SHANNON & WILSON
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

December 9, 2019

Mr. Mike Kobe
Brown & Caldwell
10235 South Jordan Gateway, Suite 300
South Jordan, UT 84095

RE: SETTLEMENT AT PIPING CONNECTIONS TO STRUCTURES, CENTRAL VALLEY WATER RECLAMATION FACILITY, SALT LAKE CITY, UTAH

Dear Mr. Kobe,

At your request, Shannon and Wilson, Inc. has prepared this letter report providing estimated settlement at the connections of pipes to structures for the deep basins for the nutrient upgrade project for the Central Valley Water Reclamation Facility (CVWRF) in Salt Lake City, Utah. This letter report supersedes our October 30, 2019 and November 11, 2019 draft reports, and our September 20, 2019 document regarding the same subject, titled "Piping Backfill Letter".

BACKGROUND INFORMATION

Brown and Caldwell is under contract with Salt Lake City to design and oversee construction of upgrades to the CVWRF. The upgrades will result in the construction of several new structures and create a network of pipes carrying liquid media across the site as it is processed and reclaimed prior to being released from the facility (Figure 1). We understand that the pipes will vary in diameter from 6 to 63 inches depending on use and cross above and below each other in a complex arrangement as the pipes traverse between the various structures. (Figure 2 shows a 3-D view of the underground piping network at one location between Areas 18 and 22.)

Smaller diameter piping (less than about 12 inches in diameter) will typically be located within 10 feet of the ground surface and have flexible, double dresser connections to structures to allow for movement between the structures and the piping. This movement is mainly anticipated by Brown and Caldwell to result from settlement of soil placed as backfill for lower elevation structures that require deep excavations. These smaller diameter pipe connections are not discussed in this letter report.

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The depth of larger diameter piping will vary. Figure 1 indicates that a number of larger diameter connections are planned, ranging in diameter from 28 to 63 inches. Based on the Nutrient Removal CC30B BNR Basins/PEPS/RAS Selector Bid Issue plans by Brown and Caldwell, we understand that the depth of backfill varies at each connection. We understand that the backfill could reach up to 20 feet below some of the large diameter pipe connections. Brown and Caldwell requested our opinion regarding the potential differential movement at these locations in order to design the connection details.

POTENTIAL SETTLEMENT AT LARGE DIAMETER PIPE CONNECTIONS

Shannon and Wilson , Inc. has recommended that the deeper structures, such as the aeration, anaerobic and RAS basins, be designed to be fully compensated (i.e., to limit the gross allowable bearing pressure at the bottom of the mat foundations to less than the current in-situ stress at the same elevation) in order to reduce post-construction settlement from structure loads. However, the unloading of soil (from over-excavation) will induce heave and the reloading from structure loads will cause post-construction settlement to occur. Brown and Caldwell requested that we provide estimated settlements for the large diameter pipeline connections for three scenarios: (1) backfill (2) long-term, static settlement from structure loads, and (3) seismic settlement from the design earthquake event. Each of these scenarios is discussed below. These settlements may be cumulative depending on when the connections are made to the structures, when the backfill is placed, and when the structure loads are placed.

Backfill Settlement

Based on the current plans provided by Brown and Caldwell, we understand up to 20 feet of backfill may be placed below the pipes. In our opinion, well compacted granular backfill (such as Granular Fill as described in our November 6, 2019 draft Blower Building report) can be expected to settle about 0.25 percent of the height of the backfill. Therefore, a 20-foot section of backfill could settle between ½ and ¾ inch. This settlement would be expected to occur within the first year following construction.

Static Settlement

The magnitude of static settlement and the differential movement at and beyond the structure walls will depend on the subsurface conditions at the connection (discussed below) and the construction methods and schedule, which are not fully understood at this time. For example, Brown and Caldwell developed a conceptual excavation plan for construction. The plan involves a combination of sloped excavations and shoring for construction of the deep basins. However, the contractor will not be required to follow the Brown and Caldwell excavation plan. Further, a dewatering plan and the contractor's construction sequencing/schedule are not developed at this time.

Because the basin structures are large and founded on mat foundations up to 25 feet below existing grade, we only considered the deeper CPT soundings that were completed to 100 feet in developing subsurface profiles for settlement analysis rather than shallower borings. In particular, we used SCPT-03 (Intermountain GeoEnvironmental Services, Inc. [IGES]), and SWB-26 and SWB-33 (Shannon and Wilson) which are located within the aeration basin. After a comparison of the three soundings, we determined that analyses using subsurface layering developed from SWB-26 and SCPT-03 would bracket the upper and lower settlement potential for the area. Based on a brief comparison with the subsurface conditions encountered in the borings within the basins and corresponding laboratory test results from boring samples, the results of the CPT settlement analyses appear reasonable.

We made several assumptions in developing our models and completing our analyses, as discussed below.

- We modeled subsurface conditions based on the two deeper CPT soundings completed within the aeration basin. Because of the limited subsurface information in the basins, we used both CPT soundings to develop a potential range of conditions at each basin.
- Because the foundations are fully compensated, we used elastic soil properties.
- We used building structure elevations/depths based on an email provided by Brown and Caldwell (dated October 24, 2019); we used structure sizes as shown on Figure 1.
- We used structure pressures/distributions as provided by Brown and Caldwell (dated October 29, 2019).
- Heave from excavation was not modeled. In our opinion, the size and depth of the basins are such that heave will occur throughout the excavation process. Further, because of the size and depth of these structures, we assumed that all heave would occur prior to reloading.

- We modeled the excavations as being shored to the edge of the structures.

The results of our analyses are attached in Figures 3 through 5, for the RAS Anoxic Basin, Anerobic Basin and Aeration Basin, respectively. Each figure shows the edge of the mat and the total settlement anticipated based on the pressures provided by Brown and Caldwell. The differential settlement plots show the difference in settlement between adjacent nodes on the corresponding total settlement plot.

As a result of the uncertainty in the construction methods and sequencing, along with the potential for variability in subsurface conditions, these settlement estimates should be considered as approximate values. In general, we anticipate the settlements from structure loading to occur relatively quickly provided the existing state of stress in the ground is not exceeded by the new structure loads. In our opinion, there is a geotechnical advantage to waiting to connect large diameter pipes to structures until after construction and leak testing is completed.

Seismic Settlement

We previously evaluated the total seismic settlement potential across the site and submitted this in a seismic report. This seismic report includes two maps: one with potential total seismic settlement at the ground surface and the other with potential settlement below 22 feet. The total seismic settlement provided in the figures is a combination of liquefaction-induced settlement and dry sand seismic settlement, or in other words, settlement induced by earthquakes above and below the groundwater table, respectively. We understand that Brown and Caldwell will use these maps to evaluate the total seismic settlement using the closest explorations to the pipe of interest.

OTHER CONSIDERATIONS

While the purpose of this letter report was to address settlement potential at the large diameter pipe connections to the deep basins, the following are other considerations for your understanding and planning purposes. Many of these recommendations exist in other documents previously submitted to Brown and Caldwell.

- The contract documents will need to be specific to ensure that the foundations remain in a fully compensated state throughout construction. Submittals with review and approval by the owner are one method to verify this condition.

- Fully compensated foundations have essentially an infinite factor of safety against bearing failure provided that the existing ground surface is in proximity to the current grade. Deep and wide excavations adjacent to the basins should be avoided as the adjacent overburden pressure provides resistance to bearing failure.
- We anticipate that dewatering will be required to construct the deeper basins. Dewatering increases the effective stress in the subsurface, which can induce settlement if there is not a corresponding decrease in stress (from excavation). Because some of the clays appear to be nearly normally consolidated, the stress increase from dewatering can move the soil into virgin consolidation and the resulting settlement be significant (depending on the duration of the dewatering and the drawdown depth).
  - Dewatering within the structure limits prior to construction is not anticipated to be a concern, as any induced settlement from dewatering would not be detrimental to the excavation process. However, being in a dewatered state after construction is completed and during the leak test would likely increase stresses in the subsurface in excess of the stresses from the fully compensated bearing pressures from the structure loads. The magnitude of resulting settlement will depend on the structure pressures during the leak test and the duration of the tests.
  - Dewatering outside of the structure limits can induce settlement that could impact existing utilities and structures. Based on our preliminary estimate, it is possible that several inches of settlement could occur where the groundwater level is lowered more than 10 feet. The amount of dewatering-induced settlement can be reduced if the grades are excavated to the groundwater level prior to commencement of dewatering. However, this may not be possible at many locations at the site, and dewatering may need to be limited or recharge wells required where settlement of existing utilities or structures would be detrimental.
- Due to the relatively deep excavations and soil conditions at those depths, the risk of base heave should be considered by the excavation/shoring contractor. The risk of base heave can be reduced by excavation geometry, shoring depth and/or soil improvement. We recommend that the project specifications be updated to include a requirement for the contractor to evaluate base heave in their shoring/sloping design. We recommend that this be a submittal with required approval by the owner.
- We recommend we be retained to review the contract documents and submittals to verify that our recommendations are understood and being followed.

CLOSURE

Within the limitations of the scope, schedule and budget, the analyses, conclusions and recommendations presented in this geotechnical letter report were prepared in accordance with generally accepted professional geotechnical engineering principles and practices in

this area at the time the report was prepared. We make no other warranty, either express or implied. We assumed that the subsurface conditions in the project area are not significantly different from those disclosed by the explorations performed for this project.

We appreciate the opportunity to be of service to you. If you have questions regarding this letter report, please call me at 801-441-8223.

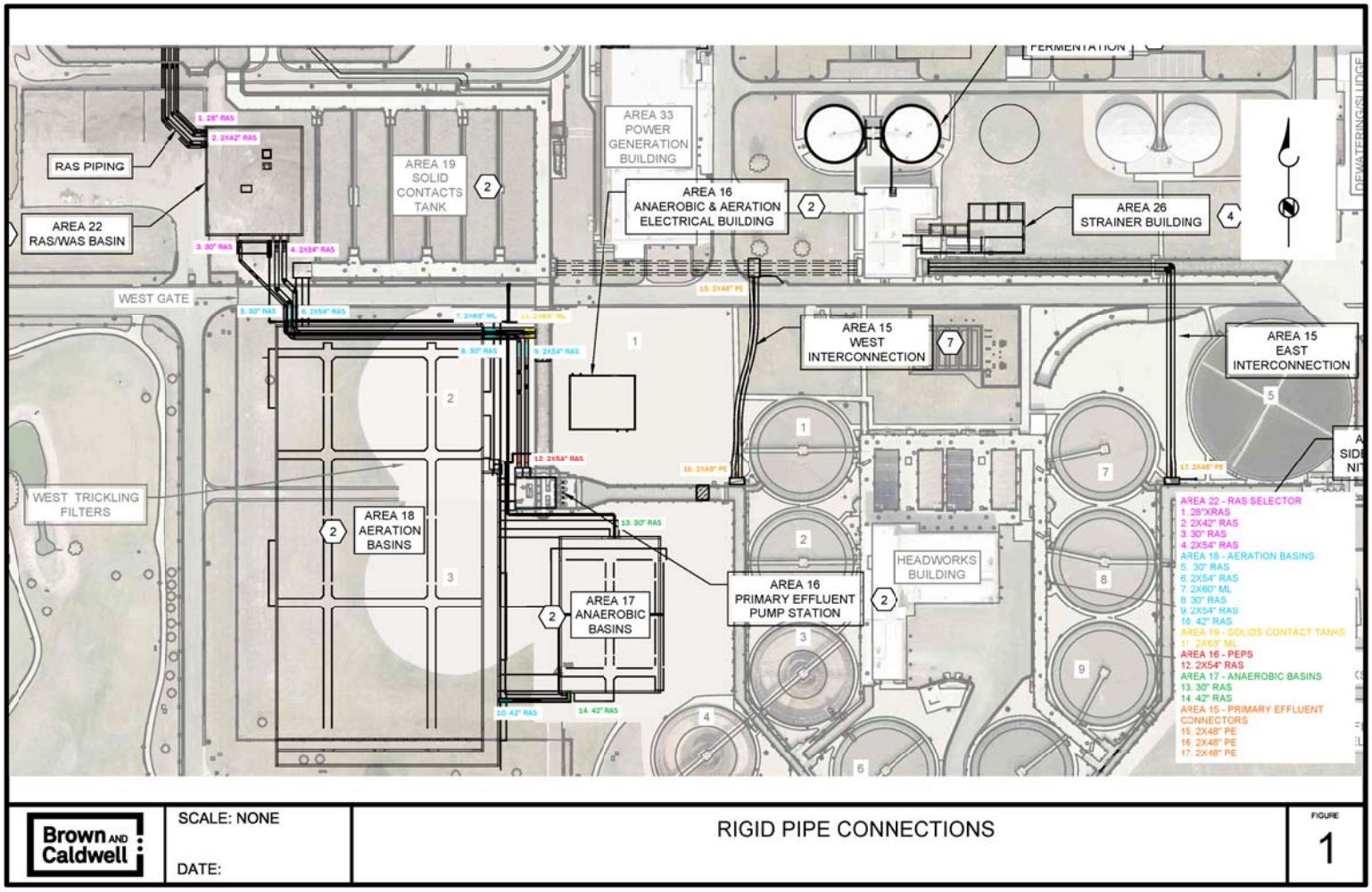
Sincerely,

SHANNON & WILSON, INC.

Corbett M. Hansen, PE
Senior Associate

CMH:GRF/dlj

Enc. Figure 1 – Large Diameter Pipe Connection
Figure 2 – 3D Underground View of Piping
Figure 3 – Building Static Settlement, RAS Anoxic Basin (2 sheets)
Figure 4 – Building Static Settlement, Anerobic Basin (2 sheets)
Figure 5 – Building Static Settlement, Aeration Basin (2 sheets)



Brown AND Caldwell	SCALE: NONE DATE:	RIGID PIPE CONNECTIONS	FIGURE 1

NOTE

Image adapted from Figure 1 - RIGID PIPE CONNECTIONS provided on October 27, 2019.

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LARGE DIAMETER PIPE CONNECTION

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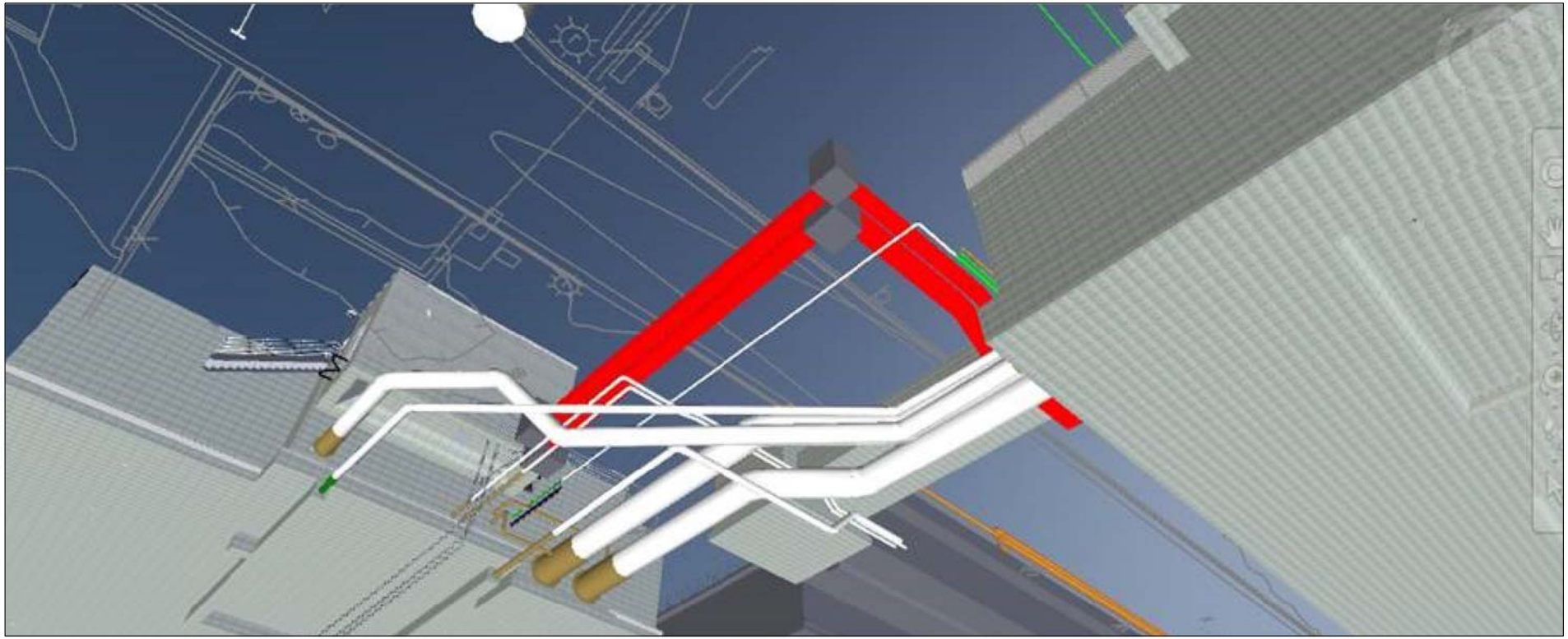
FIG. 1



NOTE

Figure adapted from Brown and Caldwell via email dated August 9, 2019.

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3D UNDERGROUND VIEW OF PIPING

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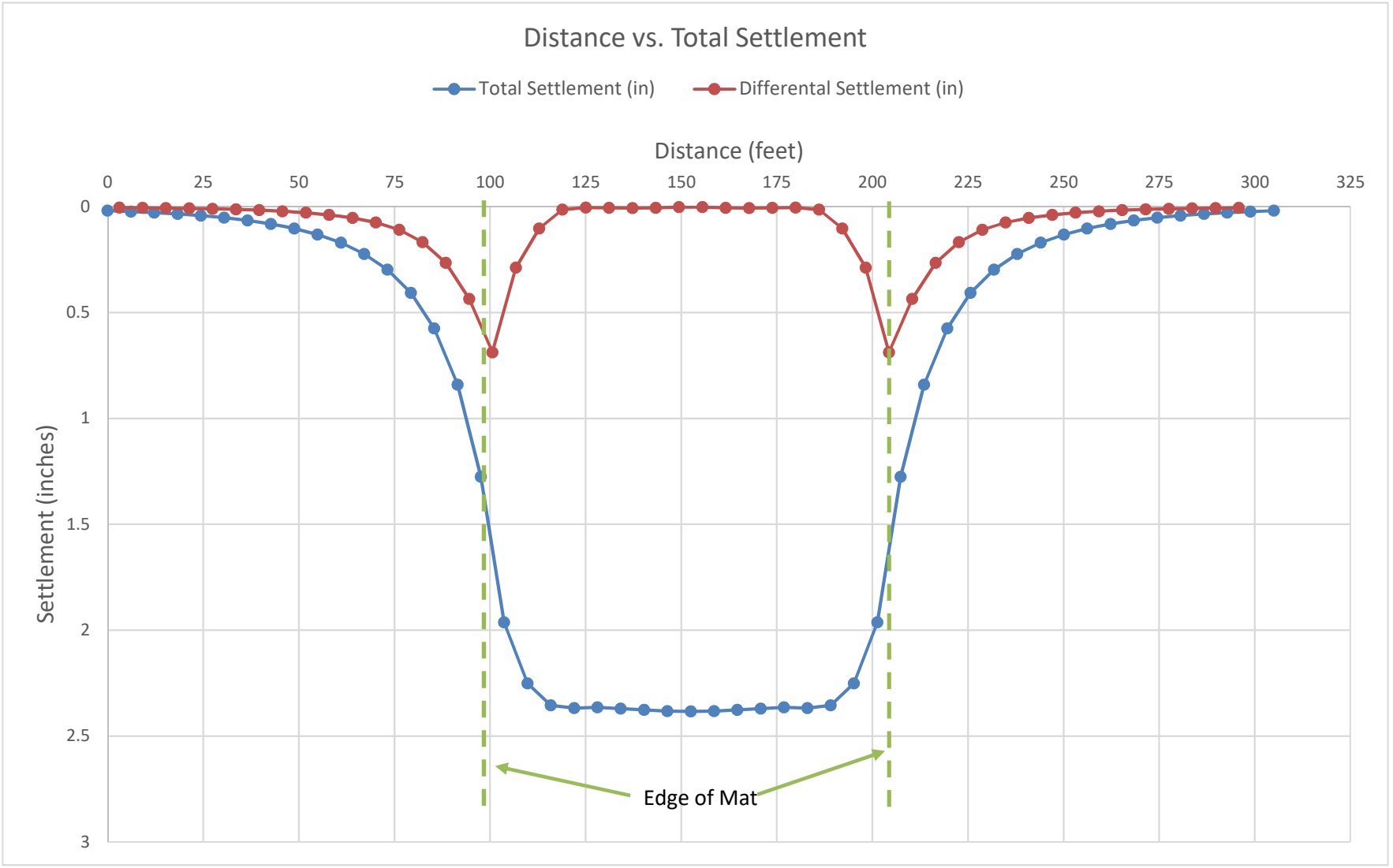
FIG. 2



Note: These settlements were calculated using subsurface exploration SCPT-03.

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BUILDING SETTLEMENT
RAS ANOXIC BASIN

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FIG. 3
Sheet 1 of 2

FIG. 3
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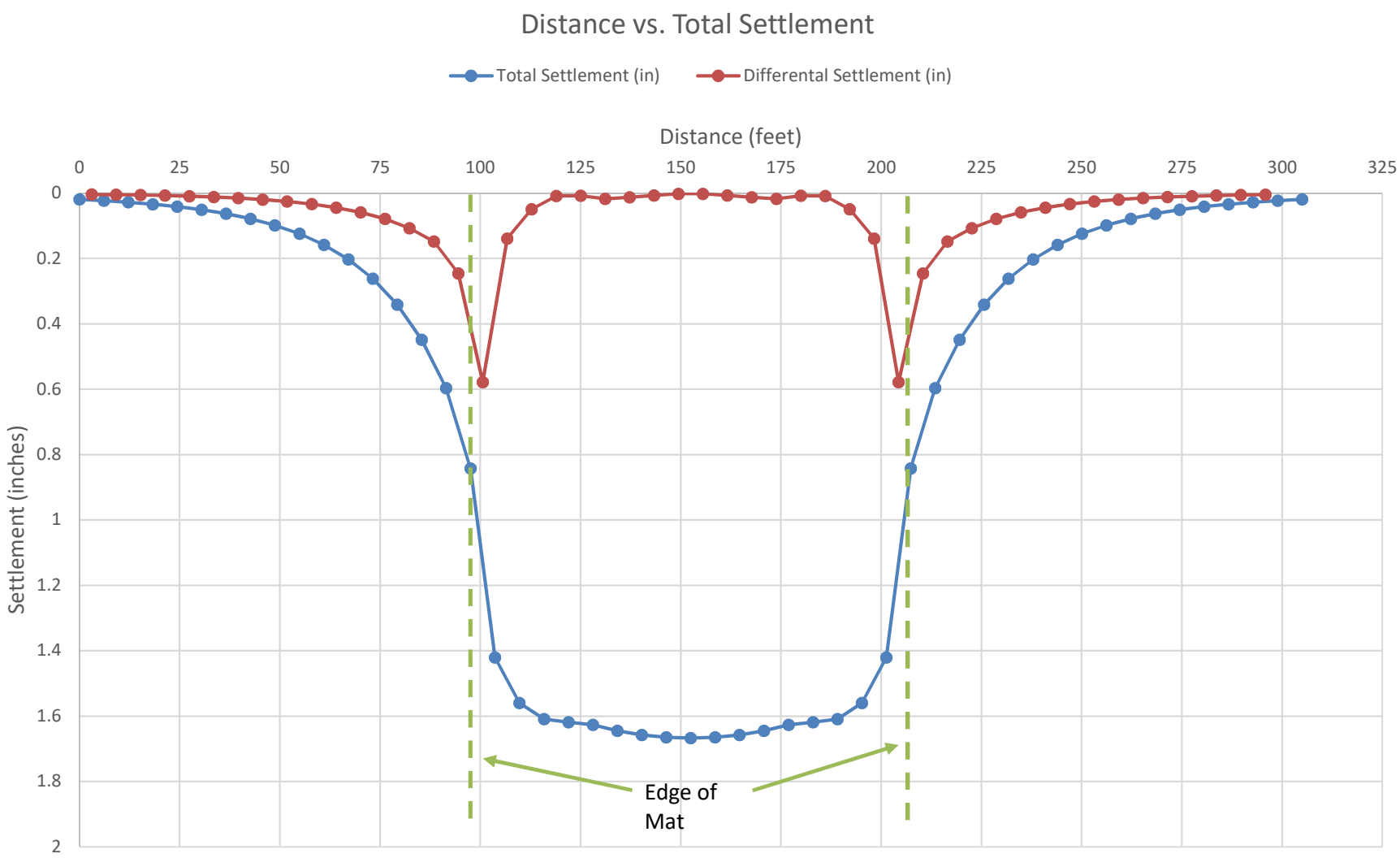

Note: These settlements were calculated using subsurface exploration SWB-26.

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BUILDING SETTLEMENT
RAS ANOXIC BASIN

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FIG. 3
Sheet 2 of 2

FIG. 3
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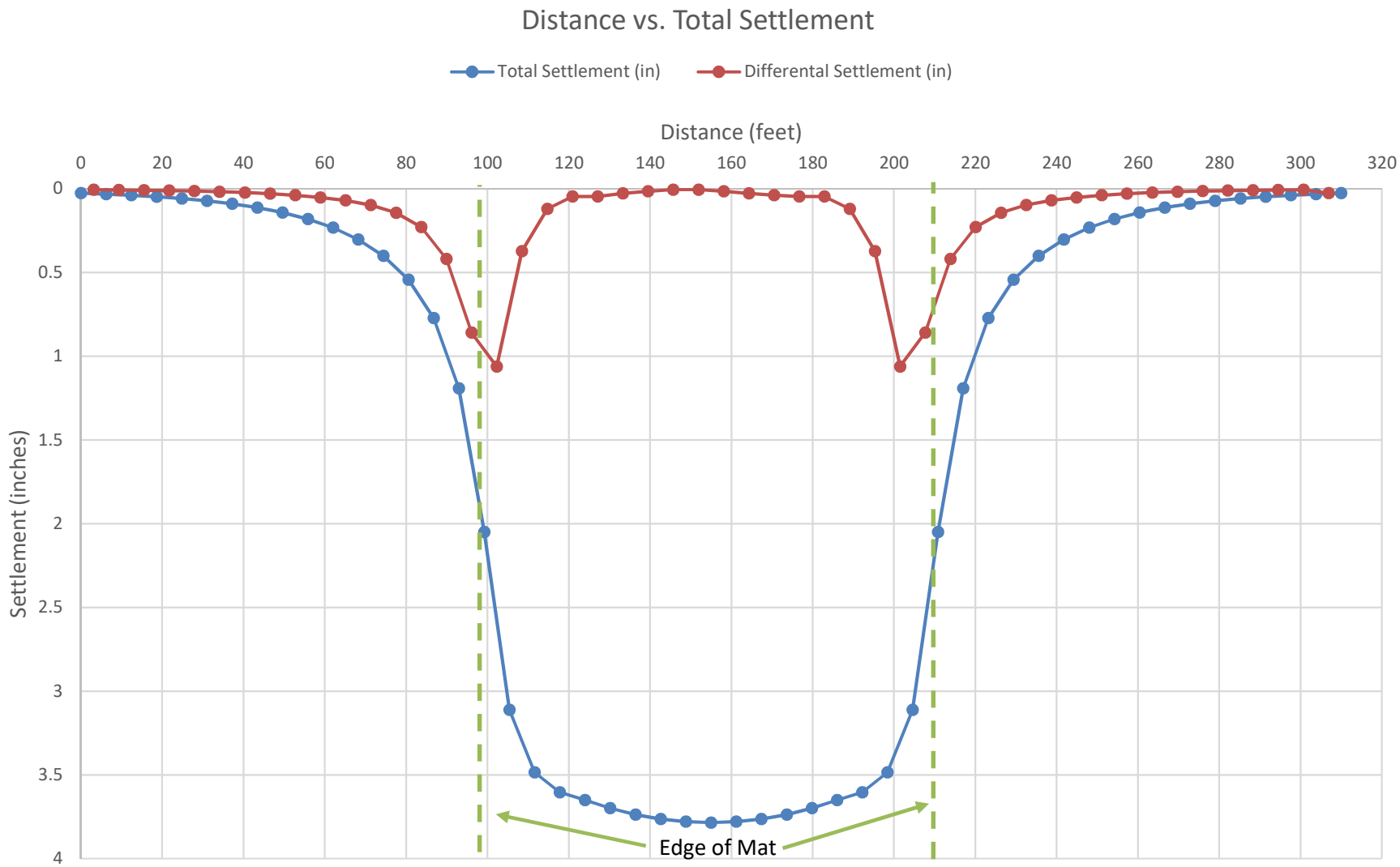

Note: These settlements were calculated using subsurface exploration SCPT-03.

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BUILDING SETTLEMENT
ANEROBIC BASIN

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FIG. 4
Sheet 1 of 2

FIG. 4
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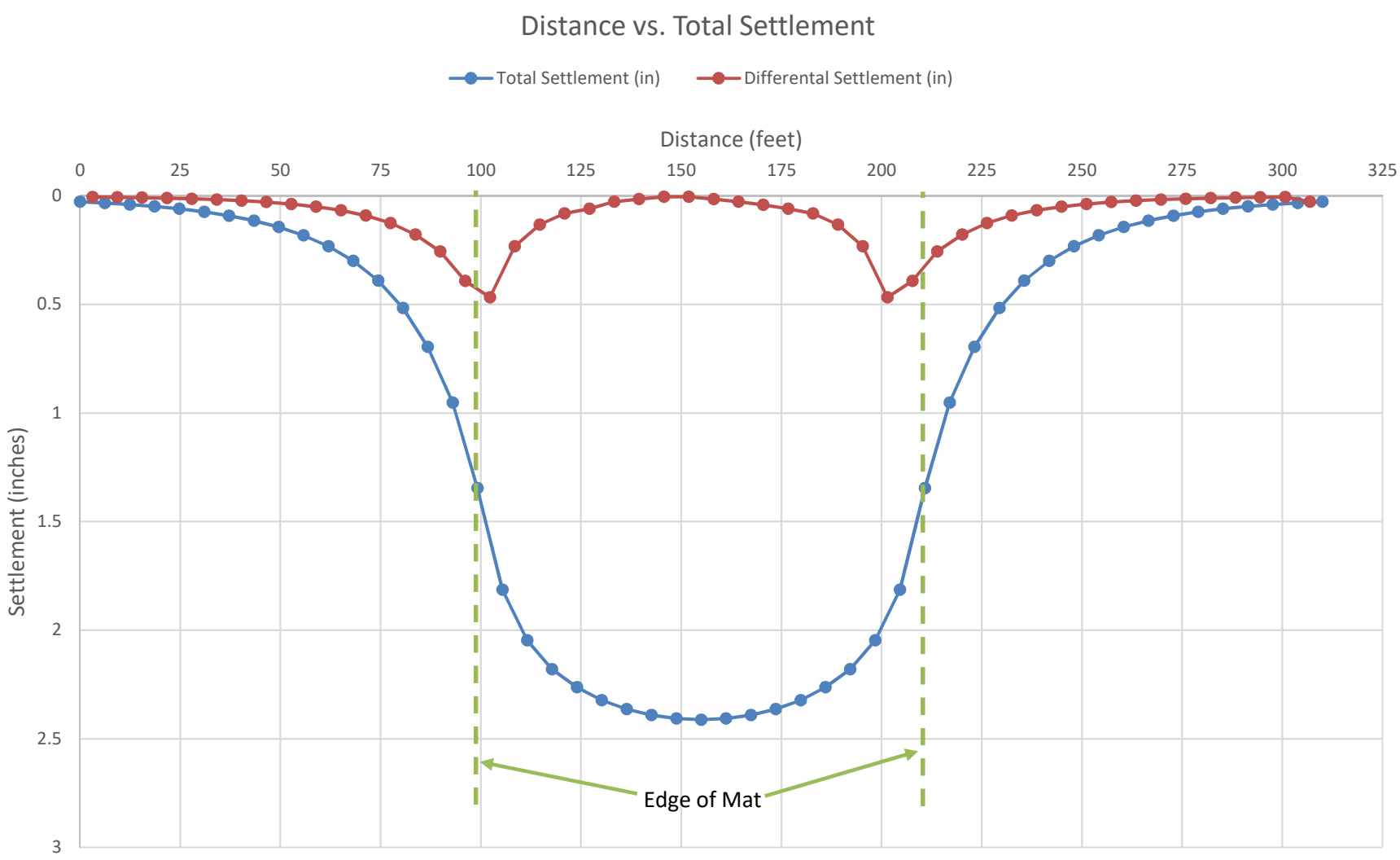

Note: These settlements were calculated using subsurface exploration SWB-26.

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BUILDING SETTLEMENT
ANEROBIC BASIN

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FIG. 4
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FIG. 4
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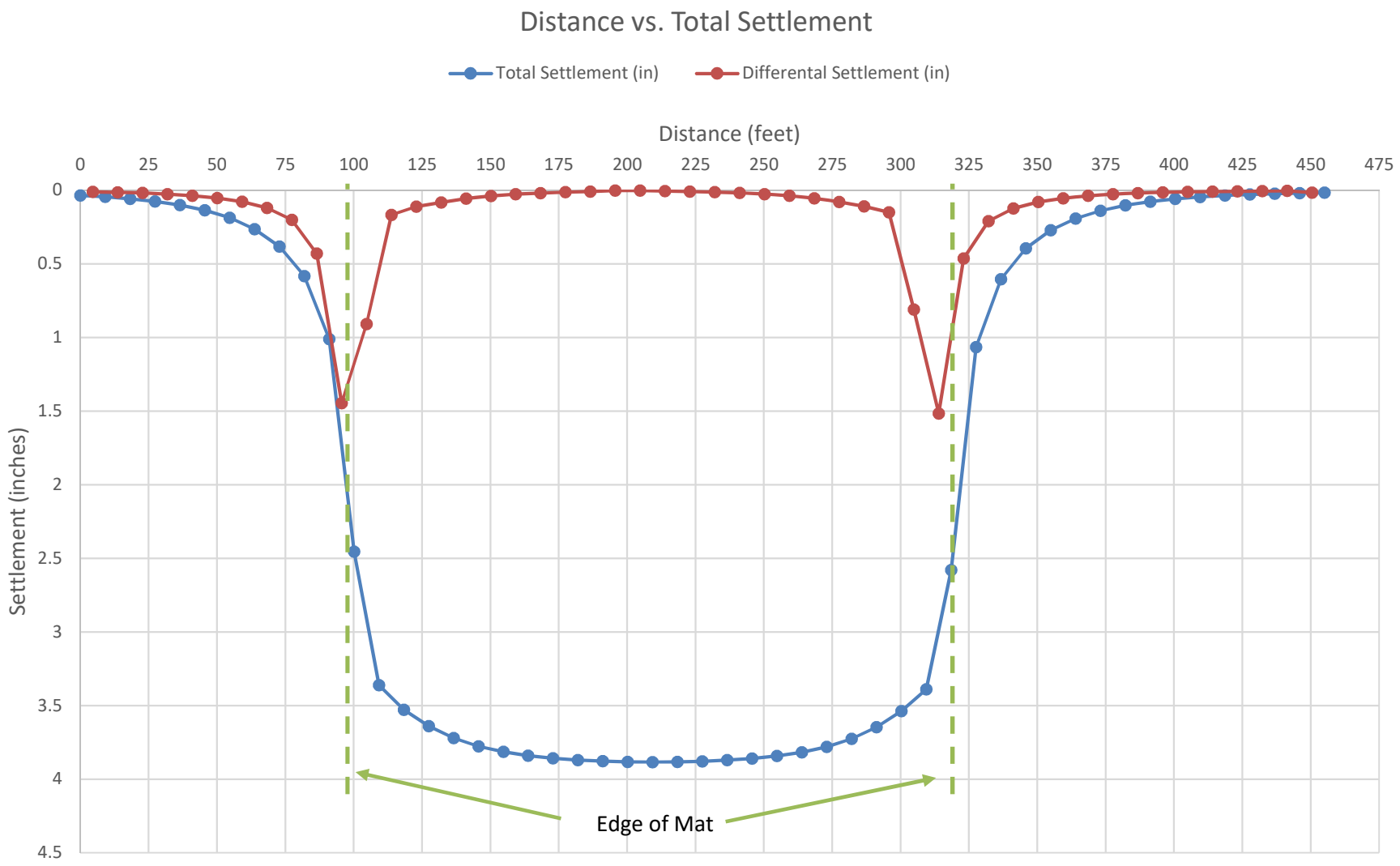

Note: These settlements were calculated using subsurface exploration SCPT-03.

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BUILDING SETTLEMENT
AERATION BASIN

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FIG. 5
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FIG. 5
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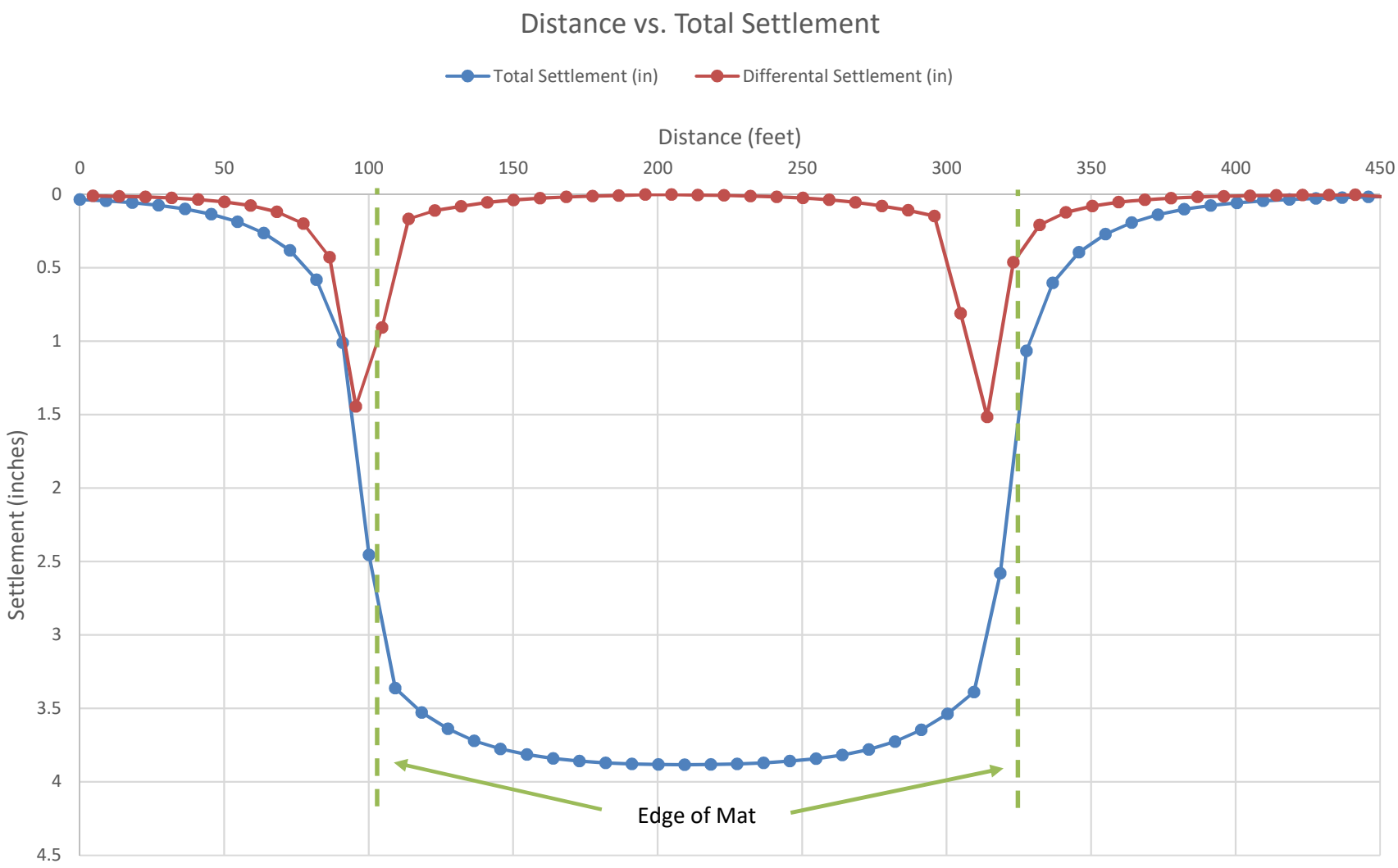

Note: These settlements were calculated using subsurface exploration SWB-26

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BUILDING SETTLEMENT
AERATION BASIN

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FIG. 5
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FIG. 5
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