--LAKE SHIRLEY DAM --

PHASE I

INSPECTION / EVALUATION REPORT

Dam Name:	Lake Shirley Dam
State Dam ID#:	4-9-270-3
NID ID#:	MA00455
Owner:	Town of Lunenburg
Town:	Lunenburg
Consultant:	Weston & Sampson Engineers, Inc.
Date of Inspection:	July 16, 2009

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EXECUTIVE SUMMARY

This report documents observations and evaluation of Lake Shirley Dam located in Lunenburg, Massachusetts based on a visual dam safety inspection conducted by Weston & Sampson of Peabody, Massachusetts on July 16, 2009. The Dam consists of an earthen embankment with a primary spillway and low-level outlet system. The dam is classified as a **LARGE** size, **HIGH** hazard potential structure. The dam is in **SATISFACTORY** condition overall with no major dam safety deficiencies noted based on our inspection. However, several issues were identified that should be addressed to preserve the integrity and functionality of the dam:

- The upstream slopes at the ends of the wave wall are located on private property and are overgrown with trees and brush preventing a thorough inspection of these areas. Trees and brush were also observed on the downstream slope near the left abutment area.
- Minor outward movement and vertical cracks were observed along the wave wall.
- Erosion was observed at the right end of the wave wall on the upstream slope.
- Several animal burrows were observed on the upstream and downstream slopes.
- Standing water and iron staining were observed at the toe of the downstream slope to the left of the primary spillway. This could be the result of a clogged toe drain seepage collection pipe.
- Some bare areas and weeds were observed in the grass cover on the embankment.
- Minor cracks and spalls were observed on the primary spillway weir and channel walls. The catwalk surface is spalled on the right side.
- The outlet works gates clog with leaves and debris when operated. The gate operator wheels are tight and can be difficult to operate.
- The dam does not have a formal operations and maintenance plan.

Weston & Sampson recommends the following actions to address deficiencies detected during the inspection and evaluation:

- Prepare an operations and maintenance plan to list and describe the normal maintenance and operational activities conducted at the dam. The plan should include dates and general procedures for pond level management as well as frequency and procedures for activities such as site observations, grass cutting, brush clearing and other maintenance activities. Provide the plan to the Office of Dam Safety for record purposes.
- Remove debris that becomes lodged on the primary spillway weir or in the discharge channel to ensure free flow conditions through the system.
- Monitor the upstream wave walls for vertical cracks and rotation/tilting.
- Monitor the wet area at the left downstream area of the dam. Place grade stakes at the extents of the wet area and take regular photographs to document the size of the area in relation to lake stage.
- Fill the animal burrows on the dam with compacted granular fill or crushed stone.
- Monitor the surficial spalling and cracking of the primary spillway weir and training walls.
- Remove brush up to 4 in. in diameter at the right and left ends of the upstream wave walls and on the downstream slope near the left abutment (private property). Inspect these areas for any deficiencies not detected during this inspection.
- Repair the spalled area on the concrete catwalk by removing all loose concrete and applying mortar grout.
- Remove loose soil and organics from the area around the right end of the wave wall. Place a layer of 6 in. riprap bedded in crushed stone overlying filter fabric.
- Consult an Engineer to design repairs to fix the toe drain filter collection system in the area of the standing water if the problem worsens based on recommendations above.

- Install an intake structure on the upstream side of the LLO and MLO intakes to reduce the likelihood of clogging by leaves and debris.
- Consult with a turf manager regarding methods to control weeds and reestablish and maintain a healthy turf on the dam embankment.

Section 3 of this report provides additional detail related to the recommended actions. A qualified Professional Engineer experienced in dam safety engineering should conduct the recommended evaluations, design the necessary repairs and monitor construction of the repairs to assure they are conducted in accordance with the design.

Dam Evaluation Summary Detail Sheet

1. NID ID:	**MA00455**	**4. Inspection Date:**	**July 16, 2009**
2. Dam Name:	**Lake Shirley Dam**	**5. Last Insp. Date:**	**February 12, 2007**
3. Dam Location:	**Lunenburg, MA**	**6. Next Inspection:**	**July 16, 2011**
7. Inspector:	**Mark P. Mitsch, P.E.**		
8. Consultant:	**Weston & Sampson**		
9. Hazard Code:	**High**	**9a. Is Hazard Code Change Requested?:**	**No**
10. Insp. Frequency:	**2 Years**	**11. Overall Physical Condition of Dam:**	**SATISFACTORY**
12. Spillway Capacity (% SDF)	**>100% SDF w/ no actions by Caretaker**		

E1. Design Methodology:	**5**	**E7. Low-Level Discharge Capacity:**	**4**
E2. Level of Maintenance:	**4**	**E8. Low-Level Outlet Physical Condition:**	**5**
E3. Emergency Action Plan:	**4**	**E9. Spillway Design Flood Capacity:**	**5**
E4. Embankment Seepage:	**5**	**E10. Overall Physical Condition of the Dam:**	**4**
E5. Embankment Condition:	**5**	**E11. Estimated Repair Cost:**	**20 to 50**
E6. Concrete Condition:	**5**		

Evaluation Description

E1: DESIGN METHODOLOGY
1. Unknown Design – no design records available
2. No design or post-design analyses
3. No analyses, but dam features appear suitable
4. Design or post design analysis show dam meets most criteria
5. State of the art design – design records available & dam meets all criteria

E2: LEVEL OF MAINTENANCE
1. Dam in disrepair, no evidence of maintenance, no O&M manual
2. Dam in poor level of upkeep, very little maintenance, no O&M manual
3. Dam in fair level of upkeep, some maintenance and standard procedures
4. Adequate level of maintenance and standard procedures
5. Dam well maintained, detailed maintenance plan that is executed

E3: EMERGENCY ACTION PLAN
1. No plan or idea of what to do in the event of an emergency
2. Some idea but no written plan
3. No formal plan but well thought out
4. Available written plan that needs updating
5. Detailed, updated written plan available and filed with MADCR, annual training

E4: SEEPAGE (Embankments, Foundations, & Abutments)
1. Severe piping and/or seepage with no monitoring
2. Evidence of monitored piping and seepage
3. No piping but uncontrolled seepage
4. Minor seepage or high volumes of seepage with filtered collection
5. No seepage or minor seepage with filtered collection

E5: EMBANKMENT CONDITION (See Note 1)
1. Severe erosion and/or large trees
2. Significant erosion or significant woody vegetation
3. Brush and exposed embankment soils, or moderate erosion
4. Unmaintained grass, rodent activity and maintainable erosion
5. Well maintained healthy uniform grass cover

E6: CONCRETE CONDITION (See Note 2)
1. Major cracks, misalignment, discontinuities causing leaks, seepage or stability concerns
2. Cracks with misalignment inclusive of transverse cracks with no misalignment but with potential for significant structural degradation
3. Significant longitudinal cracking and minor transverse cracking
4. Spalling and minor surface cracking
5. No apparent deficiencies

E7: LOW-LEVEL OUTLET DISCHARGE CAPACITY
1. No low level outlet, no provisions (e.g. pumps, siphons) for emptying pond
2. No operable outlet, plans for emptying pond, but no equipment
3. Outlet with insufficient drawdown capacity, pumping equipment available
4. Operable gate with sufficient drawdown capacity
5. Operable gate with capacity greater than necessary

E8: LOW-LEVEL OUTLET PHYSICAL CONDITION
1. Outlet inoperative needs replacement, non-existent or inaccessible
2. Outlet inoperative needs repair
3. Outlet operable but needs repair
4. Outlet operable but needs maintenance
5. Outlet and operator operable and well maintained

E9: SPILLWAY DESIGN FLOOD CAPACITY
1. 0 - 50% of the SDF or unknown
2. 50-90% of the SDF
3. 90 - 100% of the SDF
4. >100% of the SDF with actions required by caretaker (e.g. open outlet)
5. >100% of the SDF with no actions required by caretaker

E10: OVERALL PHYSICAL CONDITION OF DAM
1. UNSAFE – Major structural, operational, and maintenance deficiencies exist under normal operating conditions
2. POOR - Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions
3. FAIR - Significant operational and maintenance deficiencies, no structural deficiencies. Potential deficiencies exist under unusual loading conditions that may realistically occur. Can be used when uncertainties exist as to critical parameters
4. SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result In deficiencies.
5. GOOD - No existing or potential deficiencies recognized. Safe performance is expected under all loading including SDF

E11: ESTIMATED REPAIR COST

Estimation of the total cost to address all identified structural, operational, maintenance deficiencies. Cost shall be developed utilizing standard estimating guides and procedures

Changes/Deviations to Database Information since Last Inspection

Previously reported length of the dam was 400 ft. Weston & Sampson determined the length of the dam is 520 ft., see Section 1.2.4 for more information.

PREFACE

The assessment of the general condition of the dam reported herein was based upon available data and visual inspections. Detailed investigations and analyses involving topographic mapping, subsurface investigations, testing and detailed computational evaluations were beyond the scope of this report unless reported otherwise.

In reviewing this report, it should be realized that the reported condition of the dam was based on observations of field conditions at the time of inspection, along with data available to the inspection team.

It is critical to note that the condition of the dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the reported condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Mark P. Mitsch, P.E.
Associate
Weston & Sampson Engineers, Inc.
Massachusetts License No.: **46681**
License Type: **CIVIL**

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SECTION 1

1.0 DESCRIPTION OF PROJECT

1.1 General

1.1.1 Authority

The Town of Lunenburg retained Weston & Sampson Engineers, Inc. (Weston & Sampson) to perform a visual inspection and develop a report of conditions for Lake Shirley Dam in the Town of Lunenburg, Worcester County, Massachusetts. This inspection and report were performed in accordance with MGL Chapter 253, Sections 44-50 of the Massachusetts General Laws as amended by Chapter 330 of the Acts of 2002.

1.1.2 Purpose of Work

The purpose of this investigation was to inspect and evaluate the present condition of the dam and appurtenant structures in accordance with 302 CMR10.07 to provide information that will assist in both prioritizing dam repair needs and planning/conducting maintenance and operation.

The investigation was divided into four parts: 1) obtain and review available reports, investigations, and data previously submitted to the owner pertaining to the dam and appurtenant structures; 2) perform a visual inspection of the site; 3) evaluate the status of an emergency action plan for the site and; 4) prepare and submit a final report presenting the evaluation of the structure, including recommendations and remedial actions, and opinion of probable costs.

1.1.3 Definitions

To provide the reader with a better understanding of the report, definitions of commonly used terms associated with dams are provided in Appendix D. Many of these terms may be included in this report. The terms are presented under common categories associated with dams which include: 1) orientation; 2) dam components; 3) size classification; 4) hazard classification; and 5) miscellaneous.

1.2 Description of Project

1.2.1 Location

Lake Shirley Dam is located in Lunenburg, Worcester County, Massachusetts. The dam impounds Lake Shirley. The dam is located at the following coordinates in the NAD 1983 system:

Latitude:	42.5544 N
Longitude:	71.6750W

From the Town of Lunenburg Town Hall at 17 Main Street, head south on Main Street toward Route MA-2A. Continue on Lancaster Avenue for 1.2 miles. Turn sharp left onto Page Street for 0.8 miles. Turn slight right at Burrage Street for 1.3 miles. Turn right at Flat Hill Road for 0.3 miles. Turn left at Sunset Lane for 0.6 miles. Turn slight left at Robbs Hill Road for 0.6 miles.

Continue on Catacunemaug Road for 0.1 miles. Turn right at Fire Road 18, the dam will be located to the right. See Figure 1 – Locus Map.

1.2.2 Owner/Caretaker

	Dam Owner	Dam Caretaker
Name	Town of Lunenburg	Earl Graves Lake Shirley Improvement Corp.
Mailing Address	17 Main Street, PO Box 135	573 Reservoir Road
Town	Lunenburg, MA 01462	Lunenburg, MA 01462
Daytime Phone	(978) 582-4130	(978) 430-3201 (Cell)
Emergency Phone	(978) 582-4531 (Police)	(978) 582-4531 (Police)
Email Address		

1.2.3 Purpose of the Dam

Lake Shirley Dam was originally used to impound water to provide mill power. The dam now impounds Lake Shirley, which is used for recreation. It is also reported that Lake Shirley has an influence upon the groundwater wells surrounding the impoundment (Dubois & King, 2007).

1.2.4 Description of the Dam and Appurtenances

Lake Shirley Dam impounds Lake Shirley along Catacoonamug Brook in Lunenburg, Massachusetts (See Figure 1 – Locus Map). A dam was originally constructed at this location for mill power circa 1852. That dam was washed out in 1856 and rebuilt in 1857. The dam was rehabilitated to its current configuration in 1996 and 1997 (Dubois & King, 2007). Lake Shirley Dam is an earthen embankment dam with a structural height of 21 ft. (Dubois & King, 2007) and a length of approximately 520 ft. (Previously reported length was 400 ft., Dubois & King, 2007). The dam has a primary spillway and outlet works. There is no auxiliary spillway at this dam.

The upstream face of the dam consists of vertical reinforced concrete wave walls extending to the right and left of the centrally located primary spillway. The wave walls do not extend to the abutments nor do they extend to the dam crest. The top of the wave wall to the right of the primary spillway is reportedly El. 302.7 (Dubois & King, 2007). The wave wall to the left of the spillway is 1 ft. to 2 ft. lower than the wall to the right of the spillway. All elevations in this report reference the National Geodetic Vertical Datum (NGVD).

Grass surfaced earthen slopes extend above the wave walls to the crest of the dam. The slope is reportedly 3H:1V to the left of the spillway and 5H:1V to the right of the spillway (Dubois & King, 2007). Near the right abutment, the upstream slope is vegetated with trees and brush and is on private property. The upstream slope near the left abutment is a combination of beach area and trees, and is also on private property.

The crest of the primary section of the embankment is approximately 15 ft. wide and surfaced with grass. The crest elevation of the embankment is reportedly El. 307.67 (Dubois & King, 2007). The embankment extends approximately 190 ft. to the right abutment from the primary spillway. An access gate for maintenance and dam operation is located near the right abutment. The embankment crest extends approximately 90 ft. to the left of the spillway where it meets

private property. The private home site is essentially part of the embankment and may have been the former site of a mill structure associated with the dam. This portion of the embankment widens to between 40 ft. and over 120 ft. and extends approximately 210 ft. to the left where it meets natural ground that slopes up and away from the dam (the left abutment). The private property currently includes a house, driveway, other secondary buildings and site improvements.

The downstream slopes of the primary embankment sections are graded at approximately 2.5H:1V and are surfaced with grass. A toe drain system is present along the toe of the slope to the left and right of the primary spillway. The toe drain system reportedly consists of a mineral filter with seepage collection pipes that discharge into the primary spillway channel. Cleanouts are located at the toe of slope near the right and left abutments.

The primary spillway consists of a 30 ft. long (measured parallel to the dam crest) ogee-shaped reinforced concrete weir with a weir crest elevation of El. 298.25. The primary spillway discharge channel has concrete training walls and floor extending through the dam approximately 90 ft. to the downstream area. The spillway discharges into the stone lined natural channel of Catacoonamug Brook. A reinforced concrete catwalk extends over the spillway channel to allow access to both sides of the dam embankment.

There is a gatehouse immediately to the right of the primary spillway that houses a low-level outlet (LLO) and a mid-level outlet (MLO). The gatehouse is a wood framed structure with a concrete dry well valve pit and asphalt shingle roof. The invert in of the MLO and LLO are reportedly El. 292.00 and El. 288.25, respectively (Dubois & King, 2007). Both outlets are controlled by 24 in. gate valves (Dubois & King, 1995) that discharge to one 30-inch discharge pipe. The 30-inch pipe daylights through the right wall of the primary spillway discharge channel. The valves are operated via hand wheel operators located in the gatehouse.

1.2.5 Operations and Maintenance

There is no formal operations and maintenance manual for the dam. The assigned Caretaker operates the LLO and MLO valves and performs regular visual inspections of the structure. The Caretaker keeps records of gate operation, reason for operation, and lake levels during operation. The valves are operated to maintain required minimum flow in Catacoonamug Brook downstream of the dam based on twice weekly staff gauge readings from the Catacunemaug Road Bridge. In the fall (October and November) prior to ice formation on the Lake, the gates are opened and the pond level is lowered 6 ft. to control plant growth and allow beach/dock maintenance. The water level in the Lake must be returned to normal pool with discharge over the primary spillway by April 1. The Lake Shirley Improvement Corporation also hires a landscape company to mow the earthen embankment sections on Town property on a monthly basis.

1.2.6 DCR Size Classification

Lake Shirley Dam has a height of dam of approximately 21 ft. and a maximum storage capacity of 7,719 acre-feet (Dubois & King, 2007). Refer to Appendix D for definitions of height of dam and storage. Therefore, in accordance with Department of Conservation and Recreation Office of Dam Safety classification, under Commonwealth of Massachusetts dam safety rules and regulations stated in 302 CMR 10.00 as amended by Chapter 330 of the Acts of 2002, Lake Shirley Dam is a **LARGE** size structure.

1.2.7 DCR Hazard Potential Classification

Lake Shirley Dam is located upstream of the Catacoonamug Brook, Catacunemaug Road Bridge, residential homes, Brook Trail Bridge, a railroad bridge, Leominster Road Bridge, Shaker Road, and Lowell Road. It appears that a failure of the dam at maximum pool will likely cause loss of life and serious damage to homes, industrial or commercial facilities, important public utilities, main highways, or railroads. Therefore, in accordance with Department of Conservation and Recreation classification procedures, under Commonwealth of Massachusetts dam safety rules and regulations stated in 302 CMR 10.00 as amended by Chapter 330 of the Acts of 2002, Lake Shirley Dam should be classified as a **HIGH** hazard potential dam. The Hazard Potential Classification recommendation is consistent with the Hazard Potential Classification on record with the Office of Dam Safety for Lake Shirley Dam.

1.3 Pertinent Engineering Data

1.3.1 Drainage Area

The drainage area for Lake Shirley Dam is approximately 14.3 square miles as reported by Dubois & King and confirmed by Weston & Sampson (See Figure 1 – Locus Map). The drainage area extends through the communities of Leominster, Lancaster, and Shirley, but is primary located in the Town of Lunenburg. Multiple streams and brooks flow into Lake Shirley including Catacoonamug Brook and Easter Brook. Located in the upper portions of the watershed are Lake Whalom, Massapoag Brook, Turkey Hill Pond, Dead Pond, and White Rabbit Swamp. The drainage area includes some hilly terrain as well as low lying wetlands. The elevation difference across the watershed is approximately 375 ft.

1.3.2 Reservoir

See the table in Section 1.4 for data on normal, maximum, and spillway design flood (SDF) pools. These data were taken from the February 12, 2007 Phase I Inspection Report by Dubois & King.

1.3.3 Discharges at the Dam Site

No data are available regarding discharges from the dam at the time of this report. The primary spillway can reportedly discharge approximately 3,570 cfs (Dubois & King, 2007) if the water surface elevation in Lake Shirley was at the dam crest (Maximum Pool). This value appears reasonable based on a cursory review of the watershed size and hydraulic features of the structure. The Dam Caretaker indicated that the maximum depth of flow he has observed over the primary spillway is 16 in. The Dam Caretaker also informed us that 80 turns of the MLO gate are required to keep minimum flows in the downstream brook.

1.3.4 General Elevations (feet)

Elevations listed below are based on those provided in the February 12, 2007 Phase I Inspection Report of Lake Shirley Dam by Dubois & King. The elevations reference the National Geodetic Vertical Datum (NGVD). The elevations listed below are useful for understanding relative differences between components of the dam but should not be used for design or construction purposes.

A.	Top of Dam	El. 307.67*
B.	Spillway Design Flood Pool	El. 307.1**
C.	Normal Pool	El. 298.50
D.	Spillway Crest	El. 298.25
E.	Upstream Water at Time of Inspection	El. 298.5+/-
F.	Streambed at Toe of the Dam	El. 287+/-
G.	Low Point along Toe of the Dam (Discharge Channel)	El. 287+/-

*According to the 2007 Phase I Report by Dubois & King, the design elevation of the dam crest was El. 308. However, based on a check of this in 2007, the crest elevation was found to be approximately El. 307.67. It is not clear whether the crest settled or whether this was the as-built condition of the crest after rehabilitation construction in 1996 and 1997.
**The spillway design flood pool elevation is reportedly based on a study performed by Dubois & King that was not reviewed by Weston & Sampson.

1.3.5 Primary Spillway Data

A.	Type	Ogee Spillway
B.	Weir Length	30 ft.
C.	Weir Crest Elevation	El. 298.25
D.	Upstream Channel	El. 287.5
E.	Downstream Channel	El. 287.0

1.3.6 Outlet Works Data

A.	Type	Mid-Level Outlet (MLO), 24 in. dia. C.I. Low-Level Outlet (LLO), 24 in. dia. C.I. Both outlets controlled by gate valves into a 30 in. pipe.
B.	Invert In MLO	El. 292.00
C.	Invert In LLO	El. 288.25
D.	Outlet Works Invert Out	El. 288.50
E.	Valve Pit Floor	El. 286.50

1.3.7 Design and Construction Records and History

A dam was originally constructed at this location for mill power circa 1852. That dam was washed out in 1856 and rebuilt in 1857. The dam was rehabilitated to its current configuration in 1996 and 1997 (Dubois & King, 2007). The 1996 and 1997 rehabilitation included raising the dam crest several feet to increase the freeboard during the Spillway Design Flood (SDF), flattened the downstream slope to improve stability, installing a toe drain filter system along the downstream toe of the dam, installing a 30 ft. wide reinforced concrete spillway, and installing a new gatehouse and outlet works system. The Record Drawings from this rehabilitation are available with the Dam Owner and Caretaker.

1.3.8 Operating Records

There is no formal operations and maintenance plan for this dam. However, the Dam Caretaker keeps records of valve operations. The records are kept in the gatehouse at the dam.

1.4 Summary Data Table

Required Phase I Report Data	Data Provided by the Inspecting Engineer
National ID #	MA00455
Dam Name	Lake Shirley Dam
Dam Name (Alternate)	Shirley Reservoir Dam
River Name	Catacoonamaug Brook, tributary to Nashua River
Impoundment Name	Lake Shirley
Hazard Class	High
Size Class	Large
Dam Type	Earth Embankment
Dam Purpose	Originally Mill Power, Recreation
Structural Height of Dam (feet)	21 (Dubois & King, 2007)
Hydraulic Height of Dam (feet)	20.1 (Dubois & King, 2007)
Drainage Area (sq. mi.)	14.3 (Dubois & King, 2007)
Reservoir Surface Area (sq. mi.)	0.61 (393 Acres, Dubois & King, 2007)
Normal Impoundment Volume (acre-feet)	2,969 (Dubois & King, 2007)
Max Impoundment Volume ((top of dam) acre-feet)	7,719 (Dubois & King, 2007)
SDF Impoundment Volume* (acre-feet)	6,266 (Dubois & King, 2007)
Spillway Type	Ogee Style Weir
Spillway Length (feet)	30
Freeboard at Normal Pool (feet)	5
Principal Spillway Capacity* (cfs)	3,570 (Water at dam top, D&K, 2007)
Auxiliary Spillway Capacity* (cfs)	Not applicable
Low-Level Outlet Capacity* (cfs)	Not determined
Spillway Design Flood* (flow rate - cfs)	1/2 PMF / 8,110 (D&K, 2007)
Winter Drawdown (feet below normal pool)	6 ft. below normal pool (Estimated)
Drawdown Impoundment Vol. (acre-feet)	Not determined
Latitude	42.5544 N
Longitude	71.6750 W
City/Town	Lunenburg
County Name	Worcester
Public Road on Crest	Not applicable
Public Bridge over Spillway	Not applicable
EAP Date (if applicable)	39241
Owner Name	Town of Lunenburg
Owner Address	17 Main Street, PO Box 135
Owner Town	Lunenburg, MA 01462
Owner Phone	(978) 582-4130
Owner Emergency Phone	(978) 582-4531 (Police)
Owner Type	Municipality or Political subdivision
Caretaker Name	Earl Graves

Caretaker Address	573 Reservoir Road
Caretaker Town	Lunenburg, MA 01462
Caretaker Phone	(978) 430-3201 (Cell)
Caretaker Emergency Phone	(978) 582-4531 (Police)
Date of Field Inspection	7/16/2009
Consultant Firm Name	Weston & Sampson
Inspecting Engineer	Mark P. Mitsch, P.E.
Engineer Phone Number	(978) 532-1900

SECTION 2

2.0 INSPECTION

2.1 Visual Inspection

Lake Shirley Dam was inspected on July 16, 2009. At the time of the inspection, the weather was 75 degrees F and partly cloudy. Photographs to document the current conditions of the dam were taken during the inspection and are included in Appendix A. The level of the impoundment was approximately El. 298.5. Underwater portions of the dam were not observed. A copy of the inspection checklist is included in Appendix B.

2.1.1 General Findings

In general, Lake Shirley Dam was found to be in **SATISFACTORY** condition. Specific comments on the condition of the dam are provided in the sections below:

2.1.2 Dam

- ***Abutments***

The right and left abutments of the dam area located on private properties. The upstream slope of the right abutment is overgrown with trees and brush. The upstream and downstream slope of the left abutment is overgrown with trees and brush. The crest of the left abutment consists of a private lawn, driveway, and buildings. It should be noted that the crest width at the left abutment is in excess of approximately 120 ft. No signs of abutment seepage, surface cracking, or displacement were observed. See photos 3, 5, 9 and 10.

- ***Upstream Face/Slope***

The upstream vertical, reinforced concrete wave walls protect the upstream face of the dam. The wall alignment is good with the exception of minor outward movement to the right of the gatehouse. The overall wall condition appears to be satisfactory to fair. The wall appears to pre-date the 1996/97 rehabilitation construction. The wave walls do not extend to the abutments. No sinkholes were observed behind the walls although some erosion was observed around the right end of the wall to the right of the spillway. Several vertical cracks causing minor wall movement were observed. There is evidence of attempted crack caulking/sealing. The top of the left wave wall is lower than the top of the right wall. Cut, vertical steel bars were observed on top of the wave wall to the left of the primary spillway. See photos 1, 2, and 4 through 6.

No slides, slough, or scarps were observed on the earthen slope up gradient from the vertical concrete wave walls. The slopes are protected by well maintained grass. One animal burrow was observed on the upstream slope and some areas of minor disturbance were observed. Brush and trees are present at the right and left ends of the wave walls where the walls contact private property. The brush growth prevented thorough inspection of those areas. Minor erosion around the right end of the wave wall was

observed. No unusual movement of the slope was detected. The slope has a well maintained grass surface with some minor weed growth noted. See photos 1, 2, 3, and 5.

- ***Crest***

The majority of the dam crest is surfaced with well maintained grass. No surface cracking, sinkholes, ruts, or animal burrows were observed. The crest is reportedly 4 in. lower than the indicated design crest elevation based on the 1996/97 rehabilitation construction plans (Dubios & King, 2007). It is not clear whether this is due to settlement or if the crest was constructed slightly lower than the intended design grade. The horizontal alignment of the dam is good. The crest in the vicinity of the left abutment is on private property and consists of a well maintained lawn, driveway, and buildings. The crest width in this area varies from 40 ft. to approximately 120 ft. See photos 7 through 10.

- ***Downstream Slope***

No active seepage was observed on the downstream slopes. However, at the toe of the downstream slope to the left of the primary spillway, standing water and iron staining were observed. It is possible that the toe drain seepage collection pipe in this area could have failed causing this condition. No slides, sloughing, or scarps were observed on the downstream slope. Several small, shallow animal burrows were observed to the right of the spillway. No erosion or sinkholes were observed. Several minor depressions along the slope were noted. The downstream slope is surfaced with a well maintained grass cover. However, some bare areas and weeds were observed near the left abutment. Trees and brush were observed on the downstream slope near the left abutment area. It should be noted that the embankment in this area is approximately 120 ft. wide. See photos 10 through 15.

- ***Drains***

There is a seepage collection system along the downstream toe of the dam. The wet area observed to the left of the primary spillway discharge channel along the toe of the slope could be attributed to a clogged or improperly functioning drain in the system.

- ***Instrumentation***

There is no instrumentation on the dam. A staff gauge is located on Catacunemaug Road Bridge approximately 350 ft. downstream of the dam. The flow depths at this location are recorded and submitted to the MA DEP to show that the minimum amount of base flow in the downstream brook is being maintained. The water depth at the bridge is recorded twice weekly. See photo 22.

- ***Access Roads and Gates***

The dam is accessed from the right abutment area off of Fire Road 18 and Catacunemaug Road. A gated entrance is located near the right abutment. Vehicular access to the spillway is possible for authorized personnel. The gatehouse is kept locked as is access to the primary spillway catwalk.

2.1.3 Appurtenant Structures

- ***Primary Spillway***

The primary spillway is a reinforced concrete ogee-shaped weir with concrete training walls. The overall condition of the spillway appears to be good. The training walls are reinforced concrete. Several minor cracks were observed in the walls. The spillway is a fixed crest, uncontrolled weir. No unusual movement or debris on the weir or discharge channel was observed. Multiple small cracks and spalls were observed on the downstream side of the weir causing minor flow disturbance. The reinforced concrete catwalk over the primary spillway is spalled on the surface near the right side. See photos 16 through 19.

- ***Outlet Works***

The outlet works consists of a LLO and MLO. The intake structure was not observable. The trash rack is reported a bar rack which is only marginally effective as the gates reportedly become clogged with leaves on a regular basis. The gates are in good condition although the caretaker has noted that the gates are "stiff" to operate. No seepage or leakage related to the outlet works was observed. No unusual movement or erosion related to the outlet works was noted. The gatehouse building appears to be in satisfactory condition. See photos 20 and 21.

- ***Auxiliary/Emergency Spillway***

There is no auxiliary or emergency spillway system at this dam.

- ***Dikes***

There are no remote dikes related to this dam.

2.1.4 Downstream Area

No abutment leakage or active foundation seepage were observed. Access to the downstream area is fair and is possible only by foot. The immediate downstream area is wooded. The downstream channel (Catacoonmaug Brook) is stone lined and appears to flow freely. Catacunemaug Road Bridge is located approximately 350 ft. downstream of the dam.

2.1.5 Reservoir Area

The lake is approximately 393 acres at normal pool elevation. Lake Shirley is irregularly shaped consisting of two main pool areas. The dam is located along the eastern shoreline in a cove of the southern pool area. The reservoir depth was not obtained but the water level at the time of the inspection was approximately El. 298.5. The shoreline of the lake is wooded with some residential development. The slopes do not appear to be susceptible to slides or other occurrences that could affect the water level elevation.

2.1.6 Estimated Inundation Area

The Emergency Action Plan for the dam dated June 8, 2007 by Dubois & King provided an estimated inundation area as well as depth of flooding at selected downstream locations under different dam breach scenarios. The Estimated Inundation Area from the dam includes Catacoonamug Brook, Catacunemaug Road Bridge, residential homes, Brook Trail Bridge, a railroad bridge, Leominster Road Bridge, Shaker Road, and Lowell Road.

2.2 Caretaker Interview

The assigned Dam Caretaker is Mr. Earl Graves who represents the Lake Shirley Improvement Corporation. Mr. Graves was present during the inspection. The following information was provided by Mr. Graves during the inspection:

- Twice per week, Mr. Graves takes water level readings on the staff gauge at the downstream bridge for submission to the MA DEP.
- Mr. Graves indicated that 80 turns of the MLO gate are required to keep minimum flows in the downstream brook.
- The maximum depth of flow that Mr. Graves has observed over the primary spillway is approximately 16 in.
- Mr. Graves indicated that the spalled catwalk over the primary spillway could be a tripping hazard.
- Mr. Graves indicated that the embankment is mowed by a landscaping company hired by the Lake Shirley Improvement Corporation on a monthly basis.
- The LLO and MLO gates clog somewhat frequently requiring the fire department dive team to dive down and remove leaves and debris. The existing trash rack does not seem to be effective.
- Mr. Graves indicated the gates are “stiff” to operate. Also, that it takes 300 turns to fully open the gates.
- Mr. Graves indicated he is not in possession of a manual for the gate valves, but would like to have one to better understand their operation and maintenance procedures.
- Mr. Graves has been monitoring the wet area along the downstream toe of the slope to the left of the primary spillway.

The following information was provided by Mr. Graves based on a phone interview conducted on August 14, 2009:

- Mr. Graves generally visits the dam twice per week but more frequently in the fall when he visits the dam as frequently as on a daily basis.
- Mr. Graves indicated the Dubois & King recommendation from the 2007 Phase I Report to place riprap at the MLO to prevent erosion was not performed.
- Mr. Graves indicated the Dubois & King recommendation from the 2007 Phase I Report to remove excess riprap that could restrict flow at the Catacunemaug Road Bridge was not performed. Mr. Graves indicated he has not seen an issue with flow restriction at that location and is not sure what riprap, if any, should be removed.
- Mr. Graves indicated that he keeps personal records of outlet works operation using his own form. Mr. Graves records include which valve was operated, reason for operation, and lake levels at the time of operation. Mr. Graves indicated he submits reports of his

operations in monthly meetings with the Lake Shirley Improvement Corporation. The reports are also available to the Town of Lunenburg selectmen.

- Mr. Graves indicated he operates the valve in the fall and during high flow events throughout the year to maintain between 4 in. and 10 in. of flow over the primary spillway weir without causing downstream flooding.
- Mr. Graves indicated he begins lowering the pool elevation in Lake Shirley in October and November prior to ice formation in the Lake. The target is to lower the lake 6 ft. below normal pool for weed control, beach maintenance, and dock removal/maintenance. Mr. Graves indicated this target is not always achieved and sometimes frequent operation throughout the winter is necessary to keep the lake level down. Mr. Graves indicated the MA DEP requires that by April 1st, the water level must be back to normal pool and flow should be discharging over the weir. Minimum downstream flow must be maintained throughout the year.

Also as part of the interview process, Mr. Jack Rodriquenz, Director of Operations for the Lunenburg DPW was contacted on August 17, 2009 via telephone. Mr. Rodriquenz provided Weston & Sampson with a set of Record Drawings from the 1996/97 rehabilitation. Mr. Rodriquenz indicated that the Town of Lunenburg DPW does have in their possession keys that unlock the access gate and gatehouse in the case of an emergency. Mr. Rodriquenz also indicated that to his knowledge, the June 8th, 2007 Emergency Action Plan (EAP) that was developed for the dam by Dubois & King was in the process of being reviewed and signed off on by the Town and other parties.

2.3 Operation and Maintenance Procedures

2.3.1 Operational Procedures

There is no formal operation and maintenance plan for the dam. However, the Caretaker keeps records of gate operation, reason for operation, and lake levels at the time of operation and submits monthly reports to the Lake Shirley Improvement Corporation and the Town of Lunenburg Selectmen. The gates are operated to lower the pool elevation during the winter months to control weed growth and beach/dock maintenance in Lake Shirley. The water level is generally lowered 6 ft. beginning in October and November before ice formation on Lake Shirley. Lake Shirley must be returned to normal pool elevation with discharge over the primary spillway by April 1. A minimum base flow is required to be passed by the dam at all times to keep up water levels in Catacoonamaug Brook. According to Mr. Graves, 80 turns of the MLO gate are required to meet this minimum discharge. Mr. Graves takes readings of downstream water depths at the staff gauge at Catacunemaug Road Bridge biweekly.

2.3.2 Maintenance of Dam and Operating Facilities

Maintenance is conducted at the dam on an as needed basis. The embankment is mowed monthly by a landscape company hired by the Lake Shirley Improvement Corporation. The LLO and MLO gave valves are the only operating works at this dam.

2.4 Emergency Warning System

There is no Emergency Warning System in place at the dam. An Emergency Action Plan (EAP) has been developed for this dam by Dubois & King. The EAP was developed for the dam by

Dubois & King and is dated June 8, 2007. It is our understanding that the Town and related parties are in the process of signing off on the plan and submitting it to the Office of Dam Safety and other required parties.

2.5 Hydrologic/Hydraulic Data

A hydrologic and Hydraulic analysis of the watershed and dam was performed by Dubois & King in 1995 and 1996 as part of the dam rehabilitation design effort. The analysis was not obtained or reviewed by Weston & Sampson. Dubois & King reportedly utilized the U.S. Army Corps of Engineers HEC-1 Flood Hydrology computer model. The following results were taken directly from the February 12, 2007 Phase I Dam Inspection by Dubois & King:

A. Spillway Design Flood (SDF) Return Period = ½ PMF
B. SDF Inflow (CFS) = 8,110
C. SDF Outflow (CFS) = 3,052
D. Spillway Capacity (CFS) = 3,750 (Water at El. 308, top of dam)
E. Peak Water Surface Elevation (ft.) = El. 307.1+/-
F. Depth of Overtopping (ft.) = Not Applicable. Dam does not overtop. Approximately 0.6 ft. of freeboard would be present based on top of dam El. 307.67

2.6 Structural and Seepage Stability

2.6.1 Embankment Structural Stability

Engineering analyses of static and dynamic stability of the embankment were not available for review at the time of this report and have not been conducted for this study. Reportedly, Dubois & King conducted slope stability analyses as part of the rehabilitation design effort. Based on the findings of this study, the downstream slopes of the dam were flattened from 1.75H:1V to 2.5H:1V with granular material that is more pervious than the existing embankment material. A toe drain seepage collection system was also incorporated at the toe of the downstream slope (Dubois & King, 2007). Based on visual observations, the embankments of Lake Shirley Dam appear to be stable.

2.6.2 Structural Stability of Non-Embankment Structures

The non-embankment structures at this dam include the upstream wave wall, the primary spillway weir and channel walls, the catwalk over the primary spillway, and the gatehouse structure. Engineering analyses of static and dynamic stability of the non-embankment structures were not available for review at the time of this report and have not been conducted for this study. Based on visual observations, the non-embankment structures for Lake Shirley Dam appear to be stable.

Several vertical cracks in the upstream wave wall were observed as was minor outward movement. Continued monitoring of this condition is recommended. Minor surface spalling and cracking was observed on the training walls, weir, and catwalk bridge, but these conditions appear surficial in nature.

2.6.3 Seepage

Active seepage was not observed along the downstream toe of the slope. The flow through the primary spillway channel prevented the detection of any seepage or leakage into the channel. Standing water and iron staining was observed to the left of the primary spillway at the toe of the slope. This condition could be due to a clogged toe drain seepage collection pipe. Continued monitoring of this area is recommended.

SECTION 3

3.0 ASSESSMENTS AND RECOMMENDATIONS

3.1 Assessments

In general, the overall condition of Lake Shirley Dam is **SATISFACTORY**. The dam was found to have the following minor deficiencies:

1. The upstream slopes at the ends of the wave walls (located on private property) are overgrown with trees and brush preventing a thorough inspection of these areas. Trees and brush were also observed on the downstream slope near the left abutment area.
2. Minor outward movement and vertical cracks were observed along the wave wall.
3. Erosion was observed at the right end of the right wave wall on the upstream slope.
4. Several animal burrows were observed on the upstream and downstream slopes.
5. Standing water and iron staining were observed at the toe of the downstream slope to the left of the primary spillway. This could be the result of a clogged toe drain seepage collection pipe.
6. Some bare areas and weeds were observed in the grass cover on the embankment.
7. Minor cracks and spalls were observed on the primary spillway weir and channel walls. The catwalk surface is spalled on the right side.
8. The outlet works gates clog with leaves and debris when operated. The gate operator wheels are stiff to operate.
9. The dam does not have a formal operations and maintenance plan.

Previously Identified Deficiency,	***Resolution or Current Condition***
Minor erosion at the downstream ends of the right and left spillway training walls.	No Action
The crest has settled approximately 4 in. since the rehabilitation construction in 1996 and 1997.	No Action. Approximately 0.6 ft. of freeboard is still predicted during the SDF despite this difference in dam crest elevation.
Spalling on the concrete catwalk across the primary spillway.	No Action, monitored by Dam Caretaker.
Slight cracking of the spillway channel walls and pitting of the ogee weir on the downstream side.	No Action, monitored by Dam Caretaker.
The slab adjacent to grates in the gatehouse has settled 5/8 in.	No Action, not observed during this inspection.
Upstream wave walls have minor vertical cracking and spalling. Minor erosion behind the right wave wall the far right. The left wave wall had 2 in. of horizontal movement at 11 ft. left of spillway.	Evidence of attempted crack sealing/ caulking. The condition is monitored by Dam Caretaker.

Recommendations from February 12, 2007 Phase I Inspection by Dubois & King	***Action***
Update/develop a formalized Operations & Maintenance (O&M) Manual for the dam.	The Town has acknowledged this deficiency and considered hiring a consultant to help develop a plan.
Update/develop a formalized Emergency Action Plan (EAP) for the dam.	An EAP was developed for the dam by Dubois & King dated June 8, 2007. The Town and related parties are in the process of signing off on the plan and submitting it to the Office of Dam Safety and other required parties.
Perform a Follow-up Inspection in the Spring of 2007. This inspection should include snaking the toe drain piping to the left of the primary spillway.	The Phase I Inspection satisfies this requirement. The toe drain piping was not snaked, but the area is monitored by the Dam Caretaker
Raise the embankment 4 in. where needed to return the dam crest to design elevation.	Adequate freeboard is still expected during the SDF (0.6 ft. rather than 0.9 ft. as designed).
Repair vertical cracking in wave walls using a flexible, waterproof caulk. Repair spalling in wave walls with mortar grout.	The Dam Caretaker has been monitoring the walls. Evidence of some attempted crack sealing/caulking.
Repair spalling on top surface of catwalk with mortar grout.	No Action
Fill minor holes and sinkholes with similar material found in dam structure at downstream ends of right and left spillway training walls and behind right wave wall at far right end.	No Action
Town of Lunenburg should have a set of keys to the access gate and gatehouse for emergency purposes.	The Town of Lunenburg DPW has keys in their possession.
Place riprap in the scoured entrance area at the MLO pipe inlet to prevent further erosion.	No Action
Riprap and small stones at Catacunemaug Road/Robbs Hill Road Bridge (downstream of the dam) in left span should be removed.	No Action, there appears to be no issue with flow restriction at this location.

The February 12, 2007 Phase I Inspection Report by Dubois & King indicated the dam was in **SATISFACTORY** condition. A condition rating of **SATISFACTORY** was considered during this study. The definitions of the condition rating options are as follows:

GOOD - No existing or potential deficiencies recognized. Safe performance is expected under all loading including SDF.

SATISFACTORY - Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result in deficiencies.

FAIR - Significant operational and maintenance deficiencies, no structural deficiencies. Potential deficiencies exist under unusual loading conditions that may realistically occur. Can be used when uncertainties exist as to critical parameters.

POOR – Significant structural, operation and maintenance deficiencies are clearly recognized under normal loading conditions

UNSAFE - Major structural, operational, and maintenance deficiencies exist under normal operating conditions.

The following recommendations and remedial measures generally describe the recommended approach to address current deficiencies at the dam. Prior to undertaking recommended maintenance, repairs, or remedial measures, the applicability of environmental permits needs to be determined for activities that may occur within resource areas under the jurisdiction of local conservation commissions, MADEP, or other regulatory agencies.

3.2 Studies and Analyses

It is recommended that the Town of Lunenburg engage the services of a Registered Professional Engineer as defined in 302 CMR 10.03 to complete the following studies and analyses in accordance with current dam safety regulations:

- Prepare an operations and maintenance plan to list and describe the normal maintenance and operational activities conducted at the dam. The plan should include dates and general procedures for pond level management as well as frequency and procedures for activities such as site observations, grass cutting, brush clearing and other maintenance activities. Provide the plan to the Office of Dam Safety for record purposes.

3.3 Recurrent Maintenance Recommendations

It is recommended that the owner/caretaker conduct the following routine observation and maintenance activities:

- Observe the condition of the dam for changes from those identified in this report. Observations should be made quarterly, as well as during and following rainfall events that exceed the 25-year, 24-hour storm (approximately five inches of rain in 24-hours).
- Remove debris that becomes lodged on the primary spillway weir or in the discharge channel to ensure free flow conditions through the system.
- Monitor the vertical cracks and outward movement of the upstream wave walls.
- Monitor the wet area at the left downstream area of the dam. Place grade stakes at the extents of the wet area and take regular photographs to document the size of the area in relation to lake stage.
- Fill the animal burrows on the dam with compacted granular fill or crushed stone.
- Monitor the surficial spalling and cracking of the primary spillway weir and training walls.

3.4 Minor Repair Recommendations

It is recommended that the owner/caretaker conduct the following minor repair activities as soon as practicable to limit the risk of dam failure until appropriate dam rehabilitation is designed and constructed. These activities may require design by a Registered Professional Engineer and/or permit application filing with the local conservation commission and/or DEP:

- Remove brush up to 4 in. in diameter at the right and left ends of the upstream wave walls and on the downstream slope near the left abutment (private property). Inspect these areas for any deficiencies not detected during this inspection.
- Repair the spalled area on the concrete catwalk by removing all loose concrete and patching with cement or epoxy grout as appropriate.
- Remove loose soil and organics from the area around the right end of the right wave wall. Place a layer of 6 in. riprap bedded in crushed stone overlying filter fabric.
- Consult an Engineer to design repairs to fix the seepage collection system in the area of the standing water left of the spillway (if the problem worsens based on recommended observations).
- Install an intake structure on the upstream side of the LLO and MLO intakes to reduce the likelihood of clogging by leaves and debris.
- Consult with a turf manager regarding methods to control weeds and reestablish and maintain a healthy turf on the dam embankment.

3.5 Remedial Modification Recommendations

None recommended at this time.

3.6 Alternatives

There are no recommended alternatives for this dam.

3.7 Opinion of Probable Construction Costs

Our estimate of the probable ranges of costs to implement the recommendations listed above are as follows. These estimates are based on limited information and are not intended as a basis for capital improvement budgeting.

- Studies and Analyses

  $3,000-$5,000

- Recurrent Maintenance

  $1,500 to $2,500 annually

- Minor Repairs

  $15,000 to $45,000 (depending on seepage collection system repair requirements)

FIGURES

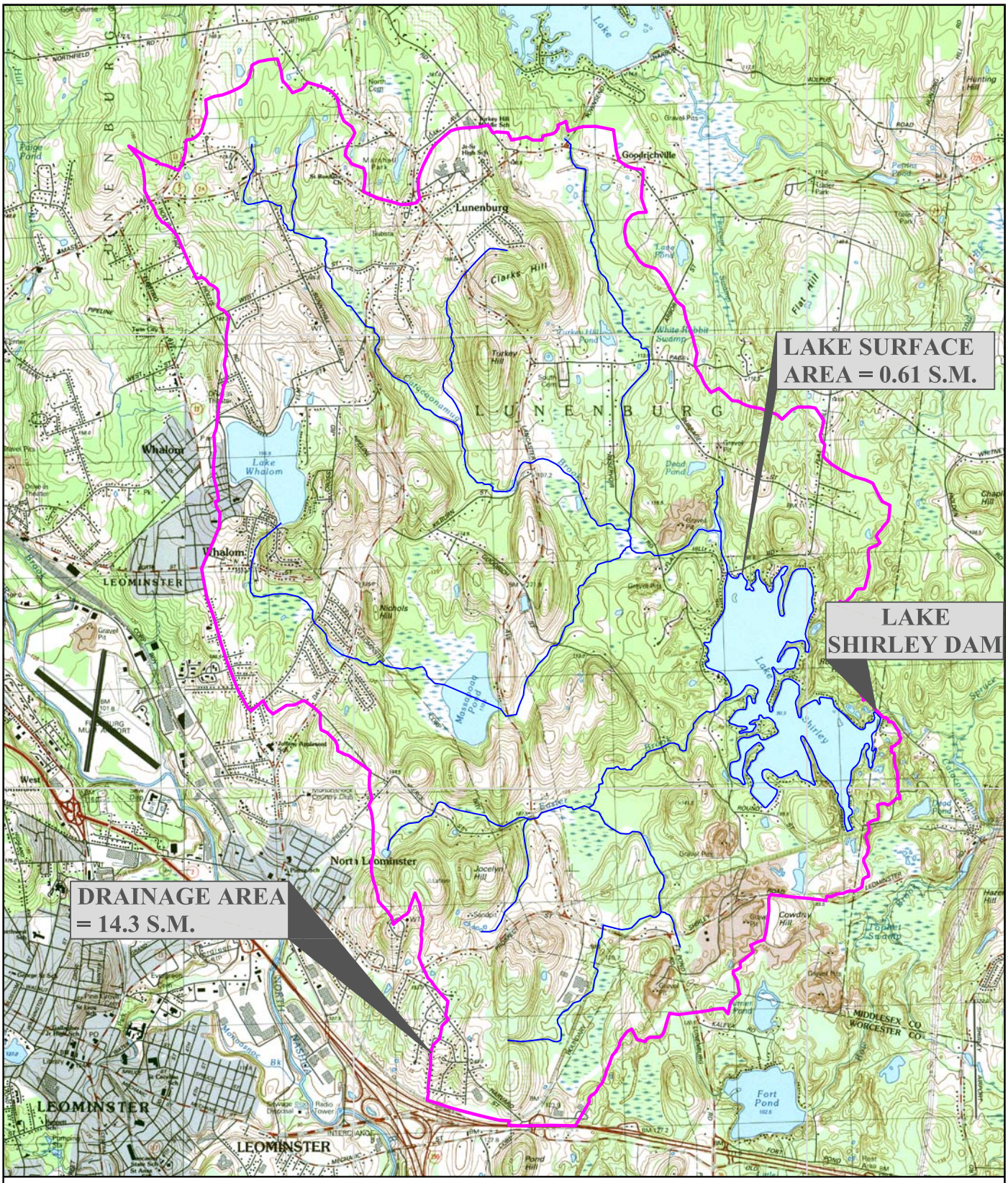

FIGURE 1
LUNENBURG, MASSACHUSETTS
LAKE SHIRLEY DAM
LOCUS MAP

APPROXIMATE SCALE: 1"=4,000'

0 4,000 8,000

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FIGURE 2
LUNENBURG, MASSACHUSETTS
LAKE SHIRLEY DAM
AERIAL PHOTOGRAPH
APPROXIMATE SCALE: 1"=80'

0 80 160

N

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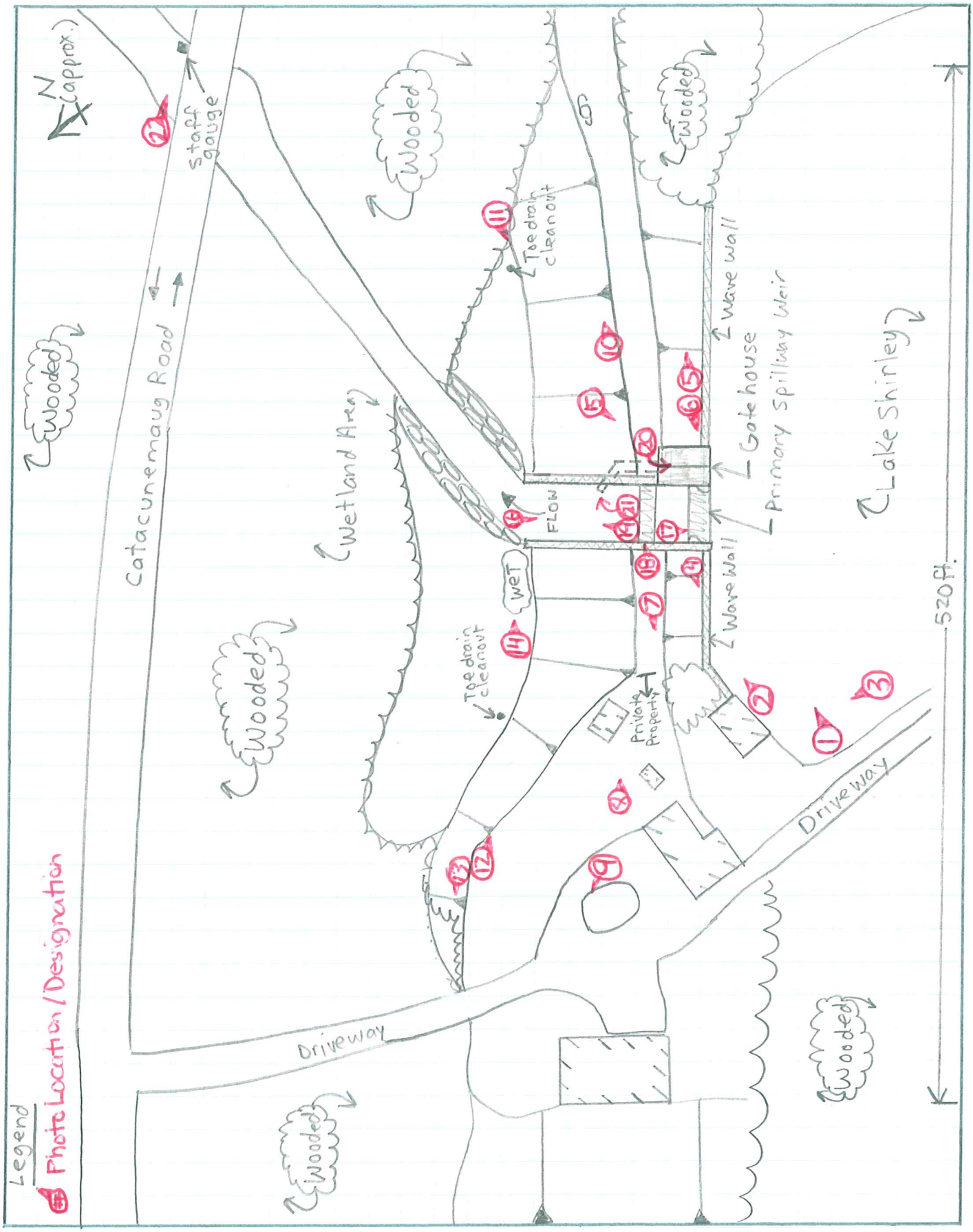
Weston & Sampson Engineers, Inc. — Innovative Solutions since 1899	PROJECT: Lake Shirley Dam, Lunenburg, MA	DATE: 8/14/09	PAGE: 1/1
		BY: BTG	
		FIGURE 3 - SITE SKETCH	



APPENDIX A
Photographs

Photo 01 - The upstream slope/face of the dam. The primary spillway, gatehouse, concrete wave walls, and grassed earthen slope are visible in this image. The right abutment is beyond the truck and telephone pole in this image.

Photo 02 - The upstream slope/face of the dam immediately to the left of the primary spillway. The trees on the upstream slope near the dock in the left side of this image are on private property.

Photo 03 - The upstream slope and crest of the dam near the left abutment. This private home site may have been the site of a former mill. The site is essentially level with the embankment crest shown in Photo 02 and is between 40 ft. wide and up to approximately 120 ft. wide where the site contacts the left abutment.

Photo 04 - The top of the wave wall to the left of the primary spillway looking to the left. The tops of cut off vertical steel bars are visible along the top of the wall.

Photo 05 - The upstream slope to the right of the primary spillway. The trees and brush on the upstream slope are on private property. The grassed portion of the slope appears to be well maintained. The right abutment is beyond the truck and telephone pole in this image.

Photo 06 - The upstream wave wall and gatehouse foundation to the right of the primary spillway. Minor outward wave wall movement was observed in this area.

Photo 07 - The crest of the dam looking towards the left from the primary spillway. The left abutment is beyond the structures visible in this image.

Photo 08 - The dam crest on the private property near the left abutment. Lake Shirley and the gatehouse are visible in the background. The crest is up to 120 ft. wide in this area.

Photo 09 - The left abutment is the toe of the slope beyond the driveway in this image.

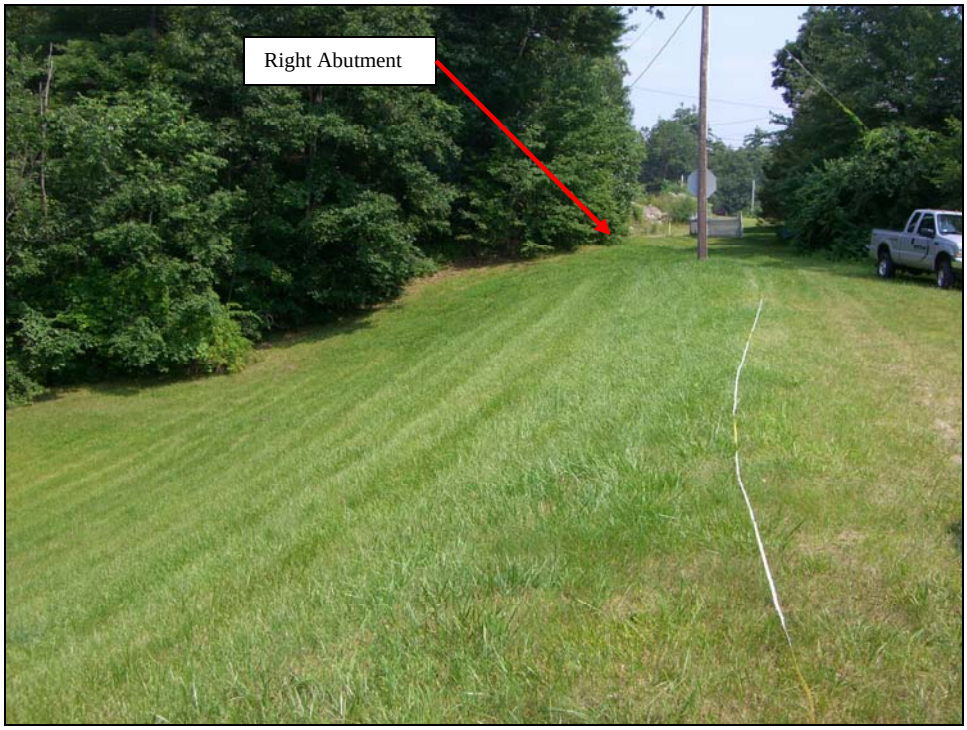


Photo 10 - The crest and downstream slope to the right of the primary spillway looking towards the right abutment. The crest and slope are surfaced with well maintained grass.

Photo 11 - The downstream slope looking towards the primary spillway from the right abutment area. The slope is surfaced with a well maintained grass cover. The left abutment is at the hill visible in the background of this photo.

Photo 12 - The downstream slope looking towards the primary spillway from the private property near the left abutment. The grass is well maintained although some weeds were observed in this area.

Photo 13 - The downstream slope looking towards the left abutment on private property. The slope near the left abutment is overgrown with trees and brush. However, the embankment crest is up to 120 ft. wide in this area.

Photo 14 - A wet area was observed at the toe of the downstream slope to the left of the primary spillway. Standing water was observed but no active seepage was detected. There is a toe drain seepage collection system in this area. The drainage pipe of the system may be clogged resulting in this wet area.

Photo 15 - A small animal burrow observed on the downstream slope to the right of the primary spillway.

Photo 16 - The primary spillway looking upstream. The ogee weir, concrete catwalk, and discharge channel walls are visible. The minor flow interruptions observed on the weir are small spalled areas. The pipe protruding from the right channel wall (left side in this image) is the discharge pipe from the gatehouse outlet works.

Photo 17 - A close-up of the ogee weir looking upstream. The minor flow interruptions observed on the weir are small spalled areas.

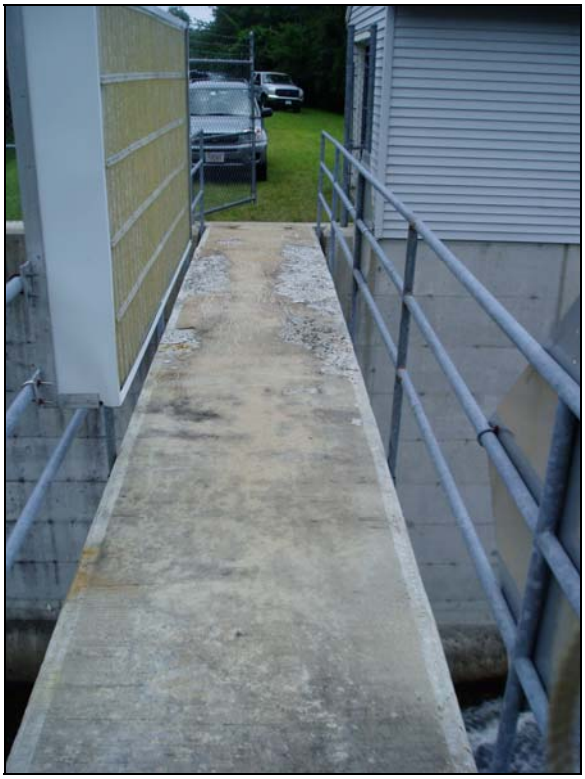


Photo 18 - The concrete catwalk looking towards the right side of the spillway. Spalling of the catwalk surface was observed.

Photo 19 - The spillway discharge channel from the catwalk.

Photo 20 - The interior of the gatehouse structure with LLO and MLO hand wheel gate operators. The gatehouse and outlet works appear to be in satisfactory condition.

Photo 21 - The discharge pipe of the outlet works protruding from the right wall of the spillway discharge channel. No seepage or leakage was observed.

Photo 22 - The staff gauge located at the Catacunemang Road Bridge downstream of the dam.

APPENDIX B
Inspection Checklist

DAM SAFETY INSPECTION CHECKLIST

NAME OF DAM: Lake Shirley Dam

STATE ID #: 4-9-270-3

REGISTERED: ☑ YES ☐ NO

NID ID #: MA00455

STATE SIZE CLASSIFICATION: Large

STATE HAZARD CLASSIFICATION: High

CHANGE IN HAZARD CLASSIFICATION REQUESTED?: No

DAM LOCATION INFORMATION

CITY/TOWN: Lunenburg

COUNTY: Worcester

DAM LOCATION: Fire Road 18 off of Catacunemaug Road
(street address if known)

ALTERNATE DAM NAME: Shirley Reservoir Dam

USGS QUAD.: Ayer

LAT.: 42.5544 N

LONG.: 71.6750 W

DRAINAGE BASIN: Nashua

RIVER: Catacoonamaug Brook, tributary to Nashua River

IMPOUNDMENT NAME(S): Lake Shirley

GENERAL DAM INFORMATION

TYPE OF DAM: Earth Embankment

OVERALL LENGTH (FT): 520

PURPOSE OF DAM: Originally Mill Power, Recreation

NORMAL POOL STORAGE (ACRE-FT): 2,969 (Dubois & King, 2007)

YEAR BUILT: 1852, Rebuilt 1857, Improvements in 1996 and 1997

MAXIMUM POOL STORAGE (ACRE-FT): 7,719 (Dubois & King, 2007)

STRUCTURAL HEIGHT (FT): 21 (Dubois & King, 2007)

EL. NORMAL POOL (FT): El. 298.50 (Dubois & King, 2007)

HYDRAULIC HEIGHT (FT): 20.1 (Dubois & King, 2007)

EL. MAXIMUM POOL (FT): El. 307.67 (Top of Dam, D&K, 2007)

FOR INTERNAL MADCR USE ONLY

FOLLOW-UP INSPECTION REQUIRED: ☐ YES ☐ NO

CONDITIONAL LETTER: ☐ YES ☐ NO

NAME OF DAM: Lake Shirley Dam | STATE ID #: 4-9-270-3

INSPECTION DATE: July 16, 2009 | NID ID #: MA00455

INSPECTION SUMMARY

DATE OF INSPECTION: July 16, 2009 | DATE OF PREVIOUS INSPECTION: February 12, 2007

TEMPERATURE/WEATHER: 75 degrees F, Partly Cloudy | ARMY CORPS PHASE I: ☐ YES ☑ NO If YES, date

CONSULTANT: Weston & Sampson | PREVIOUS DCR PHASE I: ☑ YES ☐ NO If YES, date 02/12/07

BENCHMARK/DATUM: The primary spillway crest is reportedly El. 298.25 (National Geodetic Vertical Datum, NGVD), Dubois & King, 2007.

OVERALL PHYSICAL CONDITION OF DAM: SATISFACTORY | DATE OF LAST REHABILITATION: 1996 and 1997 to current configuration

SPILLWAY CAPACITY: >100% SDF w/ no actions by Caretaker

EL. POOL DURING INSP.: El. 298.5 +/- | EL. TAILWATER DURING INSP.: Not determined

PERSONS PRESENT AT INSPECTION

NAME	TITLE/POSITION	REPRESENTING
Mark P. Mitsch, P.E.	Associate	Weston & Sampson
Benjamin T. Green, P.E.	Engineer	Weston & Sampson
Earl Graves	Caretaker	Lake Shirley Improvement Corporation
Joana Billotta	President	Lake Shirley Association
Jack Rodriquenz	Director of Operations	Town of Lunenburg Department of Public Works

EVALUATION INFORMATION

	Click on box to select E-code
E1) TYPE OF DESIGN	5
E2) LEVEL OF MAINTENANCE	4
E3) EMERGENCY ACTION PLAN	4
E4) EMBANKMENT SEEPAGE	5
E5) EMBANKMENT CONDITION	5
E6) CONCRETE CONDITION	5
E7) LOW-LEVEL OUTLET CAPACITY	4

	Click on box to select E-code
E8) LOW-LEVEL OUTLET CONDITION	5
E9) SPILLWAY DESIGN FLOOD CAPACITY	5
E10) OVERALL PHYSICAL CONDITION	4
E11) ESTIMATED REPAIR COST	20 to 50
ROADWAY OVER CREST	NO
BRIDGE NEAR DAM	NO

NAME OF INSPECTING ENGINEER: Mark P. Mitsch, P.E. | SIGNATURE:

NAME OF DAM:	Lake Shirley Dam	STATE ID #:	4-9-270-3
INSPECTION DATE:	July 16, 2009	NID ID #:	MA00455

OWNER:	ORGANIZATION	Town of Lunenburg	CARETAKER:	ORGANIZATION	Lake Shirley Improvement Corporation
	NAME/TITLE			NAME/TITLE	Earl Graves
	STREET	17 Main Street, PO Box 135		STREET	573 Reservoir Road
	TOWN, STATE, ZIP	Lunenburg, MA 01462		TOWN, STATE, ZIP	Lunenburg, MA 01462
	PHONE	(978) 582-4130		PHONE	(978) 430-3201 (Cell)
	EMERGENCY PH. #	(978) 582-4531 (Police)		EMERGENCY PH. #	(978) 582-4531 (Police)
	FAX			FAX	
	EMAIL			EMAIL	
	OWNER TYPE	Municipality or Political subdivision			

PRIMARY SPILLWAY TYPE	Concrete Ogee Weir		
SPILLWAY LENGTH (FT)	30	SPILLWAY CAPACITY (CFS)	3,570 (Water at dam top, D&K, 2007)
AUXILIARY SPILLWAY TYPE	Not applicable	AUX. SPILLWAY CAPACITY (CFS)	Not applicable
NUMBER OF OUTLETS	2	OUTLET(S) CAPACITY (CFS)	Not determined
TYPE OF OUTLETS	Mid-level outlet, 24 in., Low-level outlet, 30 in.	TOTAL DISCHARGE CAPACITY (CFS)	3,570 (Assuming gates closed)
DRAINAGE AREA (SQ MI)	14.3 (Dubois & King, 2007)	SPILLWAY DESIGN FLOOD (PERIOD/CFS)	1/2 PMF / 8,110 (D&K, 2007)

HAS DAM BEEN BREACHED OR OVERTOPPED ☐ YES ☑ NO IF YES, PROVIDE DATE(S)

FISH LADDER (LIST TYPE IF PRESENT) Not applicable

DOES CREST SUPPORT PUBLIC ROAD? ☐ YES ☑ NO IF YES, ROAD NAME:

PUBLIC BRIDGE WITHIN 50' OF DAM? ☐ YES ☑ NO IF YES, ROAD/BRIDGE NAME:

MHD BRIDGE NO. (IF APPLICABLE)

NAME OF DAM: Lake Shirley Dam STATE ID #: 4-9-270-3

INSPECTION DATE: July 16, 2009 NID ID #: MA00455

EMBANKMENT (CREST)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
CREST	1. SURFACE TYPE	Primarily well maintained grass. It should be noted that technically the crest [1]			
	2. SURFACE CRACKING	None observed.			
	3. SINKHOLES, ANIMAL BURROWS	None observed.			
	4. VERTICAL ALIGNMENT (DEPRESSIONS)	The crest near the spillway and gatehouse is slightly lower than the top of the [2]		x	
	5. HORIZONTAL ALIGNMENT	Good, straight alignment.			
	6. RUTS AND/OR PUDDLES	None observed.			
	7. VEGETATION (PRESENCE/CONDITION)	Well maintained grass, reportedly mowed monthly.			
	8. ABUTMENT CONTACT	Good, left abutment appears encroached by residence.			

ADDITIONAL COMMENTS: [1] includes the private home site near the left abutment. There is a house and several out building on the site, which may have been the site of a former mill building associated with the dam. The private property is well maintained and the crest in this area is from 40 ft. wide to over 120 ft. wide.

[2] concrete training walls of the spillway, which may indicate surface settlement in this area.

NAME OF DAM: Lake Shirley Dam STATE ID #: 4-9-270-3

INSPECTION DATE: July 16, 2009 NID ID #: MA00455

EMBANKMENT (D/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S SLOPE	1. WET AREAS (NO FLOW)	Wet area to the left of the spillway at the toe of the slope. Standing water and [(1)]		x	
	2. SEEPAGE	No active seepage observed.			
	3. SLIDE, SLOUGH, SCARP	None observed.			
	4. EMB.-ABUTMENT CONTACT	Good.			
	5. SINKHOLE/ANIMAL BURROWS	Several small, shallow burrows observed to the right of the spillway.		x	x
	6. EROSION	None observed.			
	7. UNUSUAL MOVEMENT	Several minor depressions noted.		x	
	8. VEGETATION (PRESENCE/CONDITION)	Well maintained grass on the main embankment near the spillway. Near the left [(2)]		x	

ADDITIONAL COMMENTS: [(1)] staining observed. Toe drain system in this area could be clogged.

[(2)] abutment trees and brush are growing on the downstream slope. However, the embankment width in this area is nearly 120 ft. Monitor the condition of the slope in this area.

NAME OF DAM: Lake Shirley Dam STATE ID #: 4-9-270-3

INSPECTION DATE: July 16, 2009 NID ID #: MA00455

EMBANKMENT (U/S SLOPE)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S SLOPE	1. SLIDE, SLOUGH, SCARP	None observed, short earthen slope (approximately 3H:1V or flatter) from top of [(1)]			
	2. SLOPE PROTECTION TYPE AND COND.	Vertical, reinforced concrete wave wall.			
	3. SINKHOLE/ANIMAL BURROWS	One burrow observed, some disturbance of grass surface noted.		x	x
	4. EMB.-ABUTMENT CONTACT	At ends of wave wall, brush and trees present, likely on private property.		x	x
	5. EROSION	Minor erosion around right end of wave wall.		x	
	6. UNUSUAL MOVEMENT	None observed.			
	7. VEGETATION (PRESENCE/CONDITION)	Well maintained grass, some weed growth, vegetation disturbed near left abutment.		x	x
		Trees and brush beyond the right and left ends of the concrete wave walls on private			
		property. Brush prevented a thorough inspection of the slope.			

ADDITIONAL COMMENTS: [(1)] upstream concrete wave wall to crest of dam.

NAME OF DAM: Lake Shirley Dam STATE ID #: 4-9-270-3

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INSTRUMENTATION

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
INSTR.	1. PIEZOMETERS	None observed.			
	2. OBSERVATION WELLS	None observed.			
	3. STAFF GAGE AND RECORDER	A staff gauge is located on the bridge under Catacunemaug Road, approximately [1]			
	4. WEIRS	None observed.			
	5. INCLINOMETERS	None observed.			
	6. SURVEY MONUMENTS	None observed.			
	7. DRAINS	Not applicable.			
	8. FREQUENCY OF READINGS	Staff gauge at downstream bridge read twice weekly.			
	9. LOCATION OF READINGS	Not applicable.			

ADDITIONAL COMMENTS: [1] 350 ft. downstream of the dam. The flow depths at this location are recorded and submitted to the State to show that the minimum base flow in the brook is being maintained.

[2] According to the dam caretaker, 80 turns on the mid level gate is required to keep proper water supply for the downstream brook.

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UPSTREAM CONCRETE WALLS (WAVE WALLS)

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
U/S WALLS	1. WALL TYPE	Vertical, reinforced concrete wave wall.			
	2. WALL ALIGNMENT	Good, minor outward movement of wall detected at some locations.		x	
	3. WALL CONDITION	Satisfactory to fair, appears to be pre-date the 1996/97 rehabilitation.			
	4. HEIGHT: TOP OF WALL TO MUDLINE	min: Not obtained. max: avg:			
	5. ABUTMENT CONTACT	Do not extend to right and left abutments.		x	
	6. EROSION/SINKHOLES BEHIND WALL	None observed, some erosion observed around right end of wall.			
	7. ANIMAL BURROWS	None observed.			
	8. UNUSUAL MOVEMENT	Several vertical cracks causing minor movement. Evidence of caulking/sealing.		x	

ADDITIONAL COMMENTS: *The left side of the wave wall is lower in elevation than the right side of the wave wall.

**Cut, vertical steel bars were observed on top of the wave wall to the left of the spillway.

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DOWNSTREAM AREA

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
D/S AREA	1. ABUTMENT LEAKAGE	None observed.			
	2. FOUNDATION SEEPAGE	Wetness at toe of downstream slope to left of spillway. Could be clogged toe drain.		x	x
	3. SLIDE, SLOUGH, SCARP	None observed.			
	4. WEIRS	Not applicable.			
	5. DRAINAGE SYSTEM	Toe drain at downstream toe of embankment.			
	6. INSTRUMENTATION	Staff gauge at bridge 350 ft. downtream of dam.			
	7. VEGETATION	Wooded.			
	8. ACCESSIBILITY	Fair.			
	9. DOWNSTREAM HAZARD DESCRIPTION	Catacoonamug Brook, Catacunemaug Road bridge, residential homes, Brook Trail Bridge, railroad bridge, Leominster Road bridge, Shaker Road, Lowell Road.			
	10. DATE OF LAST EAP UPDATE	June 8, 2007			

ADDITIONAL COMMENTS: *Large granite slabs and stones armor the downstream channel. Some erosion behind stones observed.

**Wetlands in woods in the left downstream area of the dam.

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MISCELLANEOUS

AREA INSPECTED	CONDITION	OBSERVATIONS
MISC.	1. RESERVOIR DEPTH (AVG)	Not obtained.
	2. RESERVOIR SHORELINE	Residential development and wooded.
	3. RESERVOIR SLOPES	Mild.
	4. ACCESS ROADS	Good.
	5. SECURITY DEVICES	Locked gate along crest, gate house and access to primary spillway is locked.
	6. VANDALISM OR TRESPASS	☐ YES ☑ NO WHAT:
	7. AVAILABILITY OF PLANS	☑ YES ☐ NO DATE: October 13, 1995 ("FOR APPROVAL" drawings)
	8. AVAILABILITY OF DESIGN CALCS	☐ YES ☑ NO DATE:
	9. AVAILABILITY OF EAP/LAST UPDATE	☑ YES ☐ NO DATE: June 8, 2007
	10. AVAILABILITY OF O&M MANUAL	☐ YES ☑ NO DATE:
	11. CARETAKER/OWNER AVAILABLE	☑ YES ☐ NO DATE: 7/16/2009, 8/14/09
	12. CONFINED SPACE ENTRY REQUIRED	☐ YES ☑ NO PURPOSE:

ADDITIONAL COMMENTS:

NAME OF DAM: Lake Shirley Dam STATE ID #: 4-9-270-3

INSPECTION DATE: July 16, 2009 NID ID #: MA00455

PRIMARY SPILLWAY

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
SPILLWAY	SPILLWAY TYPE	Reinforced concrete weir and training walls.			
	WEIR TYPE	Ogee-shaped weir.			
	SPILLWAY CONDITION	Good.			
	TRAINING WALLS	Reinforced concrete training walls., several minor cracks observed.		x	
	SPILLWAY CONTROLS AND CONDITION	Uncontrolled, fixed crest weir.			
	UNUSUAL MOVEMENT	None observed.			
	APPROACH AREA	Clear.			
	DISCHARGE AREA	Clear.			
	DEBRIS	None observed.			
	WATER LEVEL AT TIME OF INSPECTION	3.5 in. over primary spillway.			

ADDITIONAL COMMENTS: (1) Multiple small cracks or spalls on the downstream slope of the weir causing flow disturbance.
(2) The reinforced concrete catwalk over the spillway is spalled on the surface.
(3) Dam Caretaker has seen 16 in. of flow over the primary spillway.

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OUTLET WORKS

AREA INSPECTED	CONDITION	OBSERVATIONS	NO ACTION	MONITOR	REPAIR
OUTLET WORKS	TYPE	Low-level outlet (LLO) and Mid-level outlet (MLO), 24 in. pipes to one 30 in. pipe.			
	INTAKE STRUCTURE	Not observable.			
	TRASHRACK	Bar rack, reportedly ineffective, gates still regularly clog with leaves.		x	x
	PRIMARY CLOSURE	Gate valves for LLO and MLO (Dubois & King, 1995)			
	SECONDARY CLOSURE	Not applicable			
	CONDUIT	24 in. diameter pipes from MLO and LLO to 30 in. pipe.			
	OUTLET STRUCTURE/HEADWALL	Extends from right downstream channel wall.			
	EROSION ALONG TOE OF DAM	None observed.			
	SEEPAGE/LEAKAGE	None observed.			
	DEBRIS/BLOCKAGE	Leaf and debris can block gate operation during fall and winter.			
	UNUSUAL MOVEMENT	None observed.			
	DOWNSTREAM AREA	Downstream channel of primary spillway.			
	MISCELLANEOUS	Caretaker indicates gate can be hard to operate. Takes 300 turns to fully open gates.			

ADDITIONAL COMMENTS: *Gatehouse is wood framed structure with reinforced concrete dry well structure, vinyl siding, asphalt shingles.

APPENDIX C
Previous Reports and References

PREVIOUS REPORTS AND REFERENCES

The following is a list of reports that were located during the file review, or were referenced in previous reports.

1) Inspection Evaluation Report, “Lake Shirley Dam Phase I,” prepared by Dubois & King, Inc., dated February 12, 2007.

2) Draft Emergency Action Plan, “Lake Shirley Dam,” prepared by Dubois & King, Inc., dated June 8, 2007.

3) Drawings titled, “Rehabilitation of Lake Shirley Dam,” by Dubois & King, Inc., dated October 13, 1995. (Stamped FOR APPROVAL)

APPENDIX D
Definitions

COMMON DAM SAFETY DEFINITIONS

For a comprehensive list of dam engineering terminology and definitions refer to 302 CMR10.00 Dam Safety, or other reference published by FERC, Dept. of the Interior Bureau of Reclamation, or FEMA. Please note should discrepancies between definitions exist, those definitions included within 302 CMR 10.00 govern for dams located within the Commonwealth of Massachusetts.

Orientation

Upstream – Shall mean the side of the dam that borders the impoundment.

Downstream – Shall mean the high side of the dam, the side opposite the upstream side.

Right – Shall mean the area to the right when looking in the downstream direction.

Left – Shall mean the area to the left when looking in the downstream direction.

Dam Components

Dam – Shall mean any artificial barrier, including appurtenant works, which impounds or diverts water.

Embankment – Shall mean the fill material, usually earth or rock, placed with sloping sides, such that it forms a permanent barrier that impounds water.

Crest – Shall mean the top of the dam, usually provides a road or path across the dam.

Abutment – Shall mean that part of a valley side against which a dam is constructed. An artificial abutment is sometimes constructed as a concrete gravity section, to take the thrust of an arch dam where there is no suitable natural abutment.

Appurtenant Works – Shall mean structures, either in dams or separate therefrom, including but not be limited to, spillways; reservoirs and their rims; low-level outlet works; and water conduits including tunnels, pipelines, or penstocks, either through the dams or their abutments.

Spillway – Shall mean a structure over or through which water flows are discharged. If the flow is controlled by gates or boards, it is a controlled spillway; if the fixed elevation of the spillway crest controls the level of the impoundment, it is an uncontrolled spillway.

Size Classification

(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety*)

Large – structure with a height greater than 40 feet or a storage capacity greater than 1,000 acre-feet.

Intermediate – structure with a height between 15 and 40 feet or a storage capacity of 50 to 1,000 acre-feet.

Small – structure with a height between 6 and 15 feet and a storage capacity of 15 to 50 acre-feet.

Non-Jurisdictional – structure less than 6 feet in height or having a storage capacity of less than 15 acre-feet.

Hazard Classification

(as listed in Commonwealth of Massachusetts, 302 CMR 10.00 *Dam Safety*)

High Hazard (Class I) – Shall mean dams located where failure will likely cause loss of life and serious damage to home(s), industrial or commercial facilities, important public utilities, main highway(s) or railroad(s).

Significant Hazard (Class II) – Shall mean dams located where failure may cause loss of life and damage to home(s), industrial or commercial facilities, secondary highway(s) or railroad(s), or cause the interruption of the use or service of relatively important facilities.

Low Hazard (Class III) – Dams located where failure may cause minimal property damage to others. Loss of life is not expected.

General

EAP – Emergency Action Plan – Shall mean a predetermined (and properly documented) plan of action to be taken to reduce the potential for property damage and/or loss of life in an area affected by an impending dam failure.

O&M Manual – Operations and Maintenance Manual; Document identifying routine maintenance and operational procedures under normal and storm conditions.

Normal Pool – Shall mean the elevation of the impoundment during normal operating conditions.

Acre-foot – Shall mean a unit of volumetric measure that would cover one acre to a depth of one foot. It is equal to 43,560 cubic feet. One million U.S. gallons = 3.068 acre feet.

Height of Dam (Structural Height) – Shall mean the vertical distance from the lowest portion of the natural ground, including any stream channel, along the downstream toe of the dam to the lowest point on the crest of the dam.

Hydraulic Height – means the height to which water rises behind a dam and the difference between the lowest point in the original streambed at the axis of the dam and the maximum controllable water surface.

Maximum Water Storage Elevation – means the maximum elevation of water surface which can be contained by the dam without overtopping the embankment section.

Spillway Design Flood (SDF) – Shall mean the flood used in the design of a dam and its appurtenant works particularly for sizing the spillway and outlet works, and for determining maximum temporary storage and height of dam requirements.

Maximum Storage Capacity – The volume of water contained in the impoundment at maximum water storage elevation.

Normal Storage Capacity – The volume of water contained in the impoundment at normal water storage elevation.

Condition Rating

Unsafe – Major structural*, operational, and maintenance deficiencies exist under normal operating conditions.

Poor – Significant structural*, operation and maintenance deficiencies are clearly recognized for normal loading conditions.

Fair – Significant operational and maintenance deficiencies, no structural deficiencies. Potential deficiencies exist under unusual loading conditions that may realistically occur. Can be used when uncertainties exist as to critical parameters.

Satisfactory – Minor operational and maintenance deficiencies. Infrequent hydrologic events would probably result in deficiencies.

Good – No existing or potential deficiencies recognized. Safe performance is expected under all loading including SDF.

* Structural deficiencies include but are not limited to the following:

- Excessive uncontrolled seepage (e.g., upwelling of water, evidence of fines movement, flowing water, erosion, etc.)
- Missing riprap with resulting erosion of slope
- Sinkholes, particularly behind retaining walls and above outlet pipes, possibly indicating loss of soil due to piping, rather than animal burrows
- Excessive vegetation and tree growth, particularly if it obscures features of the dam and the dam cannot be fully inspected
- Deterioration of concrete structures (e.g., exposed rebar, tilted walls, large cracks with or without seepage, excessive spalling, etc.)
- Inoperable outlets (gates and valves that have not been operated for many years or are broken)