Presentation to

Board of Directors

MWRA’s Dam Safety Program 2005 - 2015

March 11, 2015
27 Individual Structures

– Spread across 18 geographic locations
– Representing:
  17 High Hazard Class dams
  8 Significant Hazard Class dams
  2 Low Hazard Class dams
– Dams range in age (149 - 60 years old)
• Administered by DCR- Office of Dam Safety (ODS)

• Requires biennial inspections

• Modeled on Federal Regulations:
  – US Army Corps of Engineers
  – FEMA
• 2004 MOU - specified roles of MWRA and DCR on dams:
  – DCR Routine Maintenance and Smaller Dams
  – MWRA Capital Maintenance/Improvements Large Dams
Emergency Inspections 2005 - “laundry list” of dam issues
Required Studies:
- Hydrology and Hydraulics (H&H)
- Seepage and Stability (S&S)
- Safety Inspections (Phase I’s)
- Emergency Action Plans

Led to Major Improvements at:
- Spillways
- Earthworks
- Masonry needs
- Tree Clearing

### Inspections Determine Dam Needs

#### Dams Improvements 2005 - 2015

<table>
<thead>
<tr>
<th>Dams Capital Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crest Gate</td>
</tr>
<tr>
<td>Wachusett Dam Promenade - PCB</td>
</tr>
<tr>
<td>Wachusett Dam Face - PCB</td>
</tr>
<tr>
<td>Dam Safety Mods (5 dams):</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dams Major Maintenance Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quabbin Spillway Repointing</td>
</tr>
<tr>
<td>South Dike Tree Removal 1</td>
</tr>
<tr>
<td>South Dike Tree Removal 2</td>
</tr>
<tr>
<td>North Dike Tree Removal</td>
</tr>
<tr>
<td>Foss Dam Tree Removal 1</td>
</tr>
<tr>
<td>Foss Dam Tree Removal 2</td>
</tr>
<tr>
<td>Blue Hill Dam Repairs</td>
</tr>
<tr>
<td>Fells Trees 1</td>
</tr>
<tr>
<td>Fells Trees 2</td>
</tr>
<tr>
<td>Norumbega Trees</td>
</tr>
<tr>
<td>Goodnouh Dike Tailwater Analysis</td>
</tr>
<tr>
<td>Quabbin Spillway Fence Rehab</td>
</tr>
<tr>
<td>Foss Dam Stump removal</td>
</tr>
<tr>
<td>Dam Safety Tech Assist Consulting</td>
</tr>
<tr>
<td>Emergency Inspections 2005</td>
</tr>
<tr>
<td>T.O. Dam Safety Inspections 2006</td>
</tr>
<tr>
<td>T.O. for Fells Dam seeps analysis</td>
</tr>
<tr>
<td>H&amp;H Analyses</td>
</tr>
<tr>
<td>Sudbury Spillway Insp. + weepholes</td>
</tr>
<tr>
<td>Dams Inundation Mapping</td>
</tr>
<tr>
<td>Emergency Action Plans Updates</td>
</tr>
<tr>
<td>OP-160 (incl inspections)</td>
</tr>
<tr>
<td>OP-228 (incl inspections)</td>
</tr>
</tbody>
</table>

Subtotal Dams: $ 17,951,111.00
Inspections Identify Required Studies, Which Reveal Needs
Major Spillway Projects
Wachusett Spillway Dismantling and New Sill
Wachusett Spillway Crest Gate Installed

Before

After
Quabbin Spillway Repointing and Grouting

Limits of work

Note grout tube
Downstream crest stone before

Downstream crest stone after
Wachusett Open Channel Lower Dam - Substantial mortar loss and offset training wall stones

Before

After
Major Earthwork Projects
North Dike Structural Stabilization of Historic Failure Zone

1907 Static Liquefaction Flow Failure of the North Dike of Wachusett Dam

By Scott M. Olson, Student Member, ASCE, Timothy D. Stark, William H. Walton, Members, ASCE, and Gonzalo Castro, Fellow, ASCE

Abstract: A static liquefaction flow failure occurred in the upstream slope of the North Dike of Wachusett Dam near Clinton, Massachusetts on April 11, 1907 during the first reservoir filling. The fine sands of the upstream dike shell liquefied and flowed approximately 100 m horizontally into the reservoir. This paper presents a description of the construction of the North Dike, failure of the upstream slope, and the results of stability analyses that were conducted to estimate the shear strength mobilized in the liquefied soils during failure. Analyses of the postfailure geometry, the prefailure geometry, and an analysis incorporating the kinetics of failure were conducted. The back-calculated shear strength considering the kinetics of failure is in agreement with other liquefaction flow failure case histories published in the literature. As a result, it is recommended that the kinetics of failure be considered to determine the shear strength mobilized during a liquefaction flow failure.
Spot Pond Dam Armoring - in-house project
Chestnut Hill Dam Improvements

Remove old CBs, fill depressions, re-grade toe area

Hydroseed
Major Masonry Projects
Wachusett Dam Promenade PCB Demo/ rebuild
Wachusett Dam PCB remediation and power washing

During

After

Cleaned

Uncleaned efflorescence
Wachusett Dam Improvements

New drainage groins

New piezometers

Dam face cleaned and repointed

Before

After
Foss Reservoir Spillway - repointing
Foss Dam Gatehouse interior masonry grouting/repainting

Leakage through stone joints

Repointing and Injection grouting

Steel plate for protection against erosion of mortar
Sudbury Spillway Inspection and Weep Hole Maintenance
Chestnut Hill Dam riprap improvements - left abutment

Missing riprap

Resetting riprap
Major Tree Work
Office of Dam Safety

Policy on Trees on Dams

Tree and woody vegetation growth on earthen dams and in close proximity to other dams such as concrete dams is undesirable and at a minimum has some level of detrimental impact upon operation, inspection, performance, and safety of dams.

The Massachusetts Office of Dam Safety requires that earth embankment dams be maintained free of the existence of trees and woody growth. Tree roots cause serious structural damage to earth embankment and appurtenant dam features such as gate wells, spillway walls, and other components.

It is recommended that earth embankment dams be maintained with a healthy uniform cover of desirable vegetation such as an appropriate variety of grasses. Earth embankment grass should be moved periodically to promote healthy cover and prevent infestation of undesirable woody growth and weeds.

Trees and woody growth can make it difficult to conduct inspections of dams. Tree roots can cause leaks, damage concrete joints and overturn during high wind events causing large voids due to pull out of root balls and cause many other problems that will be very costly to repair. Trees and woody growth located in spillways will dramatically reduce spillway flow capacity. Trees are known to accelerate deterioration of dams and can lead to dam failure.

It is recommended that the area at least 20 feet downstream from the entire downstream toe of earth embankment dams be maintained free of trees and
Tree Roots are bad for Earthen Dams
Proper Stumping/ backfill Critical to the Integrity of the Dam
Weston Reservoir Dam

1904

2010

2011

Dam Crest

Dam Crest
Weston Reservoir Dam

09.23.11

Earthen dam
Weston Reservoir Dam

10.04.11

Earthen dam
Fells Dams, Stoneham

Fells Reservoir

Fells Covered Storage Tank

Dams:
- Dam #2
- Dam #3
- Dam #4
- Dam #6
- Dam #7
- Dam #8
Fells Reservoir Dam #8 Tree Removal
Fells Reservoir Dam #6, #7  tree and riprap work

Before

After
Wachusett Reservoir circa 1930 drought

South Dike treeless condition

North Dike treeless condition
South Dike Comparison

Rock outcrop. Note dense tree cover

1904

2010
Crest – note dense tree cover
South Dike 2010 - Tree Removal Zones and in 2011

2015 project – remove remaining trees

Completed
South Dike

DAM RESTORATION PROJECT
WACHUSETT RESERVOIR SOUTH DIKE

Contract OP-182
Tree clearing on this earthen dam is critical to preserve the integrity and safety of this structure

Project Management: Massachusetts Water Resources Authority
Contact: Len Cawley, MWRA Public Affairs at (617) 469-2972
More information at www.mwra.com
South Dike Final Grading and Hydroseed
North Dike Tree Clearing
Norumbega Dam/ Dikes Tree Removal

Before

After

Norumbega Reservoir, Weston, MA 02493, USA
MWRA / DCR Dam Condition Ratings

• Significant Rehabilitation/Upgrades Completed

• 2006- Dams Ranged from “Fair – Satisfactory”

• 2014, Dams upgraded. Now range from “Satisfactory – Good”
What’s next on the Horizon for Dam Safety Needs

• Foss Reservoir Spillway – increase capacity and/or armor the earthen embankment. Pending ODS review on options.

• Install new piezometers at earthen dams lacking them: (North Dike and South Dike, Weston, Fells, Norumbega, Ware Diversion, Foss, Schencks, Chestnut Hill).

• Continue to meet ODS Biennial Phase I safety inspections’ schedule.
Quabbin Spilling @ 0.6 BGD on 04.05.10
Sudbury System Dams Under High Inflows

Sudbury in spill 03.29.10 @ 200 MGD

Foss in spill @ 250 MGD
Thank you.