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ENERGY WATER INFORMATION GOVERNMENT

Lawrence, Kansas
Bowersock Dam Inspection 2006

B&V Project 146136
B&V File B-1.1
February 14, 2007

Ms. Mary Baker
Project Engineer
City of Lawrence
P. O. Box 708
Lawrence, Kansas 66044-0708

Dear Ms. Baker:

On October 30, 2006 an inspection of the Bowersock Dam in Lawrence, Kansas was performed to assess the condition of the dam. This report summarizes the visual observations made of the dam's condition and provides a phased recommendation for corrective actions for the City of Lawrence's consideration.

Introduction

In 2000, Black & Veatch conducted an inspection of the Bowersock Dam and made recommendations for repair. The history of dam repairs and recommended remedial action are summarized in Black & Veatch's letter report dated September 18, 2000. A copy of that inspection report is also available upon request. The majority of the identified deficiencies found in 2000 were repaired in the fall/winter of 2001/2002. The repairs mainly focused on driving sheet piling, constructing an extended apron cap to protect the piling, filling eroded/failed sections of the dam with concrete, and placing riprap on the downstream of the piling to fill the riverbed and provide downstream support/protection of the piling. In addition, shotcrete was applied to the severely eroded face of the dam in the northern and southern extreme portions of the dam.

On March 2, 2004, the City of Lawrence received a letter from Mr. Stephen Hill, President of The Bowersock Mills & Power Company dated February 27, 2004 regarding the continued deterioration of the Bowersock Dam on the Kansas River. A copy of Mr. Hill's transmittal letter, along with a report provided by Mr. David Redio, Bowersock Plant Manager, is attached to this letter report for informational purposes. In summary, Mr. Redio's memorandum identified cracked and eroded concrete areas exposing timbers in the crib portion of the dam. The area in question is approximately the northern 350 to 400 feet of the stair-stepped dam face just south of the spillway area. An inspection of the dam was performed on March 25, followed by a video inspection on March 26, 2004. A draft letter report was presented to the City on April 29, 2004 summarizing the observations and providing recommendations of proposed repairs.

On August 1, 2005, Mr. Hill sent another letter to the City presenting photos of the deteriorated condition of the dam and indicated that an opportunity to inspect the dam would be available due to

low river flows. On November 4, 2005, staff from Bowersock Mills, the City, and Black & Veatch inspected the dam and observed two whirlpools upstream of the dam. On November 22, 2005, Central States Underwater Contracting conducted an underwater inspection of the dam and also installed approximately 75, 80-pound bags of grout on the upstream face of the dam in the areas of the two whirlpools, resulting in a decrease of flow through the dam.

Existing Dam Condition

On the morning of October 30, 2006, Mark Bushouse and Larry Taber of Black & Veatch conducted a visual and video investigation of the Bowersock Dam with City Staff. On that day, staff from the Bowersock Mills and Power Company was in the initial stages of performing hinge and seal repairs to the wooden flashboards. The pneumatic flashboards on the very south of the dam were down to allow water to pass over the dam and limit the pool effect behind the dam. None of the gates on the northern spillway were open. There was still a slight flow of water over the top of the lowered flashboards at various points that obscured some of the dam facing from observation due to the volume of water flowing across the dam surface. Furthermore, a significant amount of water flowing through the middle portion of the dam also made detailed observation at that location difficult. In specific locations where the dam was relatively dry, the approximate location from the centerline of the storm drain at the north edge of the concrete dam (Station 0+00) is referenced by stationing out 25 to 50 foot intervals on the dam, which were marked with orange fluorescent spray paint. The locations are approximate. On November 2, Central States Underwater Contracting inspected the underwater portions of the upstream and downstream faces of the dam. In addition, they assisted City and Bowersock Staff in installing bags of grout in two locations on the upstream side of the dam in an attempt to stop the whirlpool formations and reduce the amount of flow through the dam.

The following summarizes the conditions observed on October 30th and November 2nd:

- Between Station 0+00 and 1+25, there are areas of spalled, cracked, and deteriorated concrete near the storm drain piping and along the northern spillway flume. Refer to pictures 1 through 4, and 6 through 18.

- The apron repairs completed in 2002 appear to be in excellent condition. The bond between the new and existing concrete appears to be sound, as little to no separation of the surface was identified. The sheet piling installed also appears to be protected by the apron caps and the riprap installed in the river appears have remained in place. See photographs 5, 7, 51, 75, 84, 144, and 146.

- Bowersock staff has installed a jetty of riprap parallel to and downstream from the dam near Station 2+00 to maintain a minimum pool elevation for the turbines to reduce cavitation

potential. Refer to photographs 5, 7, 120, 121, and the video at time stamps at 9:40, 9:43, and 9:46 a.m.

- The northern portion of the applied shotcrete in 2002 is showing some erosion from approximate Station 1+25 to 2+25 as there was some exposed wire mesh. Some of the eroded shotcrete is obscured by algae growth, but these areas are comparable to those taken in 2004, and noted as Photographs 3 through 5 in the April 2004 letter report. Refer to photographs 17 through 29.

- Between Station 1+25 and 3+25, there is exposed jointing in the steps of the dam. Refer to photographs 19 through 33, and 36 through 43.

- Between Stations 1+60 and 1+80, there is some minor flow through the dam at the joints between the steps of the dam and at the joint between the bottom step and the apron. Refer to photographs No. 21, 22, and 23. In addition, near Station 1+80, there is a depression about 2 feet deep at the bottom step and the apron. See video at timestamp 9:44 a.m..

- Between Stations 2+00 and 2+50, there was evidence of flow through the apron represented by bubbling action on the water surface and rings of waves. In addition, there is a crack that runs from the lower step of the dam to the face of the apron. Refer to photographs No. 27 and 28, and video beginning at timestamp 9:46 a.m.

- Between Stations 2+00 and 2+50, there is a significant triangular piece of concrete approximately 25' by 8' that is separated from the lowest step of the dam. Refer to photographs 26 through 28 and 106 through 108.

- Between Stations 2+00 and 2+50, there is significant erosion of the top of the steps of the concrete dam exposing rebar. Refer to photographs 24 through 27.

- Between Stations 2+50 and 3+50, the concrete has eroded to expose the timbers. Refer to photographs 30, 31, 33, 35 through 49, 104 and 105.

- Between Stations 2+75 and 3+50, all three steps in the dam are in poor condition. Refer to photographs No 37 through 49, 52, and 102 through 105.

- Between Stations 3+25 and 4+75, all flow shown on the photographs is through the dam. This portion of the dam represented the largest flow through the dam section. Refer to photographs 43 through 50, 52 through 54, 56 through 59, 61 through 63, 96, 97, 100, and 102. Refer to the video at timestamp 9:51 a.m. Refer to photographs 134 through 146 for post grout bag installation results, showing the decreased flow.

- A whirlpool was observed near Station 3+75. This area was filled with bags of grout on November 2, 2006 by Central States Underwater. Refer to photograph 101 and the video at timestamp 10:22 a.m.

- Between Stations 3+90 and 4+50, there are exposed reinforcing bars and timbers on the second step down. Refer to photographs 55, 98 and 99.

- Near Station 4+40, there is a significant void in the second step, and deterioration of the lower step. See photographs 59 and 60.

- Between Stations 4+50 and 5+50, the steps have eroded into irregular shapes. See photographs 61 through 71 and 95 through 97.

- Near Station 5+35, two I-beam pilings have been exposed at the base of the second step. Refer to photographs 67 and 68.

- Near Station 5+40, old sheet piling is exposed above the top of the apron, and the concrete is eroded with numerous joints. Refer to photographs 70 and 90.

- The southern portion of the applied shotcrete in 2002 appears to have some rough exposed edges on the bottom of the dam face that reflects some cutting and loss of shotcrete from Station 5+60 to the pneumatic flashboard area near Station 7+25. Refer to photographs 72 through 80 and 82 through90.

- Near Station 5+75, the upstream edge of the new apron has experienced erosion and some slight delamination from the existing apron. Refer to photographs 76 and 90.

- Near Station 5+80, the apron is undercut and an 8' wide x 3' tall x 5'deep scour hole has developed. See photograph 85 and refer to the diving report by Central States Underwater.

- Near Station 7+00, Central States Underwater indicated that an 8' wide x 2' tall, x 5' deep scour hole has developed underwater, approximately 14.3 feet below the top of the apron on the downstream side of the dam. Refer to photograph 86 for the general location. In addition, the top of the apron has significant erosion in this area. Refer to photographs 88 and 89.

- Photographs 109 through 117 and 121 through 129 present the general condition of the upper spillway area and gates, including the significant amount of debris that has accumulated in front of the spillway gates.

- After the grout bag installation was completed, and the flow through the dam reduced, spouts of water through weepholes in the apron were observed at various locations. Refer to photograph 146.

Maintenance and Repair Recommendations

The City of Lawrence has committed to relying upon the Bowersock Dam to remain in operation by providing a pool affect with the flashboards in their upright position to submerge the City's intakes for the Kaw Water Treatment Plant. Recent repairs funded by the City in 2001/2002 addressed the major structural integrity concerns of the dam, but erosion of the concrete surfaces has exposed the steel reinforcing and timber cribbing. The steel reinforcing is provided to carry the tensile loads within the concrete, while the timber cribbing forms the interior foundation of the dam for approximately the middle two-thirds of the dam. Maintenance of the timbers in either a continuously wet or dry condition is important. Exposing the timbers to sunlight allows them to dry out and splinter and/or crack, thereby weakening them and increasing the likelihood of failing when loaded. A major loss of either of these elements would compromise the integrity of the structure.

Based upon the visual observations made alone it is not possible to determine if the dam is in immediate danger of failing, as significant structural concerns exist. There are sections of the dam that have eroded sufficiently to expose significant portions of the timber cribbing, which has subsequently eroded, and the potential for localized failures will increase, along with the cost to repair the areas in question. Recent installations of bags of grout in front of the dam have helped to reduce the amount of flow through the dam. However, the amount of flow observed in October 2006, compared to the amount of flow through the dam in the same location in 2004 has increased significantly, and several timbers that were observable in 2004 have eroded completely. The installation of grout bags in front of the dam to halt the flow is only temporary. As water continues to leak through the dam, erosion of the sediment in front of the dam causes the flow path to work its way around or through the grout bag patch area, degrading the effectiveness of the attempted repair. The first priority should be to stop the flow through the dam.

The following recommendations apply to the dam and are based upon a phased approach to distribute the costs of repairs.

Short-term Repairs

The following repairs should be completed immediately to limit further degradation of the structure:

1. Repair Leaks in Dam Between Stations 3+25 and 5+00. In order to stop the flow through the dam between Stations 3+25 and 5+00, additional grout bags and tremmie concrete will need to be installed upstream of the dam to reduce the amount of flow through the dam to a point such that the large voids can be plugged and filled with thick sanded or pea-gravel grout from downstream. It will likely be necessary to drill several injection holes on the downstream side of the dam in order to fill the voids in the concrete superstructure and the upper portion of the cribbing beneath the concrete superstructure. Because the severity of flow through the dam is variable along the length of the dam, it is difficult to accurately estimate the number of injection holes and volume of concrete required to fill these subsurface voids, but an effort has been made. The opinion of probable project cost for this activity is $200,000. Should these repairs not result in complete stoppage of the flow through the dam, consideration of additional work on the upstream face of the dam to create an upstream seal will need to be evaluated.

2. Fill Eroded Concrete Areas. There are several sections that the concrete surfacing has been eroded away over time to expose steel reinforcing and timber cribbing. These areas can be filled with mass concrete, and where the surface void is large enough, reinforcing could be drilled and grouted into place to assist in tying the new concrete into the existing structure. It is difficult to accurately estimate the volume of concrete required to fill these subsurface voids, but an effort has been made. The opinion of probable project cost for this activity is $100,000.

3. Repair Failed Shotcrete. There is a minor amount of shotcrete that has eroded away from the last repairs to expose the wire reinforcing mesh. These areas should be spot patched with a grout pack to avoid failing more of the dam face. The opinion of probable project cost for this activity is $20,000.

Long-term Repairs

The following areas should be monitored on a routine basis and repaired, as needed, to avoid the continued development of more critical problems:

1. Seal the Upstream Face of the Dam. The repairs using grout bags and tremie concrete are considered only temporary. Long term repairs should consist of methods to completely restore the upstream face of the dam to prevent leakage. The water flow through the dam

needs to be stopped to prevent degradation to the dam interior not visible during inspections. Because the dam is a gravity dam, it relies on the interior cribbing and rockfill for its stability. Degradation of cribbing and movement of rockfill can go undetected for a long time and is a cause for concern for long term stability of the dam. The upstream seal must be restored before making any required repairs to the interior of the dam. The repairs needed to the dam interior would require further intrusive investigations after the upstream face is sealed off. In order to create a seal on the upstream face of the dam, some sort of cofferdam would need to be constructed upstream to allow dewatering and exposing of the upstream face of the dam. It would be extremely difficult to install a row of sheet piling or an earthen causeway on the upstream side of the dam to hold back the water and excavate in front of the dam. Previous repairs made in 1979/1980 involved the placement of several layers of riprap and an impervious clay layer upstream of the dam to a point where the work intersected the causeway installed for the construction of the Massachusetts Street Bridge. Therefore, efforts to drive sheet pile directly in front of the dam would likely be hampered by the existing riprap. The cost and type of construction required in order to provide a self supporting sheetpile structure that would allow the area in front of the dam to be dewatered would be significant enough that the work could be used to replace the dam. The opinion of probable project cost for this activity is $7,500,000.

2. Complete Sheet Piling Downstream of Dam. Approximately 300 feet of downstream repair work was not completed in 2002. To complete stabilization of the dam, the remainder of the sheet piling, riprap, and apron repairs should be completed. This portion of the riverbed has been eroded significantly due to the continued operation of the pneumatic flashboards that that created a plunge-pool which has allowed the underlying shale to be eroded and scoured. The opinion of probable project cost for this activity is $3,000,000.

3. Automate Existing Spillway Gates. The existing pneumatic gates are operated to control the pool level behind the dam because of their controllability. However, this operation allows for continued erosion of the riverbed at this location, whereas, if the existing gates were automated, the spillway could be utilized to control the pool level behind the dam and dissipate the energy on the concrete spillway, rather than continue to allow the water to cascade over the dam. This operation would require the continued maintenance of the upstream channel to remove debris that is collected in this area. If the City were to provide the maintenance necessary to keep the upstream channel clean on a regular basis, this would provide incentive for Bowersock to stop relying on the use of the pneumatic flashboards, resulting in less erosion. The opinion of probable project cost for this activity is $400,000.

4. Construct Downstream Nappe and Energy Dissipaters. The condition, means and methods, as well as the materials of construction of the existing dam are largely unknown due to the age of the structure, phasing of construction, and repairs that have occurred throughout the

life of the dam. The 2001/2002 repairs have stabilized a majority of the foundation and apron portions of the dam, but the steps forming the exposed, vertical portion of the dam continue to erode due to the flows over and through the flashboards. A concrete nappe could be constructed over the steps to allow the water to flow over the shaped concrete, rather than drop, which provides more energy for erosion potential. In addition, energy dissipater blocks could be installed on the apron to reduce the velocity of the water, which also reduces the erosion potential. During final design of this, a roller compacted concrete overlay should be evaluated to determine if it can provide an economical solution to the nappe construction. The opinion of probable project cost for this activity is $5,000,000.

5. Replace Flashboards. As noted in the July 20, 2000 inspection report, it was recommended to replace the existing wooden flashboards with pneumatic flashboards. If the concrete nappe is constructed and the existing spillway gates are automated, the priority for this work is greatly reduced and may not be warranted. The only significant benefit these repairs would provide would be to provide better through-flashboard leakage control, which isn't significant issue with the construction of the concrete nappe. The opinion of probable project cost for this activity is $2,100,000.

All critical items identified should be completed prior to funding the long-term recommendations. The long-term recommendations should be completed in sequential order as identified as they are listed in a priority rating for the City's consideration, unless a new structure is recommended in additional evaluations.

We have made our best estimates of the quantity of materials to be replaced or repaired. Please be aware that these are only estimates and the quantity may vary substantially when the work is undertaken due to the lack of knowledge of what erosion and loss of section has occurred within the dam.

Recommendations

The Short-Term critical items need to be completed immediately to attempt to stop the flow through the dam. The need to implement Long Term Item 1, Sealing the Upstream Face of the Dam will be determined based on how effective the short-term repair is in stopping the flow through the dam. In addition, consideration of implementing Long Term Item 3, Automate Spillway Gates, should be considered to reduce the erosion downstream of the pneumatic gates and potentially delay the installation of sheetpiling in that area.

Prior to implementing any of the long term items, additional studies should be performed. It is time to consider a more in-depth economic analysis of continuing repairs versus constructing a new dam

on the river. The cost to construct a new dam would be approximately $20,000,000 to $25,000,000, and could incorporate several of the long term repair features, and provide a structure with a predictable design life of 100 years or more. This discussion will need to involve Bowersock, to understand their long-term intentions. There may be other parties that have an interest in maintaining the dam that may participate in the funding of the project.

If you have any questions concerning our recommendations, please feel free to contact us. We look forward to meeting with you to discuss how we can implement the short-term recommendations as well as the scope for the additional studies needed to further evaluate the long-term solution for the dam.

Sincerely,

BLACK & VEATCH CORPORATION

Michael G. Orth

Michael G. Orth

Enclosures

APPENDIX A

INSPECTION PHOTOGRAPHS

1. Station 0+00, North end of dam, storm drain, deteriorated concrete along storm drainage flume

2. Station 0+00, Storm drainage flume, north wall of spillway

3. North Spillway

4. North spillway looking south from station 0+00

5. View of dam from station 0+00

6. Sta 0+25±. Storm drainage flume north of spillway, eroded concrete

7. Sta 0+40±. Apron downstream of spillway. Flow from storm drain.

8. Sta 0+50±. Looking north to Sta 0+00 access road to dam apron.

9. Sta 0+50±. Storm drainage flume and north wall of spillway

10. Sta 0+50. Spillway

11. Sta 0+50. Spillway

12. Sta 0+50 to Sta 0+00. Spillway. Eroded and cracked concrete.

13. Sta 0+50 to Sta 1+50. North end of dam and flashboards. Eroded and cracked concrete on old apron.

14. Sta 0+75. Eroded concrete in spillway.

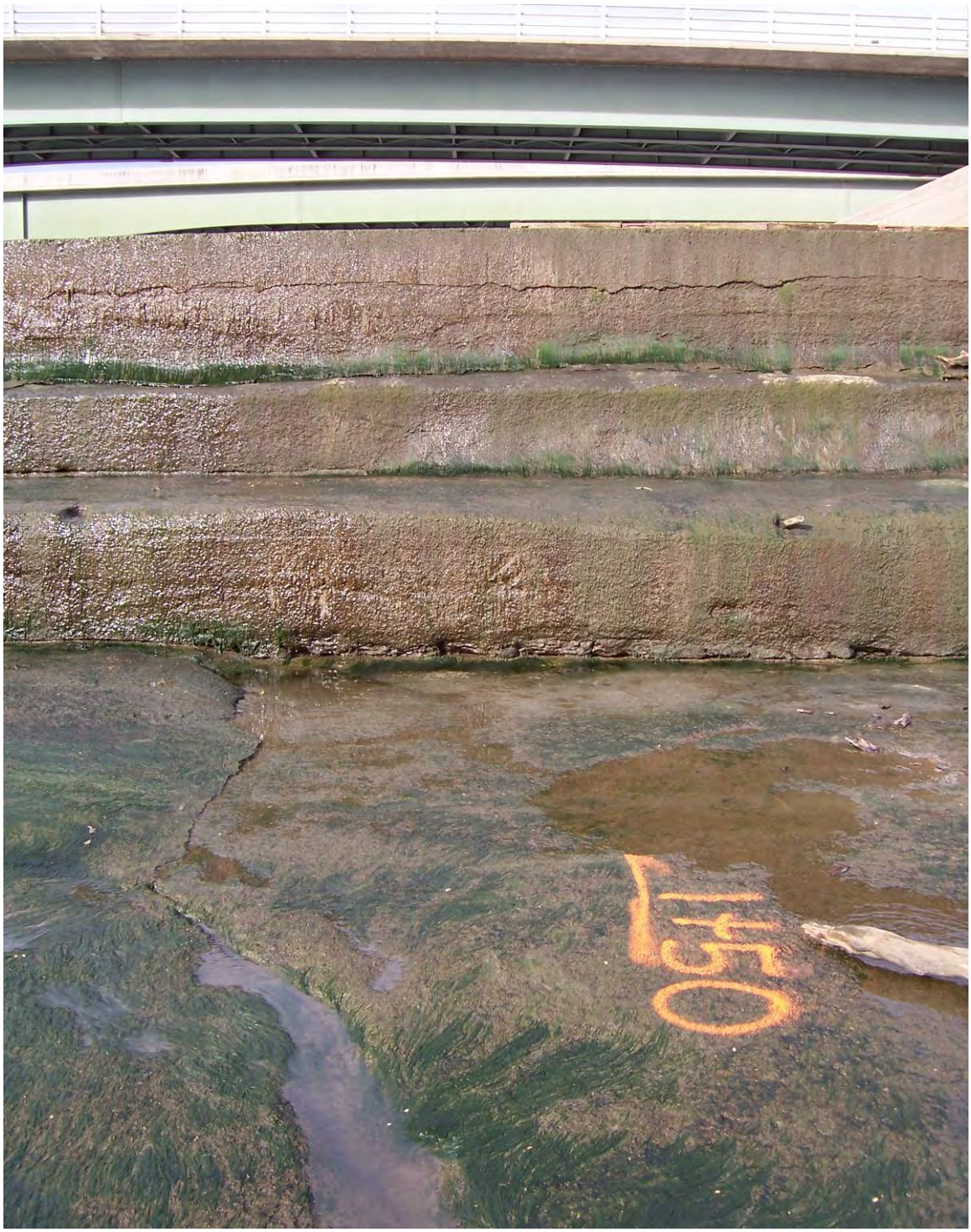
15. Sta 0+00. Eroded concrete and exposed joints in spillway.

16. Sta 1+10. North wall of dam. Eroded concrete and exposed joints in spillway.

17. Sta 1+25. Eroded concrete at north end of dam.

18. Sta 1+25. Eroded concrete at north end of dam. Exposed joints at bottom of dam steps. Eroded shotcrete near top of dam.

19. Sta 1+25 to 1+50. Exposed joints at bottom of dam steps. Eroded shotcrete at top step.



20. Sta 1+50. Exposed joints at bottom of dam steps – eroded shotcrete at top step. Exposed reinforcing rod in bottom step.

21. Sta 1+50 to Sta 2+00. Eroded concrete steps and shotcrete. Exposed reinforcing bar.

22. Sta 1+80. Eroded bottom step. Depression with 2 ft deep hole at bottom step. Eroded shotcrete.

23. Sta 1+80. Eroded concrete on bottom step. Exposed joints between steps. Eroded shotcrete on top step.

24. Sta 2+00. Eroded concrete on top of bottom step. Exposed joints at bottom of steps. Beginning of separated triangular section in bottom step.

25. Sta 2+05. Top of bottom step. Eroded concrete with exposed reinforcing mesh. Exposed joint between 2nd and 1st step. Eroded shotcrete with exposed mesh on top step.

26. Sta 2+10. Crack in lower step. Exposed joint between steps. Eroded shotcrete with exposed wire mesh. Triangular crack beginning.

27. Sta 2+25±. Triangular section broken away in bottom step. Crack in apron that extends to edge of apron. Exposed joints between steps. Deteriorated steps.

28. Sta 2+25. Back to Sta 2+00. Triangular section in bottom step. Crack in apron.

29. Sta 2+40±. Deteriorated steps. Exposed joints.

30. Sta 2+50. Exposed joints between steps. Eroded concrete in top step. Exposed rebar at old timbers.

31. Sta 2+65. Eroded, disintegrated timber holes with exposed rebar. Eroded concrete on apron.

32. Sta 2+45. Deteriorated steps exposed joints.

33. Sta 2+65±. Exposed timber holes and rebar. Eroded concrete. Exposed joint between steps.

34. Sta 2+65±. Exposed eroded timber at top of bottom step. Cast-In-Place weep hole at bottom of bottom step.

35. Sta 2+65. Exposed eroded timber at top of bottom step. Cast-In-Place weep hole at bottom of bottom step.

36. Sta 2+75±. Exposed joint and cracked middle step. Crack in bottom step. Weep hole.

37. Sta 2+80±. Exposed timber and eroded concrete. Crack in bottom step.

38. Sta 2+80±. Exposed timber and eroded concrete. Crack in bottom step.

39. Sta 3+00. Exposed and eroded timbers exposed rebar. Severely deteriorated bottom steps.

40. Sta 3+05. Eroded timber hole with exposed rebar. Exposed joint between steps.

41. Sta 3+00. Eroded timber hole with exposed rebar. Exposed joint between steps.

42. Sta 3+25. Severely deteriorated steps. Flow from channel at top of dam.

43. Sta 3+25 to Sta 3+50. Severely deteriorated steps. Flow through step joints and exposed, eroded timber holes.

44. Sta 3+50 to Sta 3+90. Severely deteriorated steps. Flow through step joints and exposed, eroded timber holes. Large flow near Sta 3+90.

45. Sta 3+30. Exposed timbers between first and second steps. Severe deterioration of steps.

46. Sta 3+40. Eroded timber holes. Flow through timber hole. Severely deteriorated concrete.

47. Sta 3+45±. Eroded timber holes. Flow through timber hole. Severely deteriorated concrete.

48. Sta 3+45±. Eroded timber hole and crack in top step. Flow through joint between 1st and 2nd step.

49. Sta 3+50. Eroded timber holes with flow through dam. Severely deteriorated steps.

50. Sta 3+65 to Sta 4+20. Significant flow through dam in numerous locations.

51. Sta 3+75±. Construction joint between old and new apron.

52. Sta 3+75±. Significant flow through Dam in numerous locations.

53. Sta 3+80±. Significant flow through Dam in numerous locations.

54. Sta 3+90. Looking south. Main flow point through dam. 4 ft deep hole at flow point.

55. Sta 3+90±. Severely deteriorated concrete with exposed rebar in top step.

56. Sta 3+90±. Looking north. Main flow point through dam. 4 ft deep hole at flow point.

57. Sta 4+20. Severely deteriorated joint at top of bottom step. Seals from flashboards.

58. Sta 4+20 to North. Significant flow through dam.

59. Sta 4+40±. Severely deteriorated steps. Exposed joints between steps.

60. Sta 4+50 to Sta 4+40. Severely deteriorated steps. Exposed joints between steps.

61. Sta 4+50±. Severely eroded concrete and exposed boulders.

62. Sta 4+75±. Eroded and irregular steps with exposed joint and flow through joint.

63. Sta 4+75 to 5+00. Severely eroded top step with flow through joint in step.

64. Sta 5+00. Deteriorated concrete at top step.

65. Sta 5+10 to Sta 5+25. Deteriorated concrete on top step. Exposed timber.

66. Sta 5+25. Exposed joints between first and second steps.

67. Sta 5+25 to 5+35. Exposed I-beam piling at Sta 5+35. Eroded shotcrete exposed joint at step.

68. Sta 5+35. Exposed I-beam pilings.

69. Sta 5+50. South end of steps. Eroded concrete exposed joints.

70. Sta 5+50. South end of steps. Exposed old sheet piling encased in apron. Eroded concrete with numerous exposed joints.

71. Sta 5+50. South end of steps. Eroded concrete exposed joints.

72. Sta 5+75. Eroded shotcrete. Depression with exposed spikes and tie-rings.

73. Sta 5+75. Eroded shotcrete. Depression with exposed spikes and tie-rings.

74. Sta 5+75 to 6+00. Eroded shotcrete.

75. Sta 5+75 to Sta 6+00 South. Eroded shotcrete. Short section of piling and new apron.

76. Sta 5+75 to 5+60 North. Eroded portion of new apron. Exposed spike in old apron.

77. Sta 6+00 to 5+75 North. Eroded shotcrete.

78. Sta 6+25. Eroded shotcrete.

79. Sta 6+50 to south pneumatic flashboards. Eroded shotcrete.

80. Sta6+50 to sour pneumatic flashboards. Eroded Shotcrete

81. South end of dam, Bowersock Turbine House.

82. Sound end of dam.

83. Sta 6+50 to south pneumatic flashboards. Eroded shotcrete.

84. Sta 6+35 to north end of apron.

85. Sta 5+80 to 6+00. Hole below old apron.

86. Sta 6+35 to Sta 7+00. Downstream side of old apron.

87. Sta 6+50.

88. Sta 6+80 to north. Severely eroded apron and shotcrete.

89. Sta 7+00 to north. Severely eroded apron and shotcrete.

90. Sta 5+60. Eroded portion of new apron. Exposed spike in old apron.

91. Sta 5+50. Top of dam to south. Flashboards being repaired.

92. Sta 5+75. Top of dam to south. Flashboards being repaired.

93. Sta 5+50. South end of steps. Eroded concrete with exposed joints.

94. Sta 5+50 to north. Top of dam to south. Flashboards being repaired.

95. Sta 5+50 to 4+50 north. Eroded and uneven steps.

96. Sta 4+50. Eroded and cracked steps.

97. Sta 4+50 from above. Severe deterioration at old timber location. Multiple joints.

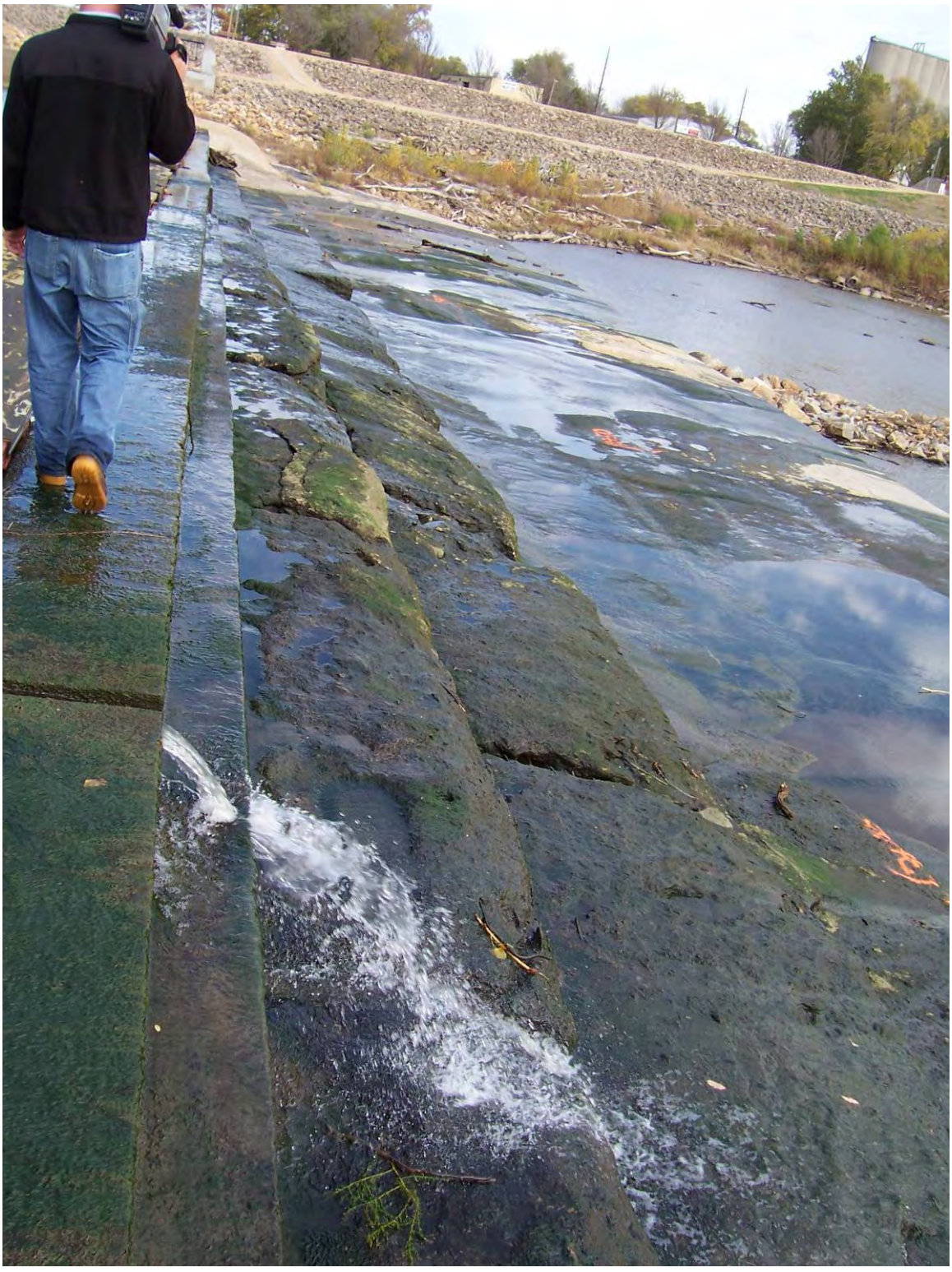
98. Sta 4+40±. Eroded concrete with exposed timber in top step.

99. Sta 3+90±. Eroded concrete with exposed wire mesh in top step.

100. Sta 3+80± from top. Severe flow through dam.

101. Sta 3+80±. Whirlpool upstream of dam at cluster of leaves.

102. Sta 3+40 to south. Severe flow through dam. Cracked and deteriorated steps.



103. Sta 3+00 from top. Flow over dam top. Severe step deterioration.

104. Sta 3+00 from top. Eroded timber hole with exposed rebar.

105. Sta 2+80 from top. Eroded timber and concrete.

106. Sta 2+00 from top. Separated triangular section in bottom step.

107. Sta 2+10 from top. Separated triangular section in bottom step.

108. Sta 1+75 to south. Separated triangular section in bottom step. Eroded concrete steps.

109. Sta 1+75 top of dam to north dam wall. Eroded concrete and open joints.

110. North end of spillway. Movable hoist.

111. North end of spillway with hoist.

112. South end of spillway.

113. North end of spillway, accumulated debris ahead of spillway inlet.

114. North end of spillway, accumulated debris ahead of spillway inlet.

115. North end of spillway, accumulated debris ahead of spillway inlet.

116. Top of spillway to north. Accumulated debris in front of gates.

117. Top of spillway to north. Accumulated debris in front of gates.

118. Upstream of dam to south from north dam wall.

119. Upstream of dam to southeast from north dam wall.

120. Upstream of dam to east from north end of wall. Riprap downstream of dam near Sta 2+00.

121. North wall of dam to east.

122. Spillway to northeast. Eroded and cracked concrete.

123. Spillway to north. Eroded and cracked concrete.

124. Spillway to north.

125. Spillway inlet at south end of spillway.

126. Accumulated debris in front of spillway gates.

127. Accumulated debris in front of spillway gates.

128. Accumulated debris in front of spillway gates.

129. Accumulated debris in front of spillway gates.

130. Sta 2+65. Exposed timber holes and rebar. Eroded concrete. Exposed joint between steps.

131. Sta 2+80. Exposed timber and eroded concrete. Crack in bottom step.

132. Sta 2+80. Exposed timber and eroded concrete. Crack in bottom step.

133. Sta 3+05. Eroded timber hole with exposed rebar. Exposed joint between steps.

134. Sta 3+30. Exposed timbers between first and second steps. Severe deterioration of steps.

135. Sta 3+30. Exposed timbers between first and second steps. Severe deterioration of steps.

136. Sta 3+30. Exposed timbers between first and second steps. Severe deterioration of steps.

137. Sta 3+40. Flow after dive repairs.

138. Sta 3+50. Eroded timber holes with flow through dam. Severely deteriorated steps.

139. Sta 3+55. Flow after grout bag repairs upstream.

140. Sta 3+80. Flow after grout bag repairs upstream.

141. Sta 3+90±. Flow after grout bag repairs upstream.

142. Sta 3+90. Flow after grout bag repairs upstream.

143. Sta 3+90 from top. Flow after grout bag repairs upstream.

144. Sta 4+50±. Flow after grout bag repairs upstream.

145. Sta 3+90±. Flows after grout bag repairs upstream.

146. Sta 3+90±. Stream of flow through weep hole in piling below apron.

APPENDIX B

CENTRAL STATES UNDERWATER DIVING INSPECTION REPORT

Waterway: Kansas River
Dam batter board inspection

On November 22, 2005 Central States Underwater Contracting, Inc inspected the batter boards supporting the Kansas River dam for the City of Lawrence. We also inspected the step 10' upstream of each batter board. There are 64 batter boards running North to South, They are joined to 15, 10' wide gate boards that finish closing the dam.

Between #31 and #32 void = 5" high x 3' 6" wide at end of the riverbed. Total void of #31 and #32 was covered with 25, 80lb grout bags. Between #32 and #33, fissure located 4" deep x 7" long. Fissure was covered with 50 8lb grout bags.

On the downstream side of the batter boards there is tiered rock slopes down to the waterline before the dam. We took water elevations and found bottom substrate was made of rock and sand. Between #56 and #57 on bottom of rock wall, before the waterline, there is a washed out area 10' wide x 4' deep x 2' high.

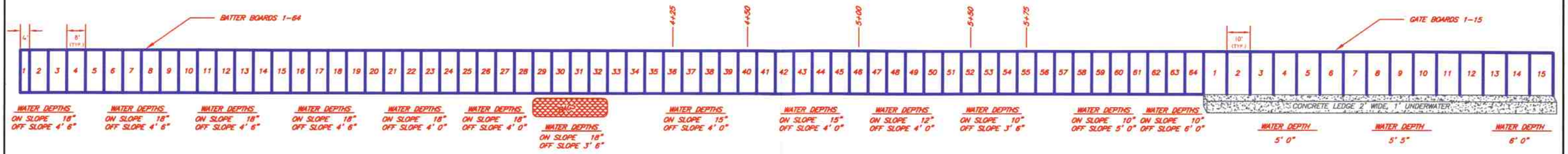
Over all everything looked good.

See attached drawing for detail.

KANSAS RIVER (UPSTREAM)

PLAN

SCALE: ~~1"=20'~~
REDUCED C
NOT TO SCALE



NOTES: 2006

- DATE OF INSPECTION: 02 NOV. 2006
- BETWEEN #28 & #33 GROUT BAG STABILIZATION STARTS 2' OUT BY 8' WIDE

NOTES: 2005

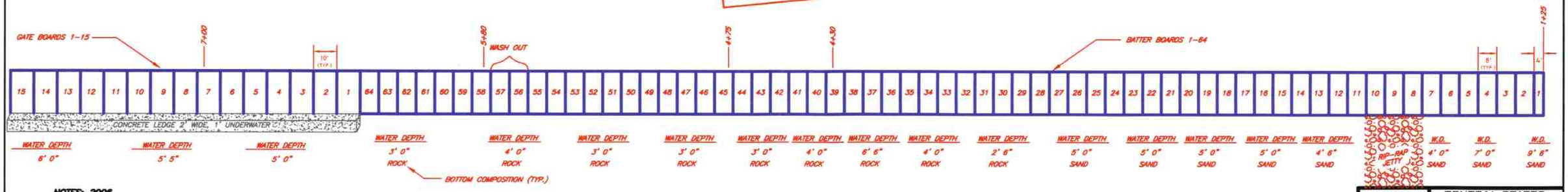
- DATE OF INSPECTION: 22 NOV. 2005
- BETWEEN #31 & #32 VOID = 5" HIGH X 3' 6" WIDE AT END OF RIVERBED
- BETWEEN #31 & #32, AFTER THE PREVIOUS VOID, THERE IS 1' OF SPACE BEFORE THE VOID CONTINOUS TOO 3' WIDE X 5" HIGH
- TOTAL VOID OF #31 & #32 COVERED WITH 25, 80LB GROUT BAGS
- BETWEEN #32 & #33, FISSURE LOCATED 4" DEEP X 7' LONG
- FISSURE COVERED WITH 50, 80LB GROUT BAGS
- THERE ARE 64 BATTER BOARDS RUNNING N TO S, THEY ARE JOINED TO 15, 10' WIDE GATE BOARDS THAT FINISH CLOSING THE DAM

KANSAS RIVER (DOWNSTREAM)

PLAN

SCALE: ~~1"=20'~~
REDUCED C
NOT TO SCALE

10' N OF #1	7' 6" W.D. ROCK BOTTOM
20' N OF #1	6' 3" W.D. CONCRETE BOTTOM
30' N OF #1	3' 2" W.D. CONCRETE BOTTOM
40' N OF #1	4' 2" W.D. CONCRETE BOTTOM
50' N OF #1	6' 2" W.D. SAND BOTTOM
60' N OF #1	5' 6" W.D. SAND BOTTOM
70' N OF #1	0' 6" W.D. ROCK BOTTOM



NOTES: 2006

- 0+55 PITTING IN BULKHEAD 3' BELOW APRON
- #9 (CENTER) 25' WIDE ROCK JETTY
- #39 – 4+30 CORROSION AROUND 2" PIPE, 3.5' FROM TOP OF APRON
- #45 – 4+75 4"ø HOLE IN BULKHEAD, 4' FROM TOP OF APRON
- #58 – 5+80 8' WIDE X 3' TALL X 5' DEEP SCOUR HOLE, 4' FROM TOP OF APRON
- #7 GATE BOARD – 7+00 8' WIDE X 2' TALL X 5' DEEP SCOUR HOLE, 14.3' FROM TOP OF APRON

NOTES: 2005

- TIERED ROCK SLOPES DOWN TO WATERLINE BEFORE DAM
- BETWEEN #56 & #57 ON BOTTOM OF ROCK WALL, BEFORE WATERLINE, THERE IS A WASHED OUT AREA 10' WIDE X 4' DEEP X 2' HIGH

CENTRAL STATES UNDERWATER CONTRACTING, INC.
P.O. BOX 815 Olathe, KS 66051
1-800-233-2213
WWW.CSUDIVING.COM

DATE: 03 NOV. 2006
APPROVED BY:
DRAWN BY: G.J.W.
DRAWING NO: 1 OF 1

CITY OF LAWRENCE
KANSAS RIVER
LAWRENCE, KS
DAM REPAIR

Waterway: Kansas River
Dam inspection

On November 2, 2006 Central States Underwater Contracting, Inc inspected the batter boards supporting the Kansas River dam for the City of Lawrence. We also inspected the step 10' upstream of each batter board. There are 64 batter boards running North to South, They are joined to 15, 10' wide gate boards that finish closing the dam.

*Between #28 and #33 grout bag stabilization starts 2' out by 8' wide.

*0+55 there was pitting in the bulkhead 3' below apron.

*#9 (Center) 25' wide rock jetty.

*#39 stationing 4+30 corrosion around 2" pipe, 3.5' from top of apron.

*#45 stationing 4+75 there's a 4" diameter hole in the bulkhead 4' from the top of apron.

*#58 stationing 5+80 8' wide x 3' tall x 5' deep scour hole 4' from the top of apron.

*#7 gate board at stationing 7+00 8' wide x 2' tall x 5' deep scour hole, 14.3' from the top of apron.

On the downstream side of the batter boards there is tiered rock slopes down to the waterline before the dam. We took water elevations and found bottom substrate was made of rock and sand.

Over all everything looked good.

See attached drawing for detail.

APPENDIX C

CORRESPONDENCE FROM BOWERSOCK MILLS

The Bowersock Mills & Power Company

P.O. Box 66
Lawrence, Ks 66044
(785) 843-1385

RECEIVED
AUG 0 5 2005
CITY MANAGERS OFFICE
LAWRENCE, KS

August 1, 2005

Mike Wildgen
City Manager
City of Lawrence
6th and Mass.
Lawrence, Kansas 66044

Re: Condition of the Bowersock Dam

Dear Mike:

We have periodically updated you on the condition of the dam. We are enclosing photos taken last week of further damage to portions of the dam that were not repaired in 2001. Repair of most of the damage shown in these photos was postponed at that time for budgetary and/or time and water conditions.

During the last four years further deterioration has occurred in the locations shown in the photos. We draw your attention to these conditions, so that timely repairs may be planned and executed before major and more costly damage occurs.

Low water flows will now permit further examination of these damaged areas that were identified in the Black and Veatch study prior to the 2001 work. Our personnel would be pleased to offer any assistance we can in identifying the location of the damage shown.

Sincerely yours,

THE BOWERSOCK MILLS & POWER COMPANY

Stephen H. Hill
President

July 25, 2005

To: Stephen Hill

From: David Readio, Plant Manager

Subject: Dam inspection

Stephen:

Ty and I used the low flows to inspect the condition of the spillway and top of the dam after the high flows we experienced during June. You will notice in photo #1 and photo #2 that the apron in front of the spillway has developed two holes and in photo #3 a crack has developed as well. Unfortunately the river level was not below the top of the dam, so there was flowing water. This flowing water does seem to follow the path that it has already eroded into the top of the dam which means it will continue to remove material and cut those channels deeper as time goes on. There are three places where water is being forced through the dam and is acting like a geyser when it exits the dam—see photos #7 and #8. There are also several cracks along the upper "step" that will become even bigger and we may loose several large chucks of concrete after this winters freeze/thaw.

As can be seem from the photos, the top of the dam is continuing to deteriorate and will only get worse as time goes by. The time to fix it is before we have a major failure.

Dave

Encl: photos

Photo #1

Photo #2

Photo #3

Photo #4

Photo #5

Photo #6

Photo #7

Photo #8

Photo #9

Photo #10

Photo #11

Photo #12

Photo #13

Photo #14

Photo #15

Photo #16

Photo #17

Photo #18

Photo #19

Photo #20

Photo #21

Photo #22

Photo #23

Photo #24

The Bowersock Mills & Power Company

P.O. Box 66
Lawrence, KS 66044
(785) 843-1385

Stephen H. Hill
President

Marcia Hannon Hill
Secretary-Treasurer

February 27, 2004

Mike Wildgen
City Manager
City Hall
6th and Mass.
Lawrence, Kansas 66044

Re: Bowersock Dam

Dear Mike:

Last week while raising two flashboards our crew observed continuing deterioration of one section of the dam that was not repaired during the recent renovation project. I believe that this section was on the list to be fixed, but either weather or budget constraints prevented repair at the time.

I am enclosing a report from our plant manager and several photos showing the problem areas. These deteriorated areas are readily accessible from the dam apron and appear to be relatively easy to repair.

Our experience over the years has taught us the benefits of fixing these more minor problems as soon as possible before conditions get worse.

Our personnel are available at any time should some one from the City want to take a look now when the water is low.

Sincerely yours,

THE BOWERSOCK MILLS & POWER COMPANY

Stephen H. Hill
President

Enclosures

February 26, 2004

To: Stephen Hill

From: David Readio

Subject: Inspection of the Bowersock Dam

Stephen:

After raising flashboards yesterday, Ty noticed that there are several places along the dam face where there are holes in the concrete and the wood members of the timber crib are visible.

The area just below the cap installed back in 1987 to the apron along the entire downstream face of the timber crib part of the dam is in need of attention. There are several holes (see photos); in addition, there are several large cracks that will cause very large chucks of the dam to break off in the very near future.

The length of dam in question is approximately 350 feet. Gunite of Missouri applied gunite to the down stream face of the gravity part of the dam in 2001 and it is in very good condition. We need to address this problem before it gets to the point where the integrity of the dam is in question.

David Readio, Plant Manager