5.10 Turbine Building South Switchyard

5.10.1 Summary of Turbine Building South Switchyard

Baseline information for the Turbine Building South Switchyard is provided in Section 2.0, Site History, Description, and Baseline Condition.

5.10.2 Inputs/References Supporting the Analysis

Table 5.10-1 lists references provided by OPPD and other documents used to support HDR's analysis.

Table 5.10-1 - References for Turbine Building South Switchyard

Document Title	OPPD Document Number (if applicable)	Date	Page Number(s)
Foundation Plan – Transformer Yard	11405-S-411, Rev. 12 (#16582)	1/29/1975	
Foundation Details – Transformer T1	11405-S-412 (#16583)	1/29/1975	
Foundation Details – Transformer T1A-1,2,3&4	11405-S-413 (#16584)	1/29/1975	
Foundation Details – 161kV Transmission Tower And Retaining Walls	11405-S-414, Rev. 1 (#16585)	1/29/1975	
Naval Facilities Engineering Command, Design Manual 7.01, Soil Mechanics		9/1986	All

Detailed site observations—field reports, field notes, and inspection checklists—for the Turbine Building South Switchyard are provided in Attachment 8.

Observed performance and pertinent background data are as follows:

- The foundation for Transformer T1 is a 1.5-ft-thick pile cap supported on ten 10BP42 steel piles (see 11405-S-412). Top-of-concrete elevation for this foundation is 1005.5 ft.
- The foundation for Transformers T1A-1 and T1-A2 is a 1.5-ft-thick pile cap supported on four 10BP42 steel piles (see 11405-S-413). Top-of-concrete elevation for this foundation is 1005.5 ft.
- The foundation for Transformers T1A-3 and T1-A4 is a 1.5-ft-thick pile cap supported on four 10BP42 steel piles (see 11405-S-413). Top-of-concrete elevation for this foundation is 1005.5 ft.
- The foundation for Transformer T1C-3B is an approximately 0.7-ft-thick pile cap supported on four 8-in.-diameter auger cast piles with tip elevation of 997 ft (see 11405-S-412). Top-of-concrete elevation for this foundation is approximately 1004.8 ft. The piles are reinforced with a single #7 bar centered in the pile, with the bar having a straight development into the slab.
- The foundation for the small switchgear located on the southwest corner of the west cable trench is an approximately 0.7-ft-thick slab-on-grade foundation.
- The Dead End/161 Structure is a two-column frame, approximately 27 ft in height, with interconnecting cross beams. There are separate foundations for each octagonal column. The piers are 5 ft by 5 ft by 3 ft in height. Top-of-pier elevation is 1004.5 ft. Top-of-concrete elevation for the pile cap is 1001.5 ft. Each cap is 4 ft thick, 7 ft by 20 ft in plan dimensions, supported by six 12-in.-diameter auger cast piles with tip elevation of 940 ft (see 11405-S-414). The piles are

reinforced with a single #11 bar centered in the pile, with the bar having a straight development into the slab.

- The driving criteria, tip elevation, and capacities of the 10BP42 piles are unknown. However, the tops of the piles are capped with a plate and anchor rods for a positive shear and uplift connection (see 11405-S-412).
- The capacities of the 8-in.- and 12-in.-diameter auger cast piles are unknown.
- A continuous cable trench is adjacent to each transformer (see 11405-S-411). This conduit trench is a cast-in-place concrete trench with intermittent drain holes in the walls. The trench also has a vertical drain pipe penetrating the west end of the trench with the perforated pipe noted as heading west "to storm sewer manhole." The trench backfill below the slab and around the walls is free-draining granular material (see 11405-S-412).
- An approximately 0.7-ft-thick concrete block separation wall is located between Transformer T1 and T1-A2. This wall is constructed on a continuous, cast-in-place, concrete grade beam spanning to isolated footings. The wall is laterally braced via anchor straps to 8WF31 piles (see 11405-S-414).
- The structures were originally contained within a cast-in-place retaining wall that projected approximately 6 in. above the surrounding grade. On approximately June 10, 2011, OPPD built an additional approximately 0.7-ft-thick cast-in-place concrete wall in insulated concrete forms (ICFs) on top of the existing wall. This additional wall was approximately 3.3 ft tall, which placed the top of concrete at about 1008.3 ft.
- Condition report summaries were not available for these structures.
- The Turbine Building South Switchyard was protected from floodwater by an Aqua Dam for the majority of the 2011 flood; however, the Aqua Dam failed for a short period of time because it was damaged, which allowed floodwater to enter the area inside the perimeter of the Aqua Dam. These structures were also protected by the cast-in-place wall in insulated wall forms.
- The areas surrounding the transformers were filled with small riprap. Small depressions were dug out in the riprap, creating a low spot where portable pumps were placed to remove water infiltration around the foundations.
- In general, there were no signs of soil movement around these structures with the exception of a soft spot on the southwest corner of the west cable trench. This soft spot resulted in differential settlement of the switch pad located adjacent to the trench.
- Portable pumps were removing groundwater from the cable trenches, and there appeared to be a layer of sediment on the cable tray, the conduit, and on the bottom of the trench.
- Assessment of survey elevations to date shows no movement of the structure.

5.10.3 Assessment Methods and Procedures

5.10.3.1 Assessment Procedures Accomplished

Assessments of the Turbine Building South Switchyard included the following:

- Visual inspection of the exterior of the structures where accessible. Observations were made from outside the ICF concrete wall due to "Danger – High Voltage" warning tape and signs.
- Assessment of collected survey data to date for indications of trends in the movement of the structure.
- Review of previously referenced documents listed in Table 5.10-1.

- Identification of relative surface soil densities (native soil, engineered fill, and limestone gravel pavement) as determined by hand probing.
- Observations and documentation of water accumulations and flows in subsurface system components (manholes and concrete trenches).

Additional investigations were performed. These included the following non-invasive geophysical and invasive geotechnical investigations:

- Seismic surveys (seismic refraction and refraction micro-tremor). (Test reports were not available at the time of Revision 0.)
- Geotechnical investigations including test borings with field tests (SPT and CPT) and laboratory tests. Note that OPPD required vacuum excavation for the first 10 ft of proposed test holes to avoid utility conflicts. Therefore, test reports will not address soil conditions in the upper 10 ft of site and locations where shallow utilities exist. (Test reports were not available at the time of Revision 0.)
- Inclinometers had not been installed at the time of Revision 0 and therefore no data were available. Inclinometer data is not required to reach a confident conclusion but is used to supplement the other data used to reach the conclusion.

5.10.3.2 Assessment Procedures Not Completed

Assessments of the Turbine Building South Switchyard that were not completed include the following:

- The interior of the cable trench was not observed except for visual observations that were possible from outside the wall because they were in an area labeled "Danger – High Voltage."
- No excavation to inspect underground systems and conditions was performed because the underground systems are located beneath the equipment in the switchyard.
- No probing or soil investigations were done within the ICF wall at the time of Revision 0 because the area was labeled "Danger – High Voltage."

5.10.4 Analysis

Identified PFMs were initially reviewed as discussed in Section 3.0. The review considered the preliminary information available from OPPD data files and from initial walk-down observations. Eleven PFMs associated with five different Triggering Mechanisms were determined to be "non-credible" for all Priority 1 Structures, as discussed in Section 3.6. The remaining PFMs were carried forward as "credible." After the design review for the structure, the structure observations, and the results of available geotechnical, geophysical, and survey data were analyzed, a number of CPFMs were ruled out as discussed in Section 5.10.4.1. The CPFMs carried forward for detailed assessment are discussed in Section 5.10.4.2.

5.10.4.1 Potential Failure Modes Ruled Out Prior to the Completion of the Detailed Assessment

The ruled-out CPFMs reside in the Not Significant/High Confidence category and for clarity will not be shown in the Potential for Failure/Confidence matrix.

Triggering Mechanism 2 – Surface Erosion

CPFM 2a – Undermining shallow foundation/slab/surfaces
CPFM 2b – Loss of lateral support for pile foundation
CPFM 2c – Undermined buried utilities

Reasons for ruling out:

- The Turbine Building South Switchyard is located a sufficient distance away from the riverbank and was inside the perimeter of the Aqua Dam, and was therefore not subjected to surface erosion.
- Surface erosion was not identified in or around the Turbine Building South Switchyard during the field assessments.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3d – Undermining and settlement of shallow foundation/slab (due to river drawdown)

Reason for ruling out:

- The Turbine Building South Switchyard is located a sufficient distance away from the riverbank and was therefore not subjected to subsurface erosion due to river drawdown.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3e – Loss of lateral support for pile foundation (due to river drawdown)

Reason for ruling out:

- The Turbine Building South Switchyard is located a sufficient distance away from the riverbank and was therefore not subjected to subsurface erosion due to river drawdown.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3f – Undermined buried utilities (due to river drawdown)

Reason for ruling out:

- The Turbine Building South Switchyard is located a sufficient distance away from the riverbank and was therefore not subjected to subsurface erosion due to river drawdown.

Triggering Mechanism 5 – Hydrodynamic Loading

CPFM 5a – Overturning
CPFM 5b – Sliding
CPFM 5c – Wall failure in flexure
CPFM 5d – Wall failure in shear
CPFM 5e – Damage by debris
CPFM 5f – Excess deflection

Reasons for ruling out:

- The Turbine Building South Switchyard was protected from floodwater by an Aqua Dam for the majority of the 2011 flood; however, the Aqua Dam failed for a short period of time

because it was damaged, which allowed floodwater to enter the area inside the perimeter of the Aqua Dam.
- Visual observation did not identify distress to the structure that can be attributed to these CPFMs.

Triggering Mechanism 6 – Buoyancy, Uplift Forces on Structures
CPFM 6a – Fail tension piles

Reason for ruling out:

- The equipment foundations within the Turbine Building South Switchyard that have either steel or concrete piles have pile caps near the ground surface and were not subjected to net buoyancy uplift forces.

Triggering Mechanism 6 – Buoyancy, Uplift Forces on Structures
CPFM 6b – Cracked slab, loss of structural support

Reasons for ruling out:

- The equipment foundations within the Turbine Building South Switchyard that have either steel or concrete piles have pile caps near the ground surface and were not subjected to net buoyancy uplift forces.
- The cable trench was designed with drain holes within the trench walls and a foundation drain system complete with free-draining backfill on the walls and below the slab. Therefore, the trench was not subjected to buoyancy forces.

Triggering Mechanism 6 – Buoyancy, Uplift Forces on Structures
CPFM 6c – Displaced structure/broken connections

Reasons for ruling out:

- The equipment foundations within the Turbine Building South Switchyard that have either steel or concrete piles have pile caps near the ground surface and were not subject to net buoyancy uplift forces.
- The cable trench was designed with drain holes within the trench walls and a foundation drain system complete with free-draining backfill on the walls and below the slab. Therefore, the trench was not subjected to buoyancy forces.

Triggering Mechanism 7 – Soil Collapse (first time wetting)

CPFM 7a – Cracked slab, differential settlement of shallow foundation, loss of structural support
CPFM 7b – Displaced structure/broken connections
CPFM 7c – General site settlement
CPFM 7d – Piles buckling from down drag

Reason for ruling out:

- The peak flood elevation prior to 2011 was 1003.3 ft, which occurred in 1993. The peak flood elevation in 2011 was approximately 1006.9 ft. Elevations in the South Turbine Switchyard are such that the area would not be subjected to first time wetting.

Triggering Mechanism 10 – Machine/Vibration-Induced Liquefaction

CPFM 10a – Cracked slab, differential settlement of shallow foundation, loss of structural support

Reasons for ruling out:

- There is no permanent equipment within the Turbine Building South Switchyard that has the capacity to produce significant dynamic forces due to vibration.
- Temporary pumping equipment located on the ground inside the perimeter of the Aqua Dam produced minimal localized vibrations and therefore was deemed to have inconsequential effect.
- Liquefaction was not observed near the Turbine Building South Switchyard.

Triggering Mechanism 10 – Machine/Vibration-Induced Liquefaction

CPFM 10b – Displaced structure/broken connections

Reasons for ruling out:

- There is no permanent equipment within the Turbine Building South Switchyard that has the capacity to produce significant dynamic forces due to vibration.
- Temporary pumping equipment located on the ground inside the perimeter of the Aqua Dam produced minimal localized vibrations and therefore was deemed to have inconsequential effect.
- No broken structural connections or structural displacement were observed.
- Liquefaction was not observed near the Turbine Building South Switchyard.

Triggering Mechanism 10 – Machine/Vibration-Induced Liquefaction

CPFM 10d – Pile/pile group instability

Reasons for ruling out:

- There is no permanent equipment within the Turbine Building South Switchyard that has the capacity to produce significant dynamic forces due to vibration.
- Temporary pumping equipment located on the ground inside the perimeter of the Aqua Dam perimeter produced minimal localized vibrations and therefore was deemed to have inconsequential effect.

- Liquefaction was not observed near the Turbine Building South Switchyard.

Triggering Mechanism 11 – Loss of Soil Strength due to Static Liquefaction or Upward Seepage

CPFM 11a – Cracked slab, differential settlement of shallow foundation, loss of structural support

Reason for ruling out:

- Visual observations and survey measurements indicate no structure movement. Therefore, differential settlement and loss of structural support did not occur at the observed structures.

Triggering Mechanism 11 – Loss of Soil Strength due to Static Liquefaction or Upward Seepage

CPFM 11b – Displaced structure/broken connections

Reasons for ruling out:

- Visual observations and survey measurements indicate no structure movement. Therefore, degradation that can be attributed to this CPFM did not occur near the Turbine Building South Switchyard.
- No instances of broken connections were observed.

Triggering Mechanism 11 – Loss of Soil Strength due to Static Liquefaction or Upward Seepage

CPFM 11d – Pile/pile group instability

Reason for ruling out:

- Visual observations and survey measurements indicate no structure movement. Therefore, degradation that can be attributed to this CPFM did not occur near the Turbine Building South Switchyard.

Triggering Mechanism 12 – Rapid Drawdown

CPFM 12a – River bank slope failure and undermining surrounding structures
CPFM 12b – Lateral spreading

Reason for ruling out:

- The Turbine Building South Switchyard is a sufficient distance away from the riverbank and was therefore not subjected to riverbank slope failure or lateral spreading because of rapid drawdown.

Triggering Mechanism 13 – Submergence

CPFM 13a – Corrosion of underground utilities
CPFM 13b – Corrosion of structural elements

Reason for ruling out:

- The Turbine Building South Switchyard has not been subjected to corrosive circumstances that would be considered beyond the normal conditions. The Turbine Building South Switchyard was protected from floodwater by an Aqua Dam for the majority of the 2011 flood; however, the Aqua Dam failed for a short period of time because it was damaged, which allowed floodwater to enter the area inside the perimeter of the Aqua Dam.

Triggering Mechanism 14 – Frost Effects

CPFM 14a – Heaving, crushing, or displacement

Reasons for ruling out:

- The equipment foundations within the Turbine Building South Switchyard have either steel or concrete piles with pile caps near the ground surface. The piles have an anchor plate with anchor rods developed into the pile cap, indicating a positive tension connection. In addition, the frost uplift on the pile caps will not be different than the condition prior to the flood.
- The cable trench was designed with drain holes within the trench walls and a foundation drain system complete with free-draining backfill on the walls and below the slab. Therefore, the trench is not subjected to frost effects.

5.10.4.2 Detailed Assessment of Credible Potential Failure Modes

The following CPFMs are the only CPFMs carried forward for detailed assessment for the Turbine Building South Switchyard as a result of the 2011 flood. This detailed assessment is provided below.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3a – Undermining and settlement of shallow foundation/slab/surfaces (due to pumping)

The nearby Turbine Building has a documented history of a void below the foundation slab and groundwater drainage to broken floor and condensate drains. The floodwater elevations associated with the 2011 flood have increased the hydraulic head feeding water to the broken pipes in the floor drain system. The sump in the Turbine Building and Manhole MH-5 were continually pumped, maintaining the hydraulic gradient between saturated soils and broken pipes in the system.

The Triggering Mechanism and CPFM could then occur as follows: the hydraulic gradient begins erosion or increases erosion of surrounding soils. Seepage is unfiltered and erosion continues unarrested. Erosion extends out beneath the Turbine Building or from Manhole MH-5 and extends toward the Turbine Building South Switchyard. Voids form under utilities and structures in the Turbine Building South Switchyard or adjacent to the Turbine Building

South Switchyard. Settlement of non-pile-supported structures and utilities occurs and causes distress or failure of improvements, utilities, or systems.

Field observations indicated that the switch foundation slab located on the southwest corner of the west cable trench is currently settling on the east side adjacent to the conduit trench, resulting in tilting of the equipment.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with this CPFM for the Turbine Building South Switchyard.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
Documented void under the foundation slab of the adjacent Turbine Building.	There have been no observed signs of structural distress in the CMU screen wall.
Differential settlement has occurred on the switch foundation located on the southwest corner of the west cable trench.	Surficial voids and other piping features were not observed during site inspections in the Turbine Building Switchyard or adjacent areas, except for the settlement noted near the switch foundation, and the sand boil/piping feature observed in the missile room of the Auxiliary Building.
Pavement failures were observed east of the Turbine Building.	
Data Gaps: • Survey data to track trends in vertical movement of the CMU screen wall and cable trench. • Visual inspection of the cable trench was not possible because the trench is located in an area that was not accessible due to safety tape. Where the trench was accessible, temporary pumps were drawing water from the bottom of the trench, and the inside was covered with sediment. • Existence, size, and location of voids. • Seismic refraction data are not yet available.	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

Many indicators for the CPFM have been observed. Pumping to remove water from the Turbine Building sump and from Manhole MH-5 carried through a system of broken pipes and granular trench backfill. This provides the system for this CPFM. Known voids exist under the adjacent Turbine Building. Settlement issues have been observed in the Paved Access Area between the Service Building and the Intake Structure. Settlement of the switch foundation slab near the southwest corner of the west cable trench has already occurred due to this CPFM. Therefore, the potential that degradation due to this CPFM is occurring due to the 2011 flood is high.

Implication

Settlement of the switch foundation slab near the southwest corner of the west cable trench has already occurred due to this CPFM. The CMU wall is supported on shallow foundations. This

CPFM could affect the shallow foundation systems. The CMU wall could show signs of distress, and wall failure could damage adjacent facilities or equipment. Therefore, the implication of the potential degradation for this CPFM is high due to the nature of the adjacent structure.

Confidence

Observations have shown that settlement has occurred on the switch foundation slab. Subsurface erosion is believed to have occurred under the adjacent Turbine Building foundation and at some nearby areas of pavement.

Therefore, the confidence in the above assessment is high, indicating that repairs and more data are necessary.

Summary

For CPFM 3a, as discussed above, the combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "significant" category. There is high confidence that there has been significant degradation to the soil surrounding the Turbine Building South Switchyard. Repairs and further monitoring are needed.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3b – Loss of lateral support for pile foundation (due to pumping)

The nearby Turbine Building has a documented history of a void below the foundation slab and groundwater drainage to broken floor and condensate drains. The floodwater elevations associated with the 2011 flood have increased the hydraulic head feeding water to the broken pipes in the floor drain system. The sump in the Turbine Building and Manhole MH-5 were continually pumped, maintaining the hydraulic gradient between saturated soils and broken pipes in the system.

The Triggering Mechanism and CPFM could then occur as follows: the hydraulic gradient begins erosion or increases erosion of surrounding soils. Seepage is unfiltered and erosion continues unarrested. Erosion extends out beneath the Turbine Building or Manhole MH-5 and extends toward the Turbine Building South Switchyard. Voids form under utilities and structures in the Turbine Building South Switchyard or adjacent to the Turbine Building South Switchyard. Settlement of non-pile-supported structures and utilities occurs and causes distress or failure of improvements, utilities, or systems.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with this CPFM for the Turbine Building South Switchyard.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
Documented void under the foundation slab of the adjacent Turbine Building.	Review of survey data indicates that there have been no observed signs of movement of the pile foundations.
Data Gaps: • Existence, size, and location of voids. • Seismic refraction data are not yet available.	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

Many indicators for the CPFM have been observed. Pumping to remove water from the Turbine Building sump and from Manhole MH-5 carried through a system of broken pipes and granular trench backfill. This provides the system for this CPFM. Known voids exist under the adjacent Turbine Building. Settlement issues have been observed in the Paved Access Area between the Service Building and the Intake Structure. Therefore, the potential that degradation due to this CPFM is occurring due to the 2011 flood is high.

Implication

Loss of lateral support for the pile supported foundations has the potential to cause structural instability of the foundations for the transformers. Therefore, the implication of the potential degradation for this CPFM is high.

Confidence

Subsurface erosion is believed to have occurred under the adjacent Turbine Building foundation and at some nearby areas of pavement. However, there are insufficient data on the existence, size and location of voids to determine whether this CPFM has or will occur at this location.

Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFM 3b, as discussed above, the combined consideration of the potential for degradation and the implications of that degradation to the structure puts it in the "significant" category. There is low confidence that there has been significant degradation to the soil surrounding the Turbine Building South Switchyard due to the lack of test data available at this time. More data or continued monitoring and inspections are needed.

Triggering Mechanism 3 – Subsurface Erosion/Piping
CPFM 3c – Undermined buried utilities (due to pumping)

The nearby Turbine Building has a documented history of a void below the foundation slab with a potential for increased erosion with greater external water head (see Section 5.8).

The Triggering Mechanism and CPFM could then occur as follows: there is a potential for the previously documented void to erode larger voids under the Turbine Building and out to the surrounding structures. Buried utilities within the Turbine Building South Switchyard include cable trenches, ductbanks, underdrains, and storm drain pipes. Three fire protection system piping is routed beneath the Turbine Building South Switchyard, just west of Transformer T1. The Aqua Dam was placed over the fire protection system piping near where it is routed into the Turbine Building. This provides a possible flow path directed toward the Turbine Building. Connectivity is possible to flow paths feeding the broken floor and condensate drain pipes in the basement.

The following table describes observed distress indicators and other data that would increase or decrease the potential for degradation associated with this CPFM for the Turbine Building South Switchyard.

Adverse (Degradation/Direct Floodwater Impact More Likely)	Favorable (Degradation/Direct Floodwater Impact Less Likely)
Documented void under the foundation slab of the adjacent Turbine Building.	There have been no observed signs of structural distress in the CMU screen wall.
Differential settlement has occurred on the switch foundation located on the southwest corner of the west cable trench.	
Data Gaps: • Visual inspection of the cable trench was not possible because the trench is located in an area that was not accessible due to safety tape. Where the trench was accessible, temporary pumps were drawing water from the bottom of the trench, and the inside was covered with sediment. • Existence, size, and location of voids. • Seismic refraction data are not yet available.	

Conclusion

Significance

Potential for Degradation/Direct Floodwater Impact

Many indicators for the CPFM have been observed. Pumping to remove water from the Turbine Building sump and from Manhole MH-5 carried through a system of broken pipes and granular trench backfill. This provides the system for this CPFM. Known voids exist under the adjacent Turbine Building. Settlement issues have been observed in the Paved Access Area between the Service Building and the Intake Structure. Therefore, the potential that degradation due to this CPFM is occurring due to the 2011 flood is high.

Implication

A large number of utilities are buried under the Turbine Building South Switchyard, which is adjacent to documented indicators in the Turbine Building. The occurrence of this CPFM could negatively impact integrity or intended function of a number of buried utilities near the Turbine Building South Switchyard. Therefore, the implication of the potential degradation for this CPFM is high.

Confidence

Subsurface erosion is known to have occurred under the adjacent Turbine Building foundation. With the increased head pressure due to the 2011 flood, the amount of water moving through the system has potentially increased, which in turn increases the likelihood of instigating subsurface erosion in the Turbine Building South Switchyard adjacent to the Turbine Building. However, there are insufficient data on the existence, size and location of possible voids to determine whether this CPFM has or will occur.

Therefore, the confidence in the above assessment is low, which means more data are necessary to draw a conclusion.

Summary

For CPFM 3c, as discussed above, the combined consideration of the potential for degradation and the implications of that degradation to a structure of this type puts it in the "significant" category. There is low confidence that there has been significant degradation to the soil surrounding the Turbine Building South Switchyard due to the lack of test data available at this time. More data or continued monitoring and inspections are needed.

5.10.5 Results and Conclusions

The CPFMs evaluated for the Turbine Building South Switchyard are presented in the following matrix, which shows the rating for the significance and the level of confidence in the evaluation.

	Low Confidence (Insufficient Data)	High Confidence (Sufficient Data)
Potential for Failure **Significant**	CPFM 3b CPFM 3c	CPFM 3a
Potential for Failure **Not Significant**		

5.10.6 Recommended Actions

The following actions are recommended for the Turbine Building South Switchyard.

The settlement of the switch foundation slab located on the southwest corner of the west cable trench should be corrected.

The CMU wall should be observed by OPPD on a regular basis for signs of distress such as cracking or tipping.

Given the Low Confidence rating for CPFMs 3b and 3c, continued monitoring is recommended to include a continuation of the elevation surveys of the previously identified targets on this structure and surrounding site. The purpose is to monitor for signs of structure distress and movement or changes in soil conditions around the structure. The results of this monitoring will be used to increase the confidence in the assessment results. Elevation surveys should be performed weekly for 4 weeks and biweekly until December 31, 2011. At the time of Revision 0, groundwater levels had not yet stabilized to nominal normal levels. Therefore, it is possible that new distress indicators could still develop. If new distress indicators are observed before December 31, 2011, appropriate HDR personnel should be notified immediately to determine whether an immediate inspection or assessment

should be conducted. Observation of new distress indicators might result in a modification of the recommendations for this structure.

Further forensic investigations and physical modifications are recommended to address CPFMs 3a, 3b, and 3c for the Turbine Building South Switchyard. CPFM 3a, 3b, and 3c are associated with unfiltered flow of groundwater into the Turbine Building basement drain piping system (KDI #1). These recommendations are described in detail in Section 4.1.3. CPFM 3a is associated with the distress in and near the Paved Access Area between the Intake Structure and the Service Building (KDI #2). These recommendations are described in detail in Section 4.2.5.

5.10.7 Updates Since Revision 0

Revision 0 of this Assessment Report was submitted to OPPD on October 14, 2011. Revision 0 presented the results of preliminary assessments for each Priority 1 Structure. These assessments were incomplete in Revision 0 because the forensic investigation and/or monitoring for most of the Priority 1 Structures was not completed by the submittal date. This revision of this Assessment Report includes the results of additional forensic investigation and monitoring to date for this structure as described below.

5.10.7.1 Additional Data Available

The following additional data were available for the Turbine Building South Switchyard for Revisions 1 and 2 of this Assessment Report:

- Results of KDI #1 forensic investigation (see Section 4.1)
- Results of KDI #2 forensic investigation (see Section 4.2)
- Assessment teams from HDR on site for continued monitoring of the KDIs have visually inspected the cable trenches and CMU wall where visible outside the area marked "Danger – High Voltage" and the settlement of the switch foundation slab near the southwest corner of the west cable trench.
- Additional groundwater monitoring well and river stage level data from OPPD.
- Results of FWD investigation by AET (see Attachment 6B).
- Results of geophysical investigation by Geotechnology (see Attachment 6C).
- Results of continued survey by LRA (see Attachment 6E).

5.10.7.2 Additional Analysis

The following analysis of additional data was conducted for the Turbine Building South Switchyard:

- Groundwater monitoring well and river stage level data from OPPD.

  Data shows that the river and groundwater have returned to nominal normal levels.

- Results of FWD investigation by AET.

  FWD and associated GPR testing performed in the Paved Access Area identified anomalies such as soft clay and broken pavement. Additional ground truthing of the investigation results were performed as part of the KDI #2 additional investigations.

- Results of geophysical investigation by Geotechnology.

  Seismic Refraction and Seismic ReMi tests performed around the outside perimeter of the power block as part of KDI #2 identified deep anomalies that could be gravel, soft clay, loose sand, or possibly voids.

- Results of geotechnical investigation by Thiele Geotech.

  Six test borings were drilled, with continuous sampling of the soil encountered, to ground truth the Geotechnology seismic investigation results as part of the KDI #2 forensic investigation. Test bore holes were located to penetrate the deep anomalies identified in the seismic investigation. The test boring data did not show any piping voids or very soft/very loose conditions that might be indicative of subsurface erosion/piping or related material loss or movement.

  All of the SPT and CPT test results conducted for this Assessment Report were compared to similar data from numerous other geotechnical investigations that have been conducted on the FCS site in previous years. This comparison did not identify substantial changes to the soil strength and stiffness over that time period. SPT and CPT test results were not performed in the top 10 ft to protect existing utilities.

- Results of continued survey by LRA.

  Survey data to date compared to the original baseline surveys have not exceeded the accuracy range of the surveying equipment. Therefore, deformation at the monitored locations, since the survey baseline was shot, has not occurred.

Follow-up inspections since Revision 0 of the report have noted that the standing water and sediment has been removed from the cable trenches around the switchyard.. The bottom of the cable trench was able to be viewed beyond the area labeled "Danger – High Voltage" but no additional information regarding the trenches was obtained from this observation. The observation also noted no visible distress or cracking of the CMU wall.

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3a – Undermining and settlement of shallow foundation/slab/surfaces (due to pumping)

CPFM 3a for the Turbine Building South Switchyard as it relates to the settlement of the switch foundation slab near the southwest corner of the west cable trench is not associated with KDIs. Additional inspection since Revision 0 indicates that the switch foundation slab was not remediated as recommended. The results of the additional forensic investigation show that this CPFM is not ruled out; therefore, the recommendation from Revision 0 has not changed. Therefore, assuming that OPPD implements the recommended physical modification, this CPFM is moved to the quadrant of the matrix representing "No Further Action Recommended Related to the 2011 Flood."

Triggering Mechanism 3 – Subsurface Erosion/Piping

CPFM 3b - Loss of lateral support for pile foundation (due to pumping)
CPFM 3c - Undermined buried utilities (due to pumping)

CPFMs 3b and 3c for the Turbine Building South Switchyard are associated with KDI #1. Section 4.1 and 8.3 presents the results of additional forensic investigation that was conducted to ascertain whether these CPFMs could be ruled out. The results of the additional forensic investigations show that if the recommendations for physical modifications in KDI #1 are implemented that this CPFM is ruled out. Therefore, these CPFMs are moved to the quadrant of the matrix representing "No Further Action Recommended Related to the 2011 Flood."

5.10.7.3 Revised Results

The CPFMs evaluated for the Turbine Building South Switchyard are presented in the following matrix, which shows the rating for the significance and the level of confidence in the evaluation. Note that the placement of CPFM 3a in the "No Further Action Recommended Related to the 2011 Flood" is dependant on the remediation of the switch foundation slab located near the southwest corner of the west cable trench.

	Low Confidence (Insufficient Data)	High Confidence (Sufficient Data)
Potential for Failure **Significant**		
Potential for Failure **Not Significant**		CPFM 3a CPFM 3b CPFM 3c

5.10.7.4 Conclusions

In the assessment of the FCS Structures, the first step was to develop a list of all Triggering Mechanisms and PFMs that could have occurred due to the prolonged inundation of the FCS site during the 2011 Missouri River flood and could have negatively impacted these structures. The next step was to use data from various investigations, including systematic observation of the structures over time, either to eliminate the Triggering Mechanisms and PFMs from the list or to recommend further investigation and/or physical modifications to remove them from the list for any particular structure. Because all CPFMs for the Turbine Building South Switchyard other than CPFMs 3a, 3b, and 3c had been ruled out prior to Revision 1, because CPFM 3a will be ruled out upon completion of the remediation to the switch foundation slab described above, and because CPFMs 3b and 3c will be ruled out when the physical modifications recommended for KDI #1 in Section 4.1 and 8.3, no Triggering Mechanisms and their associated PFMs will remain credible for the Turbine Building South Switchyard. HDR has concluded that the geotechnical and structural impacts of the 2011 Missouri River flood will be mitigated by the implementation of the physical modifications recommended in this Assessment Report. Therefore, after the implementation of the recommended physical modifications, the potential for failure of this structure due to the flood will not be significant.