INTRODUCTION:
The US97 @ Wickiup Jct (Wickiup Jct.) project proposes to eliminate the last at-grade rail crossing on US 97 in Oregon. Initially, construction funding for the project was estimated at over $25M without a funding source identified. Accordingly, the project was developed in preparation for funds as a “shelf project,” from 2009 until funds were allocated in 2013. The two-season project began construction in early 2016 and by November the contractor had placed 95% of the embankment, completed foundations, walls, and set girders for the new overcrossing.

As construction began again in April 2017, ODOT construction engineers observed settlement measurements over the winter months beyond what was anticipated from the geotechnical design team. In response, ODOT began an investigation to determine the causes of the observed settlement. The purpose of this memo is to describe the geotechnical design process prior to construction, pertinent construction observations; to summarize findings to reduce geotechnical risk in unique geological terrain; and recommendations for the construction project.

DESIGN PROCESS:

Design Acceptance Phase (2009-2011)
Process for the Design Acceptance Phase (DAP) geotechnical design begins at project kick-off. Geologists review available information regarding geology (including available maps) and work with the project team to assess locations of structures and other improvements in order to create a drill plan specific to the needs of the project.

The Wickiup Junction (Jct.) project was kicked off in 2009 and started as a shelf project, with no construction funds. The initial geo investigation included 6 borings that were drilled up to 102 feet deep. The initial borings indicated approximately 50 feet of silty sands underlain by lacustrine deposits. Cone Penetrometer Testing (CPT) was performed in 2 holes to refusal at about 125 feet. Review of Water Reclamation District (WRD) well records indicated depth to bedrock 50 feet to the southeast of the project, and up to 400 feet to the southwest.

The Wickiup Jct. Preliminary Geotechnical Report was completed in 2011, and recommended additional exploration to evaluate the use of spread footings instead of pile supported footings. The DAP Type, Size & Location (TS&L) report recommended a steel bridge superstructure with pile supported footings.

Once the DAP Preliminary Geotechnical Report is completed, the geotechnical team may choose to drill additional borings and perform laboratory tests to further evaluate subsurface conditions. Refined locations for structures and other improvements, as well as value-engineering concepts, may result in the need for additional data.

The Wickiup Jct. project DAP was approved in December 2011. The decision to continue design through Final Plans was requested by the Region Project Management Delivery Team (PDMT) in February 2012. During the Wickiup Jct. preliminary plans phase, the geotechnical team chose to perform 6 additional borings. Two borings were drilled to depths between 15-20 feet and two borings were drilled to a depth of 61 feet. The final foundation and design report was not completed due to permitting delays for another four borings located within railroad and federal lands right of way. The structural designer completed preliminary design for the steel superstructure and began developing plan sheets.

**Advanced Plans Phase (Oct 2012 – Jan 2015)**

After the Preliminary Plans phase is complete, the final foundation design report and preliminary bridge design are essentially complete. However, continued refinements to locations for structures and other improvements, as well as value-engineering concepts, may result in the need for additional structural and geotechnical analysis.

2013 Pre-Advanced Plans Phase (Oct 2012- Oct 2013)

The Wickiup Jct. project Preliminary Plans phase was complete in October 2012. During the same month, the geotechnical design team obtained permits to drill within railroad and federal lands right of way. As a result, four 101-foot deep borings were performed to provide additional foundation design data. The additional geotechnical data provided the opportunity to evaluate the selection of shallow bridge foundations. Analysis of the lacustrine soils associated with a high liquefaction potential layer in collaboration with the State Foundation Engineer began during the Advance Plans phase. The structural engineering advance plan sheets depicted shallow footings. During review of the 2013 Advance Plans package, the team noted that significant cost savings could be made should revisions to the embankment/MSE wall approach geometry be refined.

**Construction Funds Awarded (Dec 2013)**

The project received construction funding of $17M from the Oregon Transportation Commission’s Enhance discretionary funding for the 15-18 STIP. The project team was notified of the construction funding in January 2014. At the same time, the team estimated a $1.5M savings if revisions to the embankment/MSE wall approach geometry shown on the pre-advanced plans could be refined. The project development team met and decided to revise the schedule to allow for another Advance Plans phase package to include the geometric revisions.

2015 Advance Plans Phase (Jan 2014 - Jan 2015)

During review of the first Advance Plans package in October 2013, the team estimated a $1.5M savings if revisions to the embankment/MSE wall approach geometry could be designed. The geometry change required the structural designer to revisit the Bridge TS&L assumptions.

The geotechnical design team continued to evaluate the use of shallow bridge foundations in the vicinity of lacustrine soils with high liquefaction potential in collaboration with the State Foundation Engineer. The structural designer prepared a revised Bridge TS&L report based on the revised embankment/MSE wall approach geometry. Due to the decrease in required span
lengths, the bridge type was revised from a steel bridge to a concrete bridge, contributing to
the savings on the project. In addition, coordination with the railroad resulted in a modified
crash wall on the center bent. Coordination with the State Foundation Engineer continued, and
a site-specific design deviation for liquefaction mitigation received approval from the State
Bridge Engineer to use shallow footings for the structure. At each bridge abutment, MSE Walls
with shallow foundations were to be supported within the surficial 50-foot thick dense silty-sand
layer.

**Final Plans Phase (Jan 2015 – September 2015)**
During the Final Plans Phase, the project development team performs final Quality Control (QC) of
project documents. Statements of Technical Quality (STQs) are completed, mylar plan sheets and
special provisions are sealed by the Engineer of Record. For the Wickiup Jct. project, this phase was
extended beyond the typical 2-3 months to allow for additional coordination with the railroad/DOJ to
execute signed agreements, as well as an additional crash wall design on the east abutment (Bent 1)
MSE wall.

**Plans, Specifications, and Estimate (PS&E) Phase (Oct 2015)**
This phase includes compilation of all documents required by ODOT’s Office of Project (OPL) Letting
in order to review, advertise and bid the project. The Wickiup Jct. project was accepted by OPL on
Oct 12, 2015.

**Bid Opening (December 2015)**
This milestone pertains to the date that contractor’s bids are opened to award to apparent lowest
bidder. The lowest bidder for the Wickiup Jct. project was High Desert Aggregate & Paving, for
$10.98M on Dec 10, 2015.

**CONSTRUCTION OBSERVATIONS:**

**Settlement Data**
MSE wall construction at Bents 1 and 3 was completed in August 2016. Embankment adjacent to the
MSE walls was 95% complete in September 2016. Top of concrete girder elevations were projected
from the top of beam seat locations in September 2016. Girders were placed for the two-span bridge
in November 2016, before the winter shut down. As the contractor began work again in the Spring
2017, the top of girder elevation measurements were taken again in April 2017. During the
approximately 6-month period between measurements, average settlements of approximately 3-1/2
inches and 2 inches were observed in Bent 1 and 3, respectively. These measurements were
consistent with typical behavior of embankment soils, where settlement occurs in the first phases of
construction and slows down over time.
Additional measurements were taken again 5 weeks later, in May 2017. These measurements
indicated increased settlement rates had occurred after the initial phases of construction. Total
average settlements of approximately 5-1/2 inches and 3-1/2 inches were observed in Bent 1 and 3,
respectively.

**Geotechnical Data**
The increased rate of unusual settlement observed over 5 weeks from April to May 2017 prompted
ODOT to suspend the contractor’s bridge work and to perform a geotechnical assessment. To
stabilize the observed settlement activity, ODOT’s geotechnical team recommended removal of
embankment adjacent to the MSE walls at Bent 1 and 3. Drilling and installation of geotechnical
monitoring equipment was also performed.
The five geotechnical borings drilled in June 2017 indicated the presence of an approximately 50-foot layer of silty sand, underlain by approximately 175 feet of lacustrine material, underlain by 30+ feet of course sands/fine gravels. The recent investigation differed from the initial boring data and Cone Penetration Tests that indicated the presence of a lacustrine layer that was approximately 75 feet thick.

Samples from the recent 5 geotechnical borings were taken to laboratories for testing. Initially, it was suspected that plant-based organic clayey lake soils with high swelling potential could be causing the unusual settlement. Laboratory testing proved difficult, with soils that became fluid when being prepped for typical testing methods. More advanced testing methods, like X-ray diffraction analysis (XRD) and scanning electron microscopy (SEM) were selected to better understand the unusual chemical, clay mineralogy and organic content.

The tests identified a significant amount of diatoms that have been preserved in-tact beneath the ground surface. Diatoms are a single-celled algae that grow in lakes. They are microscopic in size and cannot be identified by eye. The diatoms observed using the SEM appear to have multiplied rapidly due to favorable conditions within this particular ancient lake environment. This finding was in contrast to geologic maps of the area that do not indicate the presence of diatoms. In contrast, the SEM indicated so many diatoms that they make up 50% of the upper lake deposits and as much as 80% at greater depths.

FINDINGS:
During project development, the geotechnical design team noted that a 75-foot layer of soft lacustrine deposits were present beneath a 50-foot thick dense, silty-sand layer. The recent 5 geotechnical borings indicate the presence of approximately 175-feet of soft lacustrine deposits, comprised of a significant amount (50-80%) of diatoms. This finding was in contrast to geologic maps of the area that do not indicate the presence of diatoms, and marks a significant change in geotechnical observations that were used to design the project.

The unique geologic (diatomaceous) materials are the primary contributor to the unusual settlement observed by ODOT construction engineers in the Spring of 2017. The presence of these deep saturated unconsolidated diatomaceous material that make up 50-80% of the lacustrine deposits are unprecedented in the project area.

ODOT’s Region 4 project delivery team followed geotechnical and structural practices used previously to successfully deliver numerous bridge projects in the Central Oregon area. Even so, additional steps during the project development phase could have been initiated to reduce geotechnical risks, as follows:

- Perform borings to depths beyond Cone Penetrometer Testing (CPT) depths to verify soil conditions. The deepest boring was performed to 102 feet below ground. CPT was performed to approximately 125 feet below ground.
- Ensure collaboration between the foundation engineer and soil embankment engineer on the geotechnical team to evaluate the combined effects of adjacent loads (structural and embankment) on subsurface layers.
- Include formal quality control (QC) of geotechnical and structural foundation designs by qualified staff external to the project team, such as another ODOT Region, ODOT Tech Services or a Consultant.
It is not known whether including the above additional steps in the design process would have resulted in a different outcome for the Wickiup Jct project. Diatomaceous soils are difficult to identify without forensic testing methods such as SEM and XRD. Without these advanced tests, typical embankment settlement mitigation methods (i.e., surcharge loading) would have likely initiated significant long-term secondary consolidation in the deep diatomaceous soils. Rebound behavior during removal of the surcharge loads may have concealed this long-term secondary consolidation until after the construction project was completed.

RECOMMENDATIONS:

Soils that contain saturated unconsolidated diatomaceous material have properties that are very complex and not well understood. These unknowns make certainty in engineering analyses difficult. As such, recommendations for improvements to the soil in order to stabilize future settlement and continue with bridge construction for the Wickiup Jct. project are made with a high degree of uncertainty on how those improvements will perform over time. The extent of the saturated unconsolidated diatomaceous materials are also unknown and require additional study to evaluate alternative alignments for the grade separation.

Unacceptable differential settlement of the bridge girders has occurred, so they will need to be removed. A range of mitigation options are constructible and include various combinations of lightweight fill and viaducts (bridge structures over land). However, the costs for these options appear to be prohibitive within current funding limitations. Additional geotechnical study is required in order to better understand and mitigate the risk of future investments.

A request to decommission the US97 @ Wickiup Jct. (La Pine) Project (C14860) will be presented to the Oregon Transportation Commission at the October 2017 meeting. The request will also include a recommendation to use the remaining construction funds for further geotechnical site analysis, transportation refinement planning, and to scope short-term and long-term alternative improvements within the US97/Wickiup Junction area.

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