Appendix D

Dewatering and Foundation Groundwater Flow Model, 945- 950 Kifer Road, August 27, 2019

TODD GROUNDWATER

August 27, 2019

TECHNICAL MEMORANDUM

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From: Liz Elliott, PG, CHG
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Re: **Dewatering and Foundation Groundwater Flow Model**
950 Kifer Road, Sunnyvale, California

Todd Groundwater (Todd) conducted groundwater flow modeling analyses in support of Intuitive Surgical's redevelopment projects at 945 and 950 Kifer Road in Sunnyvale, California (subject property, site). The proposed development includes construction of two underground parking garages with foundations that will extend below the groundwater table. Since the water table is shallower than the total depth of the proposed subsurface foundations, temporary dewatering will be required during construction using dewatering wells and slurry walls around the excavation perimeters.

Adjacent to and nearby the Kifer Road properties are several contaminated sites, with volatile organic compounds (VOCs) present in shallow soil and groundwater. The former Mohawk Chemical site is located at 932 Kifer Road, just west of the 945 and 950 Kifer Road properties. Note that Intuitive Surgical also plans to construct a building at 932 Kifer, but this structure will not include a deep subsurface foundation extending below the water table. In addition to the Mohawk Chemical site, the Texas Instruments ([TI], former National Semiconductor Corporation [NSC]) site at 2900 Semiconductor Drive in Santa Clara, is east of the subject property. Several other contaminated sites are located north of the Kifer Road properties. The subject property and nearby contaminated sites are shown on **Figure 1**.

Groundwater dewatering during construction of foundations, and the permanent foundations themselves, may alter shallow groundwater flow directions and rates and potentially affect migration of contaminants in shallow groundwater beneath the nearby sites.

This Technical Memorandum (TM) describes the flow modeling conducted for the 950 Kifer Road site. A separate TM documents the modeling evaluation conducted for the 945 Kifer Road site (Todd Groundwater, 2019). The purpose of the modeling evaluation is to assess the localized effects of temporary dewatering, estimate groundwater pumping rates required to dewater the excavations, evaluate the changes in nearby groundwater flow velocities during dewatering, and evaluate the effects of the permanent foundations on groundwater flow and migration of contaminants in groundwater.

To evaluate proposed site dewatering activities and the effects of the foundation, a three-dimensional steady-state and transient-state MODFLOW groundwater flow model was constructed. The groundwater model simulates shallow groundwater flow using representative aquifer characteristics and hydraulic property values based on hydrogeologic data from the subject property, the Mohawk Chemical site and the TI site.

For site construction dewatering, a series of dewatering wells were simulated based on construction concepts provided by Build GC (2019). The well pumping rates required to dewater the excavations to the target depths were estimated, and changes in groundwater elevations and flowpaths were evaluated. MODPATH particle tracks were used to estimate groundwater flow velocities and associated contaminant plume migration times under baseline (no project) and dewatering conditions. Simulations of the effects of the permanent building foundations were performed to estimate the changes in groundwater heads and flow velocities resulting from the foundation barriers.

Note that for the evaluation, all referenced groundwater and building foundation elevations above mean sea level (amsl) are based on NAVD88 datum.

1.0 SITE LOCATIONS AND CHARACTERISTICS OF STUDY AREA

This section summarizes the site conditions, hydrogeologic data, aquifer characteristics, and modeling assumptions made in this evaluation. Site conditions were evaluated based on review of documents provided by RPS and available on the State Department of Toxic Substances Control's (DTSC's) EnviroStor system for the subject site, the Mohawk Chemical, TI, and other nearby sites. The data review focused on hydrogeologic information including lithology and aquifer zones, aquifer tests and aquifer hydraulic property values, groundwater elevations and gradients, and distribution of contaminants at the nearby sites.

The Intuitive Surgical properties at 945 and 950 Kifer Road are in the Santa Clara Valley, approximately 14 miles north of the Santa Cruz Mountains and 6 miles south of San Francisco Bay. The region slopes gently northward toward the Bay, and groundwater flow is generally from south-southwest to north-northeast through the study area. Shallow groundwater beneath the two properties is currently encountered at a depth of approximately 10 feet below ground surface (ft bgs - RPS, 2018; APEX, 2018; Langan Engineering, 2018), although the depth to groundwater fluctuates a few feet seasonally and from year-to-year.

The shallow subsurface geology and groundwater flow conditions in the local study area have been extensively characterized based on numerous soil and groundwater contamination investigations performed at several adjacent and nearby contaminated sites. These nearby site investigations have included the drilling and sampling of shallow and deep soil borings, installation of monitoring wells, measurement of groundwater levels and sampling of groundwater quality, and performance of pumping tests to determine aquifer hydraulic properties. Active groundwater remediation activities including groundwater extraction and treatment and in-situ remediation are occurring at several of the sites. Data generated from these investigations were used in this evaluation to characterize the key shallow aquifer parameters that affect construction dewatering and building foundation effects on groundwater flow.

1.1 Nearby Contaminated Site Investigations

The nearby contaminated sites, labeled on **Figure 1**, include:

- Mohawk Chemical at 932 Kifer Road, west of the subject property
- Texas Instruments ([TI], formerly National Semiconductor Corporation [NSC]) at 2900 Semiconductor Drive in Santa Clara, east of the subject property
- Former United Technologies Corporation (UTC) at 1050 Arques Avenue, northeast of the subject property
- Applied Materials (former Fairchild Semiconductor/Hewlett Packard [HP]) at 974 E. Arques Avenue, north of the subject property
- Advanced Micro Devices (AMD) (formerly Monolithic Memories, Inc. [MMI]) at 1165 E. Arques Avenue, northeast of the subject property
- 999 Arques Avenue, north of the subject property
- Canadian Aviation Electronics (CAE) at 1077 East Arques Avenue, north of the subject property

Subsurface investigations have been performed at the contaminated sites, under the oversight of the Regional Water Quality Control Board, San Francisco Bay Region (RWQCB). The RWQCB defined several Operable Units (OU) and Subunits to assign responsibility for cleanup of contaminants present in different areas. These OUs include the:

- Commercial Street Operable Unit [CSOU] (Mohawk Chemical and Applied Materials/Fairchild sites)
- Operable Unit 1 [OU1] Subunit 1 (TI/NSC and UTC sites)
- Operable Unit 1 Subunit 2 (TI/NSC and AMD sites)
- Operable Unit 1 Subunit 3 (TI/NSC, UTC, and AMD sites)
- Stewart Drive Operable Unit [SDOU] (999 Argues Avenue and CAE sites)

Figure 1 also shows the locations of shallow groundwater volatile organic compound (VOC) contaminant plumes associated with the adjacent Mohawk Chemical and TI sites based on a recently-published map (RPS, 2018). As illustrated, the Mohawk Chemical VOC plume is west of 945 and 950 Kifer Road and extends to the north. The Texas Instruments VOC plume is east of 945 Kifer Road and extends to the north. No known groundwater contamination exists directly north of the Kifer Road properties.

1.2 Lithologies / Aquifer Zones

Available subsurface investigation data collected at 932, 945, and 950 Kifer Road and at the adjacent contaminated sites were reviewed to evaluate shallow aquifer lithologies and determine groundwater model layering and aquifer hydraulic properties. Lithology data at each of the three Surgical Intuitive properties include lithologic logs for soil boring EB-1 through EB-5 and cone penetrometer test (CPT) logs (Cornerstone Earth Group, 2019a,b,c). Lithologic log data and hydrogeologic cross-sections from the TI and Mohawk Chemical sites as documented in the Remedial Investigation/Feasibility Study Reports and Remedial Action Plans also were reviewed.

The site investigations indicate that the shallow aquifer materials in the study area comprise moderate permeability alluvial "sand channel" aquifer zones, interbedded with lower permeability silt and clay aquitard zones (HLA, 1991; Risk-Based Decisions, Inc., 1998). The sand channels were deposited by paleo streams flowing from south to north from the Santa Cruz Mountains toward San Francisco Bay. The deposits are relatively heterogeneous and localized, with discontinuous sand channels sometimes only a few feet thick. The sand channels are more continuous in a south-north direction than east-west.

Mohawk Chemical and TI divided the shallow aquifer materials into depth zones, referred to as the A- zone from 0 to 25 ft bgs (subdivided into A1 and A2 zones by Mohawk Chemical) and a deeper B-zone from 30 to 90 feet (subdivided into B1, B2, and B3 zones by TI). The shallow aquifer contamination is limited to A-zone and upper portion of the B-zone. Continuous aquitard layers are not present between the aquifer zones, and therefore groundwater flow (and contaminant transport) occurs across zones.

For the groundwater modeling evaluation, the shallow A- and B1- aquifer zones were simulated with two model layers, with representative thicknesses and hydraulic properties. **Figure 2** shows cross-section views of the model layers used for the baseline, dewatering, and foundation simulations. For the model, the upper layer represents the A-Zone and uppermost part of the aquifer that will be dewatered and contain the building foundations. Underlying Layer 2 represents the B1-/B2-Zone that provides a source of groundwater during dewatering. The model layers and terraces are further described in Section 2. Representative aquifer hydraulic property values were assigned to the model layers for the groundwater flow analyses, based on aquifer pumping tests at the nearby sites.

1.3 Aquifer Hydraulic Properties

Aquifer hydraulic conductivity values of the shallow aquifer zone (A- and B-zones) were estimated based on numerous pumping tests conducted on wells at the TI, UTC, AMD, and 999 Arques sites. TI conducted a detailed review and statistical analysis of the aquifer test results. TI documented 77 valid aquifer hydraulic conductivity values calculated from on-and off-site tests of TI monitoring and extraction wells, six values from UTC well tests, 42 hydraulic conductivity values from AMD well tests, and three aquifer hydraulic conductivity values from the 999 Arques site well tests (HLA, 1991).

These hydraulic conductivity values were normalized for sand intervals only (the total saturated thickness of sand zones screened by the tested wells), and arithmetic and geometric means and standard deviations were calculated to determine a reliable mean and range of values for the sand channels in the A- and B-aquifer zones.

The geometric means of hydraulic conductivity for the sand channel deposits for the reliable A- and B-zone pumping tests were similar, 286 and 315 gallons per day per square foot (gpd/ft^2), respectively. The value representative of the A-aquifer zone was used as the basis for the flow modeling analysis. TI also determined that vertical permeabilities of the A- and B-aquifer zones were much lower, by a factor of around 100 (HLA, 1991).

Representative storage coefficients and effective porosity values also were used in the transient flow model and particle tracking simulations, as described in Section 2.

1.4 Groundwater Flow Direction and Gradients

Historical and recent groundwater elevation data and contour maps published in the Mohawk Chemical and TI monitoring reports were reviewed to characterize A- and B-aquifer hydraulic gradient directions and magnitudes. According to the February 2018 Mohawk Chemical and 2017 TI monitoring reports, recent groundwater gradients in the study area range from 0.0051 to 0.0066 in the A-Zone and 0.0042 to 0.0046 in the B-Zone (Apex, 2018; Langan, 2018). These hydraulic gradients are consistent with the historical gradients documented in the study area since the 1980's. The depth to water in 2017 and 2018 at the Mohawk Chemical and TI sites ranged from 7 to 12 ft bgs.

1.5 Distributions of Contaminants

The general distribution of the groundwater VOC plumes from the Mohawk Chemical and TI sites are shown on **Figure 1**. This map shows general distribution and concentration contours for several VOCs (RPS, 2018). The Mohawk Chemical plume has migrated to the north and co-mingled with groundwater plumes originating from other sites in the CSOU. Concentrations of up to 170 and 130 ug/L of PCE and TCE, respectively were recently (2018) detected in onsite A1-Zone monitoring wells, and 720 and 510 ug/L in A2-Zone Wells. Concentrations of the degradation product cis-1,2-DCE and vinyl chloride are higher, up to 12,000 and 6,500 ug/L, respectively in A1-Zone wells, and up to 44,000 and 8,500 ug/L, respectively in A2-Zone wells. At its closest point, the eastern edge of the Mohawk Chemical VOC plume is located approximately 400 feet west of 945 Kifer Road (**Figure 1**).

The TI plume has migrated to the north and co-mingled with groundwater plumes originating from the AMD site, and extends north to near the Bayshore Freeway (Highway 101). Concentrations of up to 200 and 580 ug/L of PCE and TCE, respectively were recently (October 2017) detected in A-Zone wells, and 23 and 220 ug/L in B1-Zone wells.

Concentrations of the degradation product cis-1,2-DCE are higher, with up to 17,000 ug/L detected in A1-Zone wells, and up to 290 ug/L detected in B1-Zone wells. Only sporadic detections of VOCs are present in deeper B2- and B3-zone wells. At its closest point, the western edge of the TI VOC plume is located approximately 550 feet east of 945 Kifer (**Figure 1**).

Recent soil and groundwater sampling investigations at the 932, 945, and 950 Kifer Road properties detected very low concentrations of a few VOCs, confirming that the Mohawk Chemical and TI VOC plumes have not migrated onto the subject properties (RPS, 2019).

2.0 GROUNDWATER MODEL APPROACH AND CONSTRUCTION

Groundwater flow in the upper A-aquifer zone will be altered during construction dewatering and after the permanent building foundations are constructed. During construction dewatering, slurry walls will be installed to minimize groundwater inflow through the A-aquifer zone into the open excavations. Upward groundwater flow from the B-zone into the A- zone and excavations is anticipated to occur because permeable aquifer materials are likely to be encountered at the base of the excavations and upward hydraulic gradients will be created by pumping from the A-zone.

The two-layer MODFLOW model simulates groundwater flow within the A- and B-aquifer zones. Representative model layer thicknesses and hydraulic property values were defined to provide accurate representations of groundwater flow conditions during and after construction.

The model was calibrated to local groundwater flow conditions, then used to simulate the effects of construction dewatering and permanent foundations.

Model input parameters include:

- aquifer geometry and thickness
- aquifer horizontal and vertical hydraulic conductivity
- aquifer porosity and storage coefficients
- slurry wall hydraulic conductance
- specified head boundary conditions
- pumping rates or dewatering depths for the dewatering wells

Several simplifying assumptions were incorporated in the model. Aquifer hydraulic properties were assumed to be homogeneous. It was assumed that areal recharge in the model area is negligible. Additional groundwater pumping at other nearby wells was not simulated. Flow through deeper aquifer zones below 60 ft bgs was not simulated.

2.1 Model Grid

Figure 1 shows the model area and boundaries. The model comprises a 1.75 square mile area around the site. The model boundaries are located approximately 3,000 feet from the two sites. A telescoping finite-difference model grid was constructed with a cell spacing of

10 feet along the excavation and foundation perimeters increasing to a cell spacing of 100 feet at the model boundaries. The grid comprises 167 rows, 155 columns, and 2 layers. The grid is rotated 10.5 degrees to the east of north, parallel to the average water table hydraulic gradient across the study area.

2.2 Boundary Conditions

Specified head conditions were assigned along each lateral model boundary. The specified head values were selected based on interpolation of May 2017 and 2018 groundwater elevations reported by Mohawk Chemical and TI. The estimated average hydraulic gradient across the study area is 0.005 foot per foot (ft/ft) to the north-northeast. The southern boundary was assigned a constant head of 71.0 feet above mean sea level (ft amsl) while the northern model boundary was assigned a constant head value of 33.5 ft amsl. Consistent with measured and inferred water table elevations, the interpolated head values at 945 and 950 Kifer Road are approximately 50 and 55 ft amsl, respectively. The same boundary head values were used for both model layers, resulting in no vertical flow between layers at the boundaries. The model bottom boundary condition (base of Layer 2) was specified as no-flow.

Additional constant head boundary points were used to represent the planned dewatering wells at each site. Constant head points were defined at heads equal to the planned dewatering elevations in each excavation, as described below.

2.3 Model Layer Geometry and Thickness

Based on the available lithologic logs and hydrogeologic cross sections, the shallow A-aquifer zone extends to a depth of approximately 30 ft bgs. The B1 and upper B2-aquifer zone extends to a depth of approximately 60 ft bgs. There is not a continuous clay aquitard separating the A- and B-zones in the study area. The aquifer zones dip from south to north, at a slope roughly parallel to the land surface grade and groundwater hydraulic gradient (both approximately 0.5 percent or 0.005 ft/ft).

Geometries of the two model layers were defined to simulate the A- and B-aquifer zones. However, different Layer 1 bottom elevations were used for the model scenarios to represent the designed elevations of the dewatering wells/slurry wall and the permanent foundations (**Figure 2**).

For the baseline model, Layer 1 was defined from the ground surface to a depth of 30 ft bgs and sloped at a gradient of 0.005 ft/ft, parallel to the ground surface and water table surface gradients. Layer 2 was defined as a sloping plane to a depth of 60 ft bgs. For the dewatering and foundation models, two flat “terraces” were defined at the base of Layer 1 in the areas of 945 and 950 Kifer Road. The terrace elevations in the dewatering model for 945 and 950 Kifer Road are 35.8 and 41 feet amsl, respectively, or one foot below the deepest portion of the planned dewatering well pumping levels, which ensures that model Layer 1 remains saturated during the dewatering simulation. The terrace elevations in the foundation model for 945 and 950 Kifer Road are 41.8 and 47 feet amsl, respectively, the elevations of the deepest portions of the permanent foundations at each property.

The bottom of the Layer 2 was fixed at 60 ft bgs for each of the models.

2.4 Aquifer Hydraulic Properties

The geometric mean hydraulic conductivity of 286 gpd/ft^2 (38.2 ft/day) was used to represent the A- and B-zone sands. To conserve the aquifer transmissivity values in the model, the hydraulic conductivities were reduced 50 percent, which is the approximate ratio of sand layer thickness to model layer thickness for each layer. Therefore, the mean hydraulic conductivity of 38.2 ft/day was reduced to 19.1 ft/day in both model layers. A horizontal-to-vertical hydraulic conductivity anisotropy ratio of 100 was used for each model scenario.

For the MODPATH simulations, an effective porosity value of 0.125 was used to represent the shallow aquifer zones. This value was scaled downward relative to estimated actual aquifer effective porosity of around 0.25 by approximately the same ratio as the scaled hydraulic conductivities, to more accurately estimate the groundwater flow velocities in the flowpath simulations. For the transient MODFLOW dewatering simulation, specific storage values of 0.0067 and 0.00067 1/ft were used for model Layers 1 and 2, respectively, based on assumed storage coefficients and model layer thicknesses.

For the construction dewatering scenario, model cells were defined as hydraulic barriers along the perimeter of each of the two excavations. A hydraulic conductance of 1 x 10^{-7} day^{-1} was assigned to each wall. Hydraulic conductance is the ratio of hydraulic conductivity divided by the barrier wall thickness. For the slurry wall, a representative bentonite slurry hydraulic conductivity of 1 x 10^{-7} ft/day and slurry wall width of 1.0 foot was assumed. The slurry walls extend through model Layer 1 but are not simulated in Layer 2.

For the future foundation scenario, the areas of the northern and southern foundations were assigned a hydraulic conductivity of zero in model Layer 1, in order to simulate the flow barrier effects of the impermeable foundations.

2.5 Dewatering Wells

The construction contractor anticipates installation of 36 dewatering wells at 945 Kifer Road and 48 dewatering wells were assumed at 950 Kifer Road. It is assumed that the wells will be installed inside the slurry walls to an elevation of 31 ft amsl or deeper, and will be operated to draw the groundwater surface at 945 and 950 Kifer to 36.8 and 42 ft amsl, respectively, or 5 feet below the planned bases of the deepest portions of the excavations and foundations at each site.

To estimate the pumping rates required to dewater the excavations to the target depths, the groundwater pumping wells were simulated as "constant head" points, with head values at each well at 945 and 950 Kifer set to 36.8 and 42 ft amsl, respectively. This "inverse" model approach allows accurate quantification of predicted dewatering well flow rates, as compared with "forward" models where pumping rates (over time) are specified as input. The dewatering model was run in transient mode for a duration of 1 year, the maximum anticipated duration of excavation dewatering. The inverse model calculates the pumping rates over time required to achieve the specified drawdown amount.

Two dewatering simulations were performed for the 945 site; the first simulates both sites dewatering simultaneously, while the second simulates dewatering only at the 945 Kifer site.

2.6 Model Scenarios

Four scenarios were simulated:

Scenario 1 – Baseline, No Project: This scenario simulated groundwater flow under current conditions without the proposed buildings. The steady-state baseline simulation was calibrated to recent groundwater elevations in the study area, and the results were used as initial conditions for the construction and foundation simulations (Scenarios 2 and 3).

Scenario 2 – Construction Dewatering Both Sites: This scenario simulated simultaneous dewatering during construction of both of the two structures. For this scenario, the model was run in a transient-state mode to simulate dewatering pumping and groundwater elevations over time. Pumping rates over time necessary to dewater both excavations were estimated, and the simulated drawdowns and groundwater flowpaths were compared with baseline flow conditions.

Scenario 3 – Construction Dewatering Only at 950 Kifer: This scenario simulated dewatering during construction 950 Kifer, without dewatering of 945 Kifer. The model was run in a transient-state mode to simulate dewatering pumping and groundwater elevations over time. Pumping rates over time necessary to dewater the single excavation were estimated, and the simulated drawdowns and groundwater flowpaths were compared with baseline flow conditions.

Scenario 4 – Future Foundation: This scenario simulated the two future building foundations and assumed that the buildings will be impermeable barriers to shallow groundwater flow. For this scenario the model was run in steady-state mode, to simulate the long-term effects of the foundation barriers. The effects on shallow groundwater flowpaths and rates were evaluated relative to baseline conditions.

3.0 GROUNDWATER MODEL RESULTS

The following section summarizes results of the three model scenarios. A series of figures showing the simulated groundwater elevations, drawdowns, and flowpaths are attached to illustrate the results.

Scenario 1 – Baseline, No Project

This scenario simulated groundwater flow under current pre-construction conditions without the proposed buildings and was calibrated to 2017-2018 groundwater elevations. The simulated groundwater elevations and flowpaths are shown on **Figure 3.** The simulated groundwater elevations range from 71 ft amsl (NAVD88 datum) at the southern model boundary to 33.5 ft amsl at the northern boundary. The hydraulic gradient of 0.005 is uniform across the model area. Simulated groundwater levels in each of the two model layers are identical, and no vertical flow between aquifer zones is simulated. For the MODPATH simulations, particles were assigned in a line upgradient of 945 and 950 Kifer Road, and simulated groundwater flowpaths are linear from south to north. The markers on the flowpath lines represent 1-year travel times. Groundwater velocities are estimated to be around 0.81 ft/day (290 feet per year).

Scenario 2 – Construction Dewatering at Both Sites Simultaneously

This scenario simulated simultaneous dewatering during construction of the subsurface parking structures at both sites. Eighty-four dewatering wells were simulated within the slurry walls, 36 wells at 945 Kifer Road and 48 wells at 950 Kifer Road. Each dewatering well at 945 Kifer was assigned a specified head of 36.8 ft amsl, or 5 feet below the planned base of the excavation. The dewatering wells at 950 Kifer were assigned a specified head of 42.0 ft amsl, also 5 feet below the planned base of the deepest portion of the 950 Kifer excavation. The head solution from the baseline scenario was assigned as initial conditions for the construction dewatering (and future foundation) simulations, to calculate drawdowns and flow rates. The dewatering model was run in transient mode for a one-year duration, to evaluate drawdowns, flowpaths, and pumping rates over time. The transient model assumes one year of construction dewatering.

Figure 4 shows the simulated Layer 1 groundwater elevations for the construction dewatering scenario after one year of dewatering, and **Figure 5** shows the simulated drawdowns relative to the baseline model. The simulated groundwater elevations at 945 and 950 Kifer within the excavations are 36.8 ft and 42.0 ft amsl, respectively, and the average total drawdowns in the two excavations are around 14 feet at 945 Kifer and 12 feet at 950 Kifer. Groundwater flow from upgradient and cross-gradient areas converges toward the excavations as illustrated by the simulated groundwater elevation contour lines, and upward groundwater flow into the excavations and dewatering wells occurs from the underlying B-aquifer zone. In response to the increased hydraulic gradients, increases in groundwater flow velocities are simulated as groundwater approaches the dewatering wells.

During dewatering, drawdown is simulated in both model Layers 1 and 2. Drawdown propagates vertically and horizontally through the interconnected A- and B-aquifer zones. Even though the horizontal groundwater flow into the excavations through the A-aquifer zone/model Layer 1 will be controlled with slurry walls, water table drawdown occurs outside of the walls due to leakage between the A- and B-aquifer zones. After one year of continuous pumping, drawdown up to 5 feet occurs between the excavations and drawdown of up to 3 feet is simulated outside of the excavations. The simulated drawdown and the flow rates required to dewater the excavations are sensitive to both the vertical and horizontal hydraulic conductivities used in the model.

Figure 6 shows the predicted total pumping rates required to dewater each of the excavations to their respective dewatering depths. The start-up flow rate is simulated at approximately 80 gpm for 945 Kifer Road and approximately 95 gpm for 950 Kifer Road, and flow rates decrease over time as the water table is drawn down. The flow rate reduces to approximately 50 gpm at 945 Kifer Road and approximately 56 gpm for 950 Kifer Road, after one year of pumping. These simulated startup pumping rates are similar to preliminary estimates previously provided by the site dewatering contractor, while predicted long term rates are slightly higher than rates estimated by the contractor (albeit for a different dewatering depth and area Build GC, 2019).

Scenario 3 – Construction Dewatering at 950 Kifer Only

This scenario simulated dewatering during construction of 950 Kifer, with no pumping at 945 Kifer. Again, 48 dewatering wells are simulated at 950 Kifer, with each dewatering well assigned a specified head of 42.0 ft amsl, or 5 feet below the deepest portions of the base of the excavation.

Figure 7 shows the simulated Layer 1 groundwater elevations for the construction dewatering scenario after one year of dewatering, and **Figure 8** shows the simulated drawdowns relative to the baseline model. The simulated groundwater elevation at 950 Kifer within the excavation is 42.0 ft, and the total drawdown in the excavation is 12 feet. During dewatering of 950 Kifer only, less drawdown is simulated outside of the excavation (2 to 3 feet) than is predicted when both excavations are pumped simultaneously.

Figure 6 shows the predicted pumping rates required to dewater 950 Kifer when only that excavation is pumped. The start-up flow rate again is simulated at approximately 95 gpm for 950 Kifer Road, and the flow rate reduces to approximately 64 gpm after one year of pumping. The pumping flow rate when only 950 Kifer is pumped after one-year is higher than the predicted rate when both excavations are pumping, due to the superposition effects of pumping both excavations.

Scenario 4 – Future Foundations

Figure 9 shows the simulated shallow aquifer groundwater elevations for the future foundations scenario. The foundations at 945 and 950 Kifer create barriers to groundwater flow in Layer 1, resulting in deflection of groundwater flowpaths around (and underneath) the foundation perimeters. Groundwater flowpaths approaching the southern edges of the foundations diverge to the east and west and move around the building perimeters and then converge on the northern side of the foundations. Some of the shallow groundwater is simulated as flowing vertically under the base of the foundations, through the underlying model Layer 2. The model shows that the future underground parking garages will have relatively little impact on groundwater flow directions and rates at the nearby plume areas.

3.1 VOC Plume Migration During Dewatering and After Construction of Foundations

To evaluate potential impacts of dewatering and the future foundations on plume migration, one-year flowpath simulations were performed using particles located at the edges of the Mohawk Chemical and TI VOC plumes. **Figure 10** shows the one-year flowpaths for the baseline scenario and for each dewatering scenario (both excavations pumped simultaneously and only 950 Kifer pumped), with one-month markers illustrated on the flowpaths.

Baseline scenario results (yellow dots) show that groundwater in the areas of the plumes migrates approximately 290 feet in one year parallel to the regional north-northeast groundwater flow direction. Dewatering slightly alters the flow directions at the Mohawk Chemical and TI sites, and causes local convergent flow from the west and east toward the project excavations. For the pumping at 950 Kifer only scenario (orange dots), flow directions near the edges temporarily converge toward the excavations, with greater influence on areas closer to the excavation (south of Kifer Road). For the pumping at both sites simultaneously scenario (red dots), greater convergent flow is simulated than when only 950 Kifer is pumped. For both dewatering scenarios, only very small increases in groundwater flow velocities are simulated at the particle track locations, and groundwater migrates approximately the same distance over a one-year dewatering periods as under baseline conditions. However, in both dewatering scenarios the simulated plumes are not predicted to migrate into the excavation at 950 Kifer Road.

Particle tracking for the future foundation scenario over a one-year period is shown on **Figure 11.** Comparison of the baseline particle tracks (yellow dots) with the particle tracks for the permanent foundations (blue dots) shows that the foundations have practically no impact on VOC plume migration.

Note the particle tracking results are based on groundwater advection rates only, and do not account for contaminant dispersion, adsorption, or biodegradation processes. Dispersion tends to increase spreading of solutes in groundwater, while adsorption and biodegradation tend to reduce the effective contaminant migration rates relative to advective groundwater flow rates.

3.2 Sensitivity Analyses

Several sensitivity simulations were performed using different horizontal and vertical hydraulic conductivities. Higher horizontal and vertical hydraulic conductivity values result in larger flow rates required to dewater the excavations and larger groundwater velocities. Both of these parameters are linearly related to hydraulic conductivity, i.e., doubling the horizontal hydraulic conductivity results in twice the required dewatering flow rates. Conversely, lower hydraulic conductivities result in lower dewatering flow rates and groundwater velocities. The dewatering simulations are also sensitive to slurry wall barrier conductance. Again, higher conductance values result in greater required dewatering flow rates and more drawdown outside of the barriers, and lower conductance values result in less required dewatering and less drawdown outside of the barriers.

4.0 LIMITATIONS AND CONCLUSIONS

The groundwater flow modeling presented above is a first-order analysis. Numerous simplifying assumptions were incorporated, including uniform groundwater flow in the shallow A- and B-aquifer zones, homogeneous horizontal and vertical hydraulic conductivities, homogeneous slurry wall barrier conductance, and uniform background hydraulic gradient. Areal recharge in the model area was assumed to be negligible. Flow through deeper aquifer zones below the combined B1-/B2-zone was not simulated.

Groundwater remediation extraction wells and other potential pumping wells near the site were not simulated. In addition, solute fate and transport processes and natural attenuation were not evaluated.

Dewatering flow rates over time are predicted to decrease as the shallow aquifer zone is dewatered and approaches an equilibrium inflow condition. For construction planning purposes, it is recommended that a safety factor be applied to any use of model estimates of dewatering flow rates to account for potential greater aquifer and slurry wall barrier permeability conditions, potentially greater upward vertical groundwater inflow from deeper aquifer zones than was simulated.

Based on the modeling evaluations, only limited, short-term impacts to groundwater flow are predicted during construction dewatering. Groundwater flow directions are predicted to change slightly during the temporary dewatering period. However, the simulated plumes at the Mohawk Chemical and TI sites are not predicted to migrate into the 945 Kifer Road excavation. The presence of the future building foundations has essentially no impact on groundwater flow directions and rates at the Mohawk Chemical and TI sites, and therefore, would have no impact on their plumes.

5.0 REFERENCES

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ATTACHMENTS

Figure 1 Model Area and Boundaries
Figure 2 Model Grid and Layer Geometry
Figure 3 Simulated Steady-State Groundwater Elevations and Flowpaths – Baseline Scenario
Figure 4 Simulated Transient-State Groundwater Elevations After One Year – Both Excavations Dewatered Simultaneously

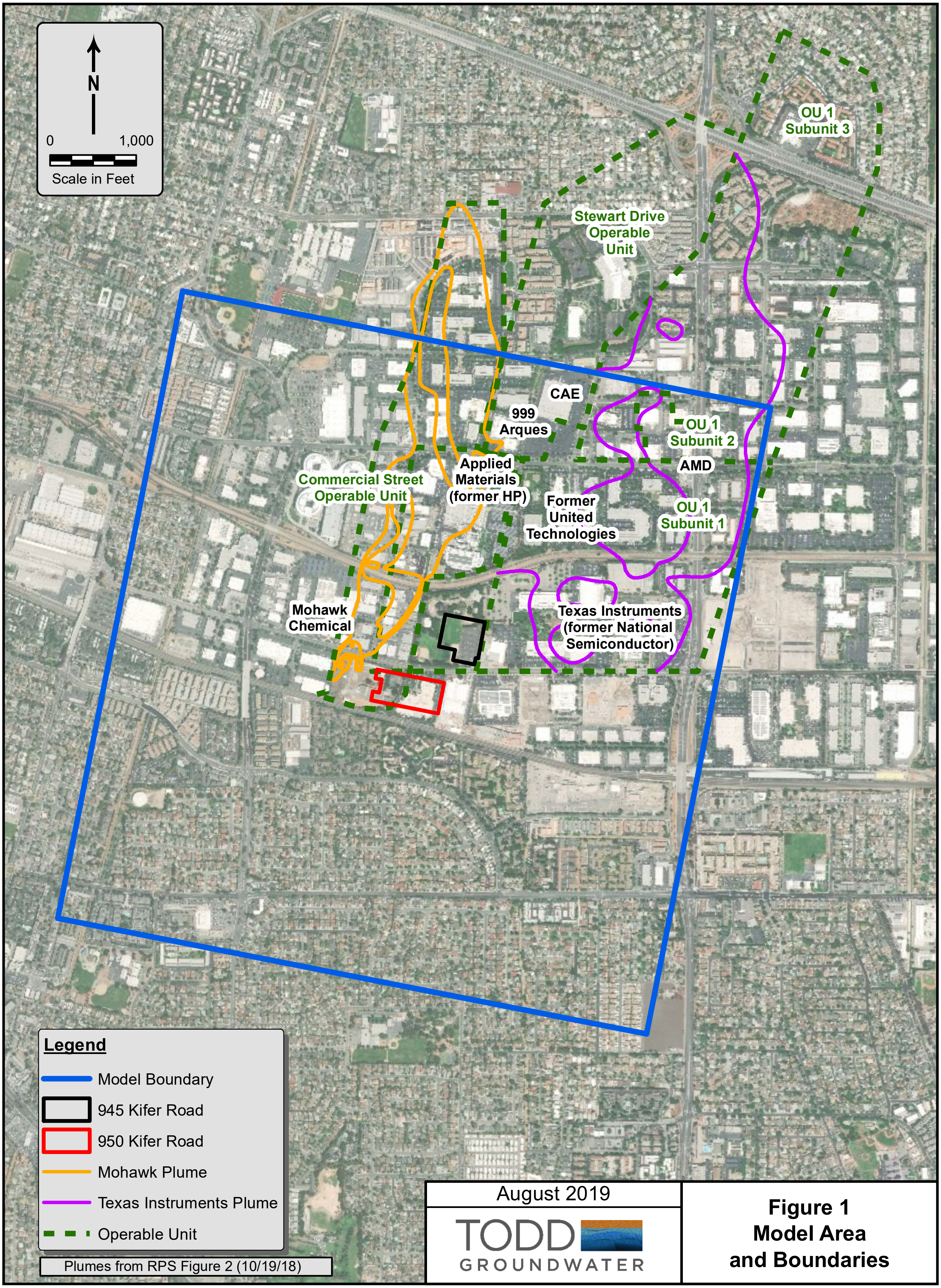

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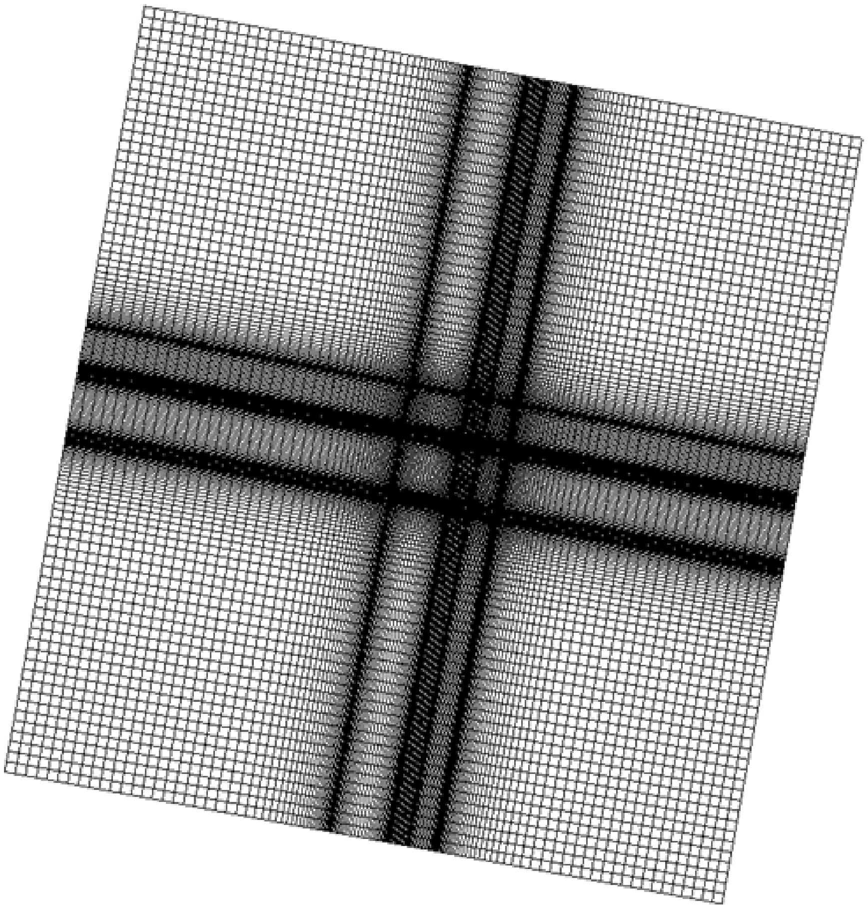
Figure 1
Model Area and Boundaries

Model Grid
(Plan View)



Model Layers
(Cross Section View)

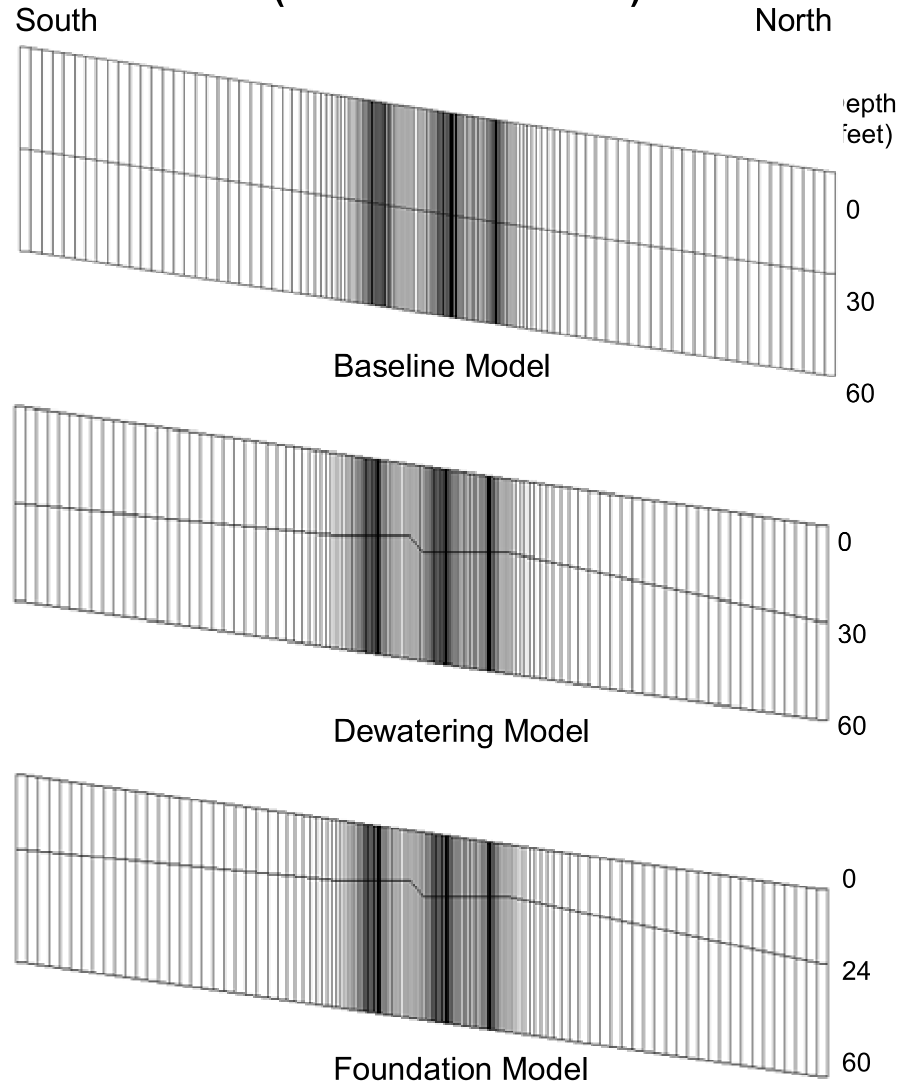


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Figure 2
Model Grid and Layer Geometry

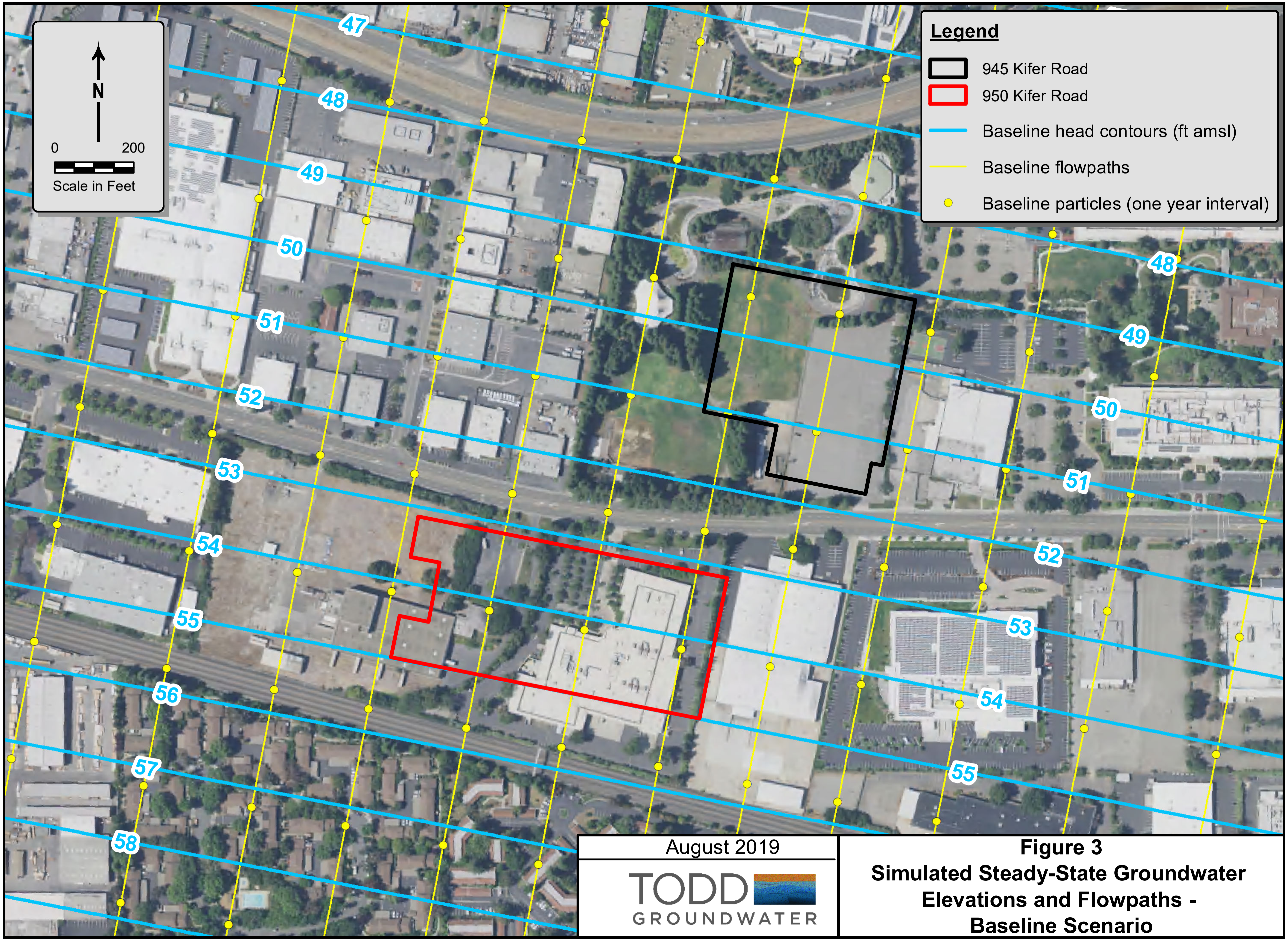

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Figure 3
Simulated Steady-State Groundwater Elevations and Flowpaths - Baseline Scenario

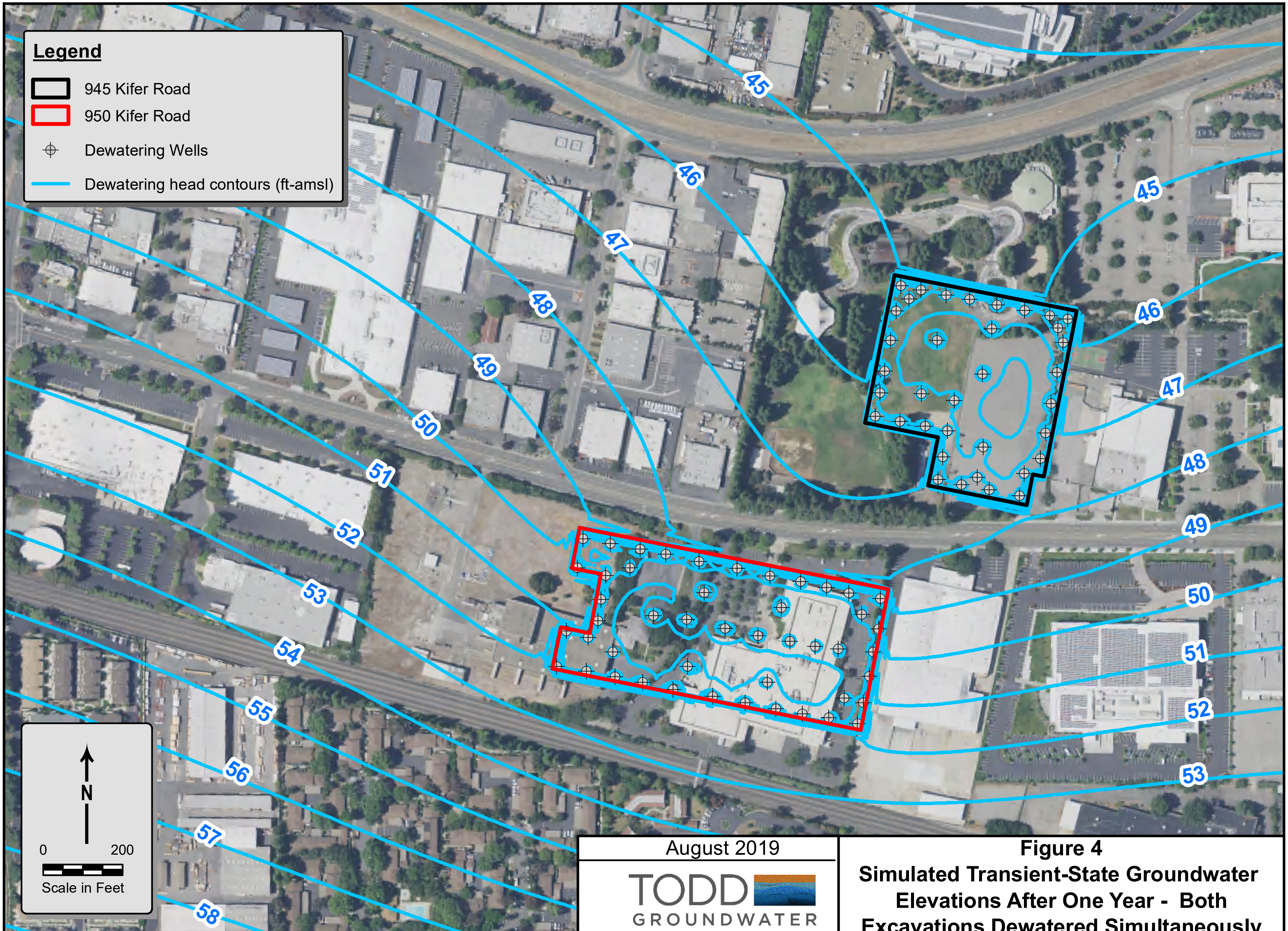

Figure 4
Simulated Transient-State Groundwater Elevations After One Year - Both Excavations Dewatered Simultaneously

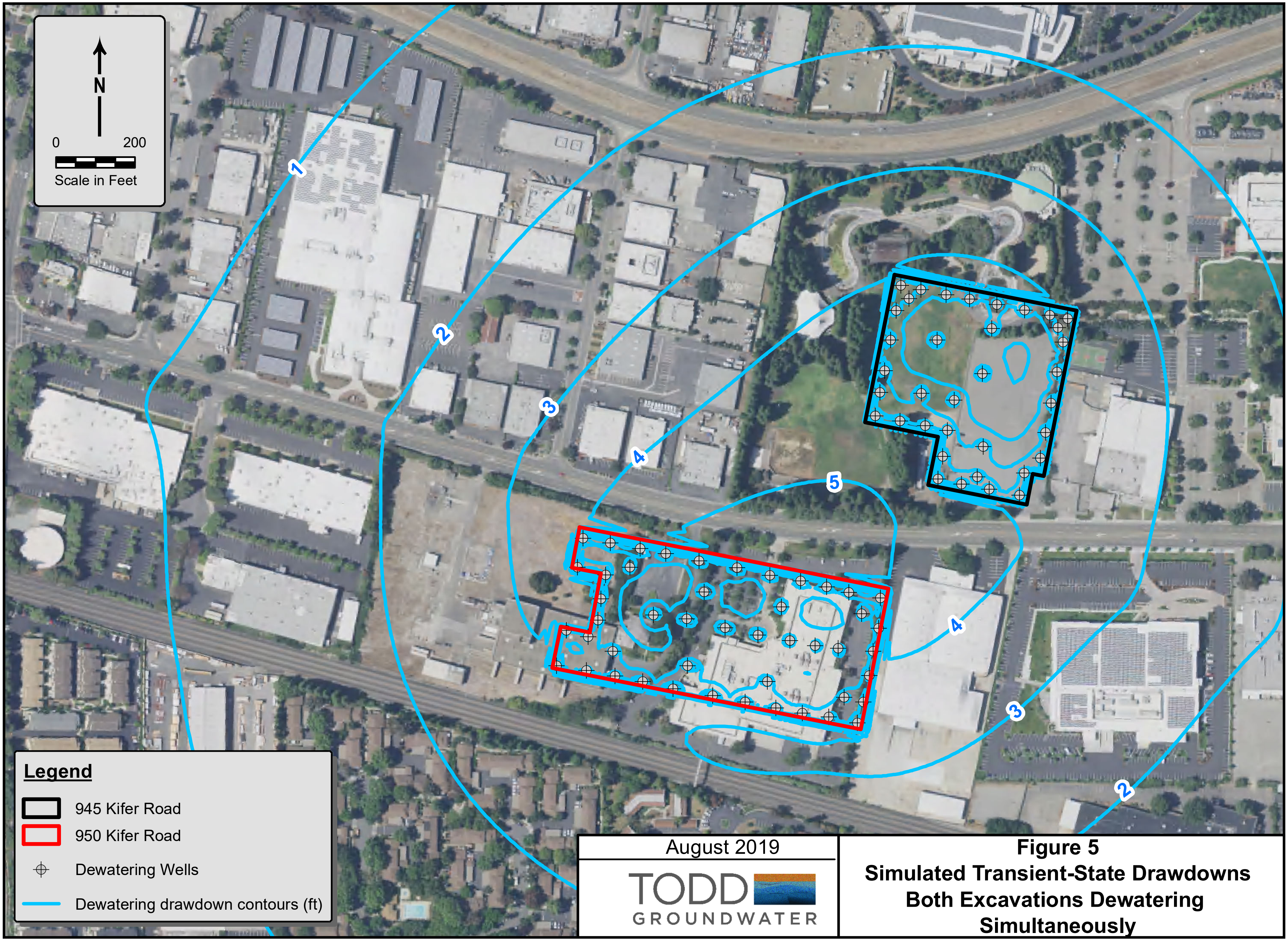

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Figure 5
Simulated Transient-State Drawdowns Both Excavations Dewatering Simultaneously

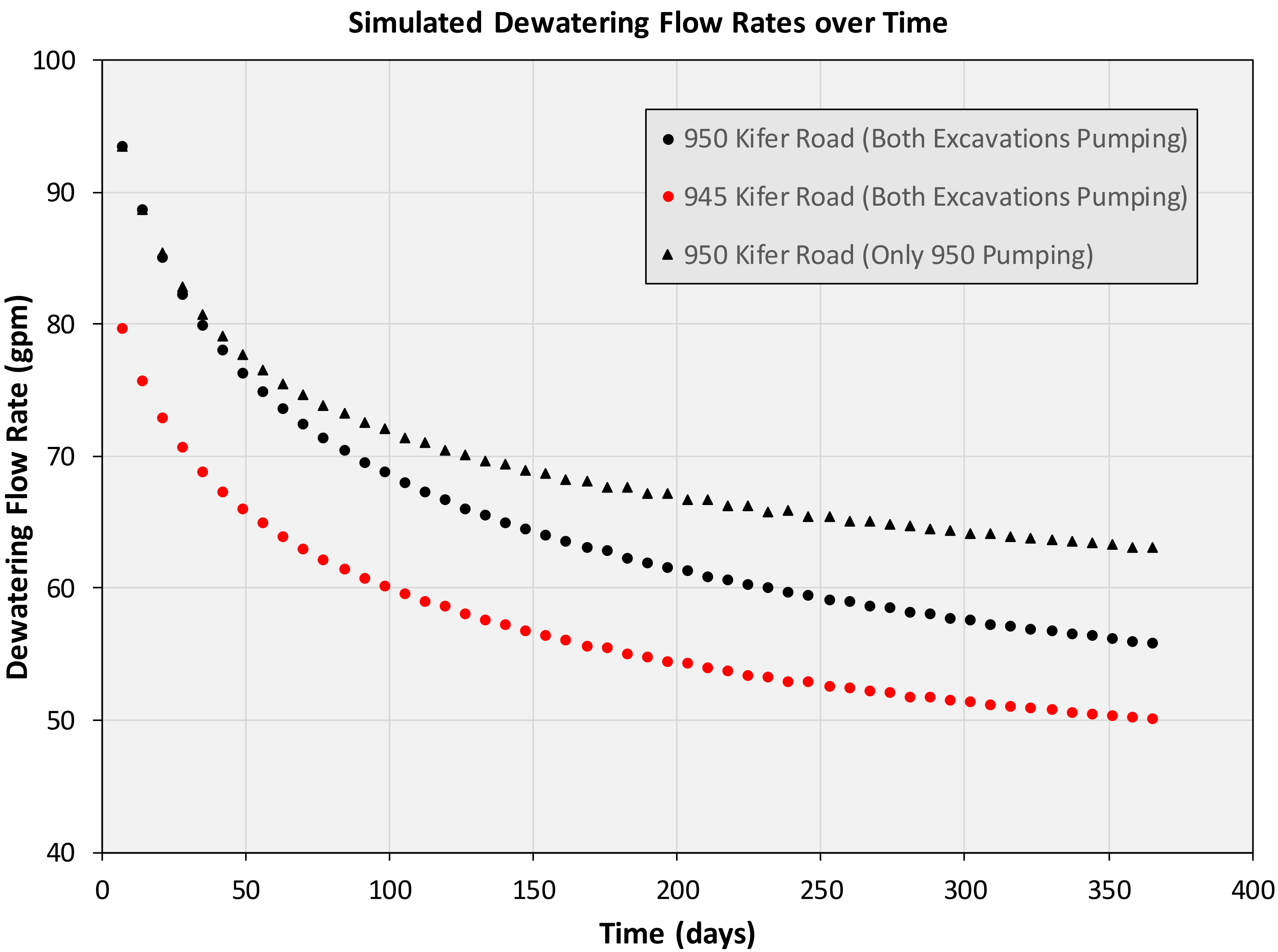

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Figure 6
Simulated Dewatering Pumping Rates over Time

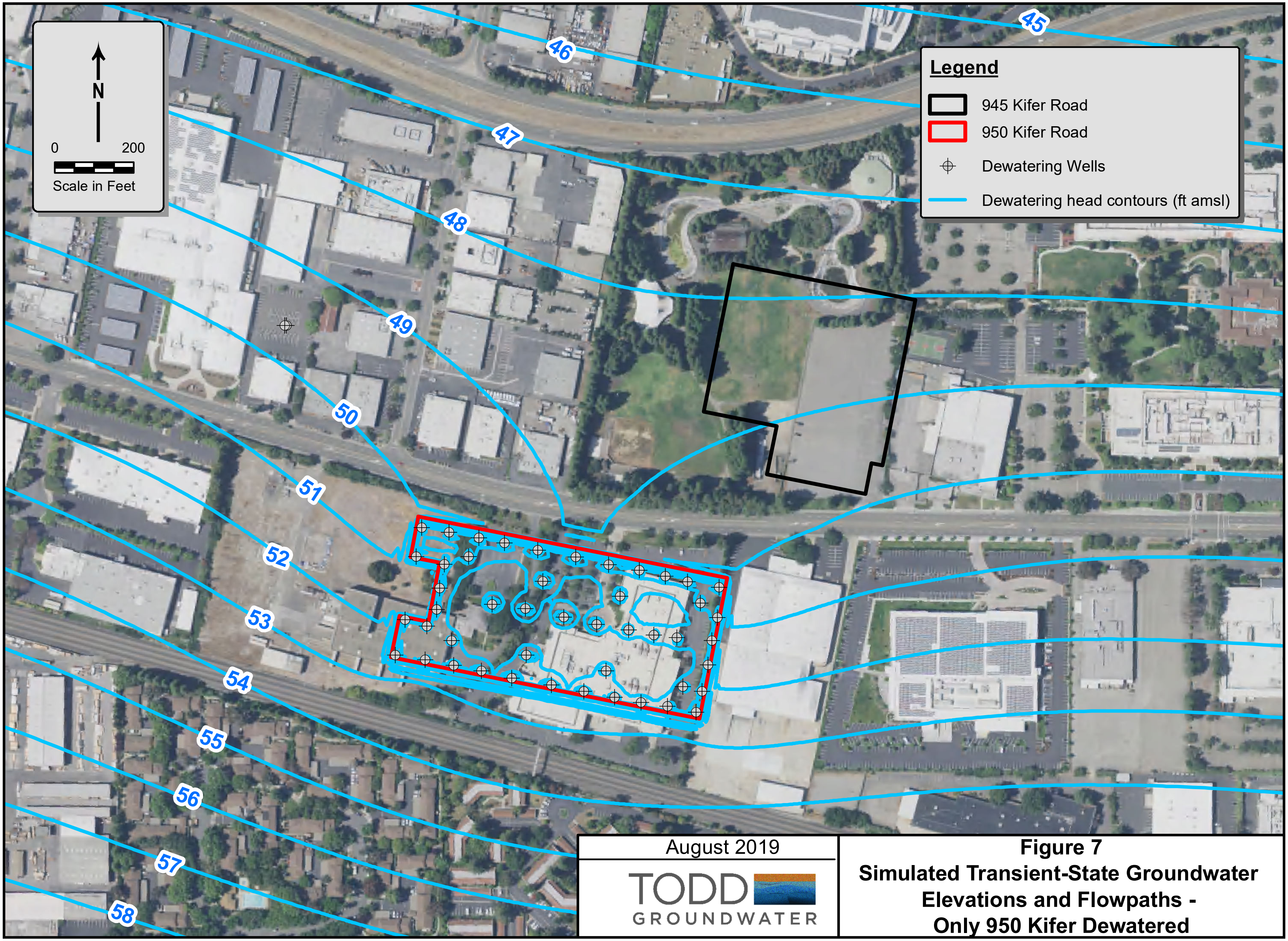

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Figure 7
Simulated Transient-State Groundwater Elevations and Flowpaths -
Only 950 Kifer Dewatered

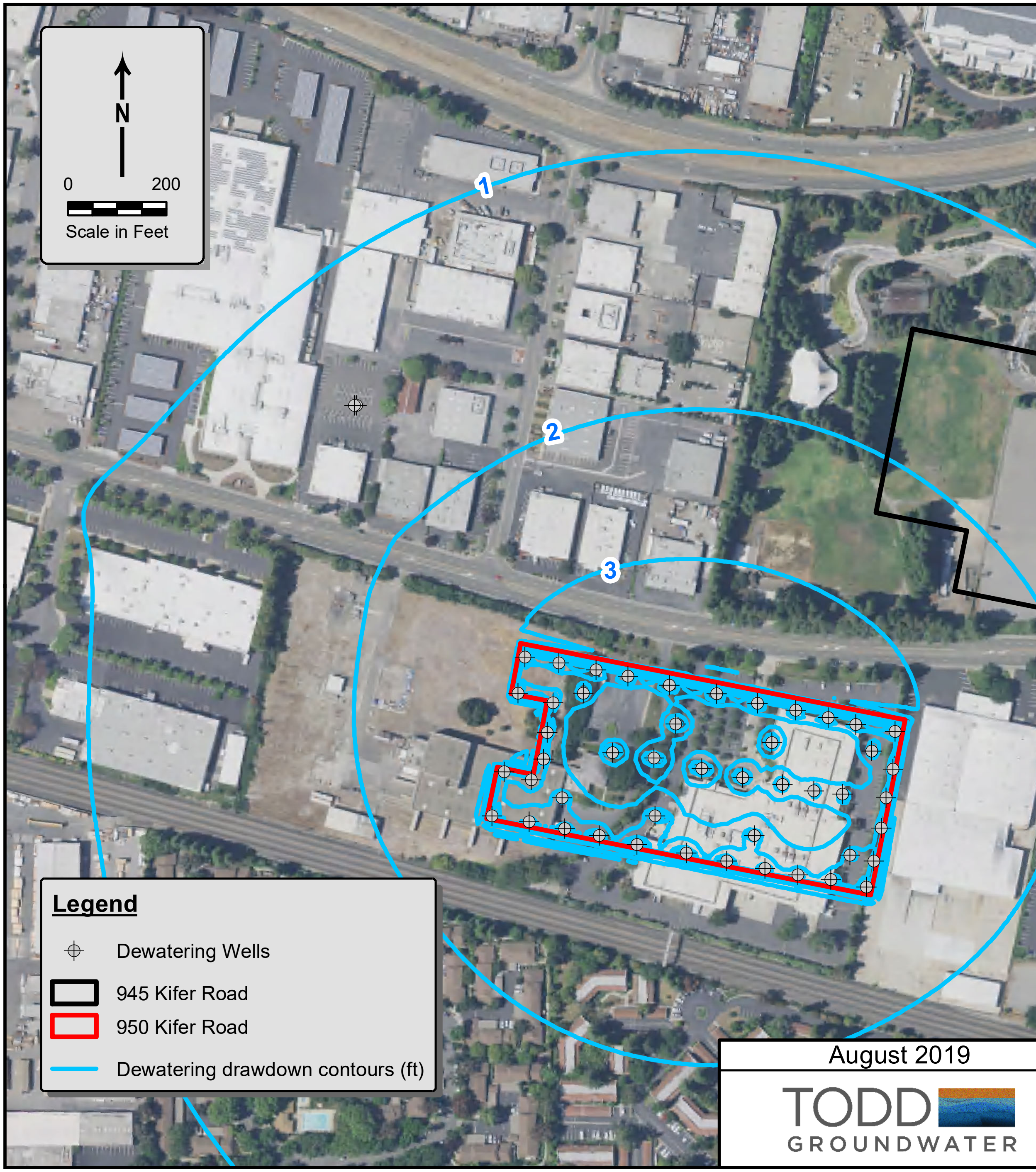

Figure 8
Simulated Transient-State Drawdowns After One Year - Only 950 Kifer Dewatered

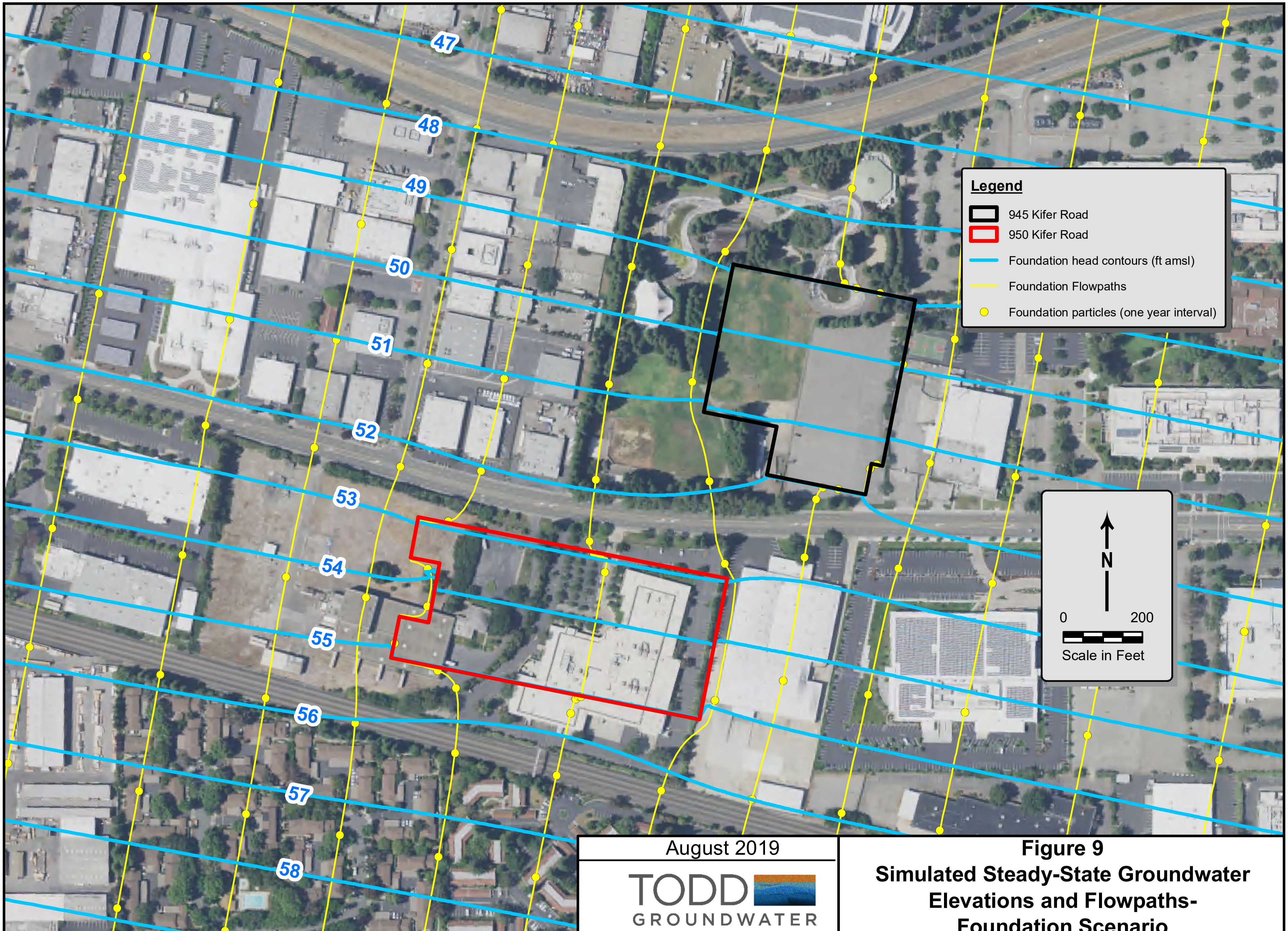

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Figure 9
Simulated Steady-State Groundwater Elevations and Flowpaths-Foundation Scenario

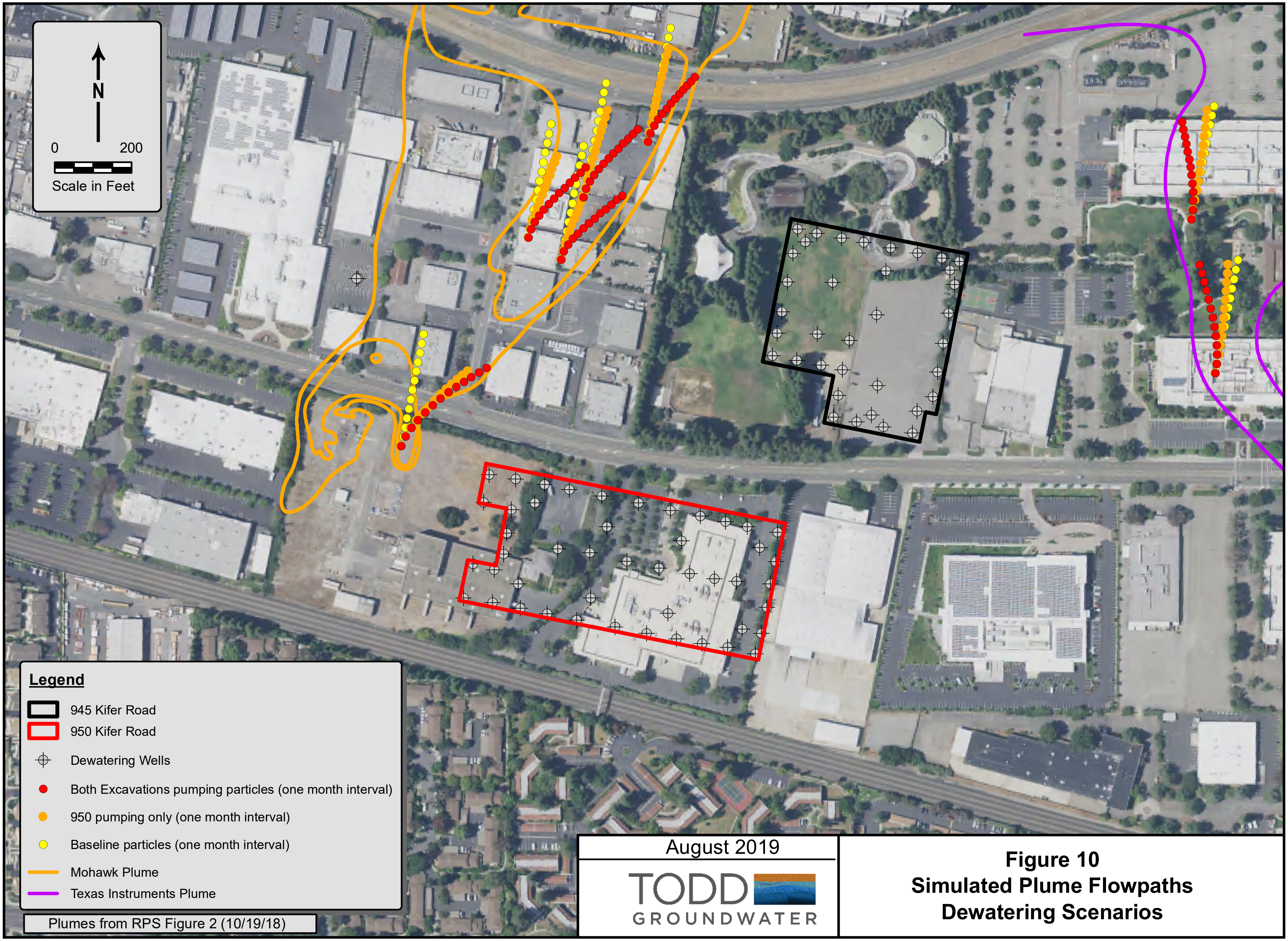

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Figure 10
Simulated Plume Flowpaths
Dewatering Scenarios

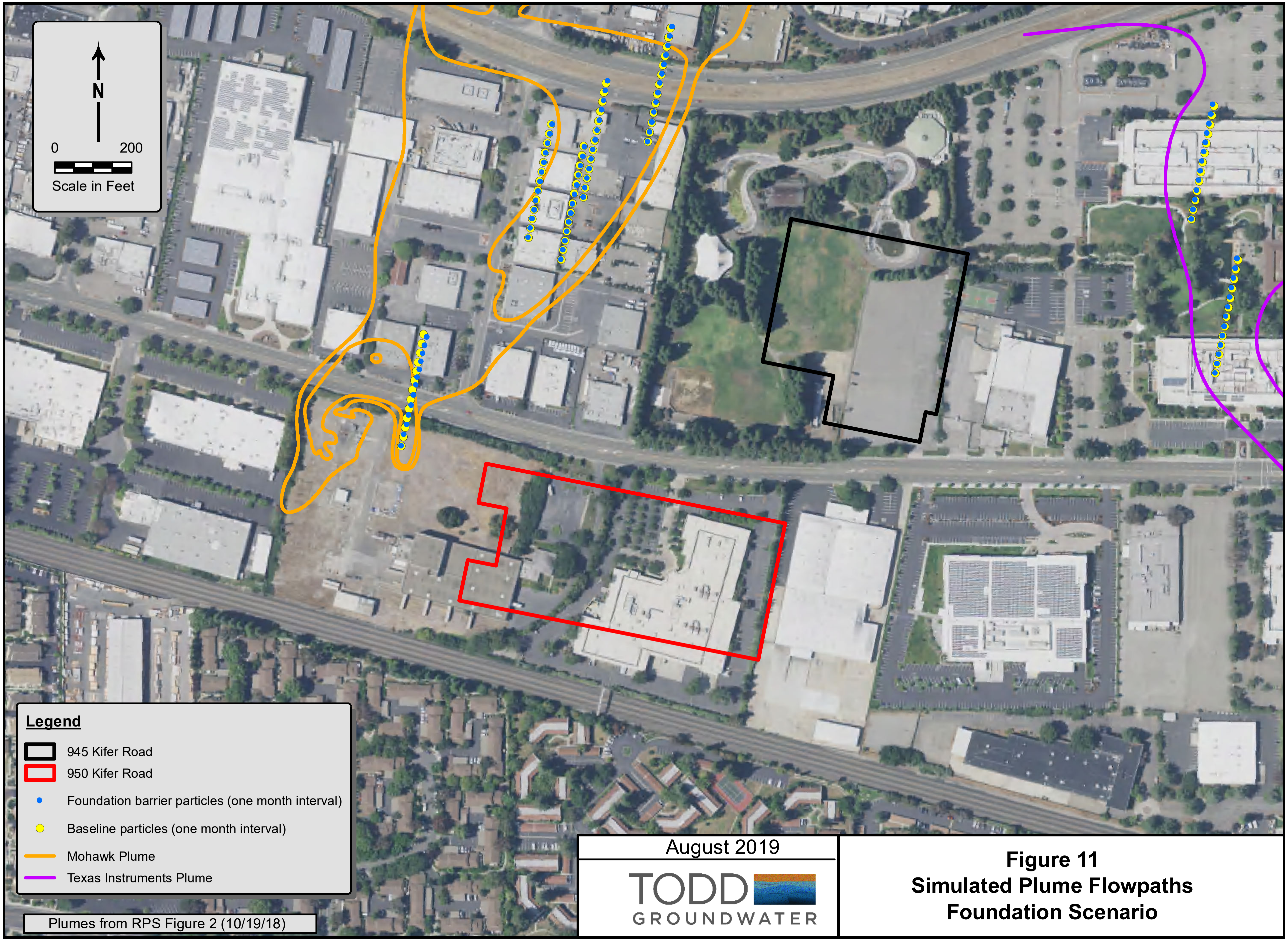

Figure 11
Simulated Plume Flowpaths
Foundation Scenario