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Technical Memorandum

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FLOOD INUDATION CONDITION ASSESSMENT

Background

History of water levels at the site

Missouri River water levels inundated the Fort Calhoun Station (FCS) site for several months during the late spring and summer of 2011. Water levels have recently begun dropping, allowing access for inspection and assessment of potential damages and impacts that may have occurred as a result of the flooding. This Technical Memorandum provides an update on the site assessment that is being performed by HDR Engineering, Inc., and some of the key findings to date.

Assessment Process

Several HDR teams have been assessing potential damages through a series of observation and investigation methods built around a Potential Failure Modes (PFM) assessment framework. This process has been utilized by a number of Federal agencies including the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers (USACE), and the Federal Energy Regulatory Commission for dams, levees and large civil infrastructure located in or adjacent to large river systems similar to the FCS. To date, a number of potential triggering mechanisms and a series of corresponding PFM's have been identified and are under evaluation using the process illustrated on Figure 1. A simplified, qualitative risk analysis is being completed for each potential failure mode. Further evaluation will take place for PFM's that pass through an initial screening and are found to be credible. It is the goal of this process to provide a general assessment of each of the credible potential failure modes as well an opinion on the level of confidence that assessment teams have in the qualitative risk assessment. Based on this assessment, the credible PFM's for each structure will be placed into one of four categories as follows:

> **Low Risk/High Confidence**; "Low Risk" indicates that the combined probability of failure and severity of consequences has been qualitatively evaluated as "low". A description of the reason why a PFM for any particular structure was placed in this category, including a description of which element of the equation produced the Low Risk ranking will be included in the report. "High Confidence" indicates that additional information and studies are not likely to increase the confidence in the findings or change the conclusions.

> **Low Risk/Low Confidence**; "Low Risk" indicates that the combined probability of failure and severity of consequences has been qualitatively evaluated as "low". A description of the reason why a PFM for any particular structure was placed in this category, including a description of which element of the equation produced the Low Risk ranking will be included in the report. "Low Confidence" indicates that additional information and studies are required to increase confidence in the findings.

High Risk/Low Confidence; "High Risk" indicates that the combined probability of failure and severity of consequences has been qualitatively evaluated as "high". A description of the reason why a PFM for any particular structure was placed in this category, including a description of which element of the equation produced the High Risk ranking will be included in the report. "Low Confidence" indicates that additional information and studies are required to increase the confidence in the findings.

High Risk/High Confidence; "High Risk" indicates that the combined probability of failure and severity of consequences has been qualitatively evaluated as "high". A description of the reason why a PFM for any particular structure was placed in this category, including a description of which element of the equation produced the High Risk ranking will be included in the report. "High Confidence" indicates that additional information and studies are not likely to increase the confidence in the findings or change the conclusions.

Recommended Actions

The ultimate goal is to gather enough data to place each of the credible PFM's for a given structure into one of the High Confidence categories. This may not be possible by the end of the current assessment process. If that is the case, HDR will recommend long-term actions to increase confidence. This may include long-term monitoring and/or more detailed forensic investigations.

Findings with a High Confidence may be accompanied by recommendations on remediation alternatives. Some of these remediation alternatives may require a professionally stamped design, which would be outside the scope of the current investigation.

Key Distress Indicators

During the first round of site inspection and assessment activities, three key distress indicators were identified suggesting potential damage to the site as a result of the flooding conditions. These indicators require the highest priority of attention at this time in order to identify the root cause (triggering mechanism); to identify the extent of the damage that has occurred, to complete the potential failure mode assessment, and to begin the process of identifying potential recommended action(s) requirements. The general location of these key indicators are illustrated on Figure 2 and summarized below.

- ***Turbine Building Sump Discharge*** – Beginning in the 1990's, OPPD identified breaks in the drain pipe system that flows into a sump in the basement of the turbine building. This allowed foundation seepage that resulted in damage (void formation) under the floor slab. Previous attempts to repair this damage were not successful in eliminating the flow of foundation seepage into the drain pipe system. During the flood conditions this year, water flowing in this pipe system increased substantially. These pipes were designed as closed systems without any openings to the soils under the structure. All five of the pipes discharging to the sump were observed to be flowing on September 14th, 2011 indicating that there are breaks in each of these lines. These breaks represent unfiltered seepage discharge locations that provide a mechanism for the initiation and continuation of erosion and piping of foundation materials into and through the pipe system. The seepage gradients in the foundation contributing to the potential erosion and piping process were very high and lasted for an extended period of time. The combination of the number of breaks (openings) in the pipes, high seepage gradients, and the volume of flow combine to create a condition that likely caused extensive damage beneath the Turbine Building floor slab. We have identified one triggering mechanism that may be associated with the sump discharge:
    - Erosion and piping of foundation soils

- ***Access and Utility Corridor Settlement, Sinkhole, Hydrant Failure, and Softened Subgrade development along Northeast, East, and Southeast Perimeter of the Power Block*** – Slab settlement, heave, sink hole development, development of soft subgrade conditions, and piping and erosion of the upper 5 to 10 feet of foundation soils in this area combine to create a significant increased risk of failure of all the utilities in this corridor area. We have identified five possible triggering mechanisms that may be the root cause of the distress that has occurred including:
  - Erosion and piping of foundation soils
  - Settlement of poorly compacted soils adjacent to the exterior of the Turbine Building foundation walls
  - Slope deformation or spreading
  - Collapse of karst features in the upper bedrock materials
  - Previous repair failure

- ***Column, Floor Slab and Wall Settlement in Maintenance Shop adjacent to the Turbine Building*** – Significant settlement of a building column, floor slab and cracking of masonry partition walls has occurred the southwest corner of this building immediately adjacent to the Turbine Building. The extent of the damage suggests the development of a relatively large area of distress below the Maintenance Shop floor. We have identified four possible triggering mechanisms that may be the root cause of the distress that has occurred including:
  - Erosion and piping of foundation soils
  - Settlement of poorly compacted soils adjacent to the exterior of the Turbine Building foundation walls
  - Collapse of karst features in the upper bedrock materials.
  - Collapse of abandoned utilities

A number of other distress indicators have been identified by our assessment teams. However, they do not appear at this time to have the same level of significance as those described above. They are currently under further evaluation.

Status of Potential Failure Modes Assessment

At this point in the screening process the following PFM's remain credible for the structures and utilities listed in the next section:

- Subsurface Erosion/Piping, Undermining and settlement of shallow foundation/slab (due to pumping).
- Subsurface Erosion/Piping, Loss of lateral support for pile foundation (due to pumping).
- Subsurface Erosion/Piping, Undermining and settlement of shallow foundation/slab (due to river drawdown).
- Subsurface Erosion/Piping, Loss of lateral support for pile foundation (due to river drawdown).
- Subsurface Erosion/Piping, Undermined buried utilities (due to river drawdown).
- Hydrostatic Lateral Loading (water loading on structures), Wall failure in flexure.
- Hydrostatic Lateral Loading (water loading on structures), Wall failure in shear.
- Hydrostatic Lateral Loading (water loading on structures), Excess deflection.
- Rapid Drawdown, River bank slope failure and undermining surrounding structures.

- Rapid Drawdown, Utility trench subsidence.
- Submergence, Corrosion of structural elements.

The structures and plant systems that may be impacted as a result of these credible potential failure modes include:

- Aux Building
- Containment Building
- Security Building
- Condensate Storage Tank
- Intake Building
- Turbine Building
- Turbine Building South Switch Yard
- Circ Water Tunnel
- Main Underground Cable Bank
- Raw Water
- Fire Protection Loop and FP-1B FO
- Trenwa Cableway
- FO-10
- Rad Waste Disposal
- BBRE's

Planned field investigations and analysis are underway, but are not complete as of the preparation of the Technical Memorandum. Subsurface investigations, including borings, installation of inclinometers, and geophysical analyses have yet to be completed and/or the data has yet to be analyzed. Some visual inspections, most notably the visual inspection of the riverbank and the portion of the Trenwa Cable Trench along the river, have not been completed because of the continued high Missouri River stages. The USACE is currently reducing releases from the Missouri River Mainstem Reservoir System, which will lower river stages at the FCS, allowing for this inspection in the coming weeks. The completion of the subsurface investigations currently underway and the remaining visual inspections will increase HDR's confidence in their findings. However, it is anticipated that many of the PFM's will remain credible upon completion of the HDR report. Therefore, it is very likely that recommended actions to increase confidence will be included in the report.