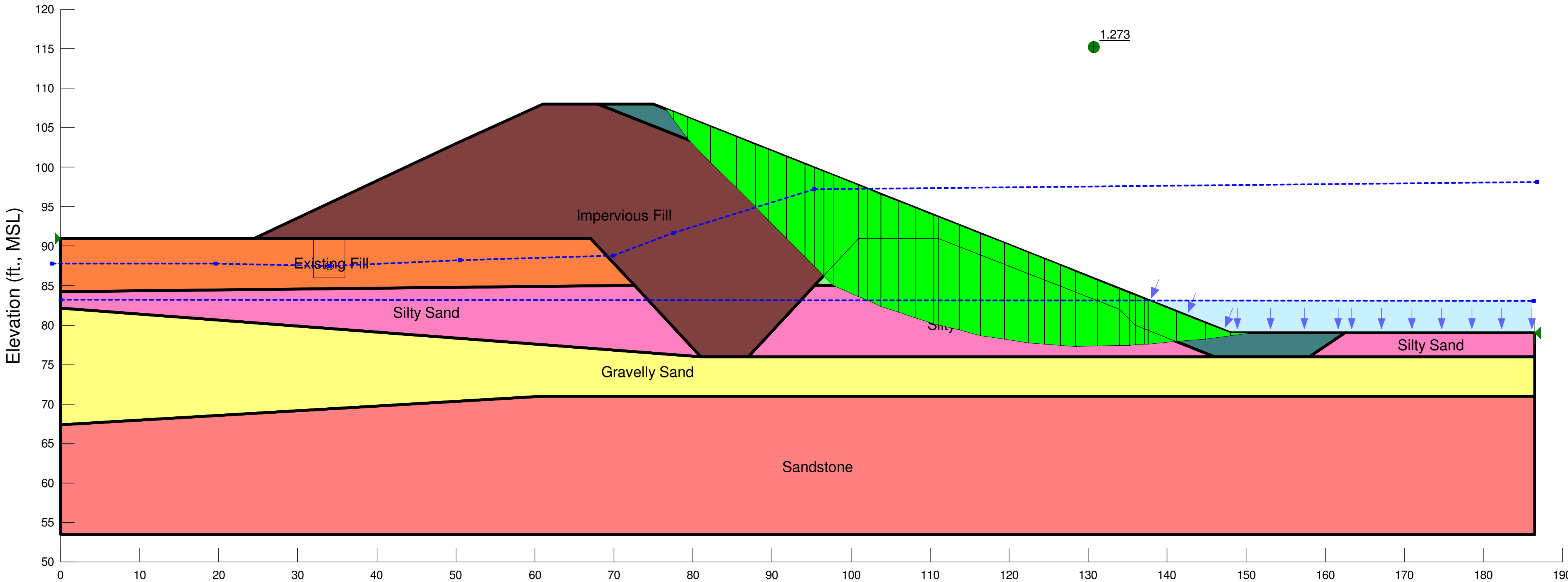

Station 13+30 Riverside Slope Stability - 100yr Drawdown

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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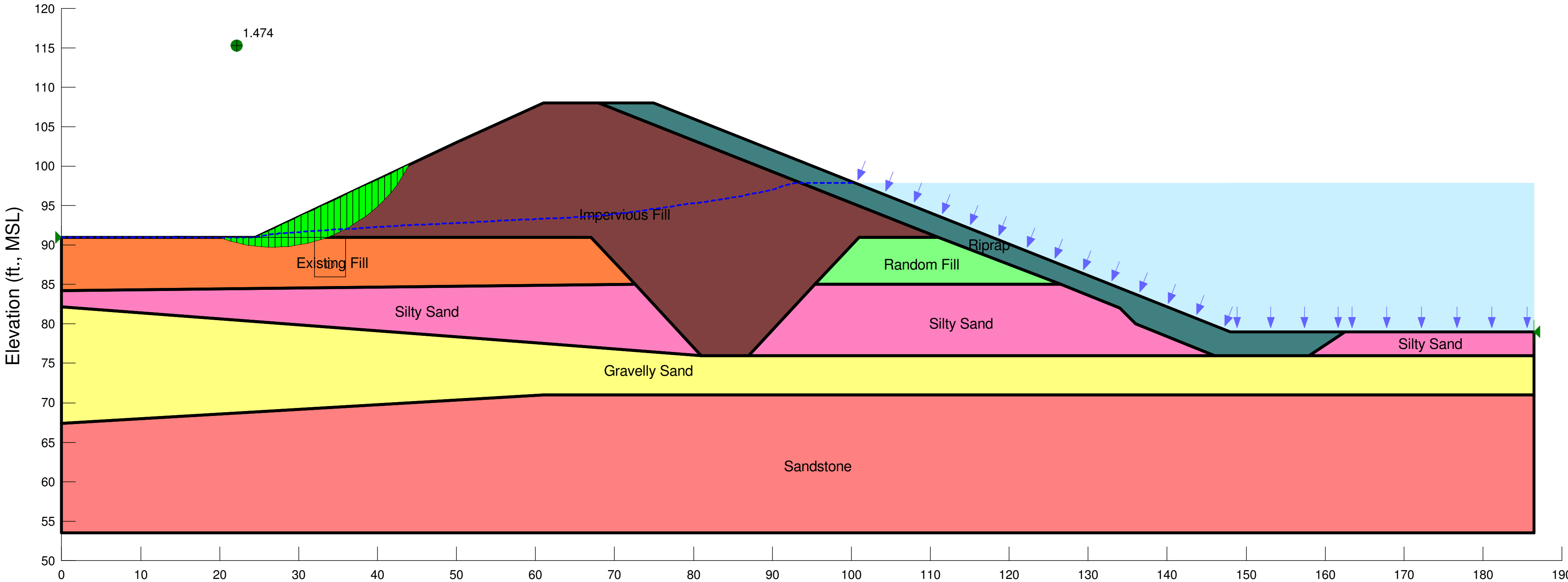

Station 13+30 Landside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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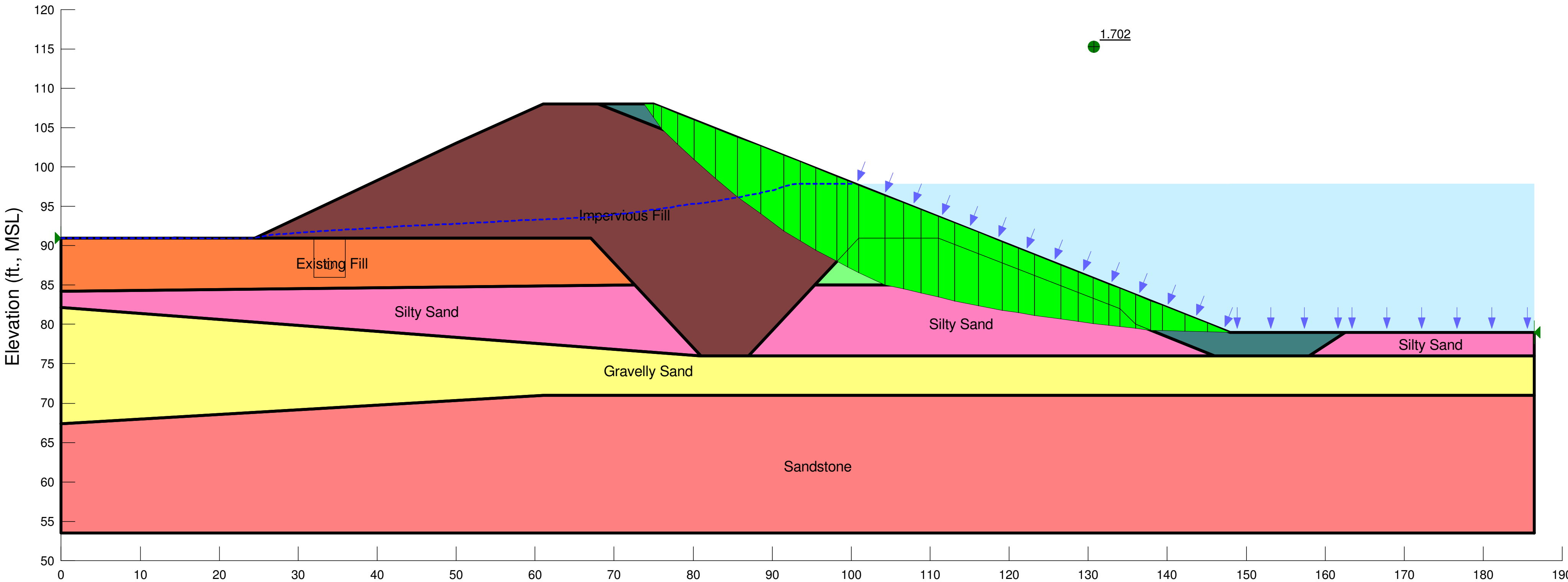

Station 13+30 Riverside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Chicopee Flood Control - Chicopee Falls Section
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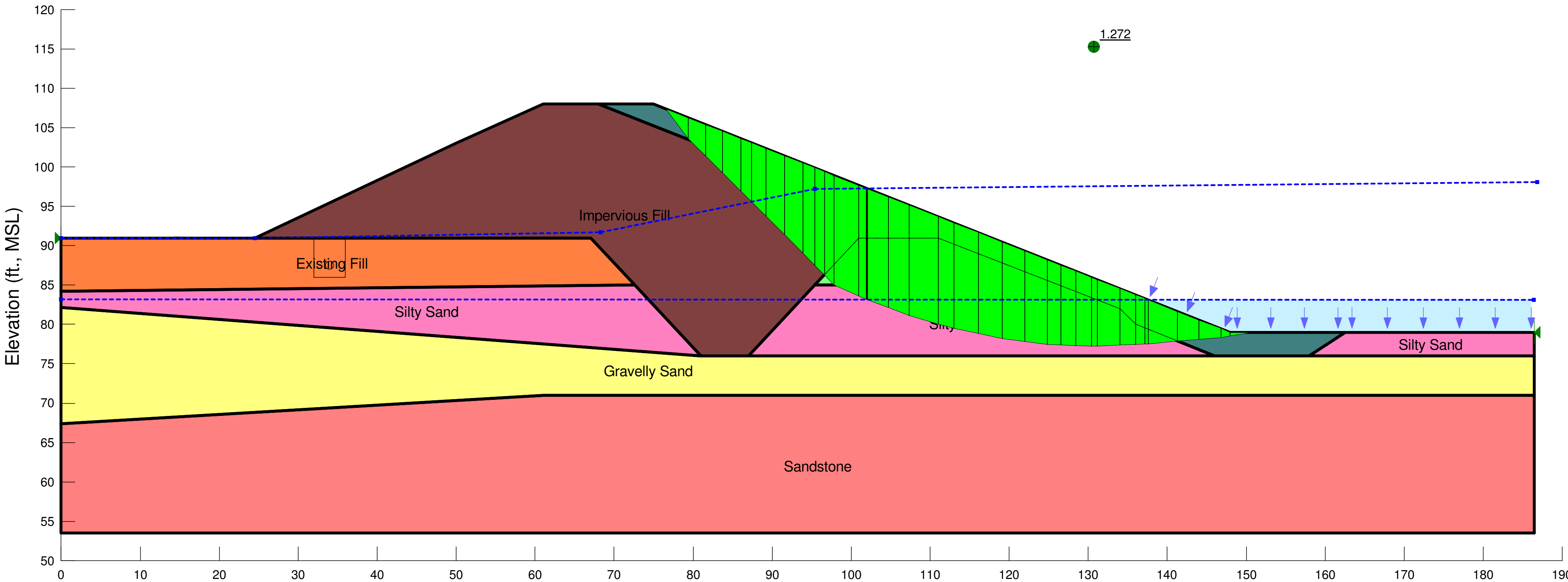

Station 13+30 Riverside Slope Stability - 100yr Drawdown (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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SHEET NO.	1	OF	2
CALCULATED BY	RDH/JGD	DATE	5/13/2010
CHECKED BY	JGD	DATE	5/13/2010
SCALE	N/A		

Objective: To assess seepage and stability of the **Chicopee Falls Section** of the Chicopee Flood Control Works

Method:

1) Develop typical cross section of levee at **Station 41+00, typical from Station 39+25 to 51+15** (See attached figure).
2) Determine material parameters from test borings and typical values of similar materials.
3) Calculate location of phreatic surface within levee for normal and flood conditions, using SEEP/W. Calculate factor of safety against piping failure (where applicable).
4) Using pore water data from SEEP/W, calculate factors of safety against slope failure for the following load cases defined by requirements of EM 1110-2-1913, Section 6-7302. Steady-state factors of safety calculated for both riverside and landside slopes using Spencer method. Rapid drawdown factor of safety calculated using USACE 3-stage method.

Case #1 - Steady-state seepage at normal pool
Case #2 - Steady-state seepage at 100 yr Flood
Case #3 - Rapid Drawdown from 100 yr Flood (Riverside only)

5) Where applicable, the above load cases were also checked for non-functioning drains

Subsurface Information:

- Test borings CF-8 through CF-11 and Exploration Location Plan by GZA (2009)
- "Chicopee River Flood Control - Chicopee Falls, Chicopee River, Massachusetts" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated April 1963
- "Chicopee Falls Local Protection Project - Design Memorandum No. 5 - Embankments and Foundations" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated March 1963

Assumptions:

- Soil strata interpreted from available test boring data and design drawings, actual configuration may vary.

Material Properties:

Strata	Total Unit Weight, γ_t	Effective Strength		Total Strength		K Ratio (k_v/k_h)	Saturated Horizontal Permeability, k_{sat}		Notes
		Cohesion,	Friction	Cohesion, c	Friction				
Impervious Fill	118	0	35	0	35	1	4.6E-06	1.4E-04	(2),(3)
Random Fill	120	0	32	0	32	1	2.5E-03	7.6E-02	(1),(3)
Existing Fill	120	0	25	0	25	1	3.3E-04	1.0E-02	(4),(5)
Silty Sand	110	0	30	0	27	1	4.6E-06	1.4E-04	(2),(4)
Gravelly Sand	130	0	35	0	35	1	6.6E-05	2.0E-03	(2),(4)
Riprap	140	0	42	0	42	1	8.0E-03	2.4E-01	(1)

(1) - Unit weight and permeability values based on typical values for similar materials
(2) - Permeability values estimated from correlations with grain size distribution
(3) - Drained strength values based on correlations from SPT-N testing, total strength values are estimated
(4) - Drained strength based on values in USACE design
(5) - Permeability values based values used in USACE report
(6) - Strength of sandstone not included in slope stability analysis (assumed impenetrable)

Analysis Results:

SEEPAGE ANALYSIS RESULTS - EXISTING CONDITIONS

Case	River Elevation	Unit Flowrate, Q (1) (through slope into drain)	Exit Gradient, i_e (1)	Limiting Gradient(2)	OK?
1	Normal (El. ±80)	-	N/A	0.5	Y
2	100yr Flood (El. 93)	9.7E-05	0.05	0.5	Y
2a	100yr Flood (No Drain)	-	0.08	0.5	Y

- Note: Factor of safety values less than recommended values are shown in italics
(1) - Flow and exit gradient estimated from results of SEEP/W analysis at toe drain or landside face of the levee
(2) - Limiting gradient per requirements of US Army Corps Technical Letter ETL 1110-2-569 "DESIGN GUIDANCE FOR LEVEE UNDERSEEPAGE"

GZA
GeoEnvironmental, Inc.
One Edgewater Drive
Norwood, MA 02062
781-278-3700
FAX 781-278-5701
http://www.gza.com

Engineers and Scientists

JOB	15.0702100.50 - Chicopee River Levee		
SHEET NO.	2	**OF**	2
CALCULATED BY	RDH/JGD	**DATE**	5/13/2010
CHECKED BY	JGD	**DATE**	5/13/2010
SCALE	N/A		

SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	1.57	
		Landside		1.56	
2	100-year Flood (Steady State)	Riverside	1.4	1.71	
		Landside		1.56	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2(1)	1.51	

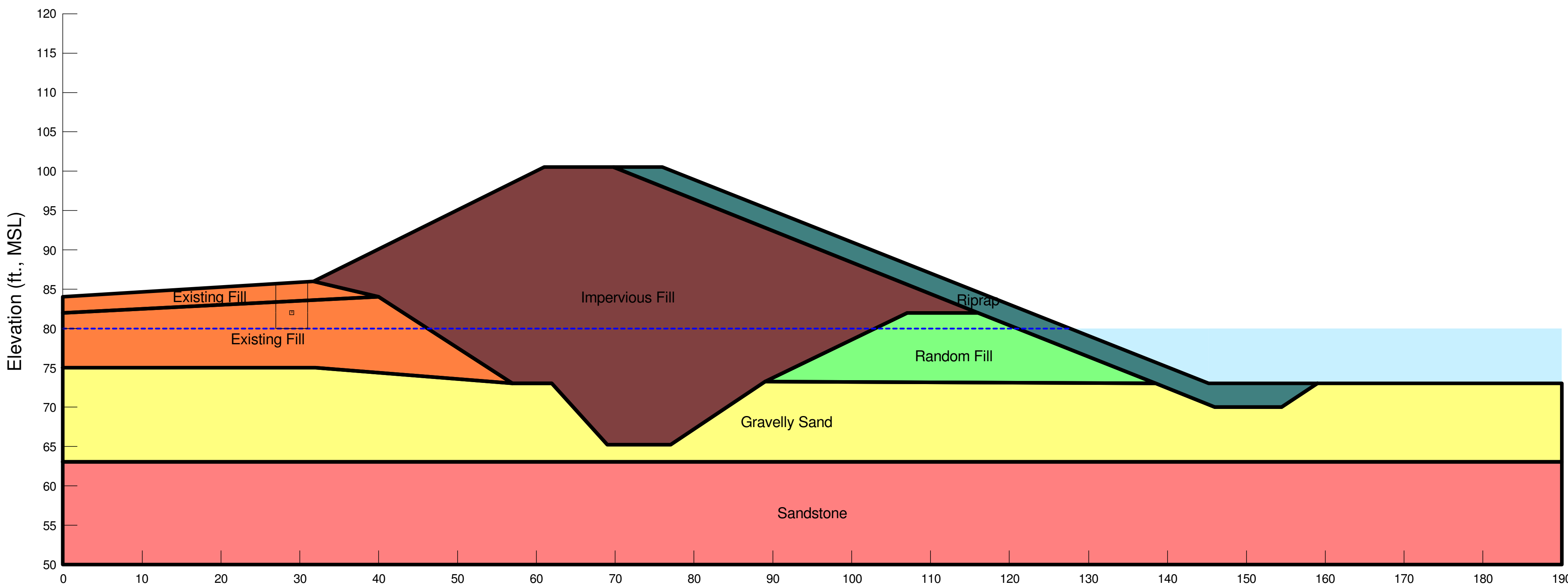
SLOPE STABILITY ANALYSIS RESULTS - EXISTING CONDITIONS - NON-FUNCTIONING DRAINS

Load Case	Loading Condition	Levee Face	Factor of Safety		Comments / Notes
			Minimum	Existing	
1	Normal Conditions	Riverside	1.4	-	Same as Previous
		Landside		-	Same as Previous
2	100-year Flood (Steady State)	Riverside	1.4	1.70	
		Landside		1.55	
3	Sudden drawdown from 100yr Flood	Riverside	1.0 - 1.2(1)	1.51	

- Note: Factor of safety values less than recommended values are shown in italics
(1) - FS = 1.0 applies to flood levels unlikely to persist for long periods prior to drawdown, FS = 1.2 applies to levels likely to persist for long periods prior to drawdown.
(2) - Factor of safety not provided in EM 1110-2-1913

- Refer to Attached SLOPE/W slope stability analysis graphical results

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50

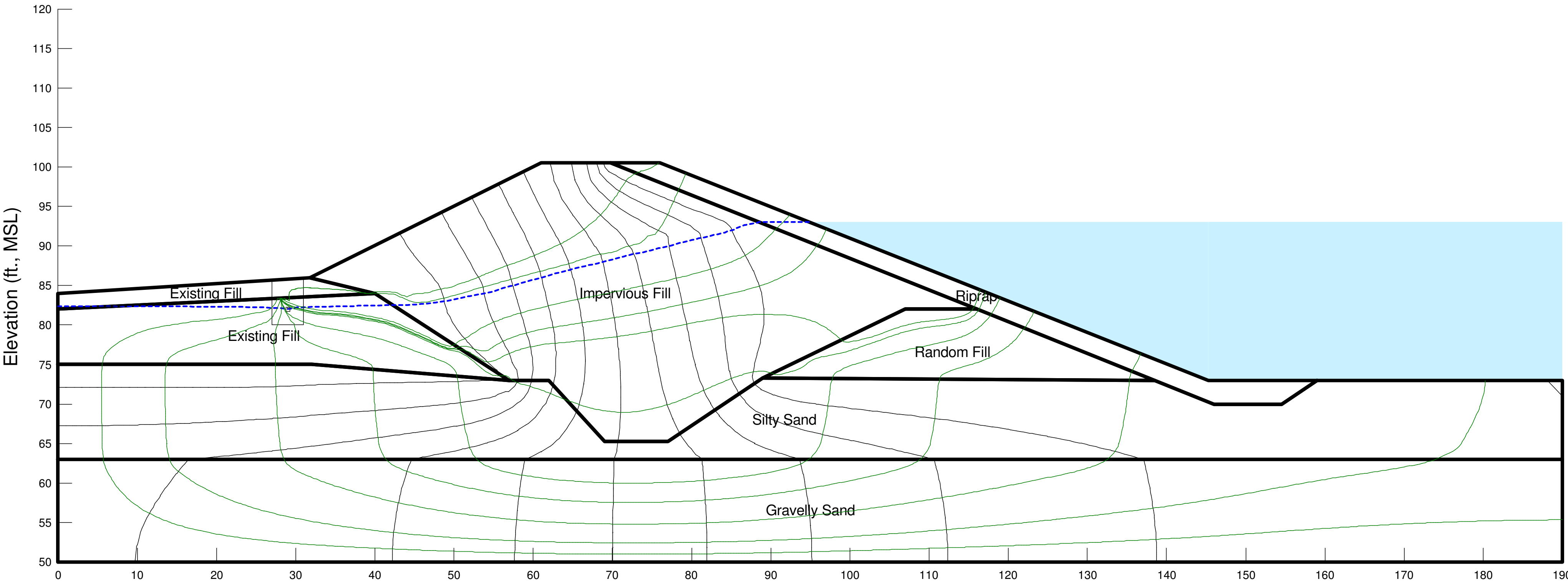


Station 41+00 - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

J:\Branch\NORWOOD\CHICOPEE-LEVEE\Chicopee Falls Explorations\Calcs\Final\Sta 39+25 to 51+15\

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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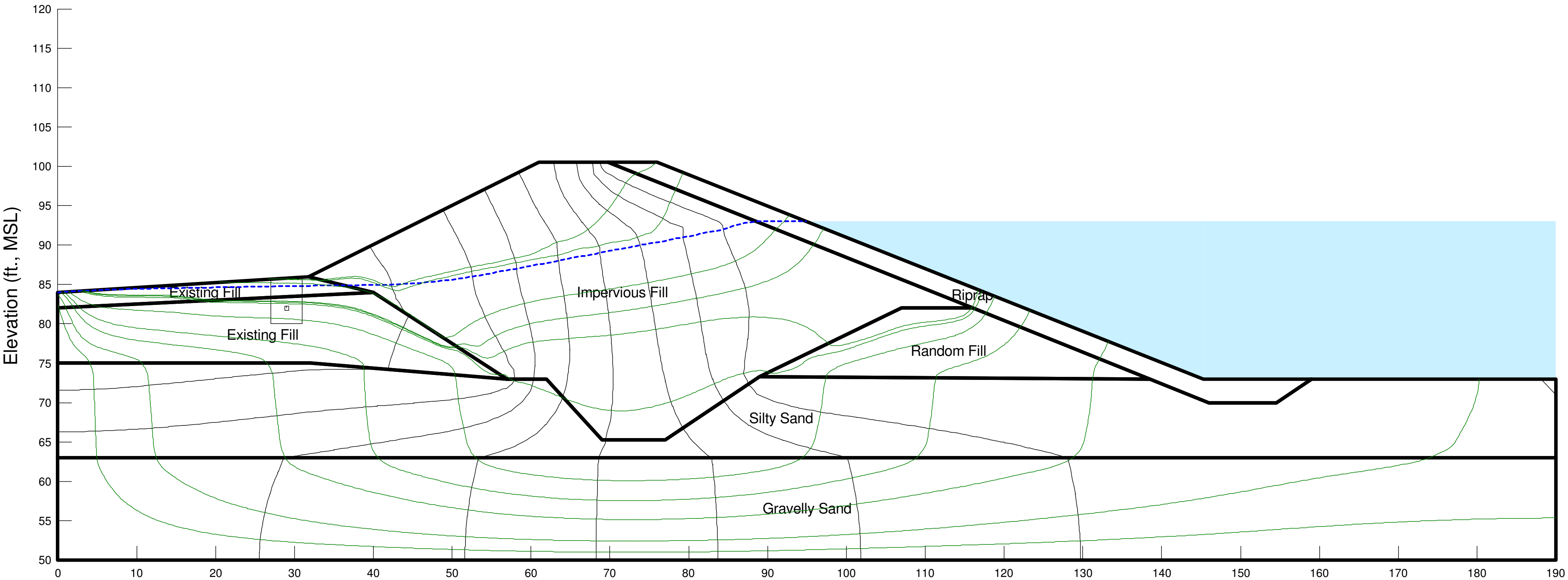
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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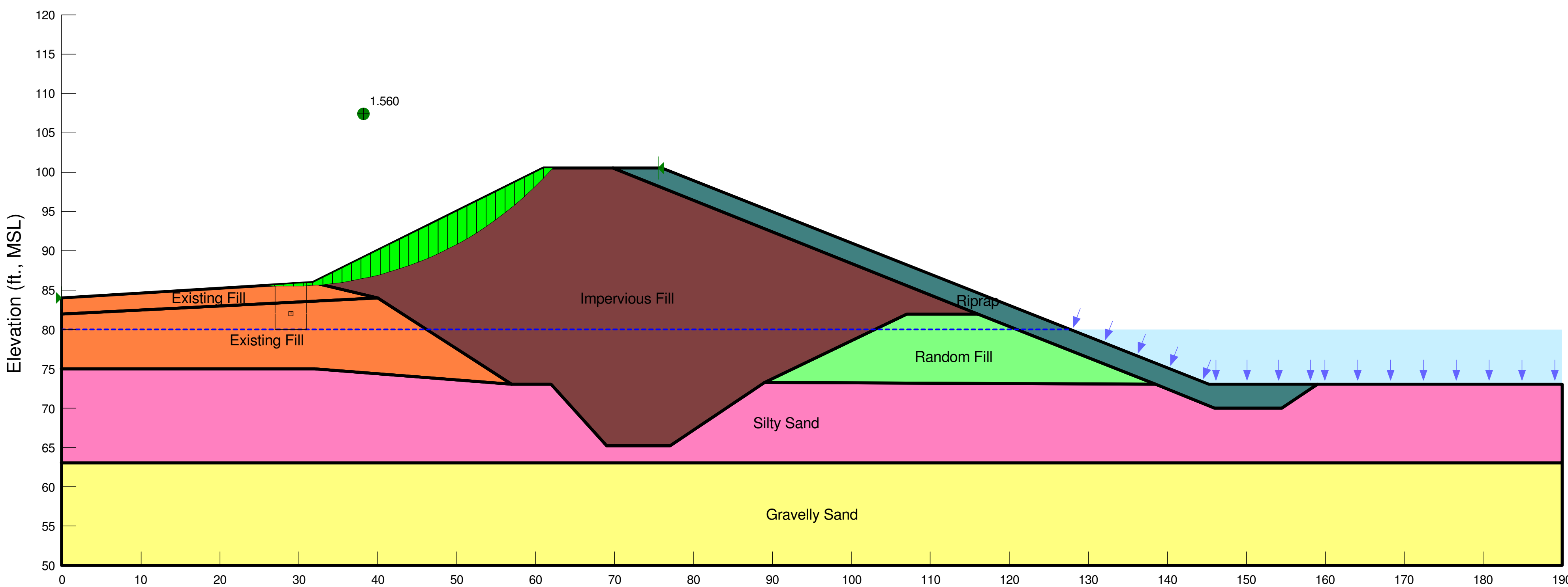
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50

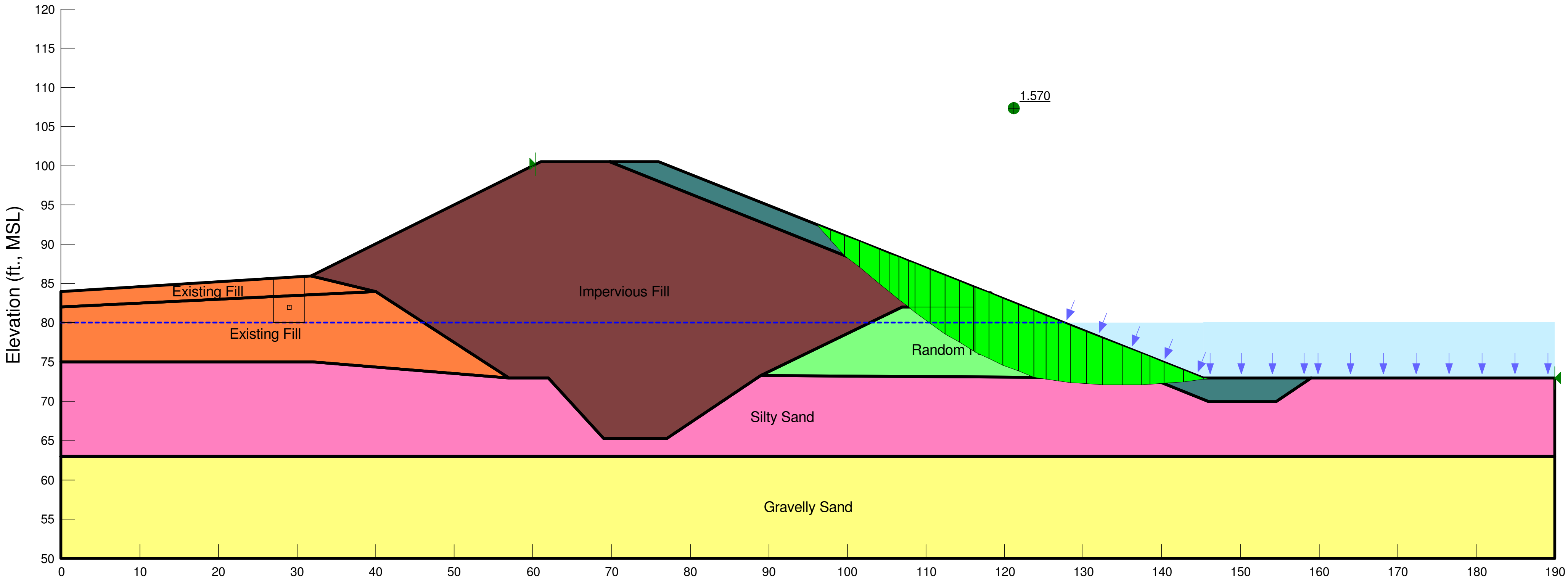


Station 41+00 - Landside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

J:\Branch\NORWOOD\CHICOPEE-LEVEE\Chicopee Falls Explorations\Calcs\Final\Sta 39+25 to 51+15\

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50

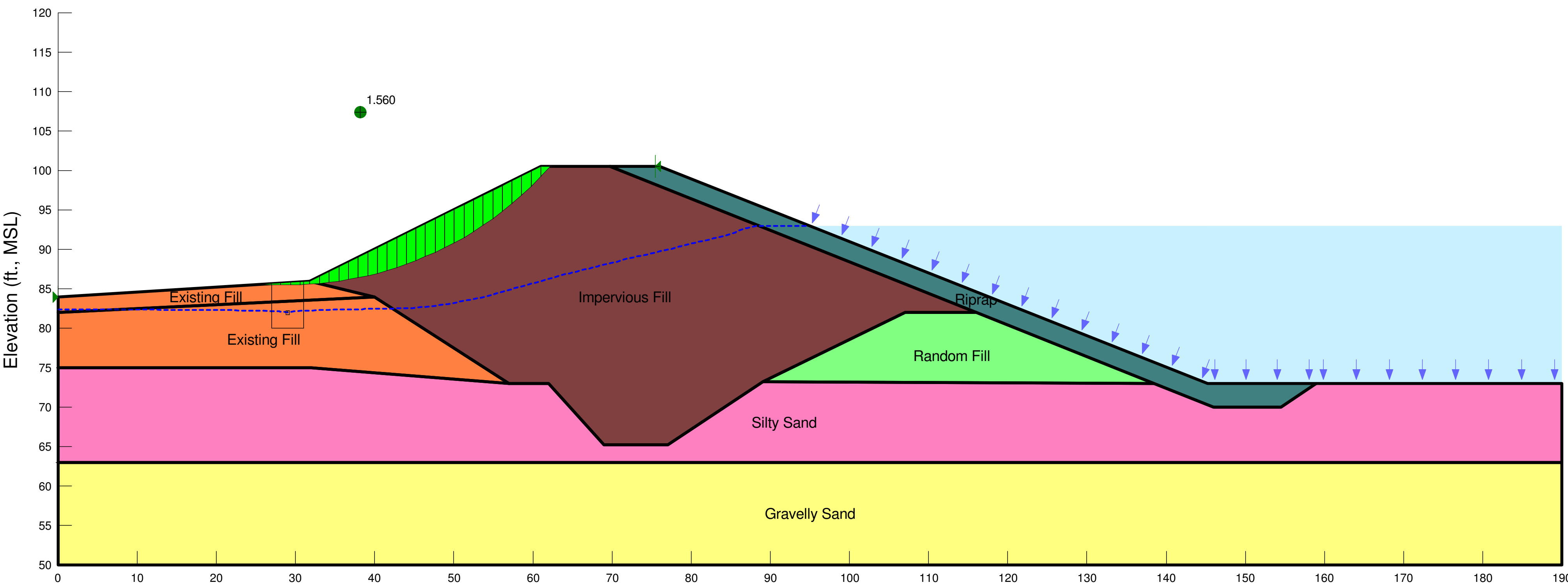


Station 41+00 - Riverside Slope Stability - Normal Conditions

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

J:\Branch\NORWOOD\CHICOPEE-LEVEE\Chicopee Falls Explorations\Calcs\Final\Sta 39+25 to 51-

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Landside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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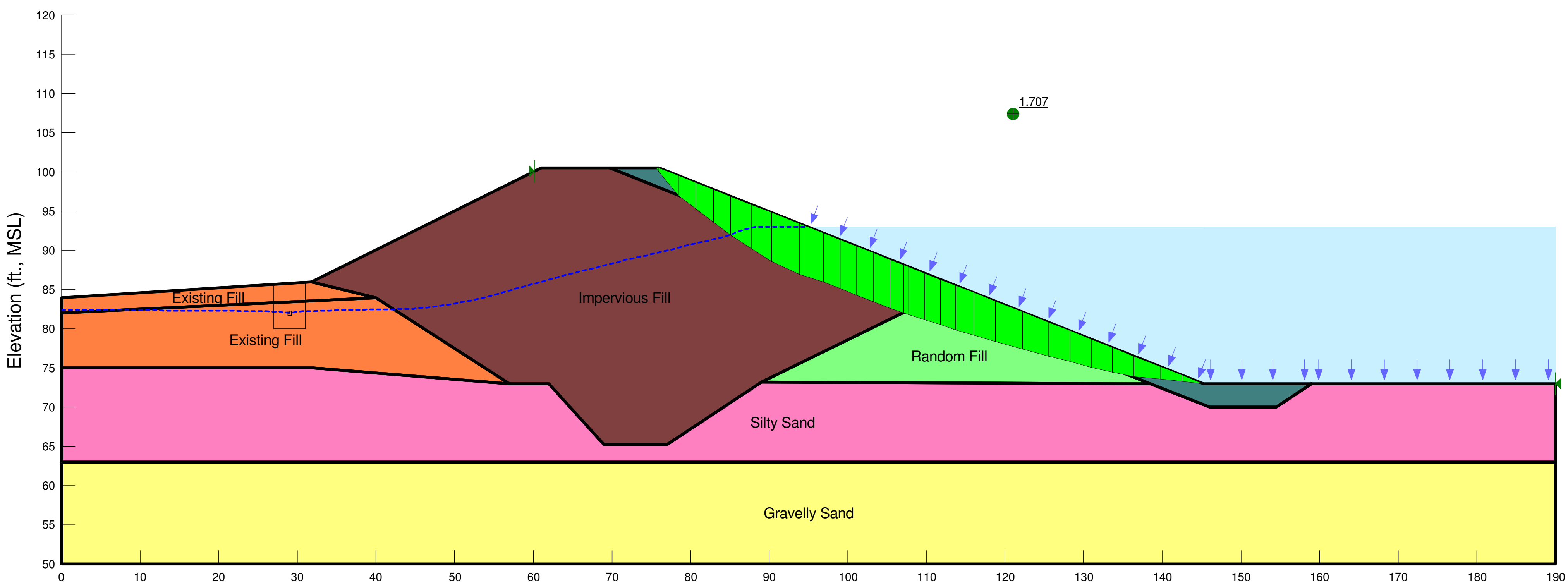
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50

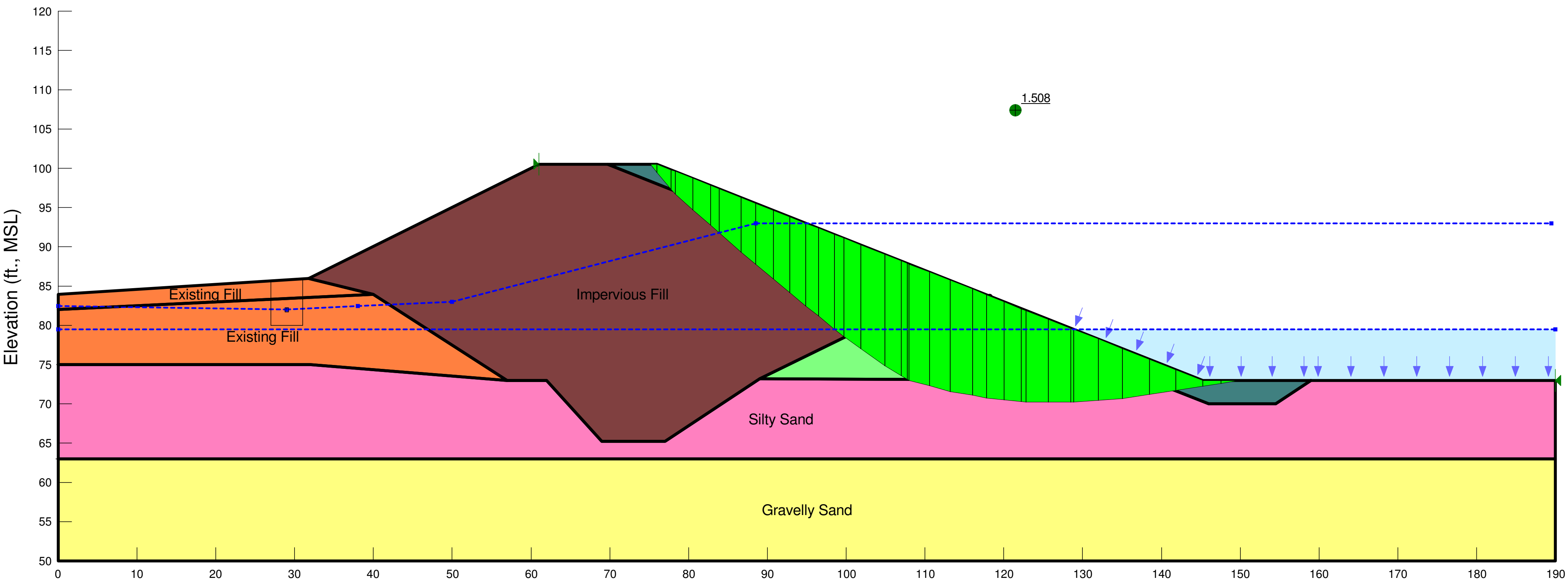


Station 41+00 - Riverside Slope Stability - 100yr Flood

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

J:\Branch\NORWOOD\CHICOPEE-LEVEE\Chicopee Falls Explorations\Calcs\Final\Sta 39+25 to 51+15\

Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - 100yr Drawdown

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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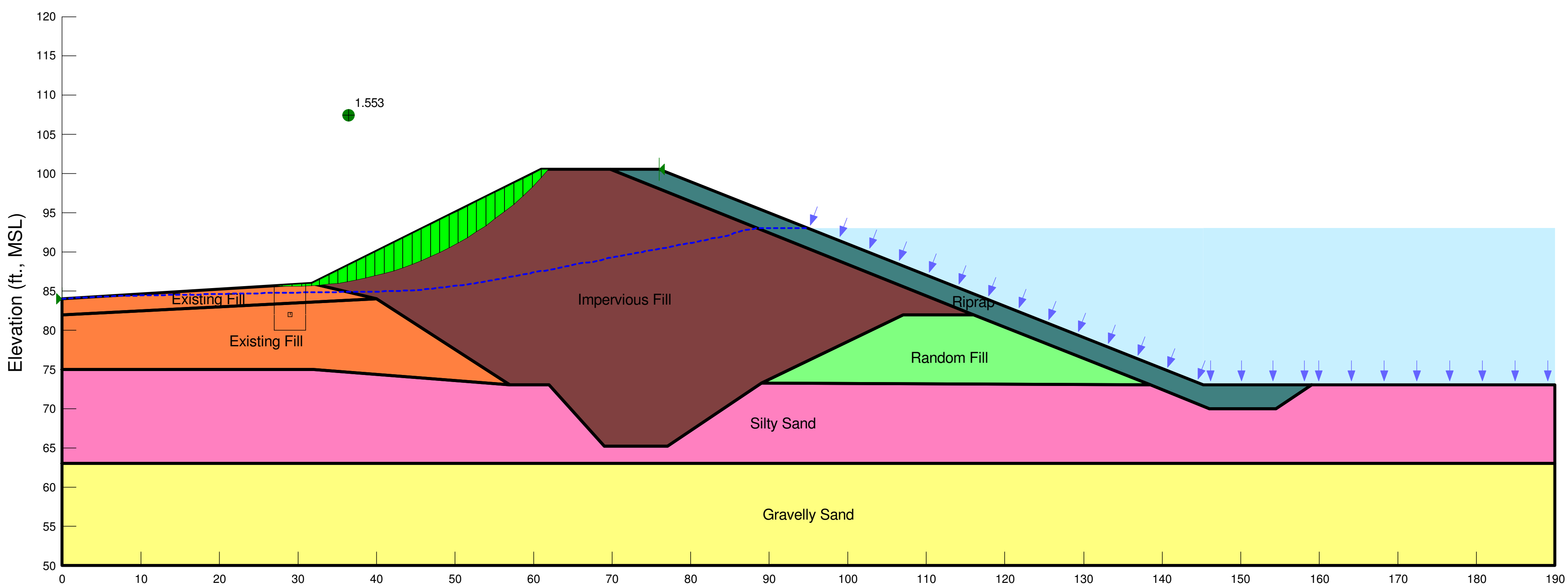
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Landside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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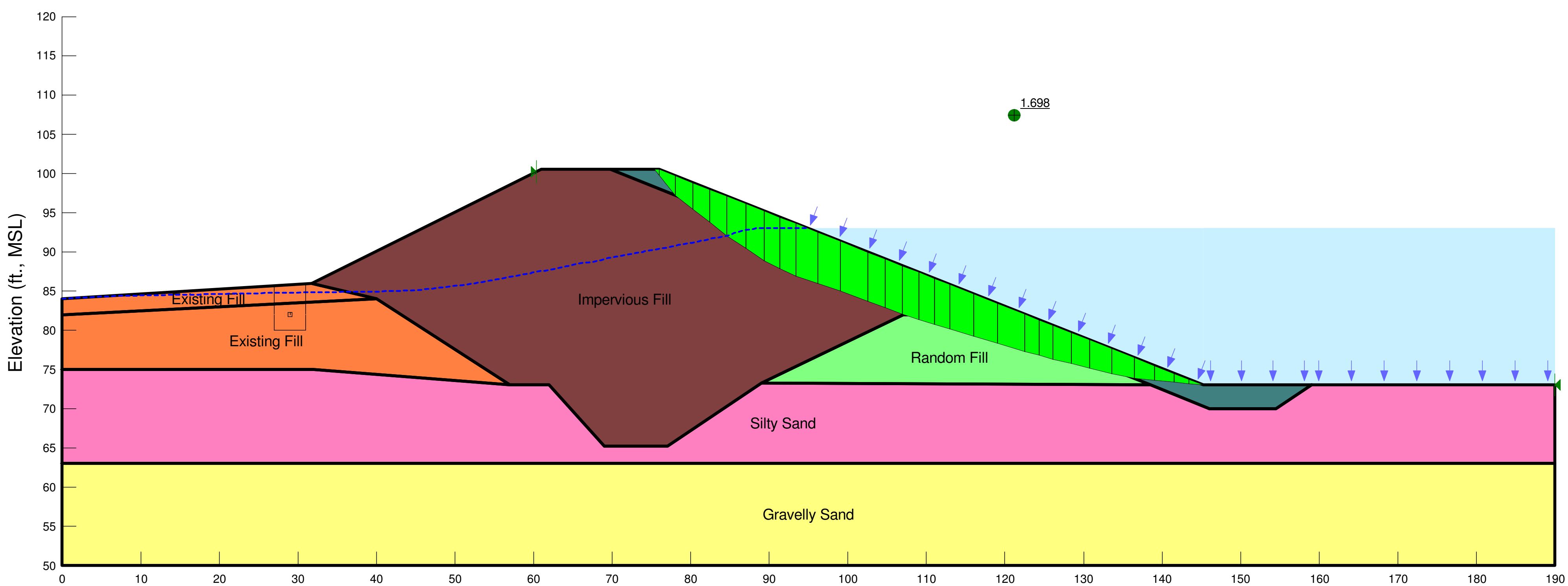
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - 100yr Flood (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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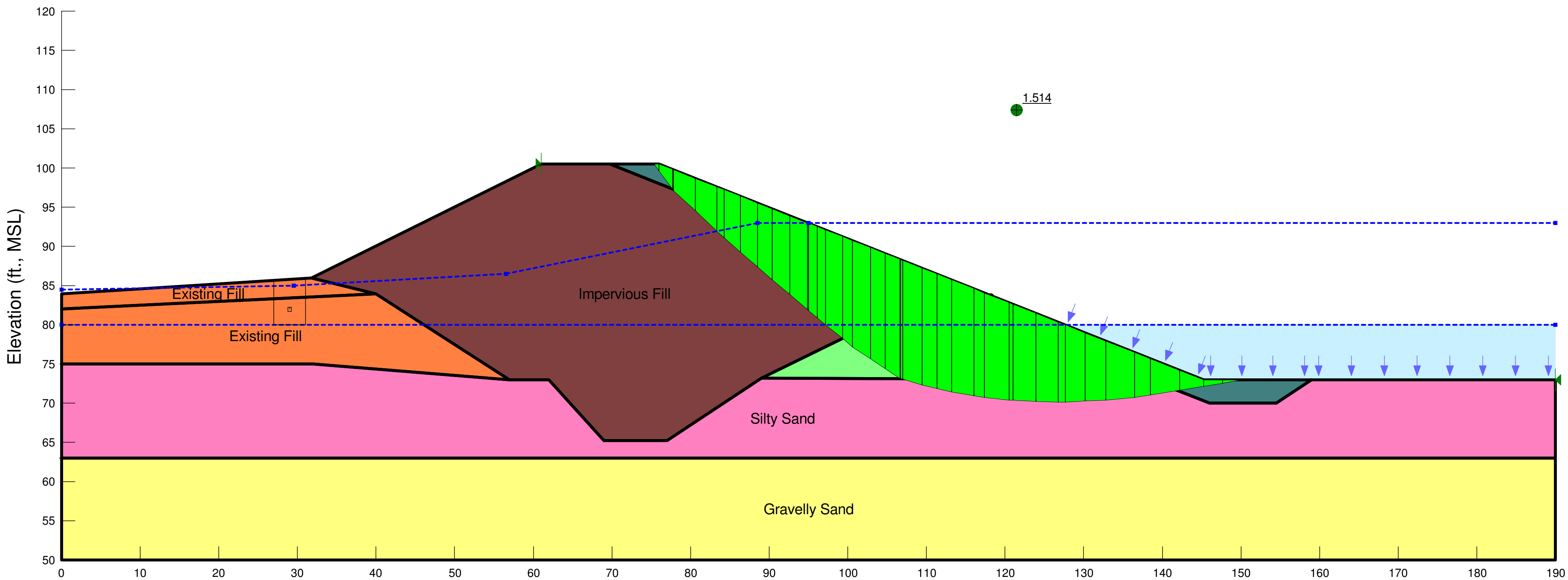
Chicopee Flood Control - Chicopee Falls Section
Chicopee, Massachusetts
GZA Project No. 15.0702100.50



Station 41+00 - Riverside Slope Stability - 100yr Drawdown (No Drain)

Note: Elevations in Means Sea Level datum. To convert to NAVD88, subtract 0.7' (MSL = NAVD88 + 0.7').

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Objective: To assess seepage FS for the flood walls of the **Chicopee Falls Section** of the Chicopee Flood Control Works

Method:

1) Develop typical cross section of flood wall at "worst-case" stations.
   a) Stations having the largest difference bewteen flood elevations and landside grade
   b) Stations having the largest difference bewteen the bottom of footing and top of bedrock.
2) Determine subsurface profile from closest test borings and Corps design drawings.
3) Using soil parameters developed for levee embankment analyses, calculate exit gradient using SEEP/W. If a soil layer exists for the wall section which wasn't used in the embankment analyses, estimate permeability using grain-size correlations (if tested) or typical values for similar materials.
4) The following cases were analyzed and compared to the USACE limiting gradient of 0.5:

   Case #1 - 100-yr Flood - Operating Drain
   Case #2 - 100-yr Flood - No Drain

Subsurface Information:

- Test borings CF-1 through CF-11 and Exploration Location Plan by GZA (2009)
- "Chicopee River Flood Control - Chicopee Falls, Chicopee River, Massachusetts" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated April 1963
- "Chicopee Falls Local Protection Project - Design Memorandum No. 5 - Embankments and Foundations" U.S. Army Engineer Division, New England Corps of Engineers, Waltham, Mass. Dated March 1963

Assumptions:

- Soil strata interpreted from available test boring data and design drawings, actual configuration may vary.

Material Properties:

Strata	K Ratio (k_v/k_h)	Saturated Horizontal Permeability, k_{sat} ft/s	cm/s	Notes
Random Fill	1	3.3E-04	1.0E-02	(3)
Existing Fill	1	3.3E-05	1.0E-03	(1)
Silty Sand	1	4.6E-06	1.4E-04	(2)
Gravelly Sand	1	6.6E-05	2.0E-03	(2)
Riprap	1	8.0E-03	2.4E-01	(1)
Sandstone	1	1.6E-06	5.0E-05	(1)
Concrete	1	3.3E-11	1.0E-09	(1)

(1) - Permeability values based on typical values for similar materials
(2) - Permeability values estimated from correlations with grain size distribution
(3) - Permeability values based values used in USACE report

Analysis Results:

SEEPAGE ANALYSIS RESULTS - STATION 9+00 (TYPICAL FROM STATION 0+00 TO 9+50)

Case	River Elevation	Landside Elevation(1)	Max. Exit Gradient, i_e(2)	Limiting Gradient(3)	OK?
1	100yr Flood (El. 99.3)	83	0.03	0.5	OK
2	100yr Flood (No Drain)	92	0.13	0.5	OK

SEEPAGE ANALYSIS RESULTS - STATION 20+00 (TYPICAL FROM STATION 16+82 TO 25+50)

Case	River Elevation	Landside Elevation(1)	Max. Exit Gradient, i_e(2)	Limiting Gradient(3)	OK?
1	100yr Flood (El. 99.3)	84	<0.01	0.5	**OK**
2	100yr Flood (No Drain)	88.5	0.03	0.5	OK

- Note: Factor of safety values less than recommended values are shown in italics
(1) - Landside elevation refers to grade or toe drain, depending on the case
(2) - Flow and exit gradient estimated from results of SEEP/W analysis at toe drain or landside ground surface
(3) - Limiting gradient per requirements of US Army Corps Technical Letter ETL 1110-2-569 "DESIGN GUIDANCE FOR LEVEE UNDERSEEPAGE'

APPENDIX A-4.5

SETTLEMENT

APPENDIX A-4.6

INTERIOR FLOODING

U.S. Department of Homeland Security
Region I
99 High Street, 6th Floor
Boston, Massachusetts, 02110-2320

FEMA

July 19, 2010

The Honorable Michael D. Bissonnette
17 Springfield Street
Chicopee, MA 01013

Appeal Resolution and Revised Preliminary Digital Flood Insurance Rate Map

Dear Mayor Bissonnette:

Thank you for your interest and engagement with us through the floodmap revision process. As you recall, preliminary Hampden County Digital Flood Insurance Rate Maps (DFIRMs) and Flood Insurance Study (FIS) report were provided to your community on April 30, 2009. We recognize the impact the revised flood mapping could have on the community and have devoted close and serious attention to the matter. The purpose of this letter is to provide you with a revised preliminary DFIRM for your community, as well as to give you a status update and describe next steps in the process.

We have completed our preliminary review of the Interior Drainage Analysis submitted to FEMA on May 26, 2010 in support of the City of Chicopee's prior technical appeal that was submitted to FEMA during the 90-day appeal period offered for Hampden County. This appeal addressed the extent of the flooding represented on the preliminary DFIRMs in the vicinity of the drainage pump station locations behind the Chicopee Flood Control Systems and demonstrated a new extent of flooding based on an interior drainage analysis. While the technical analyses submitted for each individual pumping station demonstrates the ability of the flood control system to reduce flooding on the protected side of the levee system, FEMA cannot accept the appeal until the City attains certification of the Chicopee flood control system as providing protection from the 1-percent-annual-chance flood. We are aware that the City continues to work closely with USACE to make improvements so that the Chicopee flood control systems may ultimately be certifiable. FEMA greatly appreciates your continued efforts towards reaching this goal. Once certification is achieved, the City may submit data at any time showing that the criteria of Title 44, Chapter 1, Section 65.10 of the Code of Federal Regulations (44 CFR 65.10) have been met. If the required data and documentation are acceptable, FEMA will initiate a map revision to accredit the levee system and map the impacted areas on the landward side of the levee system as being protected from the 1-percent-annual-chance flood. As the interior drainage analysis submitted appears to be technically valid, we will retain this appeal information so that it may be used in future mapping updates as described above and as appropriate.

In accordance with 44 CFR 65.10, it is the responsibility of the community or other party seeking recognition of a levee system, to provide the data and documentation defined and outlined in 44 CFR 65.10. Specifically, the design and construction data provided must be certified by a registered professional engineer or by a Federal agency with responsibility for levee design.

As was noted in the supporting analyses of your appeal, Plainfield Street Flood Control System along the Connecticut River is a continuation of a flood control system in the City of Springfield. As a result of the Springfield accredited flood control system and Springfield appeal resolution, the following current preliminary DFIRM panel has been revised and affects a portion of the City of Chicopee: 25013C0213C.

For your review and comment, we have mailed you a CD containing a PDF of the above-mentioned revised preliminary DFIRM panel and a hard copy of the revised preliminary DFIRM panel was forwarded to your community's Floodplain Administrator. The revised copy will replace the current preliminary map panel for the community. Please note that not all panels in your community were affected by this revised preliminary issuance.

Your community will have 30 days from the receipt of this letter to comment on this revised information. All comments should be compiled and verified by the community and sent to FEMA Region I, attention:

David Mendelsohn
99 High Street, 6th Floor
Boston, MA 02110

After this comment period has ended and all comments have been addressed, the Letter of Final Determination (LFD) will be sent to you. The new DFIRMs and FIS report for your community will become effective 6 months later. Following the LFD date and before the effective date, you will be reminded that your community must adopt new floodplain ordinances or modify existing ordinances as necessary to reflect any changes in the DFIRMs or FIS report, including reference to the new effective date. If you or other community officials have any questions regarding the floodplain ordinance for your community, you may raise them at the community coordination meeting if such a meeting is held, or you may discuss those issues with your State NFIP Coordinator. Approximately 1 or 2 months before the effective date, we will send your community printed copies of the DFIRMs and FIS report.

The floodmap gives your community the means to mitigate flood risk through improved floodplain management policies and tactics and enables your citizens to mitigate their risk through implementing flood-resistant building techniques and/or buying flood insurance. These maps can also play an important part of your community's disaster planning. It is important to FEMA that we collaborate with you to develop the most accurate flood maps possible. If you have any questions about the flood map update process , have suggested areas for improvement, or are interested in discussing the enclosed data, please contact Kerry Bogdan with FEMA Region I, at (617) 956-7576 or David Mendelsohn with FEMA Region I, at (617) 832-4713.

Sincerely,

Michael J. Goetz, Branch Chief
Mitigation Division

Enclosure: Revised Preliminary DFIRM CD

cc: (Enclosure not included)
The Honorable Deval Patrick, Governor
The Honorable John F. Kerry, U.S. Senator
The Honorable Scott Brown., U.S. Senator
The Honorable John W. Olver, U.S. Congressman
The Honorable Richard E. Neal, U.S. Congressman
The Honorable James T. Welch, State Representative
Natalie M. Blais, Congressman Olver's Office
Thomas Hamel, Chief Operator, Chicopee DPW
Stanley W. Kulig, Superintendent of Public Works
Rosalie Starvish, Baystate Environmental Consultants, Inc.
Scott Michalak, U.S. Army Corps of Engineers
Richard Zingarelli, State Floodplain Manager, MA Dept. of Conservation and Recreation
Kerry Bogdan, FEMA Region I
David Mendelsohn, FEMA Region I
Stuart Rooney, AECOM
Laura Keating, Regional Service Center

INTERIOR FLOODING ANALYSIS

CHICOPEE FALLS FLOOD CONTROL SYSTEM

CHICOPEE FLOOD CONTROL WORKS

CITY OF CHICOPEE

HAMPDEN COUNTY, MASSACHUSETTS

May, 2010

Baystate Environmental Consultants, Inc.

A GZA Company

TABLE OF CONTENTS

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<u>Figures</u>

<u>Appendices</u>

1 INTRODUCTION

The interior drainage analysis for the City of Chicopee's Chicopee Falls Flood Control System was performed in accordance with 44 CFR 65.10(b)(6), and the United States Army Corps of Engineers (USACE) Engineering Circular on Certification of Levee Systems (EC 1110-2-6067).

The following sources were consulted for information supporting the interior drainage analysis:

- U.S. Army Corps of Engineers, *Connecticut River Flood Control; Chicopee Falls Local Protection Project; Chicopee River, Massachusetts; Design Memorandum No. 2; General Design, Hydrology, Hydraulics & Geology* (December 1962).
- U.S. Army Corps of Engineers, *Operation and Maintenance Manual For Flood Protective Works on Connecticut and Chicopee Rivers at Chicopee - Chicopee Falls, Massachusetts* (1984).
- Federal Emergency Management Agency, *Preliminary Flood Insurance Study Number 25013CV001* (April 30, 2009)

All elevations referenced in this report are NAVD88 datum.

1.1 Sources of Flooding

The Chicopee Falls Flood Control System protects the Chicopee Falls section of the City of Chicopee from flooding along the Chicopee River.

1.2 Chicopee Flood Control Works Overview

The Chicopee Flood Control Works (CFCW) includes the Chicopee Local Protection Project (CLPP) and the Chicopee Falls Local Protection Project (CFLPP). The CFCW was constructed in four separated systems, namely the Willimansett System, the Plainfield Street System, the South Bank Chicopee River System, and the Chicopee Falls System. The CFCW, its four systems, and the sources of flooding are summarized below.

Table 1. City of Chicopee Flood Control Works

Chicopee Flood Control Works (CFCW)	
Chicopee Local Protection Project (CLPP)	**Source of Flooding**
Willimansett System	Connecticut River
Plainfield Street System	Connecticut River
South Bank Chicopee River System	Chicopee River
Chicopee Falls Local Protection Project (CFLPP)	**Source of Flooding**
Chicopee Falls System	Chicopee River

This report describes the interior drainage analysis for the Chicopee Falls System. In total, the Chicopee Falls System includes two (2) pumping stations. The attached locus plan (Figure 1) illustrates the locations of the Main Street and Oak Street pumping stations.

1.3 Chicopee Falls System

The Chicopee Falls System includes two pumping stations: the Main Street Pumping Station and the Oak Street Pumping Station, which discharge stormwater runoff and toe drain seepage from the low-lying areas landward of the flood control system. The 31±acre interior drainage area is divided between the Main Street Pumping Station to the north (upstream), at 16± acres, and the Oak Street Pumping Station to the south (downstream), at 15± acres. Collector drains which run alongside the flood control system discharge to both pumping stations. There also are floodwall and levee toe drains which discharge to the collector drains.

The two pumping stations are of a similar design. Each pumping station has one (1) gravity-flow outlet to the Chicopee River, which is used during low river stages. Each has sluice gates which control and direct the flow of stormwater runoff to either the gravity outlet or the pumping wet well, depending upon river conditions.

The Main Street Pumping Station's gravity outlet is a 36-inch square conduit. The pumping station houses two (2) Detroit diesel engines driving two (2) 16-inch propeller pumps, each with a rated capacity of 20 cubic feet per second (cfs) at a static head of 19.4 feet and a total dynamic head of 21.4 feet (river at high stage). Both pumps discharge through the pumping station's riverward wall, directly to the Chicopee River.

The Oak Street Pumping Station's gravity outlet is a 48-inch square conduit. The pumping station houses three (3) Detroit diesel engines and three (3) 16-inch propeller pumps, each with a rated capacity of 16 cfs at a static head of 21.1 feet and a total dynamic head of 23.5 feet (river at high stage). All three pumps discharge to the 48-inch outlet, which serves as a pressure conduit discharging to the Chicopee River when the appropriate sluice gates are closed.

2 INTERIOR HYDROLOGIC ANALYSIS

The U.S. Army Corps of Engineers Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) was used to apply the Soil Conservation Service (SCS) curve number loss and unit hydrograph models to generate runoff hydrographs from each of the interior drainage areas. For each pumping station, the HEC-HMS model includes one or more subwatershed(s) that represents the interior drainage area. The model uses applied precipitation in the form of a hypothetical, SCS Type III, 24-hour storm distribution, and drainage area characteristics to generate runoff.

2.1 Precipitation

Precipitation was applied to each drainage area in the HEC-HMS model as a hypothetical, SCS Type III, 24-hour storm distribution. The depth in inches applied for each storm event frequency is summarized as follows.

Table 2. Precipitation

Storm Event Frequency	24-Hour Precipitation Depth (inches)
1-Year	2.5
2-Year	3.1
5-Year	3.8
10-Year	4.5
25-Year	5.2
50-Year	5.8
100-Year	6.6
500-Year	7.9

The precipitation depths for the 2-, 5-, 10-, 25-, 50-, and 100-year frequency storm events were obtained from the Intensity-Duration-Frequency (IDF) curve for Springfield, Massachusetts, from the Massachusetts Department of Transportation (MassDOT), Highway Design Manual (1997). These curves were compiled from information included in Technical Paper No. 25, *Rainfall Intensity-Duration-Frequency Curves*, U.S. Weather Bureau (December, 1955). The depth for the 1-year frequency storm event was taken from Technical Paper (TP) No. 40, *Rainfall Frequency Atlas of the United States* (1963), as the Springfield IDF curves did not exhibit a 1-year frequency event. The depth for the 500-year frequency storm event was extrapolated from the existing data.

2.2 Interior Drainage Areas

The City of Chicopee provided mapping of the areas draining to each pumping station based upon stormwater collection systems and the current status of combined sewer system diversions and separation efforts. Neither of the Chicopee Falls System pumping stations are believed to receive wet weather flow discharges from combined sewer systems within Chicopee Falls. Drainage areas were delineated based on the information provided by the City, as well as a review of existing topography taken from *Topographic Plan of Land in Chicopee, MA*, Heritage Surveys, Inc. (Preliminary-December 12, 2009), and the Massachusetts Geographic Information System (MassGIS) Digital Elevation Model (February, 2005). Other sources of information which were reviewed as part of the drainage area delineations include the USACE design documents for each of the pumping stations, and the following plans as they relate to drainage:

1. Map of Phased Recommended Plan, Final Long-Term CSO Control Plan, Chicopee, Massachusetts, Tighe & Bond Consulting Engineers (October, 2009)

Existing conditions were reviewed in the field to validate these prior plans. The interior drainage areas for the Main Street and Oak Street Pumping Stations are shown on Figures 2 and 3, and the computed areas in acres of each drainage area are included in Table 3.

The SCS (USDA's Soil Conservation Service, now the Natural Resources Conservation Service) runoff curve number (CN) is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. The CN is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular watershed or drainage area. It is a function of the hydrologic soil group (HSG), the land use/cover complex, and the antecedent moisture condition.

These three watershed factors have the most significant impact in determining runoff from a watershed, and, in conjunction with precipitation data, provide the basis for runoff volume estimation.

The HSG is identified for each soil type in the SCS soil classification system. There are four groups ranging from A, for soils with high infiltration rates and low runoff potential, to D, for soils with low infiltration rates and high runoff potential. The MassGIS SCS soil group datalayer was utilized to identify the soil types within each drainage area. Each soil type was then categorized according to its HSG by reference to the Hampden County Soil Survey (SCS). For those soils which had a compound classification (e.g. were classified as C/D, B/C, etc.), a single representative HSG was calculated, based on a weighting of the individual soils in the map unit. A map of soil types within the drainage areas to the Main Street and Oak Street Pumping Stations is included as Figure 4.

The land uses within each drainage area were identified by reference to the MassGIS Land Use 2005 datalayer. The land uses were modified to reflect current conditions as needed. Each land use is associated with a curve number depending on the HSG within the area. A composite curve number for each drainage area was generated based on the areas of each HSG within each land use. Tables summarizing the composite curve number calculation for both drainage areas are included in Appendix A. Average antecedent soil moisture conditions (Condition II) were assumed. The resulting curve numbers are listed in Table 3.

The SCS unit hydrograph method applies the lag time to scale the dimensionless generalized hydrograph to produce the unit hydrograph used in the analysis. The standard lag is defined as the length of time between the centroid of precipitation mass and the peak flow of the resulting hydrograph. Studies by the SCS found that in general the lag time can be approximated as 60% of the time of concentration, which was applied for this analysis.

The time of concentration is the time required for water to travel from the most hydrologically remote point in the drainage area to the point of collection. It is computed as the sum of the travel times of sheet flow, shallow concentrated flow, and channel or pipe flow. The travel time of sheet flow depends on the length of flow, surface cover, precipitation intensity and slope. For this analysis, the length of sheet flow was assumed to be on the order of 50 to 100 feet, while the slope was assumed to be 2 percent. The precipitation intensity was represented by the 2-year, 24-hour rainfall depth using the Welle and Woodward (1986) equation for sheet flow (McCuen, R.H., Hydrologic Analysis and Design, 2nd ed., 1998). The Manning's Roughness Coefficient (n) for overland flow surfaces represents surface cover effects.

The travel times of shallow concentrated flow and channel/pipe flow are computed based on the velocity of flow. The velocity of shallow concentrated flow was computed using the Manning's Equation. By applying assumed values for the hydraulic radius and Manning's n coefficient, the equation is simplified to provide a relationship between the velocity and the average slope of the surface. The hydraulic radius and Manning's n are incorporated into a factor, k, which varies with surface cover. The slope of shallow concentrated flow was assumed to be 2 percent for this analysis.

Chicopee Falls is a highly-developed area; thus, drainage is delivered to the pumping stations via a network of pipes. Therefore, the last segment of the time of concentration calculation assumes pipe flow. Flow capacities of these closed systems were not specifically computed, as that effort is beyond the scope of this analysis. The travel time is computed as the length of pipe flow divided by the velocity of flow. A velocity of 2.5 feet per second was assumed for pipe flow in Chicopee Falls. The lag times for each drainage area are included in Table 3.

Table 3. Drainage Area Characteristics

Drainage Area	Area (acres)	Curve Number	Lag Time (minutes)
Main Street	16	88	50
Oak Street	15	92	10

Appendix A includes the calculations for the composite SCS runoff curve number and lag time for each drainage area.

2.3 Other Sources of Pumping Station Inflow

As indicated in the table below, the Main Street and Oak Street pumping stations receive inflow from the toe drains, generally limited to periods of high river stage. The toe drain seepage flows applied in the model are based on information provided in the USACE design reports for the pumping stations. There are no additional sources of inflow to the pumping stations.

Table 4. Other Sources of Pumping Station Inflow

Pumping Station	Assumed Toe Drain Seepage Flow (cfs)
Main Street	6 (during high river stage only)
Oak Street	4 (during high river stage only)

3 INTERIOR HYDRAULIC ANALYSIS

HEC-HMS is used to evaluate the hydraulics of discharge from each interior area to the river through the levee. During an interior storm event, interior drainage may discharge to the river via a gravity outlet through the levee, or by being pumped through the pumping station. The method of discharge will depend on the exterior river stage during the interior storm event, identified on the river frequency curves as the Pump Activation Elevation. In HEC-HMS, the potential interior flooding area is represented by a reservoir. HEC-HMS has the capability of modeling discharge from a reservoir through gravity outlets and/or by pumping. Models were developed for each pumping station that incorporate both gravity outlets and pumping. In addition, the model includes setting a tailwater on each reservoir to represent the exterior river stage.

Reservoirs are defined in HEC-HMS by a stage-storage curve. Reservoir stage-storage data for each of the pumping stations was determined based on the Digital Elevation Model (Feb., 2005) provided by the Massachusetts Geographic Information System (MassGIS). The storage volume between elevations was computed using ESRI's ArcGIS 3D Analyst. The Main Street and Oak Street pumping stations do not have storage ponds; thus, the potential flood storage areas were defined by the topographical characteristics of each drainage area's lower elevations. The storage provided by the sump for each pumping station was incorporated into the stage-storage data. The stage-storage data for each pumping station is included in Appendix B.

The pumps are defined in HEC-HMS by pump-head discharge curves, which are based on the pump capacity information provided in the U.S. Army Corps of Engineers' "Analysis of Design" documents prepared for each of the pumping stations. The discharge varies with the head on the pump which depends on the exterior river stage. The pump-head discharge curves are included in Appendix C. The derivation of the curve for each pumping station is described below.

For simplicity in modeling, it was conservatively assumed that the efficiency of the drainage systems conveying runoff to each pumping station is 100%. That is, it was assumed that all direct runoff generated over the drainage area was able to enter the drainage system and reach the pumping stations with no delay or surcharging. In reality, inefficiencies (such as undersized pipes or clogged inlets) of the drainage system would impede the conveyance of direct runoff to the pumping stations. Modeling results indicated no interior flooding at Main Street and Oak Street pumping stations; thus, it was deemed unnecessary to further refine the models for these pumping stations by including some allowance for the inefficiency of the drainage systems.

The specific assumptions applied to the hydraulic model for each pumping station are described as follows.

3.1 Main Street Pumping Station

Pump capacity curves were not provided in the USACE Design Memorandum No. 2, General Design, Hydrology, Hydraulics & Geology (December 1962) for the Main Street Pumping Station. However, pump design capacities were provided for two values of pump head; thus, a simplified pump head-discharge curve was developed using the provided values. The two pumps at the Main Street Pumping Station were field tested on April 1, 2010, to verify pumping capacities. The Chicopee River elevation was below the pump discharge elevation during the test. Two trials were performed for each pump, in which the time to reach various stages in the wet well was recorded. The average pump rate for each pump was then computed. The pump tests indicated an overall pumping station pumping rate equivalent to about 82% of the design pumping rates provided. Pump test data is included in Appendix D. The subsequent interior drainage analysis was conducted for both full design pumping rates and at reduced pumping rates equivalent to 82% of the design pumping rates, which is representative of documented pumping rates. Full station capacity consists of two 16-inch pumps.

3.2 Oak Street Pumping Station

Pump capacity curves were not provided in the USACE Design Memorandum No. 2, General Design, Hydrology, Hydraulics & Geology (December 1962) for the Oak Street Pumping Station. However, pump design capacities were provided for two values of pump head; thus, a simplified pump head-discharge curve was developed using the provided values. The three pumps at the Oak Street Pumping Station were field tested on April 1, 2010, to verify pumping capacities. The Chicopee River elevation was below the pump discharge elevation during the test. Two trials were performed for each pump, in which the time to reach various stages in the wet well was recorded. The average pump rate for each pump was then computed. The pump tests indicated an overall pumping station pumping rate equivalent to about 65% of the design pumping rates provided. Pump test data is included in Appendix D. The subsequent interior drainage analysis was conducted for both full design pumping rates and at reduced pumping rates equivalent to 65% of the design pumping rates, which is representative of documented pumping rates. Full station capacity consists of three 16-inch pumps.

Elevations of interest for these pumping stations are listed below.

Table 5. Elevations of Interest, feet (NAVD88)

Pumping Station	Elevation of Gravity Outlet	Pump Activation Elevation	Approximate Exterior Ground Elevation at Pumping Station Location	Elevation of Levee at Pumping Station Location	Elevation of Riverine 100-Year Flood at Pumping Station Location
Main Street	76.3	81.8	89.0	104.4	94.6
Oak Street	75.3	78.3	85.1	99.3	91.4

4 COINCIDENT FREQUENCY ANALYSIS

The federal regulations pertaining to mapping of areas protected by levee systems indicates that the analysis of interior flooding must be based on *"the joint probability of interior and exterior flooding"* (44 CFR 65.10(b)(6)). The USACE Engineering Circular on Certification of Levee Systems (EC 1110-2-6067) states: *"The analysis of interior flooding is based on a coincident analysis of exterior and interior stages that includes the capacity of gravity and blocked gravity drainage features. Coincident analysis for interior areas is explained in Chapter 4 of EM 1110-2-1413, Hydrologic Analysis of Interior Areas. For riverine levee systems, the interior analysis considers interior rainfall events during both low river stages (gravity conditions) and high river stages when the gravity outlets are closed (blocked conditions) and the performance of pumping stations as might exist."* The U.S. Army Corps of Engineers' Engineer Manual, "Hydrologic Analysis of Interior Areas" (EM 1110-2-1413) provides guidance for a "Coincident Frequency Method" of analysis which computes the percent chance exceedance frequencies of various interior flooding elevations based on the probabilities of exceeding given exterior river stages during different interior storm events. Coincidence is the degree to which the interior and exterior events occur at the same time. The Coincident Frequency analysis provides a method to compute the joint probability of interior and exterior flooding and to determine the base flood elevation for interior areas.

The Coincident Frequency Method is a probabilistic approach that is applicable to areas where the occurrence of the exterior and interior events are independent, such that the physical and meteorologic processes of the exterior and interior events are unrelated. Relatively small interior areas located along large rivers, such as in Chicopee, are typically independent. At the confluence of the Connecticut River and the Chicopee River, the watershed to the Connecticut and Chicopee Rivers are 9,000± square miles and 722± square miles, respectively. The drainage area to the Main Street Pumping Station is 16 acres and to the Oak Street Pumping Station is 15 acres. The ratio of river watershed to interior drainage area is approximately 30,000:1. As such, the behavior of interior runoff generation is highly independent of the river's hydrologic behavior, and the Coincident Frequency Method is a valid approach in this setting.

In accordance with the Coincident Frequency Method, the probability of exceeding a given interior flooding elevation, "A", is computed as follows:

$$P(A) = \sum_{i=1}^{n} [P(A/Bi) \times P(Bi)]$$

Where:

A = given interior flooding elevation;

Bi = given exterior river stage, from i = 1 to n stages;

P(A) = total probability of attaining a given interior flooding elevation;

P(Bi) = probability that the river is at a given exterior river stage;

P(A/Bi) = probability of attaining a given interior flooding elevation if the exterior river stage is at a specific elevation.

The river stages, Bi, and probabilities of each river stage, P(Bi), were determined from the Chicopee River Stage Frequency curves developed by the local USGS gage data at Indian Orchard, Springfield, MA (USGS 01177000). The period of record spans from 1928 to the present. The Chicopee River modified stage frequency curves at Main Street and Oak Street Pumping Stations were determined by translating the Indian Orchard gage data to the locations of the pumping stations based on the stages at each location, as indicated by the flood profiles computed by the U.S. Army Corps of Engineers in the Chicopee Falls Local Protection Project Design Memorandum No. 2. The differences in stage vary with discharge; thus, the translated stages were computed depending on the recorded discharge at Indian Orchard.

Table 6. Adjustments for Stage Frequency Curves

From USACE Profiles:

Chicopee River Discharge, cuft/sec	Main St. Stage, feet (NAVD88)	Oak St. Stage, feet (NAVD88)	Indian Orchard Stage, feet (NAVD88)
10,000	85.0	82.4	136.6
70,000	96.8	94.7	142.6

Stage Adjustment, as compared to Indian Orchard gage data:

Chicopee River Discharge, cuft/sec	Main St. Stage, feet (NAVD88)	Oak St. Stage, feet (NAVD88)
10,000	- 51.6	- 54.2
70,000	- 45.8	- 47.9

Each location-specific stage frequency curve is divided into stage intervals, with each stage interval represented by an index stage, Bi. The probability of each index stage, P(Bi), is computed as the fraction of the percent of time the index stage is equaled or exceeded, in accordance with EM 1110-2-1413. The Chicopee River stage frequency curves for each pumping station are reproduced in Appendix E.

The probability of attaining a given interior flooding elevation if the exterior river stage is at a specific elevation, P(A/Bi), is considered as equivalent to the annual probability of the interior storm events evaluated in the model, as follows:

Table 7. Probability of Attaining a Given Interior Flooding Elevation, if the Exterior River Stage is at a Specific Elevation.

Interior Storm Return Period (Year)	Interior Storm Annual Probability (P(A/Bi))
1	1.000
2	0.500
5	0.200
10	0.100
25	0.040
50	0.020
100	0.010
500	0.002

Each interior storm event is analyzed at each exterior river index stage to compute each corresponding interior flooding elevation. The probabilities associated with the various combinations of interior storm events and exterior stage which produce a given interior flooding elevation are multiplied and then summed to compute the total probability of exceeding that interior flooding elevation. A plot of interior flooding stages versus the total probabilities of exceeding each interior flooding stage reveals the interior flooding stage at which the total probability is equal to 0.01 (1%). This recurrence interval is selected by the Federal Emergency Management Agency (FEMA) as the “base flood” for estimating the extent of interior flooding and the calculation of flood insurance rates under the National Flood Insurance Program (NFIP).

Appendix F reproduces the coincident frequency analysis matrices and resultant curves. Matrix One computes the values of [P(A/Bi) x P(B)] for each of the selected river index stages. Each index stage is the midpoint elevation of a selected range of river stage. Matrix Two identifies the interior flood storage elevation for each interior storm event and for each river index stage. The family of curves on Graph One illustrates the relationship of the interior flood elevation and the [P(A/Bi) x P(B)] values for each river index stage. Then, for each interior flood elevation, the intercept of each index stage curve is summed to provide a value of ∑ [P(A/Bi) x P(B)], which is the probability of interior flooding to that particular elevation. These values are then plotted on Graph Two and, for purposes of FEMA interior flooding mapping, P(A) was set at 0.01. The 1% change interior flood elevation is then read directly off Graph Two using linear interpolation between adjacent data points.

5 RESULTS

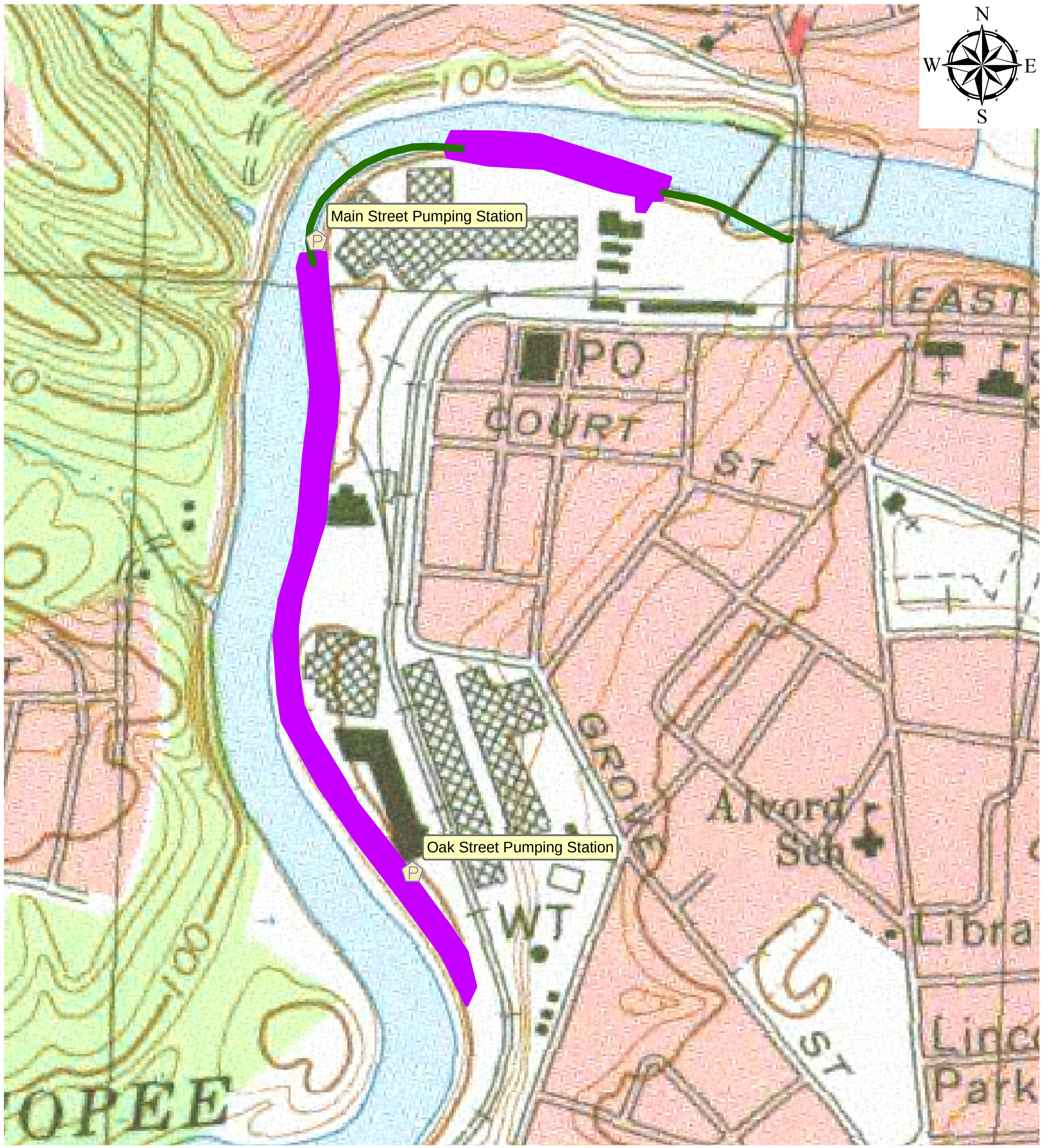
The computed interior stages resulting from the analyses of various combinations of exterior river index stage and interior storm return period for each pumping station are shown on the Coincident Frequency Analysis Matrices in Appendix F. For each pumping station, also included in Appendix F is the summation of probabilities to compute the total probability of exceeding a given interior flooding elevation and determination of the resulting 1% chance interior elevation. The 1% chance interior elevation at each pumping station is summarized in the table below. Also shown is the total area and average depth of interior flooding.

Using design pumping capacities, the computed flood elevation at the Main Street pumping station was 78.6, and at the Oak Street pumping station was 78.7. The predicted 1% chance interior flood elevations at both the Main Street and Oak Street pumping stations do not exceed the lowest ground surface elevations within their respective drainage areas, as indicated by the topographic contours generated from the MassGIS Digital Elevation Model. Therefore, there is no interior flooding associated with the 1% chance event at either of these pumping stations. Using modified pumping rates in the modeling, based on the pumping field tests as described in Sections 3.1 and 3.2, had no impact on the resulting 1% chance interior flood extent and elevations.

Table 8. 1% Chance Interior Flood Results

Pumping Station	**1% Chance Interior Flood Elevation (ft, NAVD88)**	**Total Area of 1% Chance Interior Flood (acres)**	**Average Depth of 1% Chance Interior Flood (ft)**
Main Street	78.6	0	0
Oak Street	78.7	0	0

Figures



Feet
500 250 0 500

LOCUS MAP

Project No: 15.0702100.40

Legend

- Floodwalls
- Levees
- Chicopee Pumping Stations

Chicopee Falls Flood Control System Chicopee, Massachusetts

Drawn by: ATR

Checked by: RTFS

Date: May, 2010

MassGIS Orthophoto (2005)

Figure No: **1**

Baystate Environmental Consultants, Inc.
296 North Main Street, East Longmeadow, MA

Data obtained from MASS GIS, Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs (EEA).

MAIN STREET P.S. DRAINAGE AREA

Project No: 15.0702100.40

Drawn by: MTF

Checked by: RTFS

Date: May, 2010

Figure No: 2

Legend

Pumping Station (P.S.)

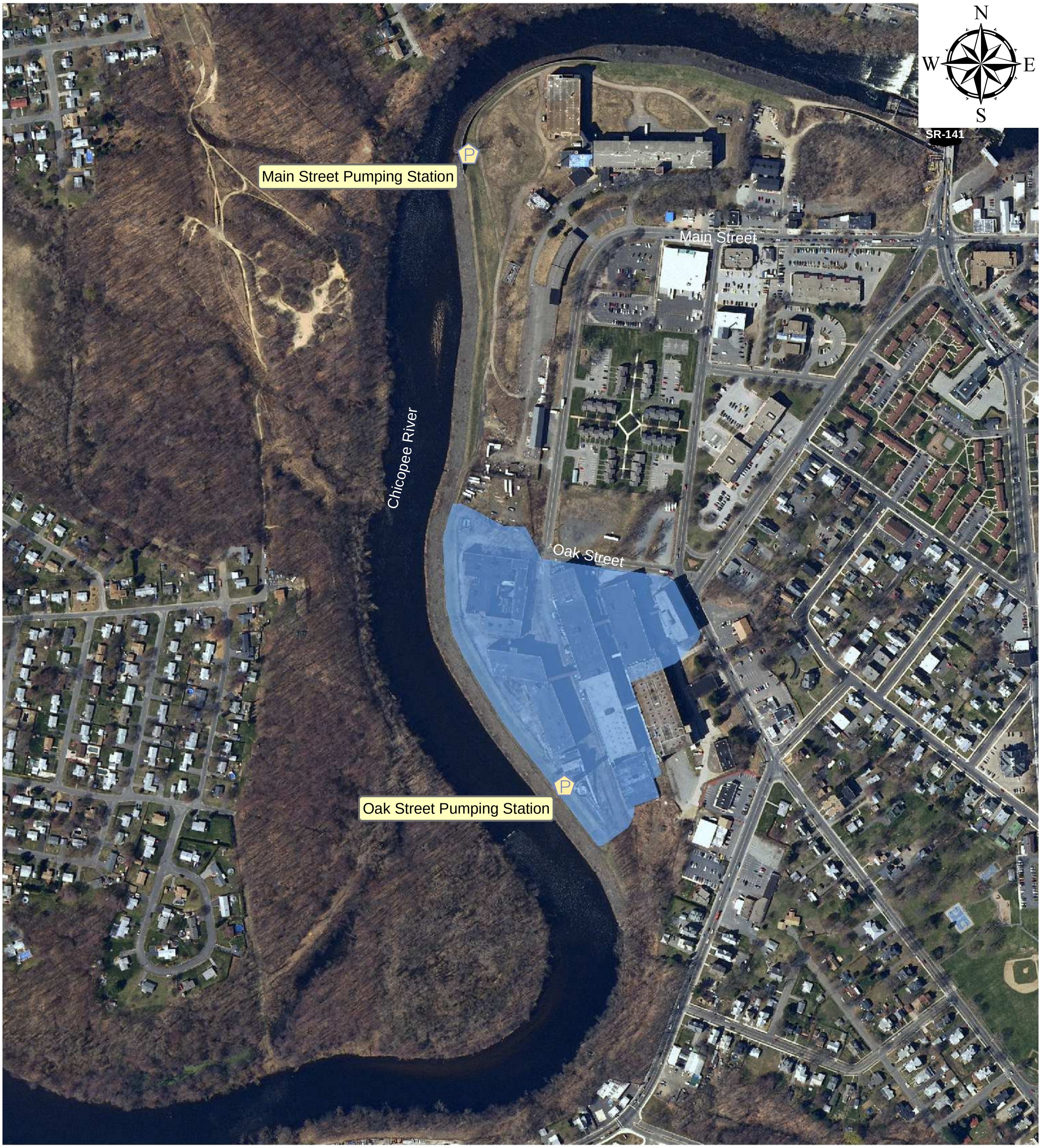
Main Street P.S. Drainage Area

Interior Drainage Analysis
Chicopee Falls Flood Control System
Chicopee, Massachusetts

MassGIS Orthophoto (2005)

Data obtained from MASS GIS, Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs (EEA).

Baystate Environmental Consultants, Inc.
296 North Main Street, East Longmeadow, MA



Feet
0 250 500 1,000

OAK STREET P.S. DRAINAGE AREA

Project No: 15.0702100.40

Legend

Pumping Station (P.S.)

Oak Street P.S. Drainage Area

Interior Drainage Analysis
Chicopee Falls Flood Control System
Chicopee, Massachusetts

Drawn by: MTF

Checked by: RTFS

Date: May, 2010

MassGIS Orthophoto (2005)

Figure No: 3

Baystate Environmental Consultants, Inc.
296 North Main Street, East Longmeadow, MA

Data obtained from MASS GIS, Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs (EEA).

Feet
0 250 500 1,000

Soils Map

Soils Legend

1 Water
602 Urban Land
737 Terrace Escarpments
739C Urban Land: Hinckley-Windsor Association

Interior Drainage Analysis Chicopee Falls Flood Control System Chicopee, Massachusetts

MassGIS Orthophoto (2005)

Data obtained from MASS GIS, Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs (EEA).

Baystate Environmental Consultants, Inc.
296 North Main Street, East Longmeadow, MA

Project No: 15.0702100.40

Drawn by: MTF

Checked by: RTFS

Date: May, 2010

Figure No: 4

APPENDIX A-4.7

OTHER DESIGN CRITERIA
(STRUCTURAL)

STRUCTURAL ANALYSIS

CHICOPEE FALLS FLOOD CONTROL SYSTEM

CHICOPEE FLOOD CONTROL WORKS

CITY OF CHICOPEE

HAMPDEN COUNTY, MASSACHUSETTS

October, 2010

Baystate Environmental Consultants, Inc.

A GZA Company

BACKGROUND

GZA's understanding of the project is based on our review of 44CFR65.10, our work at the site, discussions with the City of Chicopee, and the following project documents:

- A Plan set, entitled "Connecticut River Flood Control Project, Chicopee Falls, Mass., Plans for the Local Protection Project, Construction of, Chicopee River, Massachusetts, " prepared by the U.S Army Engineer Division, New England, Corp of Engineers, Waltham, Mass., dated June 1963, sheets 1- 68.

EXISTING CONDITIONS

The Chicopee Falls system is comprised of two sections of concrete flood wall, one approximately 530 feet long and the other approximately 860 feet long, installed at the top of an earthen embankment. The first wall section begins at the South abutment of the Deady Memorial Bridge, at project station 4+37.5 and extends about 530 feet to the west to Sta 9+69.8 along the southern/eastern shore of the Chicopee River. The final 20 feet at the western terminus of the floodwall, Sta 9+49.8 to Sta 9+69.8, is embedded in an earthen dike. The dike continues along the shore to the west until the second section of wall begins at project station 16+81.5. The second wall extends about 860 feet to the west along the eastern shore of the Connecticut River, to Sta 25+44.5. The final 20 feet at each end of the second wall is embedded in earthen dikes. The second length of dike, starting at Sta 25+24., extends to the southern terminus of the flood control system.

STRUCTURAL EVALUATION

Our structural engineers reviewed the original design documents in order to determine the assumed loading conditions and to review how the structural elements were designed. The results of the original analysis were compared to the current USACE guidance to verify that the structures meet current design requirements specified in the following documents:

1. USACE Manual EM 1110-2-2100 *Stability Analysis of Concrete Structures.*

2. USACE Manual EM 1110-2-2104 *Strength Design for Reinforced Concrete Hydraulic Structures.*

3. USACE Manual EM 1110-2-2502 *Retaining And Flood Walls.*

A total of eleven different wall sections between two sets of stations: 4+37.5 to 9+69.8 and 16+81.5 to 25+44.5 have been evaluated for this analysis with the methods prescribed in Reference 3. Our engineers evaluated each section for the load condition of the 1-percent-annual chance flood as required by FEMA Regulations 44 CFR 65.10. Analysis parameters and results are included in this Appendix 4.7. It is our opinion that the floodwalls will perform adequately under the 1-percent-annual-chance flood.

As prescribed by the USACE, the floodwalls were evaluated for sliding stability, overturning stability, foundation soil bearing capacity and strength and serviceability of the floodwalls. The floodwalls were analyzed as inland flood walls, critical structures with Case R1, “Usual Loading” conditions applied. Elevations and geometry data were taken from the 1963 USACE Construction Drawings referenced above, adjusted for the current survey datum. The flood wall section analysis is heavily based on Example 3 on page N-22 of Reference 3.

MATERIAL PROPERTIES

Subsurface conditions varied significantly over the length of the floodwalls. The original construction drawings indicate that much of the northern portion of the floodwall adjacent to the Deady Bridge is founded on rock and that the wall footing is secured with rock anchors. The subsurface investigations undertaken for this evaluation encountered weathered rock in the vicinity of the bottom of wall footing, east (up-station) of Sta 6+00±.

The effects of rock anchors were conservatively neglected in our analyses. In the original design documents, the floodwalls were designed for a flood elevation greater than the 1-percent-annual-chance flood upon which this current evaluation is based. The higher flood level necessitated the use of rock anchors (in the design calculations) to maintain wall stability. Confirmation of the rock anchor installation was not included in this evaluation as the current analyses indicate that they are not required for stability during the 1-percent-annual-chance flood.

Table 1 **-** Material properties for the wall sections analyzed were selected based on the original design calculations and field observations made for this report.

MATERIAL PROPERTIES		
Backfill Soil:		
Cohesion of Backfill soil un-drained	0.00	PSF
Cohesion of Backfill soil drained	0.00	PSF
Friction angle of backfill soil	26.50 – 35.00*	DEG
Developed friction angle = .0.667 x friction angle	17.67 – 23.33*	DEG
Coefficient of earth pressure at rest (Ko = 1-sin□)	0.43 – 0.55	
Unit weight of soil backfill per unit volume	100.00 – 130.00*	PCF
Unit weight of water	62.50	PCF
Saturated unit weight of soil	125.00 – 135.00*	PCF
Buoyant unit weight	62.50 – 72.50*	PCF
Buoyant unit weight on land side due to seepage	78.81 – 123.06*	PCF
Concrete:		
Unit Weight of Concrete	150.00	PCF
Unconfined Compressive Strength	4000.00	PSI

Steel Reinforcing Strength	60000.00	PSI
Depth of concrete cover for deign	3.00 – 4.50*	IN
Strength reduction factor □	0.90	
Shear factor	0.85	

* Values vary along length of wall. For specific values refer to Wall Analysis Data Sheets

Lateral Soil Forces

Lateral soil forces were calculated based on methods prescribed in Reference 3. We have assumed that a vertical soil tension crack will form at the riverside (RS) edge of the footing thus minimizing any active soil forces on the RS of the wall and footing. The passive soil force on the landside (LS) of the wall is included for bearing pressure and overturning calculations but neglected for the sliding stability analysis. All wall sections analyzed meet or exceed all of the USACE recommended factors of safety. For the wall section models, the ground surface elevations on the riverside and landside vary but are considered to be level as they extend away from the wall. Since the active and passive soil pressures are neglected in the sliding analysis, the coefficient of active and passive earth pressures are not calculated. To balance the wall in the lateral direction for the calculation of bearing pressures, we have calculated a required passive soil pressure and then back-calculated a required coefficient of passive earth pressure to achieve this balanced condition. The engineer then reviewed this “back-calculated” coefficient to decide if this value is reasonable. This value is presented as “Kp required to balance horizontal forces” on the analysis summary page.

Sliding Stability

Floodwall sliding stability was evaluated based on Reference 3, Section 4-14. The friction factor for sliding was based upon either a cast-concrete/soil or cast-concrete/rock interface, depending upon location. The contribution of any potential sliding resistance of the rock anchors was neglected.

Bearing Capacity

Floodwall foundation bearing capacity was evaluated based on Reference 3, Chapter 5. Given the firm nature of the underlying rock or soils and the width of the footings, bearing capacity is not an issue of concern for the subject walls.

APPENDIX A-6

CITY OF CHICOPEE OPERATION AND MAINTENANCE MANUAL (BOUND SEPARTELY)