CONDITION ASSESSMENT OF CANAL WALLS REPORT

North Canal
Lawrence, MA

40 Shattuck Road | Suite 110
Andover, Massachusetts 01810
866.702.6371

0228526.02
City of Lawrence, MA
May 2019

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APPENDICES

1. INTRODUCTION

Woodard & Curran Structural Engineer Jim Sturgis, P.E. conducted a visual condition assessment of the wall systems for the North Canal located in Lawrence, MA on May 1st & May 3rd, 2019. He was also accompanied on the first day by Woodard & Curran Structural Engineer Robert Njoroge, P.E. This visual assessment was conducted to evaluate the condition of the retaining walls that form the canal along the north and south borders.

The objective of this assessment was to make visual observations limited to only those surfaces visible as viewed from the top surface of the canal walls while canals were partially full of water. We identified signs of deterioration or instability such as out-of-plumbness, bulges, dislodged stones, missing stones, vegetation growth, mis-alignment along the face, mis-alignment along top of wall, open spaces or voids between stones, erosion, and differential settlement among other conditions. This assessment is a general overview of the condition of the canal wall system. A detailed close-up assessment in the canal, performed either by boat or in a drained accessible canal, would be required to provide a more concise and thorough evaluation of the canal system. This would include assessment of the underwater sections of the wall.

Access was very limited in some areas due to property being blocked off and the inability to safely assess wall conditions below bridge structures. All conditions were assessed from a distance on the opposite side of the canal, since we were not able to enter the canal. Photos are provided to accompany observations. This Memorandum will include the following sections:

- Memorandum (with photos provided for only the most high-risk conditions observed)
- Appendix A: North Canal Reference Plan (Google Map Showing all Stationing)
- Appendix B: North Canal Summary Table (with Observations & Recommendations by Station)

2. EXISTING CONSTRUCTION

The report provides a map and photos of observed conditions along the canal wall system and assigned a risk rating to the various conditions. The age, dimensional data, geometry, and design of the walls are unknown, as no existing record information was available during this task. As such, the characteristics of the wall structures were as observed on site. The total length of the North canal is approximately 5,400 feet based on a measurement taken from online maps. The canal flows west to east along Canal Street. The evaluation was performed by walking the length of the canal on both sides (where accessible), starting at the Broadway Street Bridge and ending at the canal discharge spillway.

Historic data suggests that the North Canal was completed in 1848 and consists of granite blocks laid on a bed of hydraulic cement. The wall system appears to be predominantly constructed of dry-laid stones of varying size and type. The appearance, stone type, method, quality, and workmanship of wall construction is inconsistent and variable along its length. Some sections were observed to have mortared joints, shotcrete facing, concrete facing, and conventional stone masonry. The function of the walls is to retain soil along each side of the canal. The height of the wall system varies and there are guardrails atop several walls that protect sidewalks and building frontage. The canal is bounded by a roadway, Canal Street, to the north and by an island with several large mill building structures to the south.

3. OBSERVATIONS

Observations were made along the entire length of both the north and south canal walls. A stationing system was developed to use for reference, starting with Station 0 + 00 at the Broadway Street Railroad Bridge to the west and ending with Station 54 + 05 at the canal discharge spillway to the east. Each section of canal wall was given a stationing range, given a condition description, then assigned a Risk Level from 1 (worst condition/highest risk level) to 5 (best condition/lowest risk level). Risk Levels 1 to 5 are further defined in Appendix B and are each designated by a unique color. An item number was assigned to each section of wall (N# for north wall and S# for south wall), where it appeared that the relative condition was observed to change. Note that this is difficult to differentiate (especially as viewed from a distance), but an attempt was made to do so in order to assign a relative Risk Level to each area and assist the owner with prioritization of future repairs.

A Google Map image was created for use as a reference plan (see Appendix A – North Canal Reference Plan), which included the following information:

- A colored Google Map image of the canal area for use as a background;
- Several named landmark stations were created along the canal to make it easier for someone to locate the stations in the field (labeled “A” through “Z”, then “AA” through “FF” and defined below the Google Map image);
- Colored Risk Levels were plotted with the five risk levels as defined in Appendix B; and
- Item numbers (N# and S#) were also plotted on this plan.

A summary document was created to summarize information pertaining to all item numbers in one place (see Appendix B – North Canal Summary Table). This summary table lists the following information:

- Item #, nearby landmark station points, start station, and end station;
- For each Item #: Type of wall; approximate height of wall above current canal water level, Observations, Recommendations, and Risk Level; and
- Definitions for Risk Levels 1 through 5, and a Legend with Abbreviations and Definitions.

4. RECOMMENDATIONS

In general, there are multiple and varying wall conditions along the length of the canal. The conditions observed are synonymous with signs of an aging wall system. In the absence of any as-built record information on the wall construction, it was difficult to ascertain whether the present conditions of the wall match the original intended geometry or what repairs have been done over time. We were only able to comment on the faces of the walls that are exposed to view. Extensive vegetation growth was observed along canal walls between stones, some of which were trees several inches in diameter. All vegetation growth can be destructive to the wall system and should be maintained and removed to prevent further damage. Refer to Appendix A and Appendix B for more detailed information about each area identified.

For all areas categorized as Risk Levels 3 through 5, it is recommended that condition and stability of areas should be monitored and re-inspected by a licensed structural engineer every 1 to 2 years to ensure that the observed conditions are not worsening. Some repairs may be required for these areas in the future.

Any wall sections that exhibit plumbness concerns, apparent instability, and/or deterioration have been categorized as Risk Levels 1 and 2. For these sections we recommend that the walls be rebuilt by an experienced contractor who specializes in building this type of rock wall system. It is difficult to assign a timetable to this without wall as-built record drawings, but it is recommended that walls be repaired within the next two to four years. However, given the nature of the wall construction, it should be understood that sections of wall could fail or collapse at any time. The following pages summarize the wall sections assigned to Risk Levels 1 and 2, presented in order of stationing first for the north wall then the south wall (with photos for each item number).

Wall Section: Item #N4; Station 1 + 90 to 3 + 80; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG (vegetation growth); top of wall uneven, potential differential settlement; appears unstable; out of plumb/top leaning into canal; large open joints and voids; missing stones; dislodged stones; overburden pushing top stones toward canal. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #N5; Station 3 + 80 to 5 + 30; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; top of wall uneven, potential differential settlement; appears unstable; out of plumb/top leaning significantly into canal; bowing; bulging; irregular and variable face; large open joints and voids; missing stones; dislodged stones; overburden pushing top stones towards canal. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #N6; Station 5 + 30 to 6 + 95; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; top of wall uneven, potential differential settlement; appears unstable; out of plumb/top leaning significantly into canal; bowing; bulging; irregular and variable face; large open joints and voids; missing stones; dislodged stones; overburden pushing top stones towards canal. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #N7; Station 6 + 95 to 8 + 05; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information.
Observations: VG; top of wall uneven, potential differential settlement; appears unstable; out of plumb/top leaning significantly into canal; bowing; bulging; irregular and variable face; large open joints and voids; missing stones; dislodged stones; overburden pushing top stones towards canal. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #N8; Station 8 + 05 to 9 + 95; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; top of wall uneven, potential differential settlement; appears unstable; out of plumb/top leaning significantly into canal; bowing; bulging; irregular and variable face; large open joints and voids; missing stones; dislodged stones; overburden pushing top stones towards canal. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #N17; Station 26 + 30 to 28 + 40; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: Heavy VG; out-of-plumb, leaning toward canal; appears unstable; major open joints and voids; dislodged stones. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #N18; Station 28 + 40 to 29 + 55; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; out-of-plumb leaning/bowing significantly into canal; unstable; many top stones pushing into canal; major open voids; large concrete public observation deck above wall with benches. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing (top portion is in the worst condition)

Wall Section: Item #N24; Station 41 + 50 to 42 + 70; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: Heavy VG; variable plumbness; questionable stability; poorly laid wall with variable stone sizes; many large open joints and voids; abandoned utility structure. See photos below.
Recommendations: Demolish existing abandoned utility structure; Rebuild this wall section with stone construction to match existing.

Wall Section: Item #S15; Station 10 + 10 to 10 + 25; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; plumb; questionable stability; large open voids near base of wall at old, deteriorated gate structure. See photos below.
Recommendations: Demolish existing abandoned gate structure; Rebuild this wall section with stone construction to match existing.

Wall Section: Item #S23; Station 18 + 90 to 22 + 10; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: Heavy VG; some areas out-of-plumb and leaning outward into canal; appears unstable; erosion along base and top of wall; many dislodged and missing stones. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #S25; Station 22 + 75 to 23 + 45; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information.
Observations: VG; 50 LF of wall to face of bridge appears unstable and is out-of-plumb with top leaning significantly into canal. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #S26; Station 23 + 45 to 26 + 30; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information.
Observations: Heavy VG; out-of-plumb and leaning into canal; appears unstable; wall is wavy along its length; major open joints and large voids; dislodged stones pushed outward in many locations, especially along top. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #S27; Station 26 + 30 to 27 + 80; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; out-of-plumb and top half of wall is pushed out and leaning into canal; appears unstable; past shotcrete repair is failing; missing stones; dislodged stones. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

Wall Section: Item #S28; Station 27 + 80 to 28 + 40; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: Section of concrete wall is in very poor condition – especially the lower half – with severe deterioration and undermining at its base; past shotcrete repair is failing; pronounced lean into canal; appears unstable. See photos below.
Recommendations: Demolish concrete wall and rebuild this wall section with stone construction to match existing.

Wall Section: Item #S31; Station 29 + 70 to 31 + 25; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: Heavy VG; out-of-plumb leaning into canal; large open joints and voids; failing mortar in joints; missing stones; old gate structure; appears unstable. See photos below.
Recommendations: Demolish old gate structure and rebuild this wall section with stone construction to match existing.

Wall Section: Item #S32; Station 31 + 25 to 31 + 65; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: This entry is for 25 LF of wall starting at face of bridge; VG; out of-plumb with major leaning into canal; **appears unstable with vehicles currently parked close to face of wall;** earth and VG along base of wall. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing. **Prohibit parking of vehicles along this wall to minimize future surcharge loading.**

Wall Section: Item #S34; Station 33 + 25 to 34 + 05; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: DLSW appears to have been repaired using formed concrete on exterior face; this concrete facing is cracked, deteriorated, and severely undermined along its base; questionable plumbness; questionable stability. See photos below.
Recommendations: Demolish existing cracked, deteriorated concrete and rebuild this wall section with stone construction to match existing.

Wall Section: Item #S36; Station 35 + 10 to 35 + 70; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; out-of-plumb and leaning into canal; appears unstable with areas that have partial and total collapse; large open joints and voids; missing stones. See photos below.
Recommendations: Rebuild this wall section with stone construction to match existing.

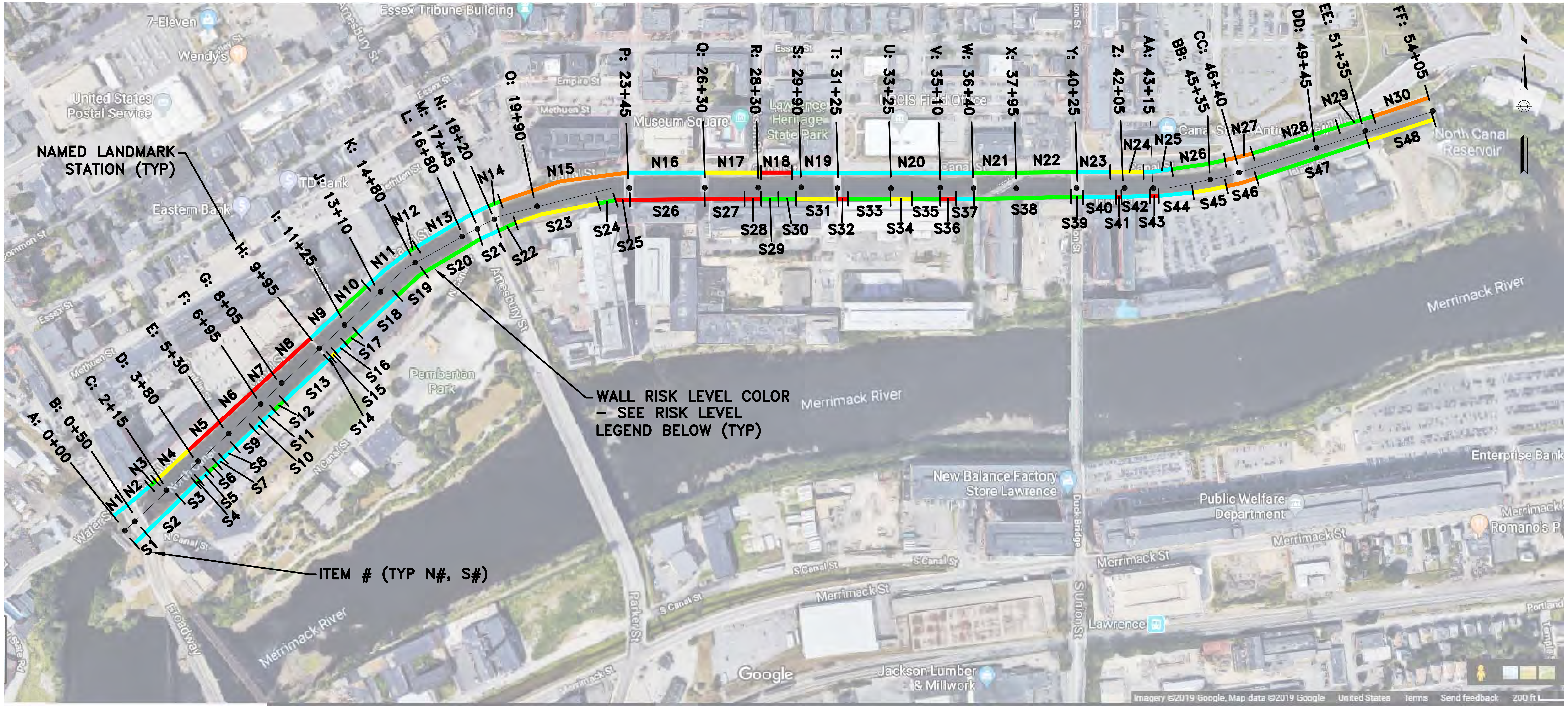
Wall Section: Item #S41; Station 41 + 80 to 41 + 95; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: DLSW combined with rotten wood framework; abandoned utility structure; heavy VG; appears unstable; partial collapse for top portion; major open joints and voids; missing stones; erosion. See photos below.
Recommendations: Demo wooden utility structure and rebuild this wall section with stone construction to match existing.

Wall Section: Item #S43; Station 43 + 00 to 43 + 20; Risk Level 1 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: DLSW combined with rotten wood framework; abandoned utility structure; heavy VG; appears unstable; partial collapse for top portion; major open joints and voids; missing stones; erosion. See photos below.
Recommendations: Demo wooden utility structure and rebuild this wall section with stone construction to match existing.

Wall Section: Item #S45; Station 44 + 50 to 45 + 90; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; out-of-plume and leaning into canal; appears unstable; major open joints and gaps; dislodged stones; abandoned concrete post foundation atop unstable DLSW stones; erosion along top supporting sidewalk and street. See photos below.
Recommendations: Demo concrete post-foundation structure and rebuild this wall section with stone construction to match existing.

Wall Section: Item #S48; Station 51 + 35 to 54 + 05; Risk Level 2 Refer to Appendix A – North Canal Reference Plan and Appendix B – North Canal Summary Table for further information
Observations: VG; out-of-plumb and top stones are leaning into canal; appears unstable; poorly-built wall with variable and irregular surface; large open joints and voids; dislodged stones; last portion of wall was previously replaced with riprap stone, likely due to a wall collapse; wall ends near canal outlet which is located at Station 54 + 05. See photos below.
Recommendations: Demo concrete post foundation structure and rebuild this wall section with stone construction to match existing.

APPENDIX A: NORTH CANAL REFERENCE PLAN



APPENDIX A: NORTH CANAL REFERENCE PLAN

A : RAILROAD BRIDGE ADJACENT WEST OF BROADWAY
B : BROADWAY BRIDGE
C : DRIVEWAY BETWEEN TWO BRICK BUILDINGS
D : CENTER OF LORENZO BUILDING (AT DOOR)
E : FRANKLIN STREET
F : 90 DEGREE BEND IN CHAINLINK FENCE
G : EDGE OF BRICK BUILDING
H : PEDESTRIAN BRIDGE
I : HAMPSHIRE STREET
J : EDGE OF BRICK BUILDING
K : EDGE OF BRICK BUILDING
L : PEDESTRIAN BRIDGE WITH NO RAILINGS
M : AMESBURY STREET BRIDGE
N : BRIDGE DIRECTLY EAST OF AMESBURY STREET
O : LAWRENCE STREET
P : BRIDGE ACROSS FROM APPLETON STREET
Q : BRIDGE ACROSS FROM WHITE MUSEUM BUILDING
R : JACKSON STREET
S : DRIVEWAY BETWEEN TWO BRICK BUILDINGS
T : BRIDGE ACROSS FROM MILL STREET
U : DOORWAY OF BRICK BUILDING
V : EDGE OF BRICK BUILDING
W : PEDESTRIAN BRIDGE
X : END OF TRUSS BRIDGE AT BOLLARDS
Y : UNION STREET BRIDGE
Z : EDGE OF BRICK BUILDING
AA : DOORWAY OF BRICK BUILDING
BB : EDGE OF BRICK BUILDING
CC : BRIDGE ACROSS FROM PARKING LOT DRIVEWAY
DD : PARKING LOT DRIVEWAY
EE : BEAMS CROSSING THE CANAL
FF : CANAL SPILLWAY

RISK LEVEL LEGEND

- RISK LEVEL 1 (red)
- RISK LEVEL 2 (yellow)
- RISK LEVEL 3 (green)
- RISK LEVEL 4 (cyan)
- RISK LEVEL 5 (orange)

BAR SCALE 1" = 200' (200' 0 200' 400')
CHECK GRAPHIC SCALE BEFORE USING

NOTES:

1. ALL STATIONING IS APPROXIMATE AND SHALL BE USED FOR REFERENCE ONLY.
2. REFER TO APPENDIX B – NORTH CANAL SUMMARY TABLE FOR STATIONING RISK LEVEL INFORMATION AND FOR OBSERVATIONS.
3. REFER TO MEMO OBSERVATIONS SECTION FOR PHOTOS FOR RISK LEVELS 1 & 2.

WOODARD & CURRAN
40 Shattuck Road, Suite 110
Andover, Massachusetts 01810
866.702.6371 | www.woodardcurran.com
COMMITMENT & INTEGRITY DRIVE RESULTS

REV	DESCRIPTION	DATE

DESIGNED BY: JPS / ZRB CHECKED BY: JPS
DRAWN BY: ZRB

APPENDIX A: NORTH CANAL REFERENCE PLAN

TOWN OF LAWRENCE, MA
NORTH CANAL REPAIR PLAN

JOB NO.: 0228526.02
DATE: 05/07/19
SCALE: AS NOTED
SHEET: 1 OF 1

APPENDIX: A

APPENDIX B: NORTH CANAL SUMMARY TABLE

Appendix B - North Canal Summary Table (see Legend & Abbreviations below for further descriptions)

#	NEAR POINTS	START LOC'N	END LOC'N	TYPE	H	OBSERVATIONS	RECOMMENDATIONS	RL 1-5
N1	A - B	0 + 00	0 + 50	DLSW	9'	Canal entrance; VG; plumb; appears stable; minor open joints; very limited access/visibility below railroad crossing	RV; further inspect walls below railroad deck area	4*
N2	B - C	0 + 50	1 + 60	DLSW	9'	VG; plumb; appears stable; minor open joints; very limited access/visibility below Broadway bridge	RV; further inspect walls below bridge area	4*
N3	B - C	1 + 60	1 + 90	DLSW	5'	VG; questionable plumbness; appears stable; sag in top of wall, potential local settlement; minor open joints; very limited access/visibility since south side locked	RV; monitor	3**
N4	B - D	1 + 90	3 + 80	DLSW	5'	VG; top of wall uneven, potential differential settlement; appears unstable; out of plumb/top leaning into canal; large open joints & voids; missing stones; dislodged stones; overburden pushing top stones toward canal	Rebuild wall	2**
N5	D - E	3 + 80	5 + 30	DLSW	5'	VG; top of wall uneven, potential differential settlement; appears unstable; out of plumb/top leaning significantly into canal; bowing; bulging; irregular and variable face; large open joints & voids; missing stones; dislodged stones; overburden pushing top stones towards canal	Rebuild wall	1**
N6	E - F	5 + 30	6 + 95	DLSW	5'	Observations similar to Item #N5	Rebuild wall	1**
N7	F - G	6 + 95	8 + 05	DLSW	5'	Observations similar to Item #N5	Rebuild wall	1**
N8	G - H	8 + 05	9 + 95	DLSW	5'	Observations similar to Item #N5	Rebuild wall	1**
N9	H - I	9 + 95	11 + 25	DLSW	7'	VG; plumb; appears stable; moderate open joints & voids	RV; monitor	4
N10	I - J	11 + 25	12 + 80	DLSW	5'	VG; plumb; appears stable; moderate open joints; several top stones are dislodged	RV; monitor	3
N11	I - K	12 + 80	14 + 80	DLSW	5'	VG; plumb; appears stable; moderate open joints;	RV; monitor	4
N12	K - L	14 + 80	15 + 15	DLSW	7'	Heavy VG; small trees growing between stones; questionable plumbness; appears stable; moderate open joints; dislodged stones; top of wall is uneven with stones pushing into canal	RV; monitor	3
N13	K - N	15 + 15	18 + 20	DLSW, CONC	6'	VG; plumb; appears stable; minor open joints; top of wall is concrete near Reference Points L & M	RV; monitor	4
N14	N - O	18 + 20	18 + 70	DLSW, CONC	7'	VG; plumb; appears stable; some large voids in stone below concrete (20 LF)	RV; large voids below concrete cap wall; monitor	3
N15	N - P	18 + 70	23 + 45	DLSW, MSW	7'	VG; plumb; appears stable; minor open joints; MSW on top portion; DLSW on bottom portion	RV; monitor	5
N16	P - Q	23 + 45	26 + 30	DLSW	6'	VG; plumb; appears stable; minor open joints	RV; monitor	4
N17	Q - R	26 + 30	28 + 40	DLSW	4'	Heavy VG; out-of-plumb, leaning toward canal; appears unstable; major open joints & voids; dislodged stones	Rebuild wall	2
N18	R - S	28 + 40	29 + 55	DLSW	4'	VG; out-of-plumb leaning/bowing significantly into canal; appears unstable; many top stones pushing into canal; major open voids; large concrete public observation deck above wall with benches;	Rebuild wall, at least the top portion.	1
N19	R - T	29 + 55	31 + 25	DLSW	5'	Heavy VG; appears stable; plumb; moderate open joints	RV; monitor	4
N20	T - W	31 + 25	36 + 40	DLSW	7'	VG; appears stable; plumb; moderate open joints; some small stones dislodged with voids in places; earth & VG along base	RV; monitor; reset any loose, dislodged stones	4
N21	W - X	36 + 40	37 + 95	DLSW, MSW, CONC	7'	VG; appears stable; plumb; moderate open joints & voids; deteriorated concrete near diagonal walking bridge; top half of wall has mortared joints	RV; monitor; repair 20 LF of deteriorated concrete	3
N22	X - Y	37 + 95	40 + 25	DLSW, MSW, CONC	7'/11'	VG; appears stable; fairly plumb; moderate open joints; many dislodged stones; lower DLSW with upper MSW or CONC	RV; monitor; reset any loose, dislodged stones	3
N23	Y - Z	40 + 25	41 + 50	DLSW, MSW, CONC	7'/11'	VG; appears stable; plumb; minor open joints; lower DLSW with upper MSW or CONC	RV; monitor	4
N24	Y - AA	41 + 50	42 + 70	DLSW	5'	Heavy VG; variable plumbness; questionable stability; poorly laid wall with variable stone sizes; many large open joints & voids; abandoned utility structure	Rebuild wall	2
N25	Z - BB	42 + 70	43 + 75	DLSW	5'	VG; plumb; appears stable; moderate open joints	RV; monitor	4
N26	AA - CC	43 + 75	46 + 05	DLSW	4'-6'	VG; out-of-plumb; appears unstable; poorly laid wall with variable stone sizes; many large open joints & voids; abandoned utility structure	RV; monitor	3
N27	BB - DD	46 + 05	47 + 05	MSW	6'-8'	Mortared stone masonry wall below and in vicinity of vehicle & pedestrian bridges in good condition	No work required	5
N28	CC - EE	47 + 05	51 + 00	DLSW	5'	VG; fairly plumb; appears stable; poorly laid wall with variable/irregular stone sizes and profile; many large open joints & voids; dislodged stones	RV; monitor	3
N29	DD - FF	51 + 00	51 + 85	DLSW, CONC	5'	Abandoned intake structure has assortment of DLSW and CONC walls, with corroded steel framework	Demo steel framework & re-inspect wall in more detail	3
N30	EE - FF	51 + 85	54 + 05	EARTH	8'	Sloped, vegetated earthen embankment which ends near canal outlet located at Station 54 + 05	No work required	5
S1	A - B	0 + 00	0 + 50	DLSW, CONC	12'	Could not inspect – concealed by railroad bridge	Re-inspect from below with safety precautions in place	4
S2	B - D	0 + 50	2 + 30	DLSW	12'	VG; plumb; appears stable; minor open joints; old steel bridge beams bear on wall	RV; monitor	4**
S3	C - D	2 + 30	3 + 55	DLSW, CONC	12'	VG; plumb; appears stable; minor open joints; upper sections are poured concrete	RV; monitor	4**
S4	C - D	3 + 55	3 + 65	DLSW	12'	VG; questionable plumbness; appears stable; localized vertical strip with missing stones, large voids, and major erosion	RV; rebuild localized area (5 LF wide); monitor	3**
S5	C - E	3 + 65	3 + 90	DLSW	12'	VG; appears stable; plumb; minor open joints	RV; monitor	4**
S6	D - E	3 + 90	4 + 35	BRICK	12'	Brick drainage gate structure with 4 pipes and wooden gates below water; brick fair condition; wood poor condition; plumb; appears stable	RV; monitor	3**
S7	D - E	4 + 35	4 + 55	DLSW	12'	VG; appears stable; plumb; minor open joints	RV; monitor	4**
S8	D - E	4 + 55	4 + 95	DLSW	11'	VG; appears stable; plumb; moderate open joints & some large voids	RV; monitor	4**
S9	D - F	4 + 95	6 + 15	DLSW	11'	VG; appears stable; plumb; minor open joints	RV; monitor	4**
S10	E - F	6 + 15	6 + 55	DLSW	11'	VG; appears stable; plumb; moderate open joints & some large voids	RV; monitor	4**
S11	E - F	6 + 55	7 + 25	DLSW	11'	VG; appears stable; plumb; minor open joints	RV; monitor	4**

Appendix B - North Canal Summary Table (see Legend & Abbreviations below for further descriptions)

#	NEAR POINTS	START LOC'N	END LOC'N	TYPE	H	OBSERVATIONS	RECOMMENDATIONS	RL 1-5
S12	F - G	7 + 25	7 + 75	BRICK	10'	Brick drainage gate structure with 4 pipes and wooden gates below water; brick fair to poor condition; wood very poor condition; plumb; appears stable	RV; monitor; repair crumbling brick	3**
S13	F - H	7 + 75	9 + 95	DLSW	8'	VG; plumb; appears stable; moderate open joints & some large voids;	RV; monitor	4**
S14	H - I	9 + 95	10 + 10	DLSW, MSW	9'	VG; plumb; appears stable; moderate open joints	RV; monitor	4
S15	H - I	10 + 10	10 + 25	DLSW	8'	VG; plumb; questionable stability; large open voids near base of wall at old, deteriorated gate structure;	Rebuild approx. 15 LF of wall	2
S16	H - I	10 + 25	10 + 75	DLSW	8'	VG; plumb; appears stable; moderate open joints & some large voids	RV; monitor	4
S17	H - I	10 + 75	11 + 35	DLSW	6'	VG; out-of-plumb; questionable stability; top of wall has outward bowing into canal (former railroad rails adjacent to wall, potential past rail surcharge); moderate open joints & some large voids	RV; monitor	3
S18	I - K	11 + 35	13 + 60	DLSW	6'	VG; plumb; appears stable; moderate open joints	RV; monitor	4
S19	J - L	13 + 60	15 + 00	DLSW, SHCT	6'	VG; plumb; appears stable; evidence of various past repairs to wall; face of wall was coated with shotcrete that is now flaking off; lower portion is faced with concrete that has cracks/deterioration that is beginning to fail;	RV; monitor	3
S20	K - M	15 + 00	17 + 45	DLSW	6'	Heavy VG; fairly plumb; questionable stability; evidence of past repair with granite blocks and crushed stone where wall presumably collapsed; missing & dislodged stones; major open joints & large open voids; some areas crumbling	RV; monitor	3
S21	M - N	17 + 45	18 + 20	DLSW, CONC	6'	Bridge area: could not gain access or visibility to inspect.	RV; monitor; further inspect walls below bridge area	4
S22	N - O	18 + 20	18 + 90	DLSW, MSW	6'	VG; plumb; appears stable; moderate open joints; previously-mortared joints are failing	RV; monitor	3
S23	N - P	18 + 90	22 + 10	DLSW	6'	Heavy VG; some areas out-of-plumb and leaning outward into canal; appears unstable; erosion along base & top of wall; many dislodged & missing stones;	Rebuild wall	2
S24	O - P	22 + 10	22 + 75	CONC, MTL	7'	Abandoned metal & concrete intake structure; metal is corroded and conceals concrete wall; could not access for inspection	Demo steel framing items and conduct wall inspection	3
S25	O - P	22 + 75	23 + 45	DLSW	7'	VG; 50 LF of wall to face of bridge appears unstable & out-of-plumb with top leaning significantly into canal	Rebuild wall	1
S26	P - Q	23 + 45	26 + 30	DLSW	6'	Heavy VG; out-of-plumb and leaning into canal; appears unstable; wall is wavy along its length; major open joints & large voids; dislodged stones pushed outward in many locations, especially along top	Rebuild wall	1
S27	Q - R	26 + 30	27 + 80	DLSW, SHCT	7'	VG; out-of-plumb and top half of wall is pushed out and leaning into canal; appears unstable; past shotcrete repair is failing; missing stones; dislodged stones	Rebuild wall	1
S28	Q - S	27 + 80	28 + 40	CONC	8'	Section of concrete wall is in very poor condition – especially the lower half – with severe deterioration and undermining at its base; past shotcrete repair is failing; pronounced lean into canal; appears unstable	Rebuild wall	1
S29	R - S	28 + 40	29 + 50	DLSW, SHCT	7'	DLSW concealed by past shotcrete repair that is flaking off; appears stable; plumb; one large void in wall	RV; monitor; infill one large hole	3
S30	R -S	29 + 50	29 + 70	DLGWR	7'	Dry laid granite block wall repair with combination of granite blocks and crushed stone; assumed that this section of DLSW previously collapsed; alignment is poor; variable plumbness and appears stable	RV; monitor	3
S31	S - T	29 + 70	31 + 25	DLSW, MSW	7'	Heavy VG; out-of-plumb leaning into canal; large open joints & voids; failing mortar in joints; missing stones; old gate structure	Rebuild wall; demo gate structure	2
S32	T - U	31 + 25	31 + 65	DLSW	8'	This entry is for 25 LF of wall starting at face of bridge; VG; out of-plumb with major leaning into canal; **appears unstable with vehicles currently parked close to face of wall;** earth & VG along base of wall	Rebuild wall**; consider prohibiting parking next to this wall**	1
S33	T - U	31 +65	33 + 25	DLSW, MSW	7'	Heavy VG; DLSW with failing mortar joints for upper areas; out-of-plumb with top stones pushed into canal; questionable stability; earth & VG along base of wall	RV; monitor; reset any dislodged top stones	3
S34	U - V	33 + 25	34 + 05	CONC-FCD DLSW	7'	DLSW appears to have been repaired using formed concrete on exterior face; this concrete facing is cracked, deteriorated, and severely undermined along its base; fairly plumb; questionable stability	Rebuild wall (impractical to repair)	2
S35	U - V	34 + 05	35 + 10	CONC	7'	Concrete wall along abandoned intake structure; wall appears plumb & stable but is concealed by intake structure framework	Demo intake structure & conduct closer inspection of wall	3
S36	V - W	35 + 10	35 + 70	DLSW	7'	VG; out-of-plumb and leaning into canal; appears unstable with areas that have partial & total collapse; large open joints & voids; missing stones	Rebuild wall	1
S37	U - W	35 + 70	36 + 40	DLSW	7'	VG; plumb; appears stable; minor open joints	RV; monitor	4
S38	W - Y	36 + 40	40 + 00	DLSW, MSW, CONC	7'/11'	VG; plumb; appears stable; major open joints & large voids; DLSW lower wall and MSW/CONC upper wall	RV; monitor	3
S39	Y	40 + 00	40 + 50	CONC BRIDGE	7'	Union Street Bridge (1939 construction) has major concrete deterioration and exposed rebar on each face, railings, and abutments	Conduct detailed structural condition assessment and repair all deteriorated concrete	3
S40	Y - Z	40 + 50	41 + 80	DLSW, MSW, CONC	7'/11'	VG; plumb; appears stable; moderate open joints; some dislodged stones; DLSW lower wall and MSW/CONC upper wall	RV; monitor	4
S41	Y - Z	41 + 80	41 + 95	DLSW, WOOD	7'	DLSW combined with rotten wood framework; abandoned utility structure; heavy VG; appears unstable; partial collapse for top portion; major open joints & voids; missing stones; erosion	Rebuild wall; demo wooden utility structure	1
S42	Y - AA	41 + 95	43 + 00	DLSW	7'	VG; plumb; appears stable; moderate open joints & gaps; DLSW lower wall and MSW/CONC upper wall	RV; monitor	4
S43	AA	43 + 00	43 + 20	DLSW, WOOD	7'	DLSW combined with rotten wood framework; abandoned utility structure; heavy VG; appears unstable; partial collapse for top portion; major open joints & voids; missing stones; erosion	Rebuild wall; demo wooden utility structure	1
S44	AA - BB	43 + 20	44 + 50	DLSW, MSW	8'	VG; plumb; appears stable; major open joints & gaps	RV; monitor	4

Appendix B - North Canal Summary Table (see Legend & Abbreviations below for further descriptions)

#	NEAR POINTS	START LOC'N	END LOC'N	TYPE	H	OBSERVATIONS	RECOMMENDATIONS	RL 1-5
S45	AA - CC	44 + 50	45 + 90	DLSW	5'	VG; out-of-plume and leaning into canal; appears unstable; major open joints & gaps; dislodged stones; abandoned concrete post foundation atop DLSW stones which appear to be unstable; erosion along top supporting sidewalk and street	Rebuild wall	2
S46	BB - DD	45 + 90	47 + 00	MSW	6-8'	Modern stone masonry wall below and in vicinity of bridge at Station Point CC is in good condition	No work required	5
S47	CC - EE	47 + 00	51 + 35	DLSW	5'	VG; appears plumb & stable; poorly-built wall with variable & irregular surface; large open joints & voids; dislodged stones	RV; monitor	3
S48	EE - FF	51 + 35	54 + 05	DLSW	5'	VG; out-of-plumb and top stones are leaning into canal; appears unstable; poorly-built wall with variable & irregular surface; large open joints & voids; dislodged stones; last portion of wall was previously replaced with riprap stone, likely due to a wall collapse; wall ends near canal outlet which is located at Station 54 + 05	Rebuild wall	2

***** The access and visibility was very limited for the rock walls below Point A Station 0 + 00 (Railroad Bridge) and below Point B Station 0 + 50 (Broadway Street Bridge); these areas were fully concealed by the bridge construction and should be further inspected from below at a future date with the proper safety protocol in place.

****** The stretch of canal between Station Points B through H had very limited access and visibility. The entire south side of the canal that borders the Cardinal Shoe property was blocked off with security gates near Points B and H. This greatly inhibited our ability to view the top of the south wall and get opposite canal views of the north wall along this stretch. Though a reasonable opinion of condition was achieved looking with binoculars from Points B and H, visibility would be greatly improved if access past the security fences could be arranged.

LEGEND & ABBREVIATIONS:

- Table Heading Title Abbreviations: # = Reference # (N# or S#); NEAR POINT = Station Letter Locations on Reference Plan for quick reference; START LOC'N = station point at start of area; END LOC'N = station point at end of area; TYPE = wall construction type; H = rough approximation of wall height above current canal water level at time of inspection (actual canal depth was variable and not determined); RL 1-5 = Risk Level # as defined below:
  - *Risk Level 1: Very poor condition with several problem areas – high risk of failure*
  - *Risk Level 2: Poor condition with several problem areas – moderate to high risk of failure*
  - *Risk Level 3: Poor to fair condition with some problem areas – moderate risk of failure*
  - *Risk Level 4: Fair condition with some problem areas – low to moderate risk of failure*
  - *Risk Level 5: Fair to good condition with minimal problem areas – low risk of failure*
- Additional Abbreviations: N# = Wall reference on North side of wall; S# = Item reference # on South side of wall; VG = vegetation growth; RV = remove/treat vegetation growth; DLSW = dry-laid stone wall; MSW = mortared stone wall; CONC = concrete wall; CONC FCD = formed concrete patch wall installed against dry-laid stone wall; BRICK = brick wall; WOOD = wood wall components; EARTH = earthen embankment; MTL = metal wall components; SHCT = shotcrete (sprayed concrete) facing over stone; DLGWR = dry laid granite block repair to wall;
- Clarifications of terms used: "plumb" = wall is generally plumb as viewed from a distance; "out-of-plumb" = wall is not plumb and appears to be leaning toward the canal as viewed from a distance; "stable or unstable" = general impression that the wall appears to be stable/unstable as viewed from a distance, but this shall not be interpreted as a statement that the wall is not at risk for failure.
- Definitions:
  - Monitor = monitor condition and stability of this wall section over time; future repairs will likely be necessary to maintain the integrity of the wall system.
  - Rebuild wall = excavating behind wall (shoring adjacent construction as needed to protect existing structures or roadways), disassembling wall, then rebuilding it with existing stones and/or additional stones to match existing appearance. This work should be performed by a skilled rock wall contractor with experience restoring historic rock walls similar to that which exists in the North Canal.
- Photos: Refer to Memorandum Observations section for photos of each Item # listed in Risk Levels 1 & 2. Photos are not provided for item #'s listed in Risk Levels 3, 4, & 5.

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