Water Resources Center Annual Technical Report FY 2013

Introduction

During FY 2013 sequestration has cut the Rhode Island Water Resources Center funding by 40% and as a result the Center has supported one research grant and one information transfer project. In previous years the Center has funded two research projects in addition to the information transfer project. The research project entitled, “Preliminary Analysis of Liquefaction Potential at the Gainer Memorial Dam,” involved an engineering analyses including seismic hazard assessments, geostatic stresses, and dynamic site response finite element analyses to evaluate the potential for liquefaction of the hydraulic fill dam. Liquefaction of the dam core could result in a catastrophic dam failure. The information transfer project supported a Clean Water Conference and a summer water academy for middle and high school students.

In addition to these activities, the Rhode Island Water Resources Center continued to partially support graduate and undergraduate students in research. This year, the Center revised the website (www.wrc.uri.edu) to make it easier to access and update.

Research Program Introduction

The Rhode Island Water Resources Center has supported one research proposal. The proposal entitled, "Preliminary Analysis of Liquefaction Potential at the Gainer Memorial Dam," was completed by PI Aaron Bradshaw, an Assistant Professor in the Department of Civil and Environmental Engineering.

The Gainer Memorial Dam located in Hope, Rhode Island is a high hazard dam and is the largest if not the most important in Rhode Island from a water resources perspective. The dam is an earthen or embankment type dam constructed by hydraulic fill methods in the early 1920's. The 109-feet high dam has a length of over 2,000 feet and retains the Scituate reservoir. This study described the field investigations, laboratory studies and engineering analyses performed in order to evaluate the liquefaction potential of the dam. The field investigations included sampling and in-situ shear wave velocity measurements. The laboratory studies included water content, grain size analysis, and cyclic triaxial testing. The engineering analyses included seismic hazard assessments, geostatic stresses, and dynamic site response finite element analyses to evaluate the potential for liquefaction of the hydraulic fill dam. The results overall show a low potential for liquefaction in a 2,500-year design earthquake with some potential for pore pressure generation during shaking.

Seismic Evaluation of the Gainer Memorial Dam

Basic Information

Title:	Seismic Evaluation of the Gainer Memorial Dam
Project Number:	2013RI115B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	2
Research Category:	Engineering
Focus Category:	Water Supply, Water Quantity, Management and Planning
Descriptors:	
Principal Investigators:	Aaron Stephen Bradshaw, Gopu Potty, George Tsiatas

Publications

There are no publications.

PRELIMINARY ANALYSIS OF LIQUEFACTION POTENTIAL AT THE GAINER MEMORIAL DAM

Bivian Reyes

Christopher Norton

Aaron Bradshaw, Ph.D., P.E

Gopu Potty, Ph.D.

DRAFT FINAL REPORT

Submitted to:

Rhode Island Water Resources Center

May 30, 2014

Abstract: The Gainer Memorial Dam located in Hope, Rhode Island is a high hazard dam and is the largest if not the most important in Rhode Island from a water resources perspective. The dam is an earthen or embankment type dam constructed by hydraulic fill methods in the early 1920's. The 109-feet high dam has a length of over 2,000 feet and retains the Scituate reservoir. This study describes the field investigations, laboratory studies and engineering analyses performed in order to evaluate the liquefaction potential of the dam. The field investigations included sampling and in-situ shear wave velocity measurements. The laboratory studies included water content, grain size analysis, and cyclic triaxial testing. The engineering analyses included seismic hazard assessments, geostatic stresses, and dynamic site response finite element analyses to evaluate the potential for liquefaction of the hydraulic fill dam. The results overall show a low potential for liquefaction in a 2,500-year design earthquake with some potential for pore pressure generation during shaking.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Background

Past experience with dam failures during earthquakes have shown the need to consider seismic effects in design. Although Rhode Island is not considered to lie in a seismically active region such as California, the design of new structures including dams must consider loads imposed by design level seismic events. Unfortunately, the majority of the dams in many states including Rhode Island were constructed in the past when current seismic design considerations and procedures were not yet developed.

In Rhode Island, the dam safety is managed by the Dam Safety Program within the Office of Compliance and Inspection at DEM. Dam safety information is available through their website (http://www.dem.ri.gov/programs/benviron/compinsp/dams.htm). Currently there are 668 inventoried dams in Rhode Island. Currently, DEM classifies each dam into one of three hazard categories (high, significant, and low) based on the potential for loss of life and economic losses. Under a past Rhode Island Water Resources Grant, Gindy et al. (2007) proposed a method to evaluate the downstream hazard potential for Rhode Island dams. The primary goal of the Rhode Island dam safety program is to restore the dams to their as-built condition. Seismic assessments of existing dams are not a focus for the dam safety program at the present time but it is something that perhaps could be considered in the long-term (Paul Guglielmino, personal communication).

The Gainer Memorial dam is a high hazard dam and is the largest if not the most important in Rhode Island from a water resources perspective. The dam is an earthen or embankment type dam with a height of 109 feet and a length of over 2,000 feet (USACE 2013). It retains the Scituate reservoir that has a capacity of roughly 40 billion gallons (USGS 2013). From a safety perspective a breach of this dam would inundate a significant population downstream in Hope, Cranston and West Warwick. From a water supply perspective the dam is responsible for over 60% of the states population, which would be compromised in the event of a dam failure. Based on conversations with DEM to the best of our knowledge this dam has never undergone any seismic evaluation. The dam was constructed using hydraulic placement methods that could have deposited the soils in a loose condition. This is a concern because loose soils are prone to soil liquefaction that could destabilize the dam in a seismic event.

Seismic evaluations of existing dams are a priority of dam safety officials in regions of high seismic activity such as the U.S. west coast. However, critical dams in the central and eastern U.S. that are not considered seismically active regions have also undergone extensive study in some cases to evaluate their seismic performance. The seismic evaluations shed light on the resiliency of the dams in extreme earthquakes and provide useful information to the dam owners and dam safety agencies in assessing their risk and possible mitigation measures.

Design manuals and guidelines documents have been developed by numerous agencies to address the issue of seismic design of dams in the United States and are compiled on the Association of State Dam Safety Officials website (damsafety.org). These guidelines are intended to manage risk in various agencies but all contain similar information and present similar approaches to addressing seismic analysis and design issues. Perhaps the most current guidelines are those published by FEMA (FEMA 2005). FEMA (2005) will be used to guide the seismic analysis of the Gainer dam as part of this study.

Two cases where seismic evaluations have been performed on dams in the eastern U.S. include the Cobble Mountain dam in Springfield Massachusetts, and the Saluda dam in Columbia, South Carolina. Both dams are similar to the Gainer dam in that they are earth dams constructed using hydraulic methods, and they lie in similar seismic settings. Urzua et al. (2002) describe a very detailed seismic analysis of the Cobble dam that involved the use of 6 different finite element programs. They performed site response, liquefaction potential analysis and deformation analysis to evaluate the dam performance under two extreme design level seismic events; one with a return period of 5,000 years and peak base acceleration of 0.12g and a 10,000 year event with peak acceleration of 0.16g. The analyses showed a low potential for liquefaction and deformations were acceptable even for the largest event.

Bair et al. (2003) describe a seismic evaluation of the Saluda dam in South Carolina that included both liquefaction potential and stability analyses. They did not specify the size of the seismic design event but their analyses indicated a high potential for liquefaction in certain soil zones within the dam. Stability analyses showed the potential for catastrophic failure of the dam if these potentially liquefiable zones were to undergo liquefaction.

The two cases described above suggest there is no general assessment that can be made about dams in the eastern U.S. Rather; the seismic performance of dams must be evaluated on a case-by-case basis. The dam geometry, soil conditions, and ground response is unique for every dam. This provides ample motivation for at least giving some consideration to the seismic performance of the Gainer dam in Rhode Island.

1.2 Objectives

This project focused on a preliminary evaluation of the seismic performance of the Gainer Memorial dam. More specifically the objective was to evaluate the liquefaction potential of the dam under a large design level earthquake. The main challenge was to assess liquefaction potential without the need to perform deep geotechnical borings at the site.

1.3 Scope of Work

The original scope of work included a full evaluation of the seismic performance of the dam including the assessment of liquefaction potential, slope stability, and deformation behavior. However, given the importance of liquefaction potential as it affects both stability and deformation behavior, it was decided to focus only on the evaluation of liquefaction potential that included the following main tasks:

Perform site investigations at the dam

Assess seismic hazards at the dam site

Perform site response analysis

Evaluate liquefaction potential

Prepare final report

1.4 Structure of the Report

This report is structured into 8 remaining sections. Section 2 gives a summary of the background of Gainer Dam. Section 3 describes the site investigations performed. Section 4 pertains to the laboratory tests conducted. Section 5 describes the analysis to obtain the geostatic stresses. Section 6 pertains to seismic hazard assessment performed. Section 7 describes the site response analysis and Section 8 describes the liquefaction potential analyses performed. Conclusions to the study are presented in Section 9.

2. BACKGROUND ON GAINER DAM

2.1 Dam Configuration

A typical cross section of the main part of the Gainer dam is shown in Figure 1. The embankment dam is approximately 3,200 feet long and has a maximum height of 109 feet. The side slopes range from 2H:1V to 3H:1V. There are two levels of benches on the downstream slope of the dam, located at elevations 267 feet and 236 feet (main sea level). The downstream side of the dam is covered with grass and the upstream side has riprap on the exposed slopes. The interior of the dam has a low permeability core extending into a large core trench. The dam soils are founded on bedrock.

2.2 Construction Methods and Materials

The following description of the construction methods and materials is taken almost verbatim from an unpublished historical document provided by the Providence Water Authority (PWA). Prior to construction of the dam, geotechnical borings were made along several proposed dam locations to determine the depth to bedrock and the character of the overlying material. From this data, and after comparative cost estimates, the current dam location was selected which lies between two rock outcrops south of what was the village of Kent.

The excavation of the core trench started on July 25, 1921. Railway traction steam shovels with 2 ½ cubic yard buckets, smaller steam shovels with buckets ranging in size from ¾ to 1 ¼ yards, and a drageline excavator operating where it was difficult for the shovels to operate, were employed in excavating the core trench. The material was removed from the trench by narrow gauge four cubic yard dump cars hauled by 20-ton dinkey locomotives operating on each side of the trench. In addition to the trains of dump cars, a cableway having an 804-foot span was used to remove material from the trench. Water entering the core trench as the excavation advanced was diverted to open sumps on both sides of the trench, which were moved towards the deeper part of the trench as the work progressed.

As the surface of the rock in the core trench was exposed, all loose and disintegrated rock was removed by barring and wedging because the use of explosives was not permitted. Two hundred and ten holes about 18 feet in depth and 20 feet apart were drilled in the rock for grouting the seams.

A concrete cutoff structure was installed on the exposed rock surface beneath the core. In addition to the cutoff, concrete retaining walls 60 feet apart were installed on either side of and at the deepest portion of the core trench to facilitate the maintenance and operation of sump pumps during the excavation of the trench, and to simplify the placing of the soil core at that location. Both walls are 11 feet high, the top of the upstream wall at elevation 136 and the downstream wall at elevation 132. The impervious core at and below elevation 198 is about 77 feet in width, its center being 15 ½ feet downstream from the center of the dam. Above elevation 198 the core narrows at the rate of 2 feet for every 3 feet of height. To compensate for settlement, the top of the core at its deepest point was carried to elevation 291, two feet higher than at the easterly and westerly ends of the dam.

Soil for the impervious core was obtained from the reservoir area, a substantial amount being obtained from wooded areas that required clearing and grubbing. The soil was removed by steam shovels and transported by 2-yard dump wagons to storage piles adjacent to narrow gauge tracks where it was loaded in cars and delivered to the dam. Soil for the core at the deepest portion of the trench was first placed by the cableway employed for the excavation, a considerable amount being dumped from moving skips without lowering. After the core was installed to an elevation that provided an adequate working area, tracks were laid on the core and thereafter the greater portion of the soil was delivered directly to the core by trains. The installation of the core became a routine operation of dumping, spreading in six-inch layers and rolling. Stones as large as 8-inches were permitted in the core provided that they were not deposited in nests and did not interfere with proper rolling. Roots were removed from the soil after spreading.

The soil was supported by an embankment or backing of porous material, its upstream face protected against wave action by light and heavy riprap installed on 12-inches of broken stone, and the downstream face was grassed. As the construction of the core progressed, the pervious material, which formed the upstream and downstream support or backing of the core, was deposited at the same time as the impervious material was deposited. The bulk of the backing was consolidated by flushing the material down slopes with 1 1/8-inch hose nozzles attached to 2 1/2 –inch hose lines supplied by 6-inch mains installed on either side of the core. During the fall and winter months, a pool of water several feet deep was maintained on the backing, and the pervious material being installed was consolidated by dumping the material directly into the pool. The amount of water used in compacting the pervious material was about equal to the volume of the material compacted by it.

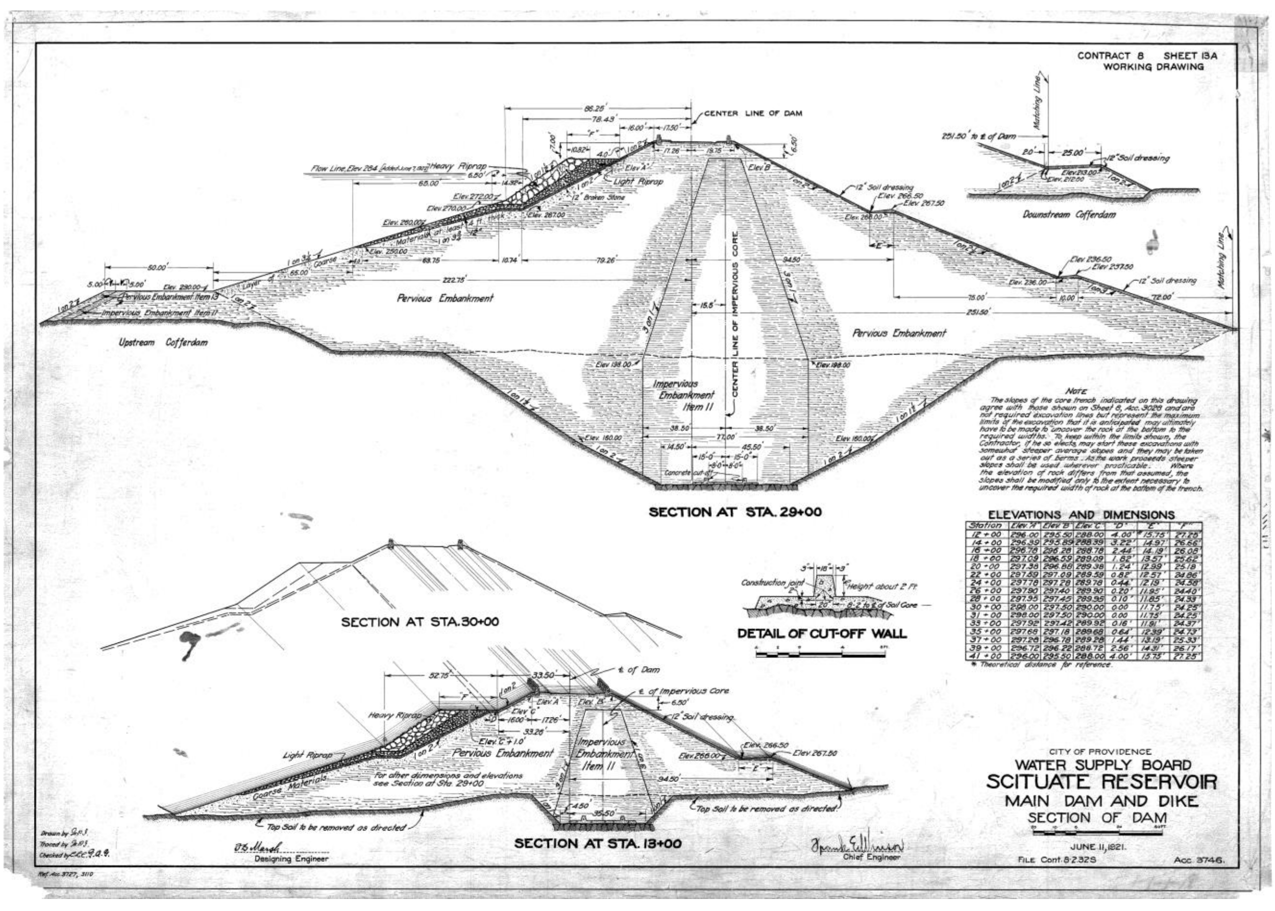


Figure 1. Cross section of the Gainer Dam at Station 29 (courtesy of Providence Water Authority).

Figure 2. Photograph of the Gainer dam looking westward. The situate reservoir is shown on the right.

3. SITE INVESTIGATIONS

The site investigations included shallow test pits to obtain representative soils for laboratory testing and in situ shear wave velocity measurements needed for the site response and liquefaction potential analysis.

3.1 Shallow Test Pits

Six shallow test pits were excavated on the downstream face of the dam to obtain representative samples of the dam shell soils for laboratory testing. A handheld GPS unit was used to record the coordinates of each test pit. The locations of the test pits are shown in Figure 3.

Test pits were accomplished by a combination of hand augering and excavation as shown in Figure 4. Significant cobbles were encountered which caused difficulties with the augering process.

One representative soil sample was obtained from the bottom of each test pit using a post hole digger as shown in Figure 5. Each sample was then placed in a 2-gallon container, sealed and labeled with the berm and test pit number, the latitude and longitude, and any important initial observations about the sample.

Some of the soil samples appeared to contain organic soils (i.e. topsoil) from sloughing of the soils into the bottom of the hole during sampling. These samples were not included in the composite sample that was made for laboratory testing.

The samples recovered from the dam were not truly representative of the in situ soil. Large cobbles were observed at the bottom of the test pits but were contained within a matrix of sandy soil. Assuming that the behavior would be controlled by the sandy matrix, only the sandy portion of the soil was collected in the containers and later used to develop the composite sample for laboratory testing.

3.2 In Situ Shear Wave Velocity Measurements

A profile of shear wave velocity in the dam was obtained using a surface wave inversion method. Measurements were made on the upper bench on the downstream face of the dam and on the dam crest.

The experimental setup for measuring the Rayleigh surface waves was placed on the first bench of the dam, descending from the top. The setup consisted of two sets of geophone arrays, two data acquisition units known as Several Hydrophone Receiver Units (SHRUs), and a tripod, which was used to drop a 100-lb weight from a height of six feet. Each geophone array consisted of 4 geophones spaced 5 m apart, spanning a total of 15 meters. The two arrays were placed in series so that the total array length became 35 m when placed parallel to each other. The geophone arrays were each attached to a SHRU unit, which would record the Rayleigh surface waves measured by the geophone arrays. The 100-lb weight was dropped at 10-foot intervals away from the geophone located furthest away from the SHRUs, until the total distance between the drop point and the nearest geophone was 50 feet.

The data recorded by the SHRU system were processed using MATLAB and phase velocity dispersion (phase velocity as a function of frequency), coherence between data from geophone pairs, and power spectral density, were calculated. The data collected at the crest of the dam lacked quality and could not be processed. All possible drop and each geophone combinations, which provided data with high signal to ratio, were processed. Estimates of the shear wave velocity profile were also made using the following equation (Lin et al. 2014):

$$V_s = A\left(\frac{\sigma_v'}{p_a}\right)^n \qquad (1)$$

where A and n are recommended parameters based on soil type. The measured phase velocity data with high confidence (with good coherence and signal to noise ratio) and that comparared reasonably well to the theoretical curve was then used as the input data in the non-linear inverse scheme.

To calculate the shear wave velocities from the Rayleigh surface wave velocities, a nonlinear inverse scheme was developed which consisted of a forward model that relates the observed data to the unknown model parameters (shear wave speeds at different layers). A dynamic stiffness matrix approach was chosen as the forward model: the dispersion relationship for the Rayleigh wave velocities was computed from a global stiffness matrix of a layered bottom system. The soil was assumed to be elastic and the soil layers in the profile were characterized by layer thickness, mass density, Poisson's ratio, shear and compressional velocities. Initial input parameters were estimated based on the anticipated soil conditions in the dam.

A genetic algorithm was used as the search engine, which generated populations of solutions that were iteratively modified based on genetic operations to find even better solutions. The algorithm was allowed to create 50 of these populations and the best shear wave velocities from each soil layer were selected and plotted to generate a shear wave velocity profile.

The resulting shear wave velocity profile is presented in Figure 10. Curves were also generated for loose and dense gravel using Lin et al. (2014) to check the reliability of the results.

As shown in Figure 16, the shear wave velocity obtained from the MASW measurements taken at the dam is higher than the Lin et al. (2014) prediction for dense gravel. This suggests that the soils composing the shell of the dam are very dense or the cobbles within the dam are driving up the shear wave velocities. It is also evident from Figure 10 that the soils appear to be loose below a depth of approximately 21 meters that correspond to the soils composing the core trench. It is interesting to note that the construction history described above, indicated that the core trench soils were placed by dumping from a skip that would likely result in a very loose in situ condition. The high shear wave velocity at a depth of 30 m indicates the bedrock level.

Figure 3. Site plan showing the test pit locations (basemap from Google Earth).

Figure 4. Photograph of the hand auger.

Figure 5. Photograph of the test pit and post hole digger used to recover samples.

Figure 6. Site map showing the SHRU locations for surface wave testing (basemap from Google Earth).

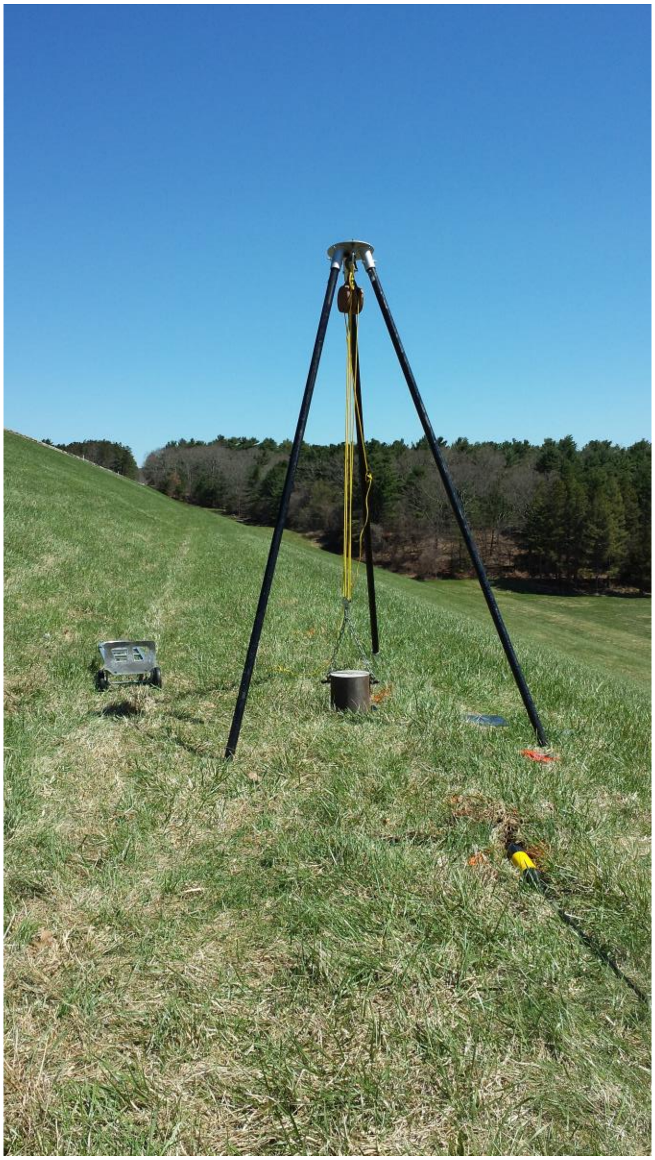


Figure 7. Photograph of the drop weight system used for the surface wave testing.

Figure 8. Photograph showing a geophone. Note that the grass was removed for better contact with the ground.

Figure 9. Photograph showing the SHRUs connected to the geophone arrays.

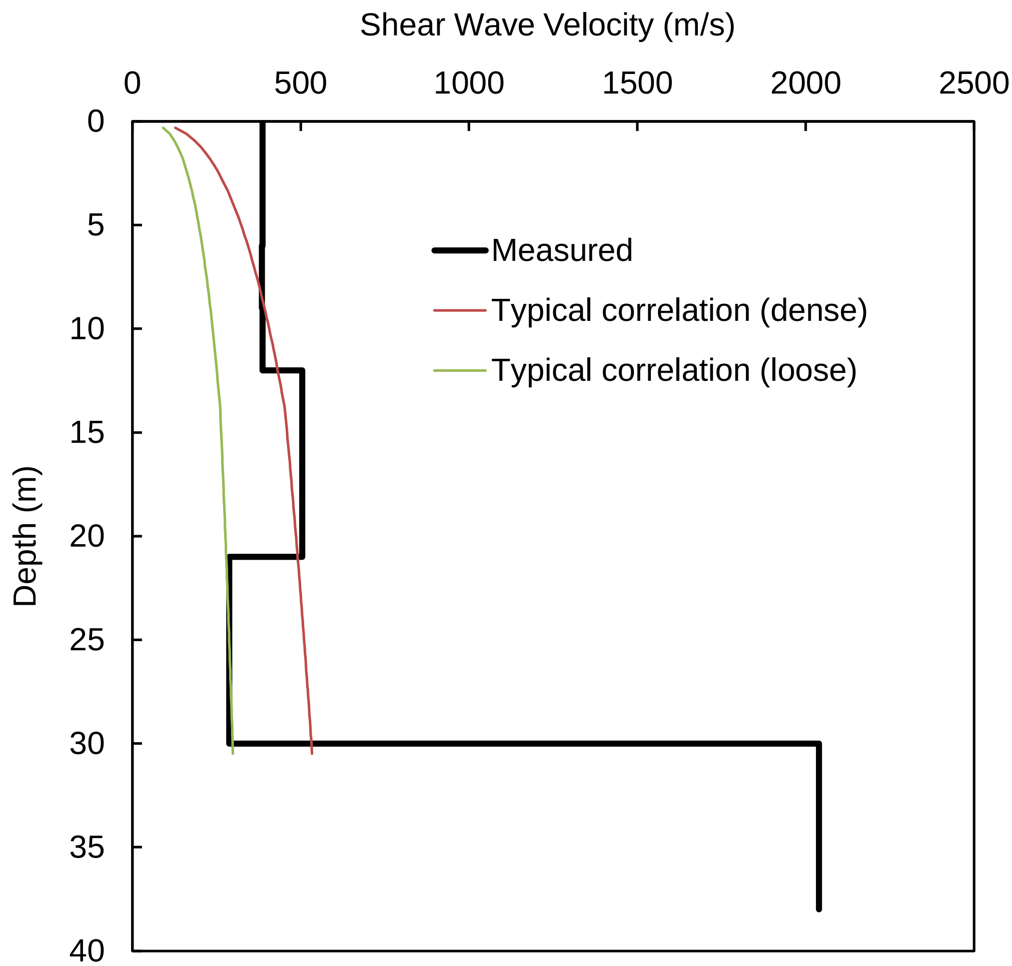


Figure 10. In situ shear wave velocity profile obtained on the downstream side of the dam using the surface wave method.

4. LABORATORY TESTING

Laboratory tests were performed on soil samples recovered from the test pits to obtain physical properties and to assess the cyclic resistance to liquefaction.

4.1 Physical Properties Testing

A composite sample was made by combining the field samples. The composite sample was then cone and quartered to provide a statistically representative sample for laboratory testing. Water content was determined in accordance with ASTM D2216. Sieve analyses were performed in accordance with ASTM C136-01.

The grain size distributions for both samples tested are presented on Figure 6. The results show a well-graded sand with a fines content of approximately 15% and a gravel content of approximately 20%. The median particle diameter for the soil (D_{50}) is 0.4 mm.

The water content results are presented in Table 1. Water contents ranged from 4.5% to 7.2%, which are typical of a gravelly sand.

4.2 Cyclic Triaxial Testing

The construction methods suggested that the dam soils were placed using hydraulic methods that may have deposited soils in a loose condition. Therefore, cyclic triaxial tests were performed on samples that were reconstituted to the loosest state possible.

Cyclic triaxial testing was performed on 2.8-inch diameter specimens in general accordance with ASTM D5311. Particles larger than $1/6^{th}$ of the specimen diameter were removed. The finer composite was then coned and quartered and placed in two different containers, which would be used alternately to reconstitute triaxial test specimens.

Samples were prepared using a technique similar to that used in the maximum void ratio test (ASTM D4254-00 Method C) in order to attempt to achieve a sample in its loosest state possible. The sample was prepared within a split mold containing a 0.012-inch thick rubber membrane. The membrane was placed over the bottom cap and two rubber o-rings were used to seal the membrane and bottom cap. Vacuum grease was applied to both sides to ensure a good seal for the split mold. The split mold was then assembled on top of the PVC ring. A second rubber o-ring was placed on the external side of the top of the split mold for use with the top cap when the sample was finished. The rubber membrane was then pulled over the top edge of the split mold, secured in place with a thick rubber band, and a 30-kPa vacuum was applied to the split mold.

A 12.45-inch tall clear PVC tube with an inside diameter measuring 2.25 inches and 0.1-inch thick walls was placed inside the split mold and the soil was then pluviated into this tube by the use of a 500 ml beaker. A plastic stopper was then placed on the open end of the clear PVC tube and the bottom of the triaxial cell, along with the membrane, split mold and capped PVC tube were inverted a total of five times, holding the bottom of the triaxial cell and the stopper at the end of the PVC tube in place. This was necessary to try to achieve a sample in its loosest state with a homogeneous distribution of particles throughout.

Once the mold had been inverted five times, the triaxial cell base was placed down and a plastic collar was placed around the top of the split mold to easily collect overflow of the sample mass. The clear PVC tube was then slowly removed by pulling upward, allowing the soil to occupy the entire split mold. Care was taken not to subject the sample to any vibrations to avoid compacting the sample.

Once the clear PVC tube was removed, the sample was leveled off with a putty knife and the top cap was placed onto the specimen and the membrane was rolled onto the top cap.

Each sample was flushed with CO_2 for half an hour prior to inundation with de-aired water. The backpressure was raised gradually to approximately 300 kPa where the sample was allowed to sit for 5 hours. At the end of saturation, a Skempton B-parameter check was performed to ensure that all samples were fully saturated (i.e., $B \geq 0.95$). Samples were isotropically consolidated to an effective stress of 100 kPa. The samples were then subjected to a two-way uniform amplitude sinusoidal deviator stress having a frequency of 1 Hz.

A total of six tests were performed, out of which only four liquefied. Typical results are shown in Figure 14. Liquefaction was defined when the pore pressure ratio reached 1.0. The average applied cyclic resistance ratio (CRR_{tx}) was calculated for each of the tests up to the point of initial liquefaction by the following equation:

$$CRR_{tx} = \frac{\Delta\sigma}{2\sigma_0'} \tag{2}$$

where $\Delta\sigma$= cyclic deviator stress, and σ_0'= initial effective confining pressure. The CRR_{tx} for these tests varied from 0.15 to 0.21 and samples liquefied between 4 and 12 cycles.

For the liquefaction analysis presented later in this report, the cyclic resistance ratios measured in the triaxial test were corrected for field conditions using the following equation (Seed 1979), which corrects for multidirectional shaking and simple shear:

$$CRR = 0.9 \times c_r \times CRR_{tx} \tag{3}$$

where c_r = correction factor for simple shear defined in Castro (1975) as:

$$c_r = \frac{2(1 + 2K_0)}{3\sqrt{3}} \tag{4}$$

The CRR versus number of cycles to liquefaction for all four tests are presented in Figure 9. A best-fit logarithmic trendline was fit to the data. The results from the cyclic triaxial testing show a very flat curve that is typical of loose samples. It is anticipated that because the samples were dry pluviated and prepared very loose, the results in Figure 9 represent a lower bound of cyclic resistance. Any densification of the soil or strengthening of the fabric (e.g., from ageing) would only increase the liquefaction resistance.

Table 1. Water contents results for the recovered soil samples.

Sample number	Water content (%)
B1B1	7.12
B2B1	7.20
B3B1	4.57
B1B2	4.51
B2B2	5.04
B1B0	5.34

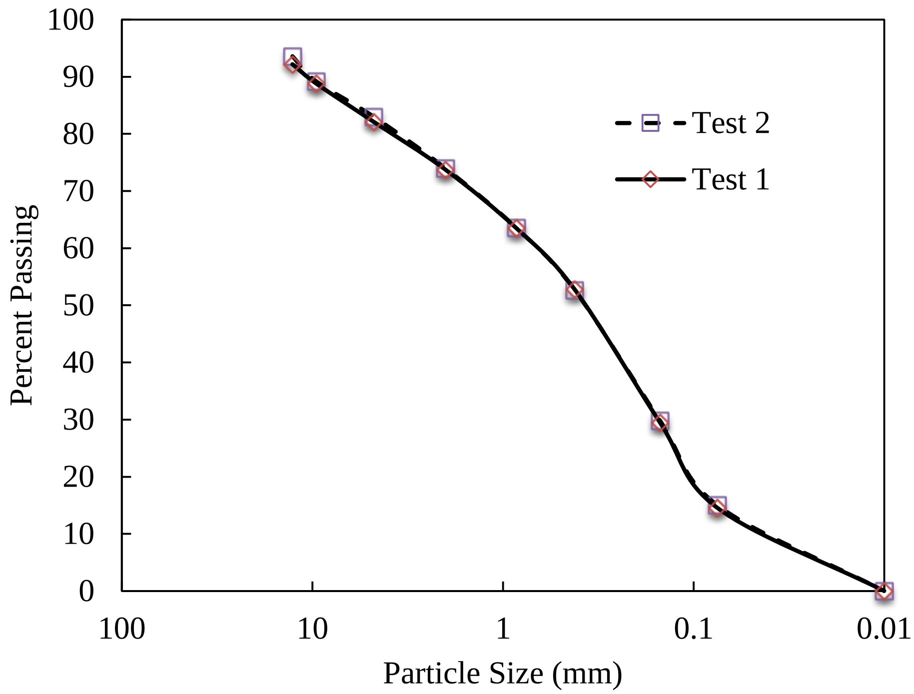


Figure 11. Grain size analysis results for the composite sample.

Figure 12. Photograph of a triaxial sample ready for testing.

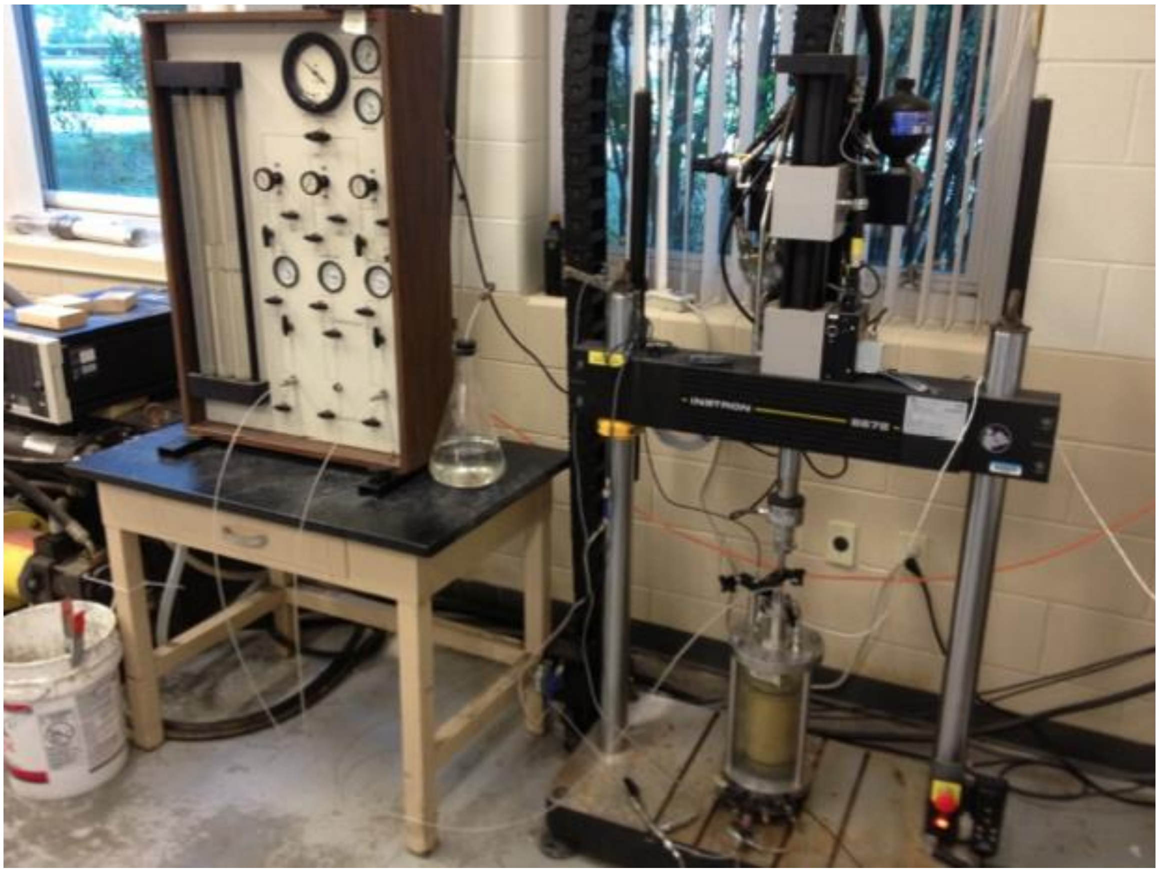


Figure 13. Photograph of the cyclic triaxial test setup.

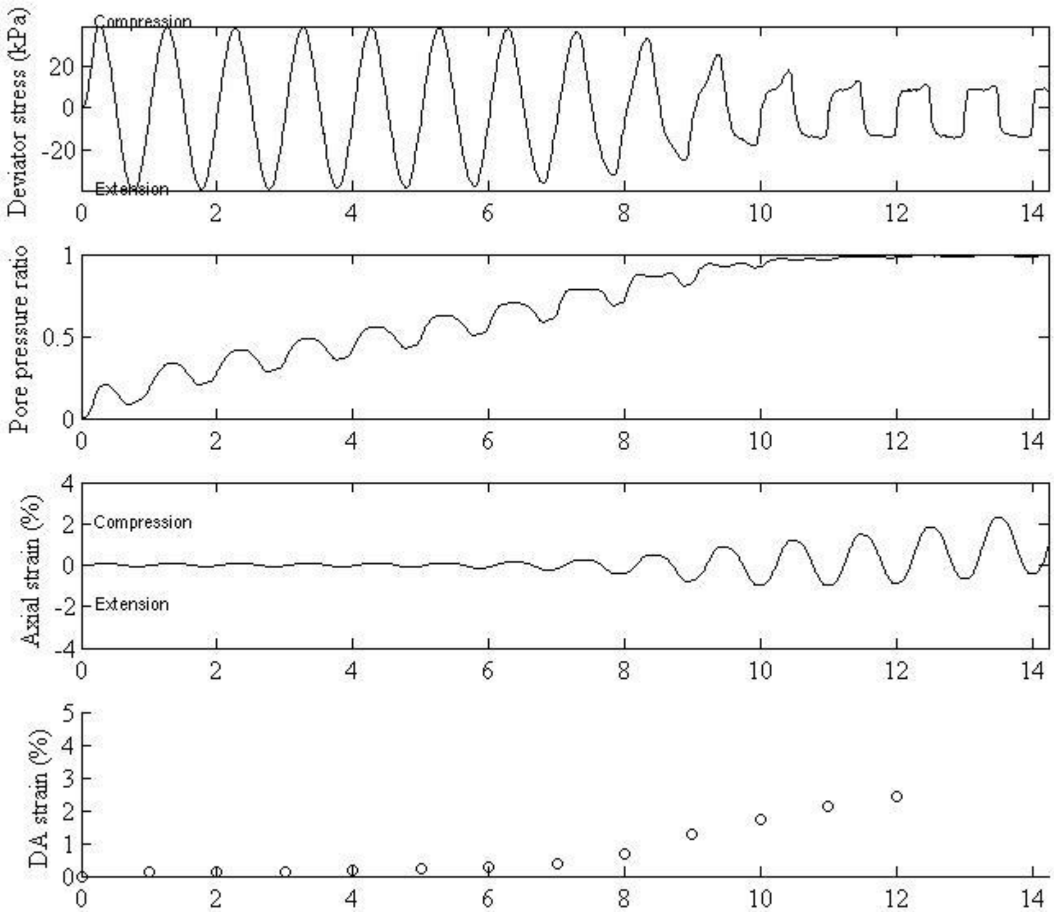


Figure 14. Typical cyclic triaxial test results. Note that initial liquefaction occurred for this test at 12 loading cycles.

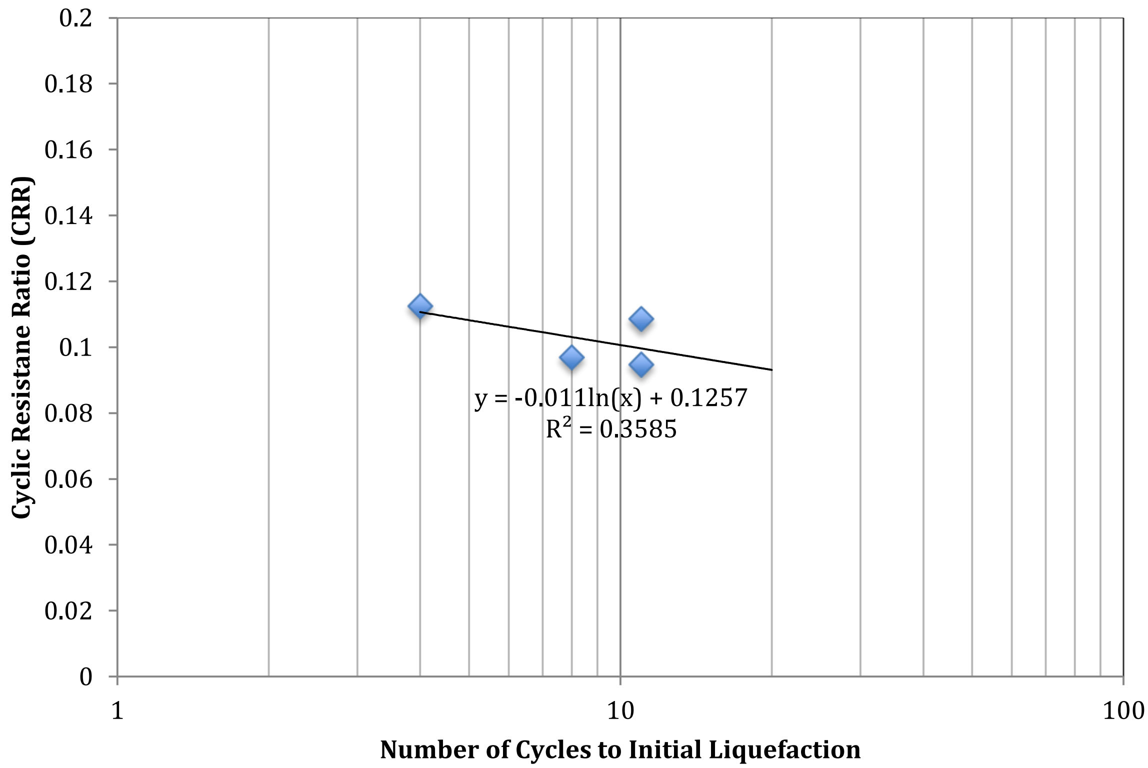


Figure 15. Cyclic triaxial test results plotted as CRR versus number of cycles to initial liquefaction.

5. ANALYSIS OF GEOSTATIC STRESSES

A commercially available finite element program called Phase2 was used to estimate the geostatic stresses in the dam, which is needed for the site response and liquefaction analysis described later in the report.

5.1 Model Development

Phase2 is an elasto-plastic finite element stress analysis program that can incorporate steady state seepage. The dam was modeled in the program by using the geometry from the dam's cross-section at Station 29.

The geometry was defined by adding both external and material boundaries to define the shell and core materials. The mesh was automatically generated using a graded mesh and three-noded triangular elements with a minimum number of 3,000 nodes on the external boundary. The final mesh for the dam model consisted of 77,526 elements in total.

The hydraulic and stress analysis boundary conditions were defined and the weight of the ponded water was added to the model in the form of a distributed load. Phase2 automatically determined the magnitude of the load based on the value of total head, the elevation of the line segments, and the unit weight of water entered in the Project Settings dialog. The field stresses were defined as gravity field stresses using the actual ground surface and finally, the hydraulic and material properties were defined. Permeability for both materials was originally estimated from common values according to soil type. The remaining material properties were chosen to be on the conservative side, in order to obtain worst-case results.

Several total and effective vertical stress values were calculated by hand and compared to the Phase2 results to check that the analysis was run correctly. The outflow on the toe of the dam was also compared to the actual outflow from the dam, in order to fine-tune the estimated permeability for both materials.

5.2 Model Results

The static shear stresses, along with the in-situ effective vertical stresses and mean stresses were obtained from the analysis. Contours for each of these stresses are shown in Figures 17 through 19.

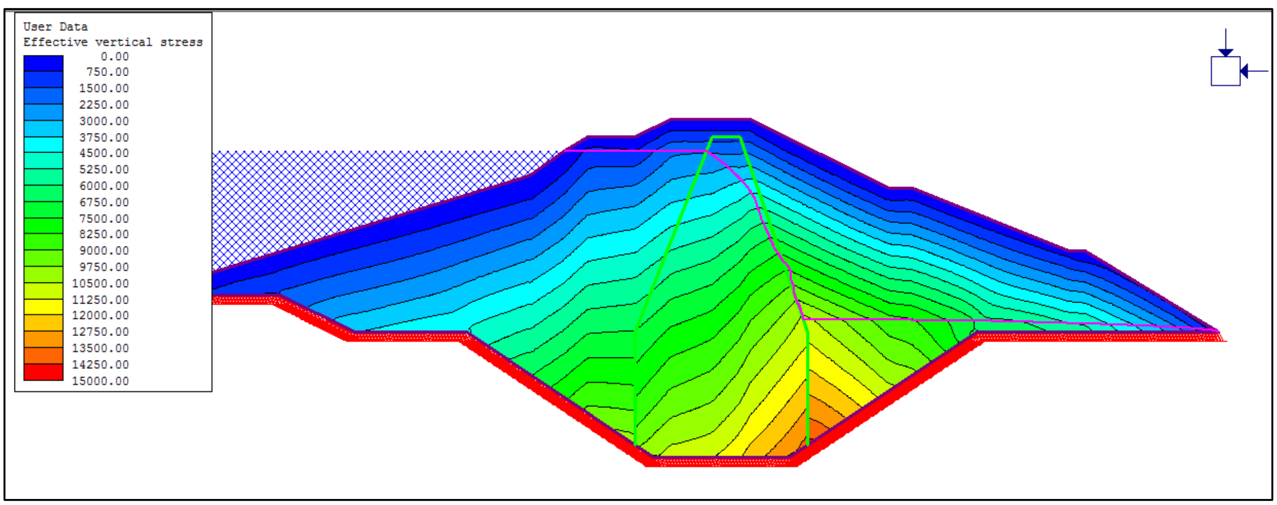


Figure 16. Phase2 output showing effective vertical stress contours.

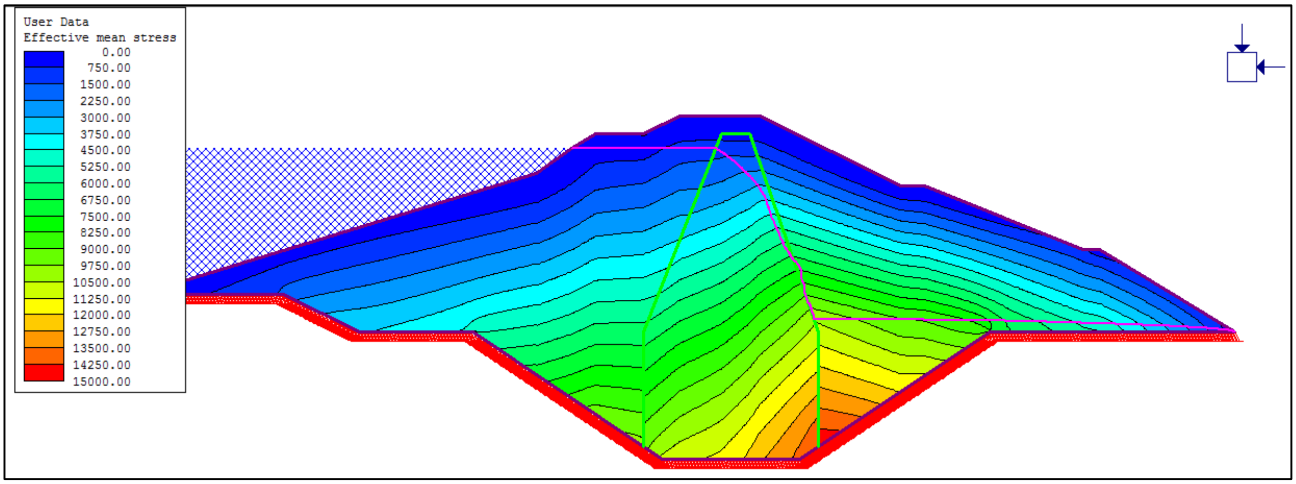


Figure 17 . Phase2 output showing mean effective stress contours.

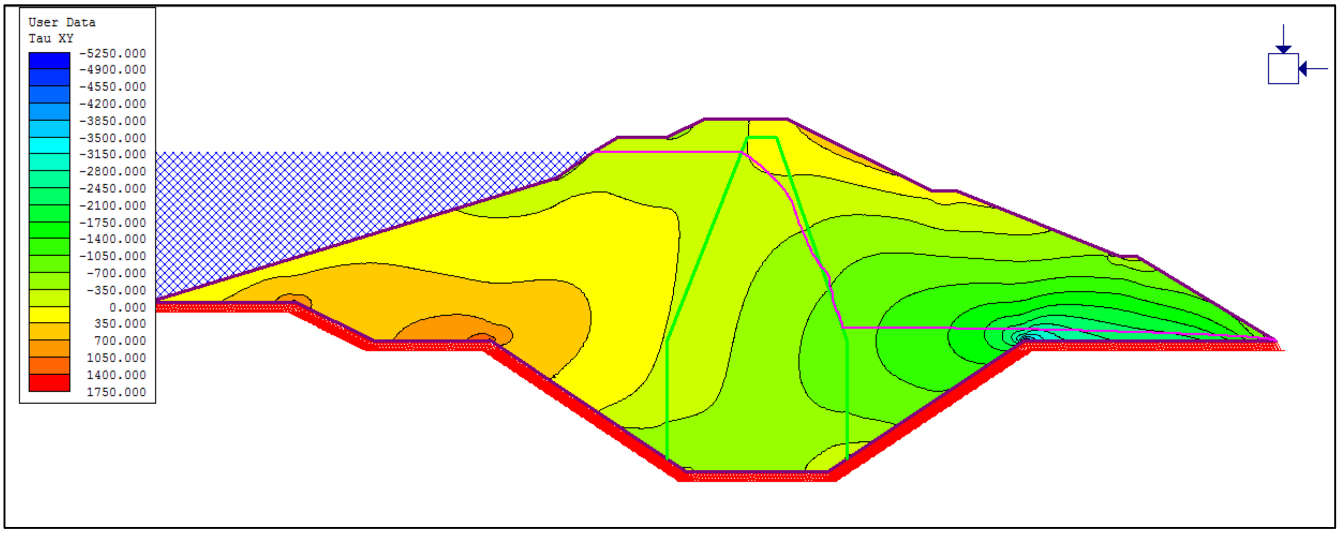


Figure 18 . Phase2 output showing static horizontal shear stress contours.

6. SEISMIC HAZARD ASSESSMENT AND GROUND MOTION SELECTION

A seismic hazard assessment was performed for the dam to establish seismic design parameters and to select input ground motions for the site response analysis described later.

6.1 Deterministic Seismic Hazard Assessment

FEMA 65 suggests the use of maximum credible and design earthquakes calculated by deterministic methods. A deterministic analysis was performed in this study by identifying the modal events from the deaggregation matrix obtained from a probabilistic seismic hazard analysis (e.g., Bradshaw et al. 2007). The deaggregation matrix was obtained for the dam site using the Interactive Deaggregations Tool available at the USGS website. The deaggregations show the magnitude (M) and site-to-source distance (R) of the sources that contribute to the seismic hazard at the site.

Using a shear beam model (Gazetas 1987; Dakoulas and Gazetas 1985) and the measured in situ shear wave velocity of the dam, the fundamental period of the dam was estimated to be 0.25 seconds. The coordinates of the dam site were entered into the Deaggregations Tool, and the deaggregation matrix was obtained at a period of 0.3 seconds, which was closest one available to the fundamental period of the dam. As shown in the deaggregation graphs in Figure 19 the predominant modal event one with a magnitude of 4.8 to 5.0 at a distance of 14 to 32 km.

6.2 Probabilistic Seismic Hazard Assessment

Common practice for the design of most structures is by a Probabilistic Seismic Hazard Analysis (PSHA). The US Geological Survey (USGS) provides seismic hazard data from a PSHA. The data is accessible from their website using a Java calculator. The uniform hazard spectrum (UHS) for bedrock at the Gainer Dam was obtained via the Java Ground Motion Parameter Calculator by inputting the coordinates of the Gainer dam and the desired return period. The UHS for both return periods is shown in Figures 20 and 21.

6.3 Ground Motion Selection and Scaling

The bedrock ground motions that will be used as input to the site response analysis were selected from a database developed by McGuire et al. (2001) that was developed for the nuclear regulatory commission. Records are available for the Central and Eastern United States (CEUS) having a range of magnitudes and site to source distances. Each ground motion record has two horizontal components and one vertical component of motion.

For the deterministic analysis ground motions were conservatively selected from the database that had a magnitudes of 5.2 with site-to-source distances of 11 km. These records were used directly in the analysis with no amplitude scaling. Three ground motions were selected as listed in Table 2.

For the probabilistic analysis, the same records that were used in the deterministic analysis were scaled to match the UHS at a period of 0.3 seconds. The scaling factors are shown in Table 2. Note that the scaling factor was determined using the horizontal components of motion and the same factor was applied to the vertical component.

Table 2. McGuire et al. (2001) ground motions selected for the 2500-year design event.

File Name	Moment Magnitude	Site-to-source distance (km)	PSA at T=0.3 sec	Scaling Factor for Probabilistic Analysis
C-ATC-UP	5.2	11	0.1597	0.204 & 0.286
C-ATC270			0.781	0.204
C-ATC360			0.5586	0.286
C-ATP-UP			0.2573	0.219 & 0.308
C-ATP270			0.7281	0.219
C-ATP360			0.5186	0.308
C-TSM-UP			0.3149	0.281 & 0.406
C-TSM270			0.5674	0.281
C-TSM360			0.3932	0.406

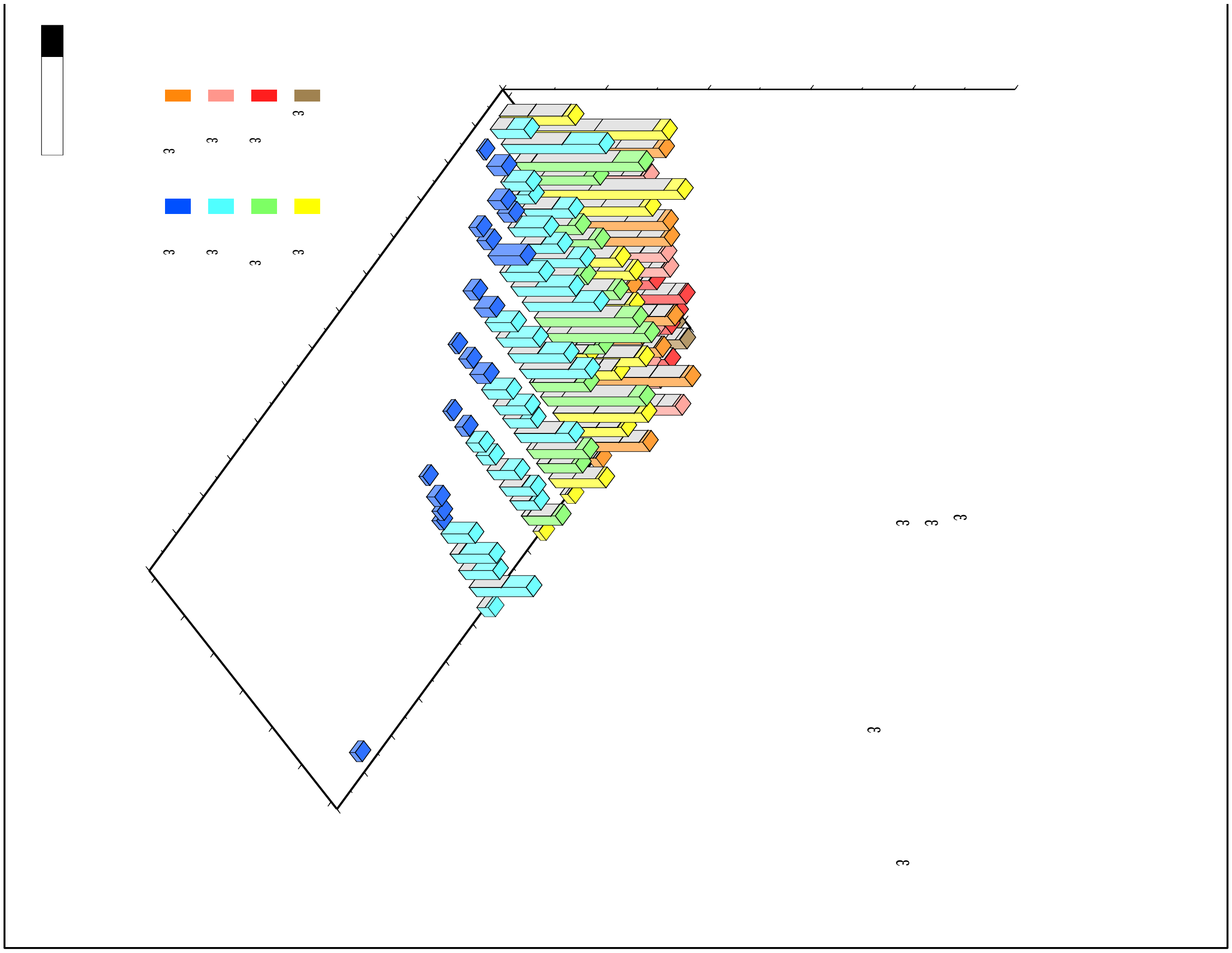


Figure 19. Deaggregation at an oscillator period of 0.3 seconds for the 2500-year return period event (USGS.gov).

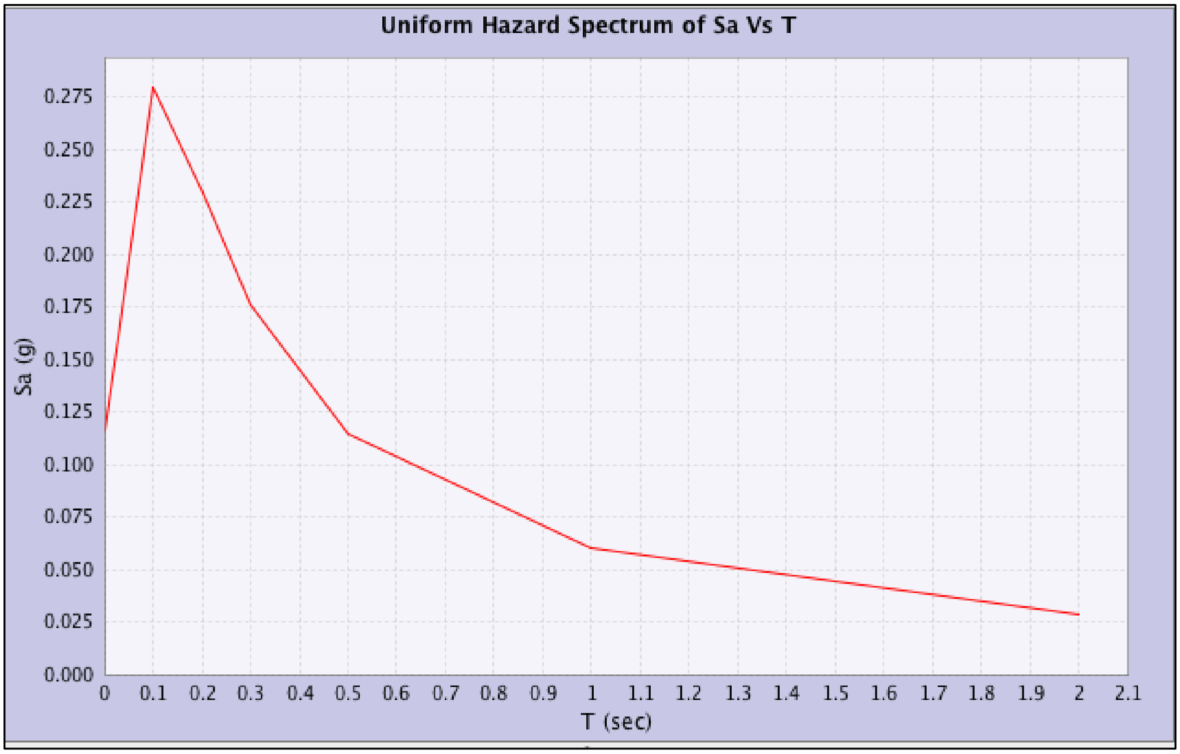


Figure 20. Uniform hazard spectrum for a 2500-year return period (USGS.gov).

7. SITE RESPONSE ANALYSIS

A site response analysis was performed using the finite element program QUAD4M to determine cyclic shear stresses and strains needed for the liquefaction analysis.

7.1 Model Development

QUAD4M is a computer program used to evaluate the response of soil structures using finite element procedures and incorporating a compliant base. The program requires a finite element mesh to be specified by defining each node with its coordinates and each element by its nodes in a counter-clockwise direction. Since the mesh previously used to calculate the in-situ conditions of the dam consisted of over 70,000 elements, a simpler mesh of 402 elements was generated using Phase2 and then input into QUAD4M. The values for the in-situ stresses were then assigned to each new element by locating it within the contours obtained in the estimation of geostatic stresses. The new mesh used for this step is presented in Figure 24.

Other basic properties are required to be specified in the QUAD4M model such as: modulus degradation and damping curves for each material, rock unit weight, p-wave and s-wave velocities, equivalent uniform strain correction factor, and scaling factors for each ground motion to be entered. It is important to note that all nodes, except the ones at the base of the dam, were specified to be free nodes: allowed to move in any direction.

The program was then run for each pair of motions, a horizontal and its vertical counterpart, and was allowed to run 10 iterations on the material modulus and damping before calculating the cyclic shear stresses.

7.2 Model Results

Aside from the cyclic shear stress for each element, The QUAD4M output also includes the peak cyclic shear strains for each element. Both these values were then used for the liquefaction potential evaluation.

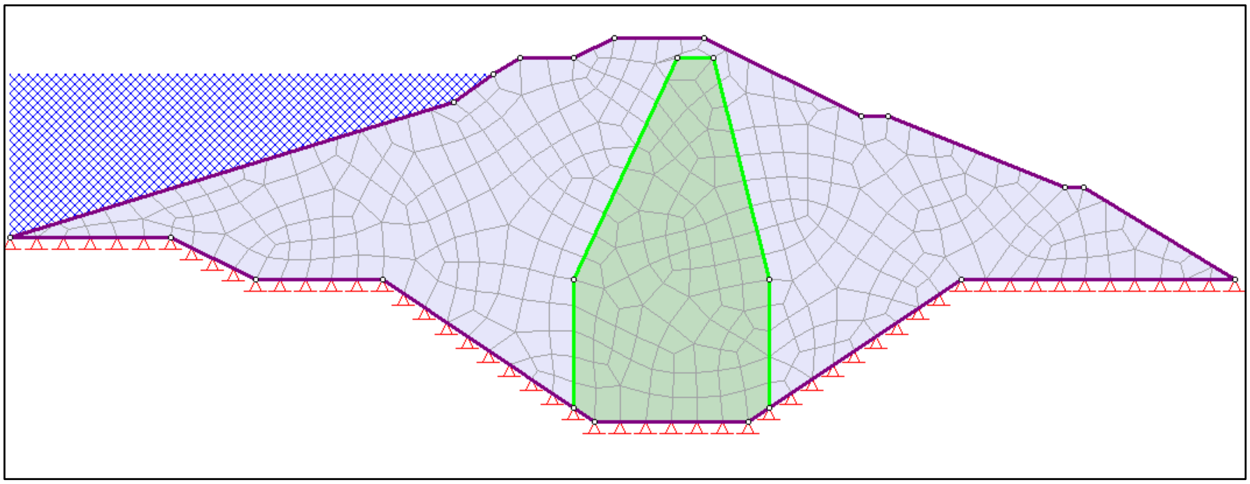


Figure 21. Finite element mesh used for QUAD4M input.

8. EVALUATION OF LIQUEFACTION POTENTIAL

The liquefaction potential evaluation of the Gainer Dam was performed by the use of three approaches as described below.

8.1 Strain-Based Assessment

The threshold shear strain approach (Dobry et al. 1984) was used to screen for the potential for the dam soils to generate excess pore pressures during ground shaking. The threshold shear strain concept suggests that if the cyclic shear strains induced by the earthquake exceed a threshold shear strain than there is a potential for the generation of excess pore pressures. The threshold shear strain for sands is typically assumed to be 0.01%.

The equivalent uniform shear strain that was calculated from the site response analysis was compared to a threshold of 0.01% at each element. The results suggest that there is the potential to generate excess pore pressures during the design event in the dam soils below the water table. Therefore, it was necessary to further analyze liquefaction triggering using the stress-based approaches outline below.

8.2 Stress-Based Assessment Using Shear Wave Velocity

The potential for liquefaction triggering was evaluated using the simplified procedure developed by Andrus and Stokoe (2000) using in situ shear wave velocity. In this procedure the factor of safety against liquefaction is calculated from the following:

$$FS = \frac{CRR}{CSR} \qquad (5)$$

where CRR=cyclic resistance ratio, and CSR=cyclic stress ratio. The CSR was estimated from the site response analysis results from the following equation:

$$CSR = 0.65 \frac{\tau_{xy}}{\sigma_{v0}'} \cdot \frac{1}{MSF} \qquad (6)$$

where τ_{xy}= cyclic shear stress on the horizontal plane, and MSF= magnitude scaling factor recommended by Youd et al. (2001). The CRR was calculated from the measured shear wave velocity using the following equation:

$$CRR = \left[a\left(\frac{V_{s1}}{100}\right)^2 + b\left(\frac{1}{V_{s1}^* - V_{s1}} - \frac{1}{V_{s1}^*}\right)\right] K_\sigma K_\alpha \qquad (7)$$

where CRR = cyclic resistance ratio corrected for overburden stress and static shear stresses, V_{s1} = measured shear wave velocity corrected for overburden stress as proposed by Robertson et al. (1992), a, b and V_{s1}* = constants recommended by Andrus and Stokoe (2000), K_s =correction factor for overburden stress, and K_a = correction factor for static shear stresses.

The values for K_σ were conservatively estimated for each element using the 1996 NCEER recommended values for loose soils. K_α was conservatively estimated for each element using the recommended by Harder and Boulanger (1997) for loose soils.

Factors of safety of 6 to 84 were obtained for the deterministic analysis. Factors of safety of 9 to 317 were obtained for the probabilistic analysis. The lowest factors of safety occurred near the sharp bedrock transitions within the core trench and within the core trench soils likely due to a combination of high shear stress concentrations and the loose nature of the core trench soils.

It is important to note that Equation 7 was developed primarily from a liquefaction database composed of sandy soils. It is possible that the shear wave velocity measurements at the Gainer dam may be higher than the soils composing the database due to the presence of cobbles and gravels. This is an area that might warrant further research.

8.3 Stress-Based Assessment using Triaxial Test Data

The liquefaction potential was also evaluated using the cyclic triaxial test results obtained in Section 4. In this approach the CRR was selected from Figure 15 at 15 cycles, which corresponds to a magnitude 7.5 earthquake that is consistent with the magnitude used to calculate the CSR. The laboratory CRR was further corrected for overburden stress and static shear stress using the same conservative factors used in the shear wave velocity approach above.

Factors of safety of 0.5 to 4 were obtained for the deterministic analysis. Fifty four of the 402 elements showed factors of safety of less than 1. These isolated areas were located within the trench soils that were very loose. Factors of safety of 0.94 to 12 were obtained for the probabilistic analysis. Only one element had a factor of safety of less than unity.

The cyclic triaxial testing was performed on the sand fraction that was prepared by dry pluviation in a very loose condition that would yield the lowest estimate of cyclic strength possible. The actual in situ soils will be coarser and more well-graded. The high shear wave velocities in the shell also suggest that the soils could be denser. Both these factors suggest that the lab based analysis might be very conservative.

9. CONCLUSIONS

This project focused on a preliminary analysis of liquefaction potential of the Gainer Memorial dam under a 2,500-year design level earthquake. The main challenge was to assess liquefaction potential without the availability of geotechnical borings at the site.

Field investigations, laboratory studies and engineering analyses were performed. Samples were collected from the dam, in-situ shear wave measurements were performed using a surface wave inversion method, cyclic triaxial tests were performed on reconstituted samples, the seismic hazard of the dam was assessed, the geostatic stresses were determined by modeling the dam in Phase2, the site response analysis was performed using QUAD4M and the liquefaction potential was evaluated by using the shear threshold approach, as well as the stress approach using both in-situ shear wave measurements and laboratory data.

The analysis was performed for a 2,500-year seismic event that had a moment magnitude of approximately 5 and a site-to-source distance on the order of 10 km. Conservative assumptions were made to deal with a number of uncertainties in the analysis. The analysis that utilized the in situ shear wave velocity showed factors of safety above one in all cases. The analysis that used laboratory test data on reconstituted samples showed factors of safety of less than one in isolated zones within the core trench soils, but this analysis is anticipated to be very conservative. The threshold shear strain analysis suggest the potential for pore pressure generation with the dam soils below the water table.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the Providence Water Authority staff including Jacqueline Brosco, Peter LePage, Gregg Giasson and Steve Soito. The authors would also like to acknowledge the support of Kevin Broccolo and Fabian Dietrich from the University of Rhode Island.

REFERENCES

Andrus, R.D., and Stokoe, K.H. (2000). “Liquefaction resistance of soils from shear wave velocity.” *Journal of Geotechnical and Geoenvironmental Engineering*, 126(11), 1015-1025.

Bair J.M., Rizzo, P.C., Fernandez, A., and Massey, K.L. (2003). “Seismic Evaluation of the Semi-Hydraulic Fill Saluda Dam.” USSD Annual Conference, Charleston SC April 14-16.

Bradshaw, A.S., Green, R.A., and Baxter, C.D.P. (2007). “Evaluation of Liquefaction Potential at a Silt Site in Rhode Island.” *Civil Engineering Practice: Journal of the Boston Society of Civil Engineers Section,* ASCE, 22(1), 5-18.

Castro G. (1975). “Liquefaction and Cyclic Mobility of Saturated Sands.” *Journal of Geotechnical and Geoenvironmental Engineering*, 101(6), 551-569.

Dakoulas P and Gazetas G. (1985). “Nonlinear Seismic Response of Embankment Dams.” *Proceedings of the 2nd International Conference on Soil Dynamics and Earthquake Engineering*, 5.

Dobry, R., R. S. Ladd, F. Y. Yokel, R. M. Chung, and Powell, D. (1982). *Prediction of pore water pressure buildup and liquefaction of sands during earthquake by the cyclic strain method*. NBS Building Science Series 138, National Bureau of Standards, Gaithersburg, Maryland: 150.

FEMA (2005). *Federal Guidelines for Dam Safety: Earthquake Analyses and Design of Dams*. FEMA. May 2005.

Gazetas, G. (1987). “Seismic response of earth dams: some recent developments.” *Soil Dynamics and Earthquake Engineering*, 6(1), 2-47.

Gindy, M., Thomas, N. and Madsen, R. (2007). *Assessment of Downstream Hazard Potential for Dam Failure in Rhode Island.* Report Submitted to the URI Water Resources Center.

Harder, L. F., and Boulanger, R. W. (1997). "Application of K-alpha and K-sigma correction factors." *Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils*, T. L. Youd and I. M. Idriss, Eds., Technical Report NCEER-97-0022, National Center for Earthquake Engineering Research, SUNY, Buffalo, 167-190.

Idriss, I.M. and Sun, J.I. (1992). *SHAKE91: A Computer Program for Conducting Equivalent Linear Seismic Response Analyses of Horizontally Layered Soil Deposits.* User's Guide, University of California, Davis, 13pp

Y.-C. Lin, S.-H. Joh and K.H. Stokoe (2014), "Analysis of the UTexas 1 Surface Wave Dataset Using the SASW Methodology." *Proceedings of Geo-Congress 2014*, GSP 234

McGuire, R.K., Silva, W.J., Constantino, C.J. (2001). *Technical Basis for Revision of Regulatory Guidance on Design Ground Motions: Hazard- and Risk- Consistent Ground Motions Spectra Guidelines.* NUREG/CR-6728, U.S. Regulatory Commission, Washington, D.C.

Mononobe, H.A. et al (1936). "Seismic Stability of the earth dam." *Proceedings, 2nd Congress on Large Dams*, Washington, D.C., Vol. 4.

Robertson, P.K., Woeller, D. J., and Finn, W. D. L., (1992). "Seismic cone penetration tests for evaluating liquefaction potential under cyclic loading." *Canadian Geotechnical Journal*, Vol. 29, pp. 686-695

Seed, H.B. (1979). "Soil liquefaction and cyclic mobility evaluation for level ground during earthquakes", Journal of Geotechnical Engineering Division, 105(GT2), 201- 225.

Providence Water Authority. *The Providence Water Works: 1869-1969.*

Urzua, A., Christian, J.T., Hover, W.H., Hee, I.A., and Bemben, S.M. (2002) "Seismic Response Analysis of Cobble Mountain Reservoir Dam." *Civil Engineering Practice*, Fall/Winter, 7-24.

Youd, et al (2001). "Liquefaction Resistance of Soils: Summary Report From the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils." *Journal of Geotechnical and Geoenvironmental Engineering,* April 2001, 127, 297-313.

Information Transfer Program Introduction

The information transfer project entitled “Clean Drinking Water in Rhode Island” focused on information technology and education utilizing two major outreach activities, a comprehensive conference for the clean water community and a summer camp for high school students. Both activities had the goal of promoting interest and transferring knowledge in clean water related careers.

Drinking Water Outreach in Rhode Island

Basic Information

Title:	Drinking Water Outreach in Rhode Island
Project Number:	2013RI114B
Start Date:	3/1/2013
End Date:	2/28/2014
Funding Source:	104B
Congressional District:	2
Research Category:	Water Quality
Focus Category:	Education, Water Supply, Treatment
Descriptors:	
Principal Investigators:	Harold Knickle, Geoffrey Bothun

Publications

There are no publications.

Drinking Water Outreach in Rhode Island

Harold N. Knickle
Professor Emeritus of Chemical Engineering
University of Rhode Island
knickleh@egr.uri.edu
Phone 401-874-2678

Abstract

The goals of this project were twofold, focusing on both the creation a conference to provide background and knowledge for working professionals in the clean water fields as well as educating graduate and undergraduate students in the scope of the clean water field. The ongoing Rhode Island conference series on clean water created by this project was promoted and held at the University of Rhode Island, with the eighth annual conference primarily focusing on Advanced Wastewater Treatment including Tertiary Treatments with a keynote presentation by Angelo Liberti, Chief RI DEM, Office of Water Resources. This focus provided water professionals in Rhode Island with an overall view of problems associated with water in Rhode Island by inviting them to participate in the conference. The second focus was to promote interests in professions associated with water resources in students. This major activity involved the hosting of a summer workshop (camp) at the University of Rhode Island for middle and high school students, which introduced them to clean water concepts using lectures, laboratories, and field trips with the goal of cultivating interest in clean water careers.

INTRODUCTION

The project focused on information, technology and education through two major outreach activities, a comprehensive conference for the clean water community and a summer camp for high school students to promote interest in clean water related careers.

OBJECTIVES

Two major objectives have been set for this project.

1. The first is to advance the awareness and knowledge of the importance of clean water in Rhode Island and provide insight into the various factors affecting the ability to obtain clean water for multiple uses in Rhode Island by hosting an annual, major Clean Water Conference. The creation of the conference provides background and knowledge of the work of professionals in the clean water fields. A goal of the conference is that graduate students will be encouraged to take courses in environmental areas and undergraduate students will be encouraged to consider pursuing degrees related to the clean water profession.

2. The second major activity is the hosting of a summer camp at the University of Rhode Island for high school students to introduce students to clean water concepts with a goal of promoting interest in clean water careers.

KNOWLEDGE TRANSFER

Dissemination was an important part of this project. Results of this project will be shared with all participants. A web page was added to the Rhode Island Water Resources web site on Clean Water. The web page contains important information on the conference and information presented at the conference. The web page will also contain a description of the summer camp. The clean water conference audience included clean water professionals, graduate, undergraduate, and high school students, faculty and administrators. The web page can be accessed at www.wrc.uri.edu.

LEADERSHIP

The conference effort was guided by a steering committee, which provided guidance in choosing key speakers and presenters and hosting special break-out sessions. The steering committee consisted of students, faculty and administrators at the University of Rhode Island and included representation from the government and industry. Specific representation on the committee include a representative from the Providence Water Board, Dr. Rose, Kingston Water District Board Member, Dr. Thiem, Director of the RI Water Resources Center, Dr. Barnett, director of the RI Pollution Prevention Center, Dr. Gray, consultant in the area of replacing solvents for cleaning, Dr. Bothun, associate professor in Chemical Engineering and Dr. Knickle with research interests in Clean Water.

TIMELINE

July 9, 2012 to July 13, 2012: Clean Water Summer Camp for High School Students.
November 8, 2012: Clean Water Conference.

SUMMER CAMP FOR HIGH SCHOOL STUDENTS ON CLEAN WATER

High school students were recruited from high schools in Providence, Rhode Island to participate in the 2012 summer camp. Recruitment took place by visiting the schools and meeting with the science teachers. With their help, students that have an interest in STEM fields with a focus on clean water were recruited. The camp was from July 9 to July 13, Monday through Friday, with students starting the day at 9:00 am and completing the day at 3:30 pm. Lunches were funded by the Dean of the College of Engineering and there were no fees for this summer camp with both lunches and buses provided for the students.

Activities included presentations of the water cycle, chemistry of water, water quality and treatment, sewage treatment and biological technology, runoff and storm water, industrial water pollution, pollution prevention, and investigation of macro-invertebrates in 30 Acre Pond on the URI campus and health effects. Laboratory exercises and experiments included surface tension, settling measurements, turbidity measurements, water quality sampling and testing, pH and dissolved oxygen measurement, bacteria pollution testing, conductivity testing, acid rain testing, aeration, adsorption, filtration and settling, oil spill spreading, and macro invertebrate identification and health effects. Field work included the collection of samples from various locations and water bodies. Field trips were made to a fresh water treatment facility and a sewage treatment plant as well as to the well water source and distribution on the URI campus.

Success of the summer camp was determined by two surveys, one at the beginning and one at the end of the camp. In addition, each student also wrote a brief laboratory report for some of the laboratory exercises and an essay indicating the activities of most interest to each individual student.

Excellent laboratory facilities were provided by the University of Rhode Island and a Providence high school for the use of the summer camp high school students. Facilities at the University of Rhode Island included Bliss Hall, where the environmental laboratories reside, and in Crawford Hall, which houses the chemical engineering laboratories. Glassware, scales, pH and conductivity meters, chemicals and other equipment was available in these laboratories for use in the summer camp activities. Classrooms and computer labs were available in both buildings with appropriate audio-visual devices. The computer lab was used to access the web to identify bacteria in water and to use excel to calculate oil spill spread on calm water. The summer camp flyer is attached.

TRAINING POTENTIAL

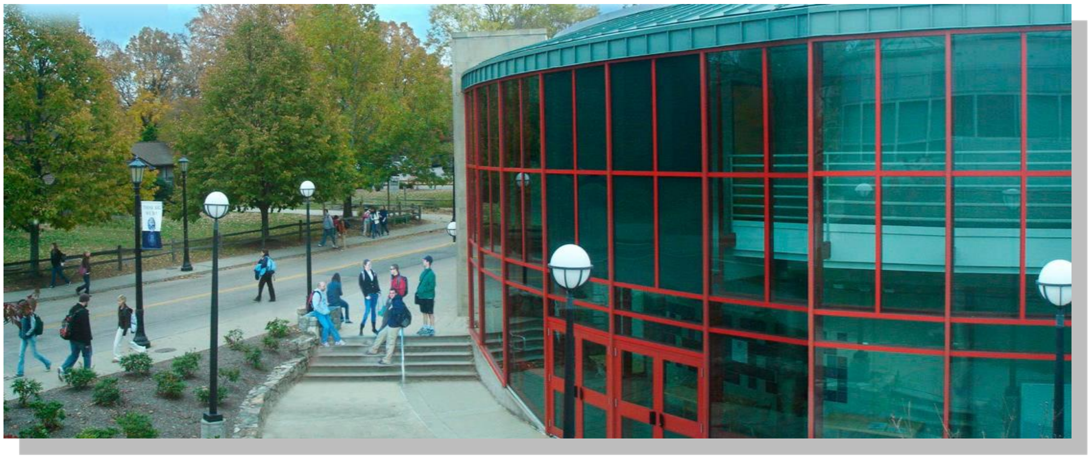
Twenty four high school students attended the summer camp representing grades 9, 10 and 11. These students were screened for having potential interests in clean water professions and the STEM disciplines.

CONFERENCE ON CLEAN WATER

The Clean Water conference of 2013 was held at the University of Rhode Island in Cherry Auditorium of the Kirk building. (See below) Invited speakers provided focus on the role of wastewater in Rhode Island. The program is included on the next page. The presentations are on the RI Water Resources web site, which is located at www.wrc.uri.edu.

About 30 graduate students and 60 undergraduates attended, with most of the undergraduates being juniors and seniors primarily from Civil and Environmental Engineering and Chemical Engineering. Approximately 20 others from outside URI attended, exceeding attendance expectations.

The Cherry Auditorium was used for the conference along with the attached gallery for displays and exhibits. Coffee breaks were held the hallways surrounding the auditorium.



Cherry Auditorium – The Engineering Conference Center-Part of the Kirk Building

Clean Drinking Water Conference

FINAL PROGRAM 2013

Eigth Annual Clean water Conference

12:45 to 1:00 pm **Registration**

1:00 **Welcome Remarks**

Raymond Wright, Dean, College of Engineering
Dr. Leon Thiem, Director, RI Water Resources Center
Dr. Harold Knickle, PI

Session 1: 1:10 pm to 2:00 pm
Advanced wastewater treatment in RI: History, status and technologies selected.
Angelo Liberti, Chief RI DEM, Office of Water Resources

COFFEE BREAK

Session 2: 2:15 to 3:00 pm
"Warwick Waste Water Treatment Improvements: Tertiary Treatment"
Janine Burke, Warwick Plant Manager

Session 3: 3:00 to 3:40pm
"East Greenwich Tertiary Treatment of Waste Water"
Mike Pacillo, East Greenwich Plant Manager

4:00 pm **ADJOURN**

Warwick Wastewater Treatment Plant

East Greenwich Wastewater Treatment Plant

Planning Committee Members
From the College of Engineering
Dr. Stanley Barnett, Dr. Donald Gray, Dr. Harold Knickle, Dr. Vincent Rose, Dr. Leon Thiem, Dr. Geoff Bothun

Sponsored by

RI Water Resources Center (www.wrc.uri.edu)

Department of Chemical Engineering (www.egr.uri.edu/che)

Department of Civil and Environmental Engineering (www.egr.uri.edu/cve)

Conference is Free All Welcome

Refreshments Courtesy of Amgen Corporation, W Greenwich, RI

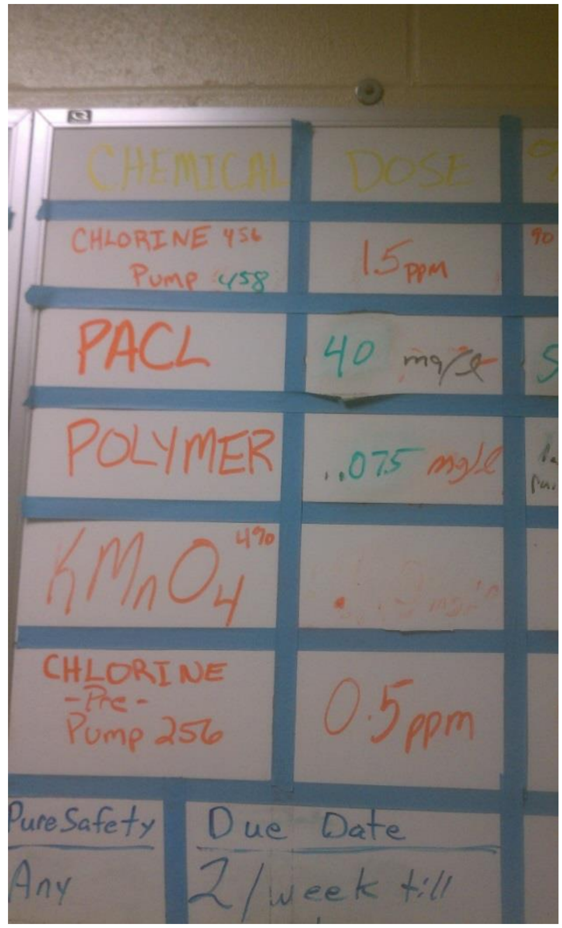
RESULTS AND BENEFITS.

The conference provided insight into the various factors affecting the ability to obtain clean water for multiple uses in Rhode Island. The breadth and depth in this project on water quality provided both awareness and knowledge to the clean water community in Rhode Island and to graduate and undergraduate students. This conference raised awareness of conservation and a broad, planned approach to water supply in Rhode Island.

The hosting of a summer camp at the University of Rhode Island for high school students brought 24 students to the URI campus and provided lectures and labs on clean water concepts with a goal of promoting interest in clean water careers.

Pawtucket Water Treatment Plant Tour

Tour of Pawtucket Water Supply Plant



Chemicals Used at Pawtucket Water Treatment Plant

Field Trip to Pawtucket Water Supply Company

Filtration Experiment and Water Testing at URI

Filtration, Settling Time and Turbidity Laboratory Exercise

Filtration Experiment in Laboratory at URI: Sand, Gravel, Charcoal and Cotton Filtration System

Water Testing at URI

Water Testing During the Summer Camp

Collecting and Analyzing Macro Invertebrates

Gathering Macro-invertebrate in 30 Acre Pond

Putting on Waders to locate macro-invertebrate in 30 acre pond

Collecting Macro-Invertebrate in 30 Acre Pond

Finding Macro-invertebrate in 30 Acre Pond

Analyzing Macro Invertebrate Samples from 30 Acre Pond

A Group of Students Writing Their Report on a Completed Lab Experience

High School Teacher, Dr. Fontaine, Receiving a Certificate for Helping with the Summer Camp Presented by Harold Knickle

Drilling a New Well at 30 Acre Pond

Program/Flyer for the Summer Camp on Clean Water June 2013

Clean water ACTIVITIES
ALL SESSIONS 9:00 TO 3:30
Breakfast Snack and Lunch Included
Sponsored by LSAMP & URI Water Resources Center Leon Thiem, Director
College of Engineering **No person shall be denied membership because of race, color, sex, handicap, nationality, religious affiliation or belief**
URI
Summer 2013
Clean Water Engineering & Science Academy
June 24 June 28
9:00 AM to 3:30 PM

CLEAN WATER ACTIVITIES
ALL SESSIONS 9:00 TO 3:30
Breakfast Snack and Lunch Included

Session 1: Monday June 24 URI
Introductions and Survey
Surface Tension: Drops on a Penny
Water Cycle Introduction
Settling Measurements
Turbidity Measurements
Intro to Water Chemistry and the Periodic Table
Water Sample Collection
Drinking Water Testing
Laboratory Report

Session 2: Tuesday June 25
Reaction Time & Temperature
Sewage Treatment Flow Sheet
Biology Technology
Nitrogen and Phosphorous
Introduction to COD, BOD
Bacteria check 4 microbes www.google.com
Warwick Sewage Treatment Plant Field Trip. J. Burke

Session 3: Wednesday Jun 26
Dissolved Oxygen and pH
Common Materials and their pH
Water Hardness Testing
Theory of Adsorption
Adsorption Measurement
Filtration and Settling
Filtration Laboratory
Laboratory Report
Water Runoff and Storm Water-Hydrology
Pollution Prevention.
Oil Spills Lab and graphs
Alternate Lab
Video: Ponds & Rivers
Laboratory and Report

Session 4: Thursday June 27 T2
Health Effects Associated With Water Quality
Filtration and Settling
Filtration Laboratory
Laboratory Report
Pawtucket Water Supply Field Trip
Field Trip Chris Collins

Friday June 28 URI
30 Acre Pond Sampling
Macro Invertebrates
Introduction and Identification
Post Assessment Survey
Certificates and Awards

Application to Clean Water Academy 2013
July 9 to July 13
CIRCLE YOUR INTEREST
Math Science Engineering
Name: ___________________________
Address: __________________________
Telephone: _______________________
Email: ___________________________
School Name:____________________
____
Grade: ___________________________
PARENTS' APPROVAL SIGNATURE
____

Return to: Dr H. Knickle, College of Engineering 874-2678, knickle@egr.uri.edu
122 Crawford Hall, Kingston, RI 02881

Clean Water Academy Summer 2013
June 24-June 28
Sponsored by URI Water Resources Center and the College of Engineering

Are you a high school student interested in math and science?
Are you interested in understanding how math and science are a key part of being an engineer?
Do you want to experience some of the fun of doing experiments?
If you answered yes, then you should participate in our own Clean Water Academy.
The Academy Coordinators want to help you to see just how exciting your future can be.
These **hands on** sessions will show you how interesting science and engineering can be, while you explore the options in engineering and learn valuable tools for success.

The University of Rhode Island's College of Engineering has eight undergraduate programs.
There are also many physical, chemical, and biological science programs at URI.
If you decide to participate, other students will join you in the following activities:
Interactive workshops.
Participate in real hands-on experimental activities.
Interact with teachers and students from the University of Rhode Island.
H. Knickle, PI

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	2	0	0	0	2
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	5	0	0	0	5

Notable Awards and Achievements

Vinka Craver, a previous Rhode Island Water Resources PI has received the prestigious NSF Career Award. In addition to this award she has been promoted to an Associate Professor.

Publications from Prior Years

1. 2009RI80B ("Nanosilver-clay composite material as a reactive permeable barrier to control microbiological and chemical contamination in groundwater ") - Articles in Refereed Scientific Journals - H. Zhang*, V. Oyanedel-Craver#. (2013). Comparison of the bacterial removal performance of silver nanoparticles and a polymer based quaternary amine functionalized silsesquioxane coated point-of-use ceramic water filters. Journal of Hazardous Materials, DOI: 10.1016/j.jhazmat.2013.05.025.
2. 2009RI80B ("Nanosilver-clay composite material as a reactive permeable barrier to control microbiological and chemical contamination in groundwater ") - Articles in Refereed Scientific Journals - J. Rayner, H. Zhang*, J. Schubert, P. Lennon, D. Lantagne, and V. Oyanedel-Craver# (2013) Laboratory investigation into the effect of silver application on the bacterial removal efficacy of filter material for use on locally produced ceramic water filters for household drinking water treatment. ACS Sustainable Chemistry and Engineering DOI: 10.1021/sc400068p
3. 2009RI80B ("Nanosilver-clay composite material as a reactive permeable barrier to control microbiological and chemical contamination in groundwater ") - Articles in Refereed Scientific Journals - E. Kallman, V. Oyanedel-Craver, and J.A. Smith (2011) Ceramic filters impregnated with silver nanoparticles for point-of-use water treatment in rural Guatemala. ASCE- Journal of Environmental Engineering, 136 (6) 407 – 415
4. 2009RI80B ("Nanosilver-clay composite material as a reactive permeable barrier to control microbiological and chemical contamination in groundwater ") - Articles in Refereed Scientific Journals - Abebe, L.S., Smith, J.A., Narkiweicz*, S., Oyanedel-Craver, V., Conaway, M., A., Singo, A., Samie, A., Brant, J., and Dillingham, R., 2013, Ceramic water filters impregnated with silver nanoparticles as a point-of- use water-treatment intervention for HIV-positive individuals in Limpopo Province, South Africa: A pilot study of technological performance and human health benefits: Journal of Water and Health. DOI:10.2166/wh.2013.185
5. 2009RI80B ("Nanosilver-clay composite material as a reactive permeable barrier to control microbiological and chemical contamination in groundwater ") - Articles in Refereed Scientific Journals - E. Fauss, R. MacCuspie, V. Oyanedel-Craver, J.A. Smith and N. S. Swami (2013) Disinfection action of electrostatic versus steric-stabilized silver nanoparticles on E. coli under different water chemistries. Colloids & Surfaces B - Biointerfaces. DOI:10.1016/j.colsurfb.2013.08.027