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Subject:
Updates to the Existing MODFLOW Groundwater Flow Model

INDUSTRIAL

Date:
January 5, 2011

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Dear Mr. Thompson:

This letter provides a summary of the updates to and re-calibration of the existing MODFLOW groundwater flow model originally constructed as part of the NTCRA 2 Design and Study activities (1996 and 1997) and further refined in 1998 as described in the NTCRA 2 Technical Memorandum (BBL, November 1998). In addition, this letter presents particle tracking simulations performed to re-assess the capture zone of the existing Hydraulic Containment and Treatment System (HCTS).

The updates to and recalibration of the existing model were performed to improve the representation of hydrogeologic conditions at the Site. Specific tasks were as follows:

- Modify model layer elevations for the outwash-till contact and incorporate additional geologic data collected since the last modeling efforts.

- Revise the hydraulic conductivity values and distributions in the overburden units and the shallow and deep bedrock units to incorporate additional data collected since the last regional MODFLOW modeling efforts.

- Re-evaluate and revise model boundary conditions consistent with recent data collection and recent weather conditions (i.e., the relatively dry 2009 to 2010 year).

- Calibrate the model to October 2010 groundwater elevations with the HTCS operating.

- Perform a sensitivity analysis with the calibrated model to evaluate model uncertainty and non-uniqueness.

The model simulates steady state flow conditions using MODFLOW-SURFACT (Hydrogeologic, Inc. 1996), a modified version of the standard MODFLOW (McDonald and Harbaugh 1988) code. The following paragraphs describe the incorporation of additional data into the model grid structure and interpretation of hydraulic conductivity distributions, the rationale for modifications to boundary conditions, and the model calibration and sensitivity analysis.

Model Domain and Grid Structure

Figure 1 presents the location of the model domain relative to the Site and surrounding topographic features. The model represents overburden and bedrock units over an area of approximately five square miles. This area is sufficient to represent the relevant regional inflows and outflows and the boundaries are far enough away from the Site, which is located in the approximate center of the domain, to avoid any boundary influence on groundwater extraction simulations.

The model grid structure was revised by splitting model layers to further refine vertical discretization within the overburden, and the overall layer elevations were modified based on new geologic data. The original model had 7 layers, with one layer representing a glacial outwash unit, the layer below that representing till, followed by one shallow bedrock layer and four deep bedrock layers. Model layer elevations were revised to incorporate information from additional borings collected during the recent RD/RA field activities in 2009 and 2010 and to incorporate the updated approach to identifying the outwash/till contact, as discussed further below. Additionally, review of the hydraulic test data results (discussed below) resulted in further vertical discretization of the outwash and till units into two model layers, equally divided based on saturated thickness for the outwash unit, and total thickness for the till. Model layer elevation changes are discussed in more detail below.

Table 1 presents a summary of the model layer designations. The model is currently constructed with nine layers, with the top four layers representing overburden (two outwash layers and two till layers), underlain by one shallow bedrock layer, and four deep bedrock layers. Figure 2 shows the horizontal grid cell discretization, which was unchanged from the previous model; currently, the greatest degree of refinement is in the vicinity of the NTCRA 2 wells at 2.5 by 2.5 feet, with successively larger cell sizes outward from that area. The largest cells are approximately 340 by 340 feet at the edges of the domain.

Geologic Contact Revisions

Since the previous model updates (part of NTCRA 2 activities in 1998), the approach to differentiating between overburden and till changed. Specifically, during the FS, BBL and TetraTech NUS developed a consistent, quantitative process to identify the top of till based on split-spoon blow count data, as summarized in a memorandum dated June 22, 2002. This procedure resulted in modifications to the top-of-till designations for many of the historical borings. Also, the geologic data from the NTCRA 2 overburden and bedrock piezometers and the wells installed in 2009 and 2010 had not been incorporated into the model. The NTCRA 2 piezometers are located in an important area with respect to plume containment and capture zone analysis. Therefore, the model layer structure was revised to more accurately reflect the current data.

To accomplish this, the layer elevations in the model that correspond to the outwash-till contact and the till-bedrock contacts were exported as x, y, z datasets, merged with the Site well and boring database elevations, and re-interpolated over the existing model grid. Figures 3 and 4 show the resulting layer elevations of the outwash-till and the till-bedrock contacts, respectively, in the vicinity of the Site. After the new layer elevations were established, the saturated outwash layer and the till layer were each split in half vertically. In some areas, the simulated water table resulted in dry cells within the outwash layers; at those locations, an arbitrary thickness of two feet was assigned in model layer 2 to maintain continuity in the layer structure across the domain.

Figures 5 and 6 present the total thickness of the saturated outwash (model layers 1 and 2) and the thickness of the till (model layers 3 and 4), respectively. As shown in the figures, the saturated outwash is relatively thin in some portions of the site or is unsaturated and is not shown. The thickest portions of outwash and till are generally south and east of the former Operations Area.

Figure 7 shows the location of model cross-section A-A', which runs north to south through the Site area and the NTCRA 2 extraction wells. Figure 8 shows the cross-section, which portrays the variable thickness of the overburden layers, and the thickness of each unit relative to the entire model thickness. The figure includes various colors (shading) on the grid cells that correspond to model hydraulic conductivity values through that cross section location; the distribution of these values can be seen in plan view for each layer on Figures 9 through 14 and are discussed in more detail below.

Hydraulic Conductivity Distributions

The hydraulic conductivity distributions assigned to the outwash and till layers in the previous model within the Site area were interpolated based on available data at the time of original model construction. The hydraulic conductivity over the rest of the model domain in these layers was based on values obtained from regional hydrogeologic reports and/or previous calibration efforts. A single hydraulic conductivity value was assigned to all bedrock layers based on a geometric mean of values obtained from regional hydrogeologic reports and site-specific hydraulic conductivity tests. Therefore, the interpolated hydraulic conductivity distributions within the area for which data exists were revised using all of the currently available data. Likewise, the value assigned to the bedrock layers was re-evaluated. The following sections describe how the new data were interpolated and assigned to the model grid in each layer.

Overburden Hydraulic Conductivity Test Data

All overburden wells for which horizontal hydraulic conductivity test data were available were assigned to an overburden model layer based on the midpoint elevation of the well screen. The well screen layer assignments resulted in 42 measurement locations in model layer 1 (outwash), 49 in model layer 2 (outwash), 33 in model layer 3 (till), and 17 in model layer 4 (till). The hydraulic conductivity distributions within each of the four overburden layers were then hand contoured using intervals of 1, 10, 100, and 1,000 feet per day based on the measured data for the wells within each overburden layer. The hand contours were converted to a series of pseudo-data points and added to the actual test data set for each layer.

Two-dimensional grids were created for each of the data sets/layers using Groundwater Modeling System (GMS) software (Aquaveo 2009), with the perimeter of each grid defined by the outer most data points in each layer. All grid cells had a constant ten foot spacing. Each dataset of hydraulic conductivity and pseudo-points were then interpolated over each of the corresponding grids using ordinary kriging tools available within the GMS software.

The kriged datasets were then merged with values assigned to the previous model outside of the kriged areas to provide hydraulic conductivity values over the entire groundwater flow model grid. For the two outwash layers (new model layers 1 and 2), the values merged into the new kriged datasets were taken from old model layer 1; likewise, for the new kriged data sets corresponding to till in new model layers 3 and 4, the data were merged with the values assigned in the old model layer 2 outside of the kriged dataset area. This resulted in four data sets consisting of hydraulic test data and contour-interval pseudo-points kriged over the data set area along with existing model values outside of the kriged areas.

The kriged/merged data sets were then divided into zones representing the range of test data values (0.02 feet per day [ft/d] to 3,000 ft/d). The zones included values from the low end of the range that increased by approximately a half order of magnitude; however, these zone values were adjusted during calibration to vary from 0.6 ft/d up to 3,000 ft/d. The range of values assigned to the calibrated model is presented on Table 2. As shown in the table, zones 1 through 11 correspond to the range of values assigned to the overburden model layers as discussed. Additionally, zones 12 through 18 represent hydraulic conductivity values in the overburden layers that represent other hydraulic features outside the kriged areas (refer to Table 2).

As discussed in previous model reports and updates, horizontal and vertical anisotropy are included in all hydraulic conductivity zones and in all model layers. Table 2 includes the horizontal and vertical components of the overburden hydraulic conductivity values. As with the original model, the horizontal anisotropy ratio for the overburden is 4:1 (y direction to x direction), and the vertical anisotropy ratio is 10:1 (horizontal to vertical). The simulated overburden hydraulic conductivity is higher in the north-south direction, parallel to the Quinnipiac River valley (BBL June 1998). The simulated bedrock hydraulic conductivity is also higher in the north-south direction approximately parallel to the strike of the bedding-plane bedrock fractures. Additional details regarding the assignment of horizontal anisotropy are provided in the RI Report (BBL June 1998) and the NTCRA 2 Technical Memorandum (BBL November 1998). The hydraulic conductivity value assigned to the sandy materials observed beneath the former railroad grade (85 ft/d) was the average value calculated based on grain-size data for three samples collected from test pits in November 2010. This hydraulic conductivity value was estimated using the USBR method, as described in Vukovic and Soro 1992. The assigned values in the model for this material do not include horizontal anisotropy. Likewise, the areas corresponding to the wetland areas (see Table 2) do not include horizontal or vertical anisotropy.

Figures 9 through 12 present the calibrated horizontal hydraulic conductivity distributions in model layers 1 through 4, respectively. In general, the lowest values of hydraulic conductivity in the overburden layers occur in the Operations Area and the areas immediately east of it, with values increasing by one to two orders of magnitude or more toward the south and southeast. It is important to note that the units referred to as “till” in this report vary significantly in terms of hydraulic properties, and the more permeable “till” zones were referred to as “gravelly drift” in the Remedial Investigation (RI) (BBL June 1998).

Bedrock Hydraulic Conductivity Test Data

Bedrock hydraulic conductivity values are also presented on Table 2. As indicated in the table, one value is assigned for the shallow bedrock (layer 5) and one (lower) value is assigned for all deep bedrock layers (layers 6 through 9). The horizontal hydraulic conductivity value representing the shallow bedrock is the geometric mean value from single-well test data at wells whose screen interval midpoint elevation corresponds to model layer 5 (47 test data); likewise, the value assigned to the deep bedrock layers is the geometric mean value from all other bedrock test locations (26 test data). The horizontal anisotropy ratio for the bedrock layers is 20:1 (y direction to x direction) as determined from the dip angle of the bedrock (Anderson and Woessner 1992) and described in the NTCRA 2 Technical Memorandum (BBL November 1998). Similarly, the vertical anisotropy ratio is 40:1 (horizontal to vertical). Figures 13 and 14 present the horizontal hydraulic conductivity in the bedrock layers (a single value of 0.39 ft/d in the shallow bedrock layer, and a single value of 0.07 ft/d for the deep bedrock layers).

Model Boundary Conditions

The model update included a thorough review and analysis of the boundary conditions, which include aerial recharge due to precipitation infiltration, the Quinnipiac River, river and drain boundary conditions representing various surface water features, constant head and general head boundaries representing regional inflow and/or outflow, assumed water-supply pumping, and on-site remedial pumping. Assumed water supply pumping was modified slightly during calibration, and on-site remedial pumping was updated to October 2010 conditions as described below. The Quinnipiac River stage was linearly re-interpolated along the entire set of reaches simulated in the model with May 2010 measurements; other modifications were made to the river hydraulic parameters as discussed below. The river and all other remaining boundary conditions were also modified based on review of topographic maps, review of 2009-2010 precipitation records, and a site-wide and area-wide field reconnaissance to evaluate current hydrologic conditions. Figure 15 presents the calibrated recharge rates, Figure 16 presents the remaining boundary conditions for overburden units (model layers 1 through 4), and Figure 17 presents the boundary conditions for bedrock units (model layers 5 through 9). The following sections describe the updated boundary conditions in the current model.

Recharge

Figure 15 presents the recharge zones, and Table 3 presents the rates for each zone with a description of what each zone represents. Recharge rates vary depending on the surficial geology and topography, as well as the presence of assumed domestic leach fields and storm drainage features. The magnitude and zonation of recharge rates were modified slightly from the previous model and adjusted during calibration. Changes in the rates and zonation since the previous model are as follows:

- Valley (aerial recharge due to precipitation over the river valley): rates were decreased during calibration from approximately 25 inches per year (in/yr) to 15.4 in/yr; the revised value is approximately 35 percent of the average annual precipitation.
- Bedrock highs (aerial recharge due to precipitation over the steeper slopes with shallower bedrock): rates were decreased during calibration from approximately 9 to 13 in/yr to 4 in/yr.
- Operations Area (aerial recharge due to precipitation): new zone established to specify reduced recharge at 1 in/yr due to the presence of pavement and building foundations.
- Neighborhood/commercial area east of the river (aerial recharge due to precipitation): new zone established to specify reduced recharge at 5 in/yr due to the presence of steeper slopes, pavement, and building foundations.
- Storm water runoff areas: rates were decreased accordingly to represent a reduction in the overall aerial recharge rates for the valley over these specific areas.

No modifications were made to the zones representing leach fields from properties northwest of the Site on Lazy Lane (13 in/yr) or from the storm water runoff area representing the neighborhood west of the Site on Ivy Drive (438 in/yr). The higher rate of 13.4 in/yr along Lazy Lane assumes an additional contribution of 9.4 in/yr along Lazy Lane due to the absence of sanitary sewers for the approximately 30 residences. This assumes the enhanced recharge is distributed over an area approximately 4,000 feet long and 300 feet wide, with an average domestic water usage of 640 gallons per day (gal/day).

The higher recharge rate of 438 in/yr is focused at a storm sewer outfall on Ivy Drive that drains approximately 1,800 feet of roadway. It is assumed that the roadway is approximately 40 feet wide and that approximately 36 in/yr of precipitation (of the average 44 in/yr total) that collects on this paved surface discharges at the outfall. It is further assumed that the discharge from the outfall infiltrates over an area approximately 20 feet wide and 300 feet long, and adds to the 4 inches per year recharge that would otherwise occurs in this area.

An additional area with 88 in/yr estimated recharge is located northwest of the site in an area with wetland soils and ponds, and near the bottom of the hillside in an area where runoff from the ditches along Lazy Lane may accumulate and infiltrate. Although this rate is a general estimate, its sensitivity in the model is limited by the presence of ponds on these properties, which are simulated using “river” cells.

Recharge rates in the other areas were adjusted downward during calibration, which is supported by the relatively dry conditions in this region during late 2009 and throughout 2010. Recharge was specified at the uppermost active model cell; therefore, if cells are dry, the recharge is specified to the next layer below and so on until an active cell is encountered. This specification results in some recharge directly applied to deeper layers including the shallow bedrock at some locations corresponding to bedrock highs.

Quinnipiac River

The Quinnipiac River is simulated in model layer 1 using the MODFLOW River Package. This package simulates the groundwater and surface water interaction as a function of the head difference between groundwater elevation and river stage, as well as hydraulic parameters defining the conductance of the river bed materials. As indicated above, the river stage was updated with May 2010 measurements from three locations near the Site (Lazy Lane and Curtis Street, and the tributary at Curtis Street). Additionally, the river conductance was modified to establish a consistent value for each river reach. The river conductance was calculated using assumed generalized river width of 25 feet, a river bed thickness of 2.5 feet, and a river bed hydraulic conductivity of 30 ft/d. The river bed thickness was estimated based on a review of river sediment sample descriptions (BBL and USEPA May 2005). The riverbed hydraulic conductivity was estimated based on river sediment grain size data using the USBR method, as described in Vukovic and Soro 1992.

Domain Boundary Inflows and Outflows

Constant head values along the eastern model boundary in model layers 1 and 2 (shown in Figure 16) were modified based on a review of topographic elevations and an assumed depth to the water table. Likewise, the specified river boundaries along the eastern edge of the domain, which represent ponds (the two northern-most river boundaries along the domain boundary) and/or a stream flowing into a pond (the southern-most river boundary extending out into the domain) were modified according to topographic map surface values and observations made during field reconnaissance.

In the previous model, a general head boundary was specified along the eastern edge of the domain in the deepest bedrock layer to represent a portion of the regional bedrock groundwater that may ultimately discharge toward the Connecticut River located approximately 13 miles east of the model domain edge. The conductance for this boundary was modified slightly by reducing the hydraulic conductivity from 1 ft/d to 0.75 ft/d. An additional general head boundary was specified along the southern edge of the domain to represent a portion of the regional bedrock groundwater that may ultimately discharge toward Long Island Sound, approximately 22 miles south of the model domain. These general head boundaries are assigned to the two deepest bedrock layers (model layers 8 and 9) as shown in Figure 17.

Other Surface Water Features

Other surface water features in the model are included in Figure 16 and include a drainage pipe that exists from the Operations Area towards the river along the northern boundary of the NTCRA 1 area, the “oxbow” wetland next to the river at the Site, and ponds north of Lazy Lane.

Drain boundary conditions are similar to river boundary conditions; however, with the drain package, groundwater will flow into the drain cells if the groundwater elevation is above the specified drain elevation, but not vice versa as does occur with the river package. This is a more realistic representation of the wetland in this area. The elevation of the wetland was specified relative to the river at that location, and the drain conductance was specified similarly to the river.

The river boundary conditions representing the ponds north of Lazy Lane shown on Figure 16 were modified from the previous model by specifying lower stage values based on further review of the topographic map.

No-Flow Boundaries

No-flow boundaries in MODFLOW represent locations within the model domain that are inactive (i.e. they are not included in the numerical flow calculations) due to unsaturated conditions. The no-flow areas in model layers 1 through 4 as shown on Figure 16 represent either high elevation areas where topographic maps indicated a groundwater divide likely exists and therefore the portion of the divide not contributing flow to the Quinnipiac River valley was inactivated, or where preliminary simulations indicated the overburden was likely unsaturated.

The inactive areas in layers 5 through 9 shown on Figure 17 are beyond high elevation areas that are assumed to represent groundwater divides; these areas therefore would not contribute significant flow into the river valley.

Groundwater Extraction Wells

The NTCRA 1 and 2 extraction wells are assigned to model layers corresponding to the well screen intervals. The pumping rates assigned to each layer for each well are allocated based on the length of screen interval intersecting a given model layer. Extraction rates were measured during the October 2010 field activities; the NTCRA 1 total extraction rate was estimated at 10.9 gallons per minute (gpm); this rate was split evenly between the ten NTRCA 1 wells in operation (wells RW-1 through RW-4, and RW-7 through RW-12). Extraction rates at the NTCRA 2 overburden wells RW-13 and RW-14 were measured at 13.1 and 18.6 gpm, respectively. NTCRA 2 bedrock well RW-1R was pumping at 0.066 gpm. The total system flow rate of the HCTS in October 2010 was approximately 42.7 gpm.

The model also includes seven “pumping wells” that represent combined domestic well withdrawals in the deep bedrock (model layer 7; Figure 17). Total flow from these domestic wells is approximately 16 gpm (combined long-term average), which assumes approximately 640 gallons per day from a total of 36 homes along Lazy Lane and Melcon Drive; these areas lack public water mains. In the original model, the 4 “wells” shown on Figure 17 located west of the Operations Area were assigned rates of 3 gpm each, and the other 3 “wells” located near or along Lazy Lane were assigned rates of 2 gpm each, for a total of 18 gpm. During calibration, the 2 “wells” located along Lazy Lane were decreased to 1 gpm each, for a total of 16 gpm to represent the combined long-term average.

<u>Model Calibration - October 2010 Conditions</u>

Standard trial-and-error techniques were used to calibrate the updated model to steady state conditions representing October 2010 pumping conditions. The trial-and-error method includes identifying the calibration parameters (parameters or boundary conditions that are unknown or have the greatest degree of uncertainty associated with them), and iteratively adjusting those parameters within a reasonable range until the calibration goals are met. Standard methods and guidance were followed (Anderson and Woessner 1992; ASTM 1993, 1994, 1996; Hill 1998; Reilly and Harbaugh 2004). The following sections describe the calibration goals and metrics, how the chosen parameters and boundary conditions were modified during calibration, and the calibration results (statistical measures of the match between simulated and observed data).

Calibration Goals and Metrics

The goal of the calibration was to adjust the parameters and/or boundary conditions in the updated model such that the difference between simulated groundwater elevations and the measured October 2010 groundwater elevations was minimized, and that the root mean squared error (RMSE) was less than ten percent of the range in observed values. Other qualitative metrics included comparing the simulated and observed hydraulic gradients and overall groundwater flow directions. Ninety well locations were used in the calibration (Figure 18). To help calibrate hydraulic heads in the upgradient area west of the site, an additional calibration target was added, namely MW-129. The target head value at this location was a representative average based on historical groundwater elevation measurements.

Calibration Parameters

During a trial-and-error calibration process, the various boundary conditions and hydraulic conductivity values were adjusted and the overall sensitivity to model results evaluated. The adjustments were made to the locations and values of boundary conditions along the model domain edges (general head and constant head boundaries, and values assigned to various rivers and drains representing surface water features other than the river), aerial recharge rates, and the hydraulic conductivity in both the overburden and bedrock. The initial simulation results indicated the model was most sensitive to the horizontal hydraulic conductivity in the overburden and the bedrock, the vertical hydraulic conductivity of the bedrock, and the aerial recharge rates. Therefore, parameters and boundary conditions other than these were adjusted to their final values and a more rigorous calibration on the selected parameters was performed. However, consistent with standard trial-and-error techniques, it is important to note that the hydraulic conductivity values modified in the overburden layers mainly focused on areas outside of where aquifer test data existed. That is, in the areas where hydraulic conductivity data have been measured, minimal changes were made to hydraulic conductivities during model calibration.

<u>Results</u>

Figures 19 through 22 present simulated groundwater elevations for the water table surface, the upper till (model layer 3), the shallow bedrock (model layer 5), and the deep bedrock (model layer 7), respectively. These figures show that, overall, the model simulates the local and regional components of flow directions from the east and the west toward the Quinnipiac River, and towards the south consistent with the regional flow within the valley. Additionally, Figures 19 through 21 show hydraulic gradients toward the NTCRA 1 extraction system in the overburden and shallow bedrock. Figure 22 shows localized depressions simulated in the vicinity of assumed domestic water withdrawals.

Table 4 presents the simulated and observed groundwater elevations, the residuals (the difference between simulated and observed) and residual statistics (mean error [ME], mean absolute error [MAE], and the RMSE) for each model layer and for all points/layers in the model. The residuals are calculated as observed head minus simulated head; therefore, negative residuals indicate the model is over simulating groundwater elevations at that location, and positive residuals indicate the model is under simulating groundwater elevations at that location. The table also shows the minimum observed groundwater elevation (at MW-910S), the maximum (at MW-129), and the range (approximately 80 feet). Residual errors range from 0.04 feet at MW-127C to -8.29 feet at PZR-2DR. Most residuals are within five percent (four feet) of the range in observations (80 feet), more than two-thirds are within two feet of error, and more than half are within one foot of measured target heads. The least error occurs in the overburden layers, with RMSE values ranging from 0.74 to 1.74 feet. There is a greater degree of statistical error in the bedrock layers, with RMSE values ranging from 2.24 feet in the deep bedrock model layer 6, up to almost 6 feet in the deepest bedrock layer for which data exist (layer 8). However, model layer 8 includes only two calibration points, one of which calibrates well within the goals. The statistics for the entire model are within the calibration goals, with a mean error of -0.55 feet and an RMSE of 2.19 feet, which is 2.7 percent of the observed range in groundwater elevation.

Figure 23 presents scatter plots of the simulated versus observed groundwater elevations. The upper plot includes all calibration points, including the highest groundwater elevation at MW-129, and the lower plot shows greater detail in the groundwater elevation range that most points represent. Both plots include a line indicating the theoretical perfect match between simulated and observed heads. Many of the points fall within one to two feet of that line (i.e. residuals less than one to two feet); however, in general, there are more over simulated points (data above the theoretical perfect match line) than under simulated points.

Figures 24 through 31 present the spatial distribution of residuals in each model layer, with the exception of model layer 9, which does not include any calibration points. The residual statistics and the spatial distribution of residuals support the following general observations:

- The model is over simulating groundwater elevations in more locations than it is under simulating groundwater elevations (56 negative residuals, 37 positive residuals).
- There is a greater magnitude of error in calibration points located east of the river, and with a couple of exceptions, all of these points represent over simulated groundwater elevations.
- The model consistently under simulates groundwater elevations in the vicinity of the NTCRA 1 system, regardless of model layer (clusters MW-705 and MW-709 in various layers; SRS-1 and CPZ-2A in till layer 4).
- The model is well-calibrated in the vicinity of the NTCRA 2 extraction wells.

Although there is some degree of spatial bias in the residuals, overall, each layer and the total model statistics are within acceptable ranges. As additional data and information are collected for the site, and the site conceptual model is further updated and refined, the numerical model will be re-evaluated and updated to further improve the match between simulated and observed conditions.

Model Sensitivity Analysis

Different combinations of hydraulic parameters and boundary conditions can yield similar results; as such, a model calibrated with trial-and-error techniques does not result in a unique model. To assess the level of uncertainty in the model as a function of non-uniqueness, a sensitivity analysis was performed focusing on the parameters that were qualitatively identified as most sensitive during model calibration.

The following parameters and parameter value changes were chosen for sensitivity analysis:

- Recharge: baseline calibrated values multiplied by 0.5, and by 2.
- Ratio of horizontal to vertical hydraulic conductivity (Kh:Kv) in bedrock layers (the baseline is 40:1): evaluated ratios of 20:1 and 60:1.
- Horizontal hydraulic conductivity in the overburden layers: baseline calibrated values multiplied by 0.2 and 5.

Results of the sensitivity analysis are presented in Table 5. Model layer residual statistics for the calibrated (baseline) model are presented, followed by the layer-by-layer and whole-model statistics for each sensitivity simulation. In the simulations with modified recharge, the lower recharge rates result in some individual layer improvements, and less over simulation within each layer, but the whole- model statistics are not as good as the baseline model. For the increased recharge simulation, with the whole-model statistics have an RMSE/range greater than ten percent, and the model is over simulated by a greater degree than with the baseline conditions. These results indicate that if recharge rates are lower, some of the residual error may improve, but for greater recharge rates, hydraulic conductivity values would have to be much higher to accommodate the additional volume of water without causing additional over simulation error.

The simulations with modified Kh:Kv in the bedrock layers indicate that at the lower ratio (higher vertical hydraulic conductivity), the model statistics are significantly improved in the shallow bedrock layer 5 and the deepest bedrock layer 8, but that overall, the model statistic improves by only a few tenths of a percent. For the higher ratio scenario (lower vertical hydraulic conductivity), the layer and model statistics are worse. These simulations indicate that higher values of vertical hydraulic conductivity in the bedrock (which is not well constrained by available data) could further improve the model calibration.

The simulations with modified overburden horizontal hydraulic conductivity generally do not improve the calibration either way. With the decrease in values, the groundwater elevations are generally more over simulated, and with the increase in values, the statistics look similar; however, increasing the overburden hydraulic conductivity by half an order of magnitude is not considered to be reasonable in the areas where numerous test data are available.

Overall, calibration and sensitivity analysis indicate that decreasing recharge, increasing overburden hydraulic conductivity in areas outside of test data locations, and/or decreasing the ratio of Kh:Kv in bedrock units (in some combination) may further improve model calibration.

Summary and Conclusions

In summary, several modifications were made to the original NTCRA 2 MODFLOW model to incorporate additional data and Site information and represent current hydrologic and remedial pumping conditions. Modifications included a refined vertical discretization of the overburden units (previously one outwash unit and one till unit, now two of each), revising the outwash-till contact based on additional data as well as the updated approach to defining till, revising the till-bedrock contact based on additional data, revising the hydraulic conductivity values and distributions in all hydrostratigraphic units in the model, and updating boundary conditions.

The model calibration to October 2010 conditions and the sensitivity analysis have revealed that the model is well calibrated, based on the calibration goals defined for the October 2010 data set. Sensitivity analysis has revealed that lower recharge rates, an increase in overburden hydraulic conductivity, and/or a lower ratio of Kh:Kz in bedrock units may further reduce model error to some degree. Overall, the model adequately simulates groundwater elevations, flow directions, and hydraulic gradients and is particularly well-calibrated in the vicinity of the NTCRA 2 extraction wells in all model layers. The model is therefore considered suitable for predictive capture zone analysis and particle-tracking simulations, as necessary. Additional model modifications can be made as further site data are collected.

Please don't hesitate to contact me if you have any questions.

Sincerely,

ARCADIS U.S., Inc.

Michael Gefell
Principal Geologist

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ARCADIS

Tables

Table 1.
Model Layer Designations
SRSNE Superfund Site, Southington, CT

Model Layer	Hydrologic Unit	Thickness (feet)
1	Outwash	Variable
2	Outwash	Variable
3	Till	Variable
4	Till	Variable
5	Shallow Bedrock	Variable; approximately 30 feet
6	Deep Bedrock	30
7	Deep Bedrock	40
8	Deep Bedrock	200
9	Deep Bedrock	300

Table 2.
Hydraulic Conductivity Zone Database - Calibrated Model
SRSNE Superfund Site, Southington, CT

Zone Number	Model-Calibrated Zones[1] (ft/d)				Material
	Kh [2]	Kx [3]	Ky [4]	Kz [5]	
1	0.6	0.3	1.2	0.06	Outwash and Till within site/dataset area
2	1	0.5	2	0.1	
3	3	1.5	6	0.3	
4	15	7.5	30	1.5	
5	45	22.5	90	4.5	
6	100	50	200	10	
7	300	150	600	30	
8	850	425	1700	85	
9	1000	500	2000	100	
10	1395	700	2780	140	
11	3000	1500	6000	300	
12	85	85	85	8.5	Sandy material beneath railroad tracks
13	3	1.5	6	0.3	Outwash - upgradient of Operations Area on bedrock hillsides
14	1	0.5	2	0.1	Till - upgradient of Operations Area on bedrock hillsides
15	20000	20000	20000	20000	Distant wetland area (potential for overland flow of ponded water)
16	400	200	800	40	Backfill/Bedding of off-site interceptor system (assumed)
17	400	200	800	40	Outwash - outside site/dataset area
18	100	50	200	10	Till - outside site/dataset area
19	0.39	0.088	1.763	0.0099	Layer 5 - Shallow Bedrock
20	0.07	0.016	0.313	0.0018	Layers 6 through 9 - Deep Bedrock

Notes:

[1] Zone values were defined based on the range of average horizontal hydraulic conductivity values from hydraulic testing (BBL June 1998; BBL and USEPA 2005; ARCADIS October 2010). Additional zones were created during calibration.

[2] Horizontal hydraulic conductivity - based on single-well hydraulic test data; for overburden materials, a horizontal anisotropy ratio of Kx:Ky = 1:4, and for the horizontal anisotropy is 1:20. The horizontal hydraulic conductivity is the geometric mean of Kx and Ky.

[3] Horizontal hydraulic conductivity value in the x-direction.

[4] Horizontal hydraulic conductivity value in the y-direction.

[5] Vertical hydraulic conductivity; for overburden materials, this value is 1/10 of the horizontal value, and for bedrock, this value is 1/40 of the horizontal value.

Table 3.
Recharge Zone Database
SRSNE Superfund Site, Southington, CT

Location	Recharge (in/yr)	Recharge (ft/d)
Valley	15.4	0.0035
Bedrock High	4.0	0.0009
Bedrock High	4.0	0.0009
Stormwater Runoff Area	13.4	0.0031
Stormwater Runoff Area	13.4	0.0031
Leach Fields	438.3	0.1000
Stormwater Runoff Area	87.7	0.0200
Ops Paved Area	1.0	0.0002
Paved Area East of River	5.0	0.0011

Notes:
in/yr = inches per year
ft/d = feet per day

Table 4.
Model Calibration Residuals and Statistics
SRSNE Superfund Site, Southington, CT

Location	Model Layer	Observed Groundwater Elevation (ft msl)	Simulated Groundwater Elevation (ft msl)	Residual (feet)	ME	MAE	RMSE
MW-501C	1	146.57	147.74	-1.172939	-1.08	1.18	1.73
MW-704S		145.40	145.40	-0.002603			
MW-708S		147.79	150.45	-2.664548			
MW-904S		146.49	147.28	-0.79			
MW-910S		143.17	147.70	-4.53			
MWL-313		146	146.74	-0.74			
MWL-314		146.2	146.39	-0.19			
P-101C		147.11	146.57	0.54			
P-102C		146.57	147.86	-1.29			
P-11B		146.76	147.20	-0.44			
P-13		146.04	146.66	-0.62			
CW-1-78	2	145.84	145.29	0.55	-0.15	0.51	0.74
CW-B-77		146.04	145.78	0.26			
MW-121B		145.62	145.70	-0.08			
MW-121M		146	145.76	0.24			
MW-127B		145.77	145.41	0.36			
MW-204B		145.4	145.82	-0.42			
MW-205B		145.74	145.54	0.20			
MW-501B		147.01	147.90	-0.89			
MW-703S		145.66	145.35	0.31			
MW-707S		145.84	145.64	0.20			
MW-710S		146.85	149.00	-2.15			
MW-801S		146.09	145.51	0.58			
MW-905M		147.23	146.65	0.58			
MW-906M		146.99	148.96	-1.97			
MW-907M		146.07	146.34	-0.27			
P-101B		147.01	146.89	0.12			
P-102B		147.26	147.91	-0.65			
PZO-204M		145.64	145.84	-0.20			
PZO-2M		144.86	145.59	-0.73			
PZO-3M		146.09	146.01	0.08			
PZO-4D		145.82	145.48	0.34			
PZO-4M		145.62	145.48	0.14			
CW-4-75	3	146	145.45	0.55	-0.61	0.84	1.08
MW-03		145.81	145.54	0.27			
MW-202B		148.5	149.38	-0.88			
MW-704M		144.53	144.82	-0.29			
MW-707M		145.83	145.70	0.13			
MW-708M		148	150.38	-2.38			
MW-903M		146.65	148.16	-1.51			
MW-904D		147.19	148.54	-1.35			
MW-906D		148.12	148.95	-0.83			
PZO-2D		145.75	145.57	0.18			
CPZ-2A	4	150.05	147.48	2.57	0.47	1.20	1.62
MW-703D		145.68	145.36	0.32			
MW-704D		144.78	144.57	0.21			
MW-707D		145.91	145.72	0.19			
MW-903D		146.61	148.76	-2.15			
MW-907D		145.86	147.00	-1.14			
PZO-3D		146.34	146.09	0.25			
SRS-1		150.17	146.99	3.18			
SRS-3		146.76	145.98	0.78			

Table 4.
Model Calibration Residuals and Statistics
SRSNE Superfund Site, Southington, CT

Location	Model Layer	Observed Groundwater Elevation (ft msl)	Simulated Groundwater Elevation (ft msl)	Residual (feet)	ME	MAE	RMSE
MW-121A	5	145.82	146.47	-0.65	-0.48	1.72	2.54
MW-121C		145.7	146.43	-0.73			
MW-124C		148.9	146.59	2.31			
MW-127C		145.74	145.70	0.04			
MW-128		145.57	145.97	-0.40			
MW-129		223	230.81	-7.81			
MW-202A		148.35	149.57	-1.22			
MW-204A		145.53	146.55	-1.02			
MW-205A		145.79	145.93	-0.14			
MW-501A		147.23	148.93	-1.70			
MW-704R		144.2	145.77	-1.57			
MW-705R		154.74	149.68	5.06			
MW-707R		145.7	146.00	-0.30			
MW-708R		148.32	150.44	-2.12			
MW-709R		155.75	150.86	4.89			
MW-710R		146.85	149.21	-2.36			
MW-801R		146.92	146.74	0.18			
P-101A		146.94	148.05	-1.11			
P-102A		147.23	148.45	-1.22			
P-11A		146.05	147.79	-1.74			
PZR-4R		145.82	145.73	0.09			
PZR-5R		146.99	145.91	1.08			
MW-705DR	6	155.25	149.92	5.33	-0.20	1.59	2.24
MW-903R		146.64	149.06	-2.42			
MW-906R		149.79	149.56	0.23			
P-8A		160.11	160.18	-0.07			
PZ-907R		147.05	147.88	-0.83			
PZR-1R		146.96	147.75	-0.79			
PZR-2R		145.59	146.96	-1.37			
PZR-3R		146.06	147.73	-1.67			
MW-702DR	7	160.47	158.77	1.70	-1.73	3.04	3.46
MW-703DR		147.75	148.92	-1.17			
MW-706DR		147.25	150.27	-3.02			
MW-707DR		145.14	148.76	-3.62			
MW-708DR		147.52	153.42	-5.90			
MW-709DR		156.02	152.01	4.01			
MW-710DR		147.41	151.31	-3.90			
PZ-903DR		146.59	150.45	-3.86			
PZR-4DR		149.24	149.07	0.17			
MW-907DR	8	154.01	154.62	-0.61	-4.45	4.45	5.88
PZR-2DR		145.46	153.75	-8.29			
Minimum Observation (MW-910S):		**143.17**		**All Layers:**	**-0.58**	**1.40**	**2.17**
Maximum Observation (MW-129):		**223**					
Range in Observations (feet):		**79.83**					
All Layers RMSE/Range:		**2.7%**					

Notes:
ft msl = feet above mean sea level
ME = Mean Error
MAE = Mean Absolute Error
RMSE = Root Mean Squared Error

Table 5.
Results of Sensitivity Analysis
SRSNE Superfund Site, Southington, CT

Model Layer	Baseline			
	ME	MAE	RMSE	RMSE/Range
1	-1.08	1.18	1.73	
2	-0.15	0.51	0.74	
3	-0.61	0.84	1.08	
4	0.47	1.20	1.62	
5	-0.48	1.72	2.54	
6	-0.20	1.59	2.24	
7	-1.73	3.04	3.46	
8	-4.45	4.45	5.88	
All Layers	-0.58	1.40	2.17	2.7%

Model Layer	Recharge x 0.5				Recharge x 2			
	ME	MAE	RMSE	RMSE/Range	ME	MAE	RMSE	RMSE/Range
1	-0.67	0.89	1.49		-1.87	1.94	2.39	
2	0.07	0.55	0.72		-0.60	0.65	1.02	
3	-0.33	0.65	0.80		-1.16	1.22	1.68	
4	0.94	1.47	2.09		-0.46	0.70	1.23	
5	1.58	2.53	5.86		-4.37	5.00	15.85	
6	1.06	1.94	2.91		-2.10	2.83	2.99	
7	0.27	2.98	3.49		-5.13	5.27	5.85	
8	-0.58	3.93	3.98		-11.51	11.51	12.08	
All Layers	0.47	1.59	3.35	4.2%	-2.49	2.76	8.25	10.3%

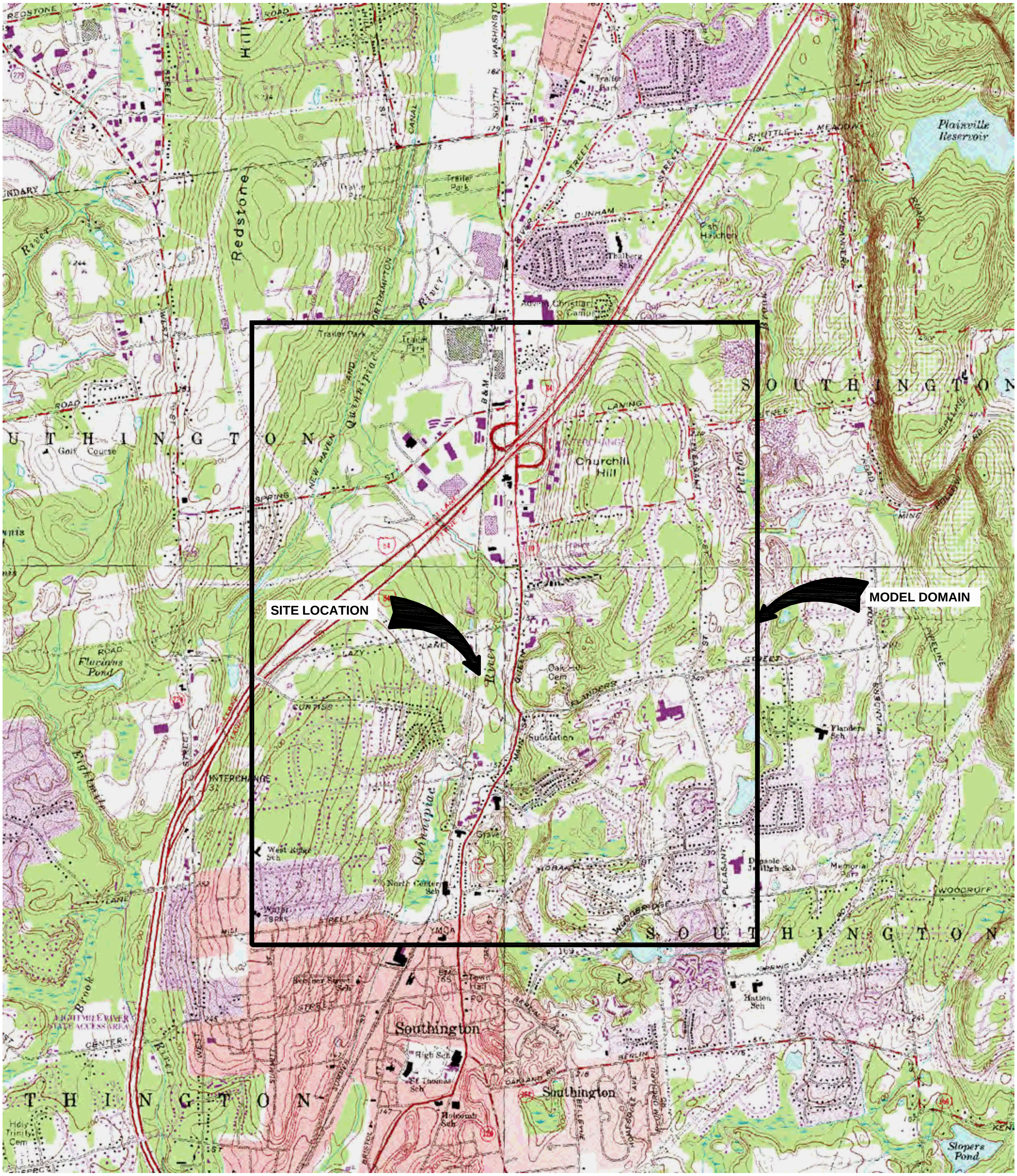
Model Layer	Bedrock Kh:Kv = 20:1				Bedrock Kh:Kv = 60:1			
	ME	MAE	RMSE	RMSE/Range	ME	MAE	RMSE	RMSE/Range
1	-1.08	1.17	1.72		-1.09	1.18	1.73	
2	-0.15	0.51	0.74		-0.16	0.51	0.74	
3	-0.61	0.84	1.08		-0.61	0.84	1.08	
4	0.47	1.20	1.62		0.46	1.19	1.61	
5	-0.02	1.33	1.81		-0.77	2.03	3.52	
6	0.01	1.40	2.08		-0.24	1.76	2.36	
7	-1.08	2.56	2.96		-1.93	3.40	3.78	
8	-2.49	3.92	4.64		-4.83	4.83	6.14	
All Layers	-0.35	1.23	1.82	2.3%	-0.68	1.53	2.54	3.2%

Model Layer	Overburden Kh x 0.2				Overburden Kh x 5			
	ME	MAE	RMSE	RMSE/Range	ME	MAE	RMSE	RMSE/Range
1	-2.07	2.44	3.19		-1.11	1.20	1.69	
2	-0.20	0.95	1.40		-0.59	0.66	0.85	
3	-1.20	2.56	3.15		-0.91	0.91	1.10	
4	0.38	1.53	2.33		0.16	1.48	1.93	
5	-1.12	2.60	4.05		-0.51	1.80	2.36	
6	-1.08	2.52	3.09		0.01	2.14	2.60	
7	-3.32	4.03	4.74		-1.45	3.33	3.70	
8	-6.38	6.38	7.43		-4.12	4.12	5.66	
All Layers	-1.20	2.29	3.36	4.2%	-0.70	1.56	2.22	2.8%

Notes:
Kh = Horizontal Hydraulic Conductivity
Kh:Kv = Ratio of Horizontal to Vertical Hydraulic Conductivity
ME = Mean Error
MAE = Mean Absolute Error
RMSE = Root Mean Squared Error

ARCADIS

Figures



NOTE:

1. SOUTHINGTON, CT USGS QUAD . 1968, MERIDIEN, CT USGS QUAD 1966 PR 1984, NEW BRITAIN, CT USGS QUAD 1966 PR 1984, AND BRISTOL CT USGS QUAD 1967 PR 1984.

0 3000' 6000'

GRAPHIC SCALE

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SITE LOCATION MAP

ARCADIS

FIGURE
1

CITY: SYRACUSE DIV/GROUP: SYR-85 DB: K. SINSABAUGH LD:(Opt) PIC:(Opt) PM:(Reqd) TM:(Opt) LYR:(Opt)ON=*;OFF=*REF*
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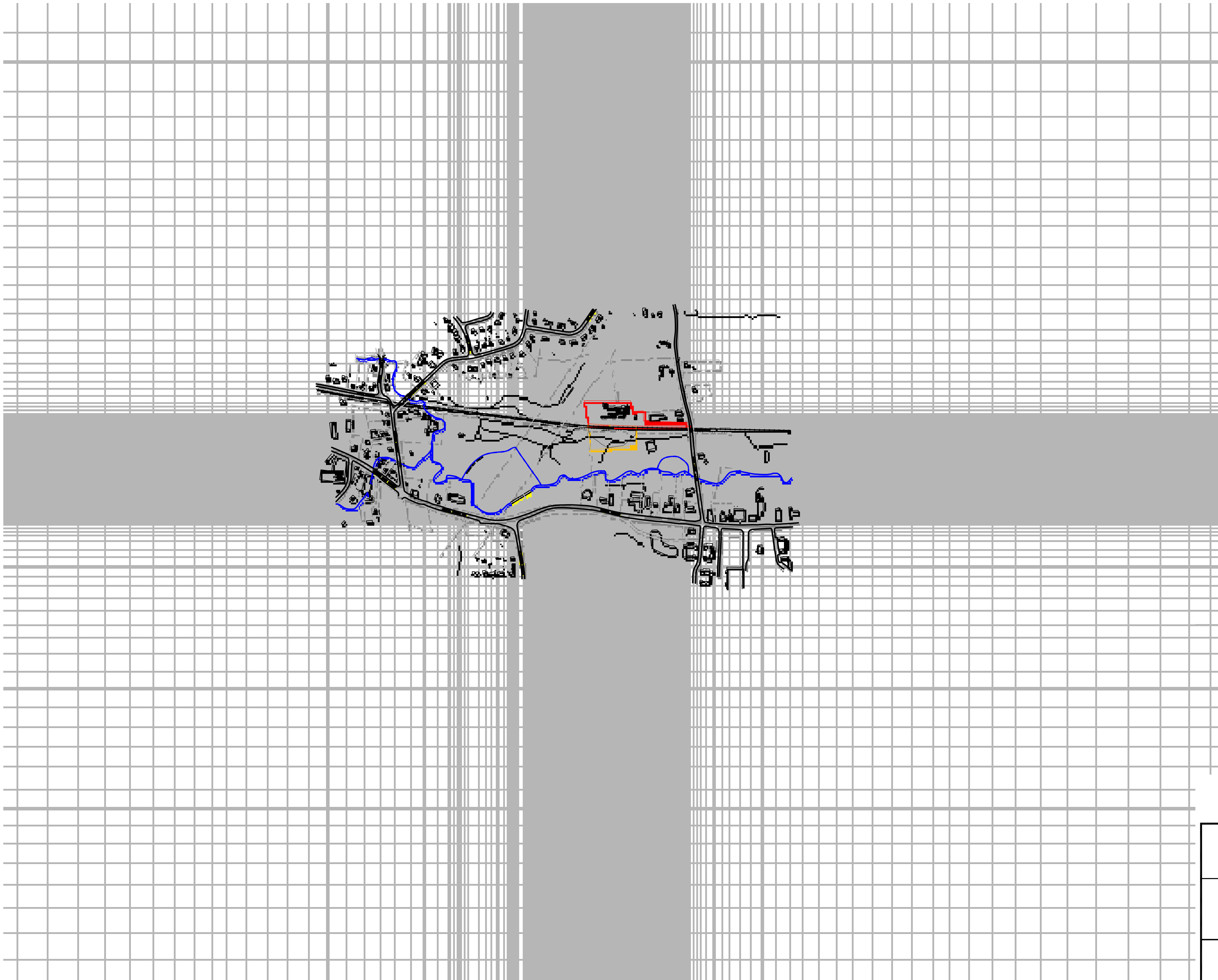


LEGEND:

- FORMER OPERATIONS AREA
- NTCRA 1 CONTAINMENT AREA
- QUINNIPIAC RIVER
- MODEL GRID CELL

NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

2. MODEL GRID CELLS IS 2.5 BY 2.5 FEET IN THE VICINITY OF THE NTCRA 2 EXTRACTION WELLS

3. MODEL GRID CELLS ARE APPROXIMATELY 340 BY 340 FEET AT THE EDGES OF THE DOMAIN.

0 1,000' 2,000'

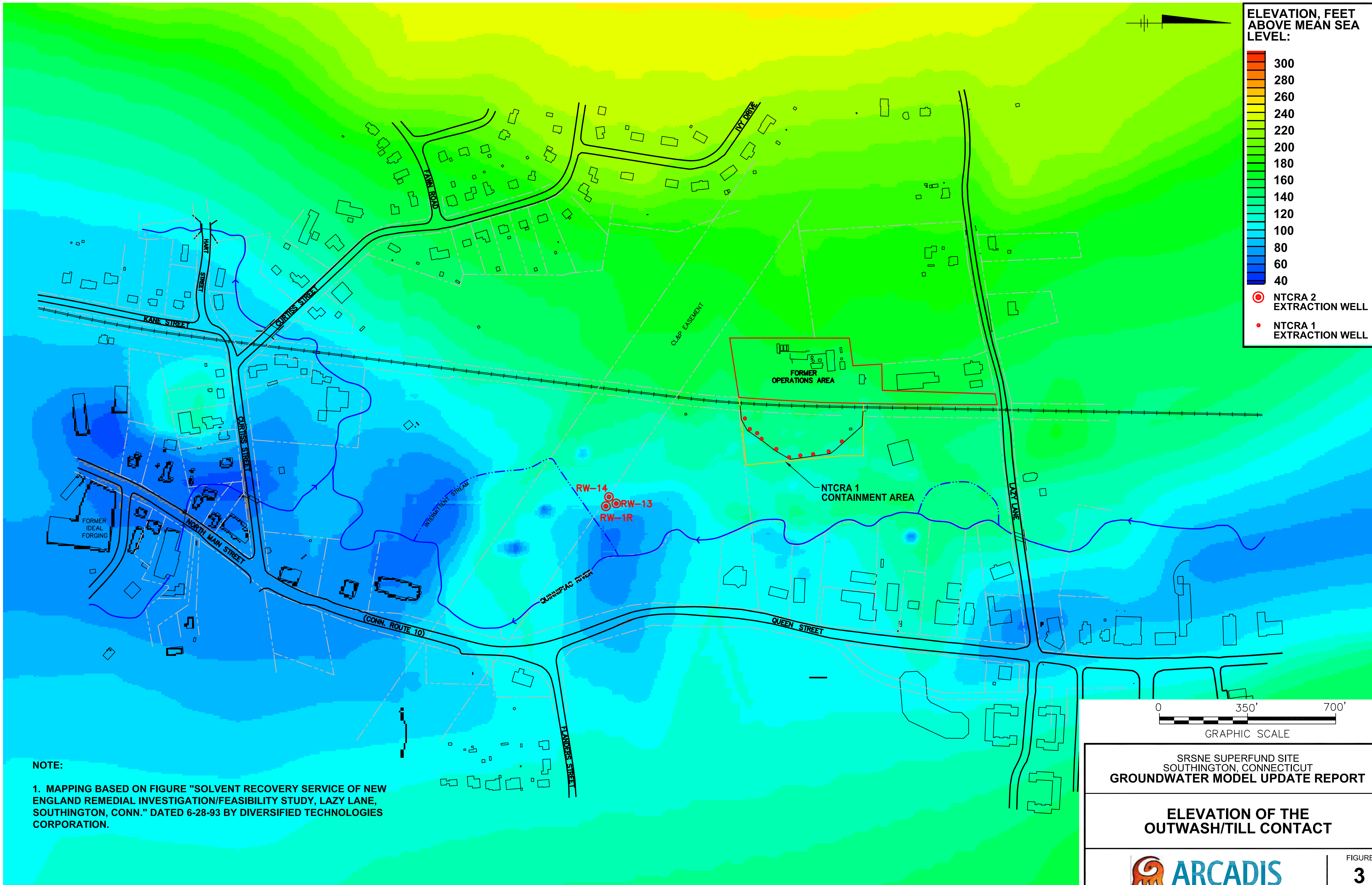
GRAPHIC SCALE

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

MODEL DOMAIN

ARCADIS

FIGURE
2



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

ELEVATION OF THE OUTWASH/TILL CONTACT

ARCADIS

FIGURE
3

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L. FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
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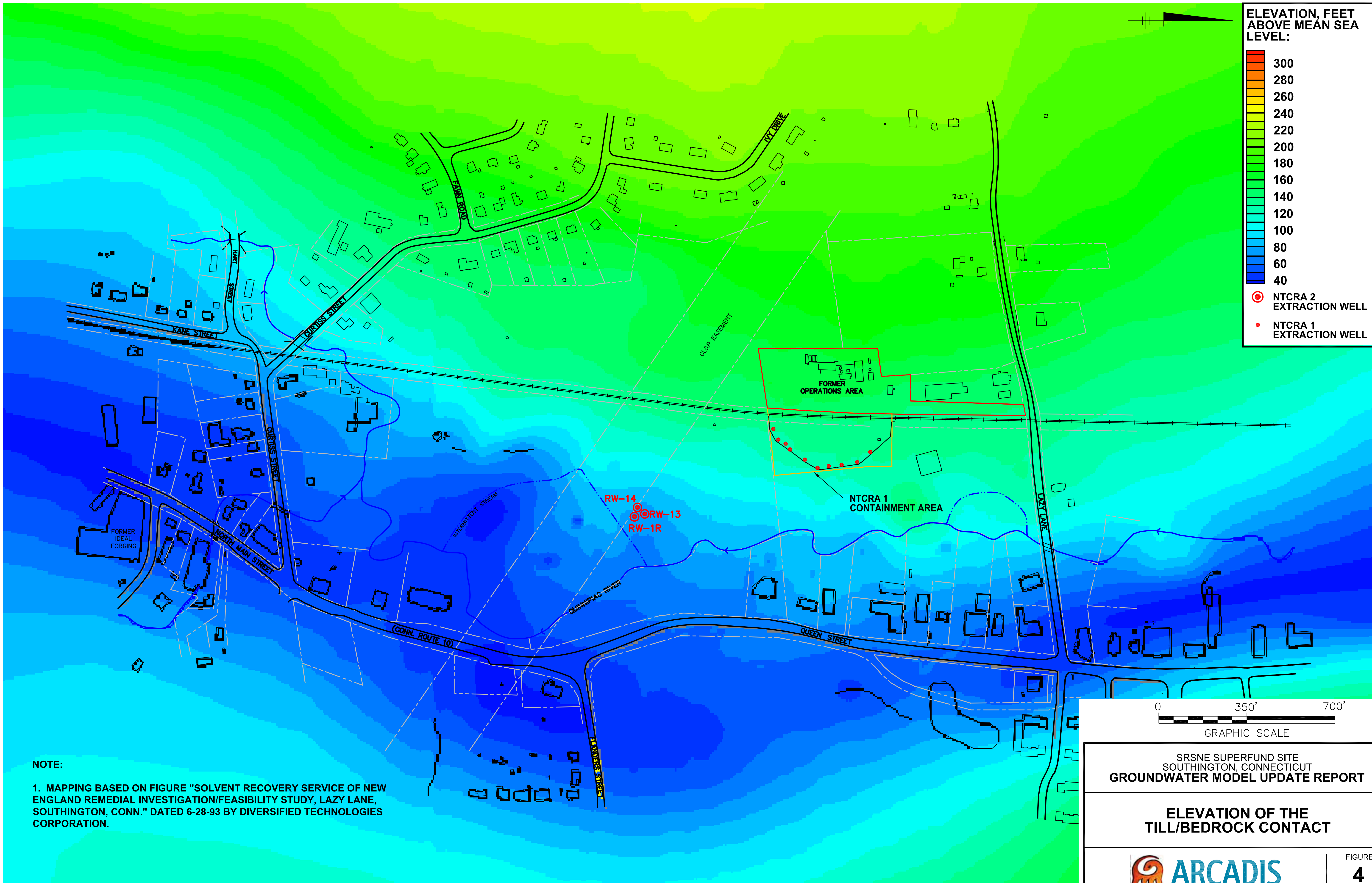


NOTE:

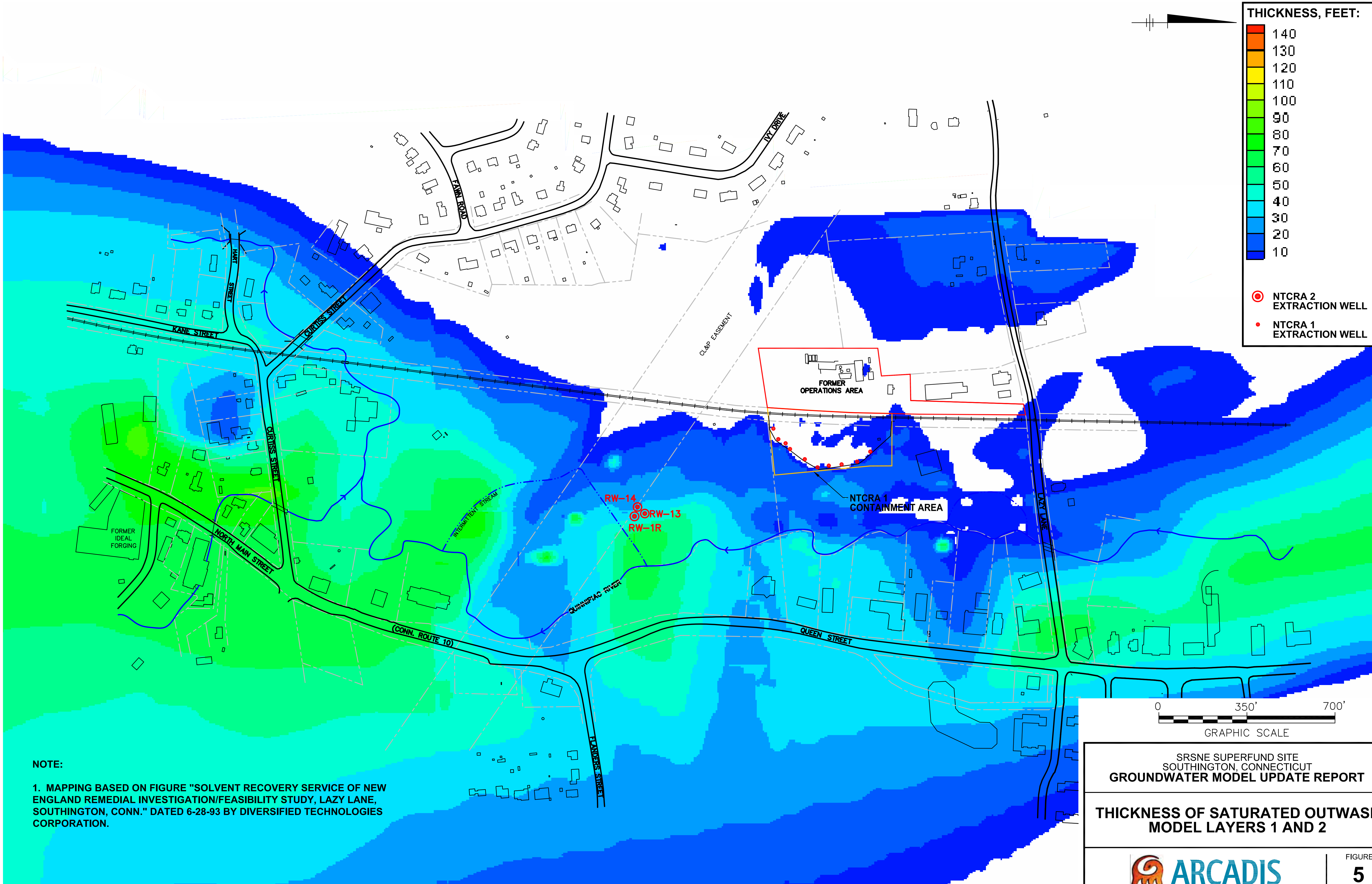
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

ELEVATION OF THE TILL/BEDROCK CONTACT

ARCADIS

FIGURE
4



NOTE:

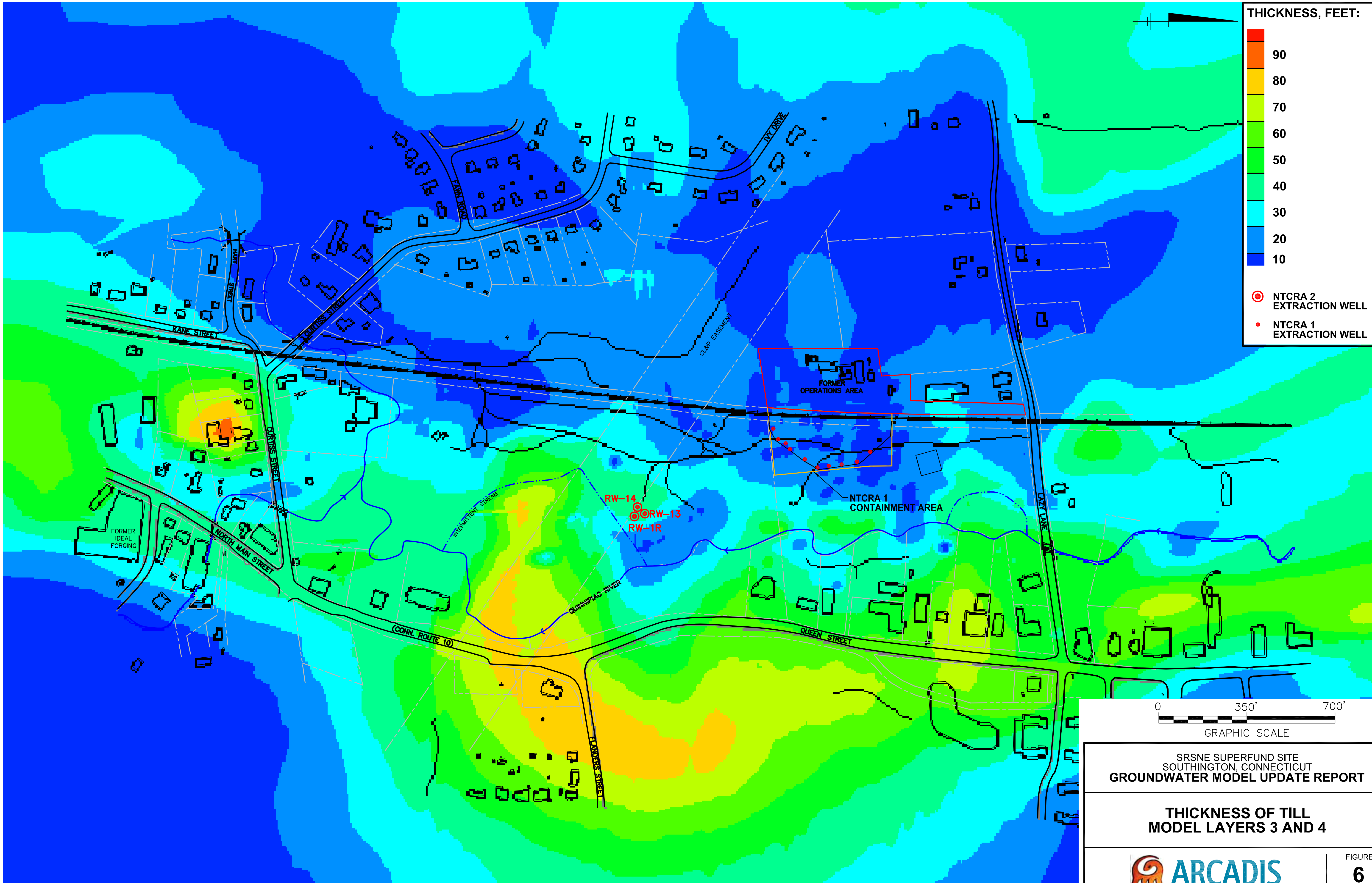
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

THICKNESS OF SATURATED OUTWASH MODEL LAYERS 1 AND 2

ARCADIS

FIGURE
5



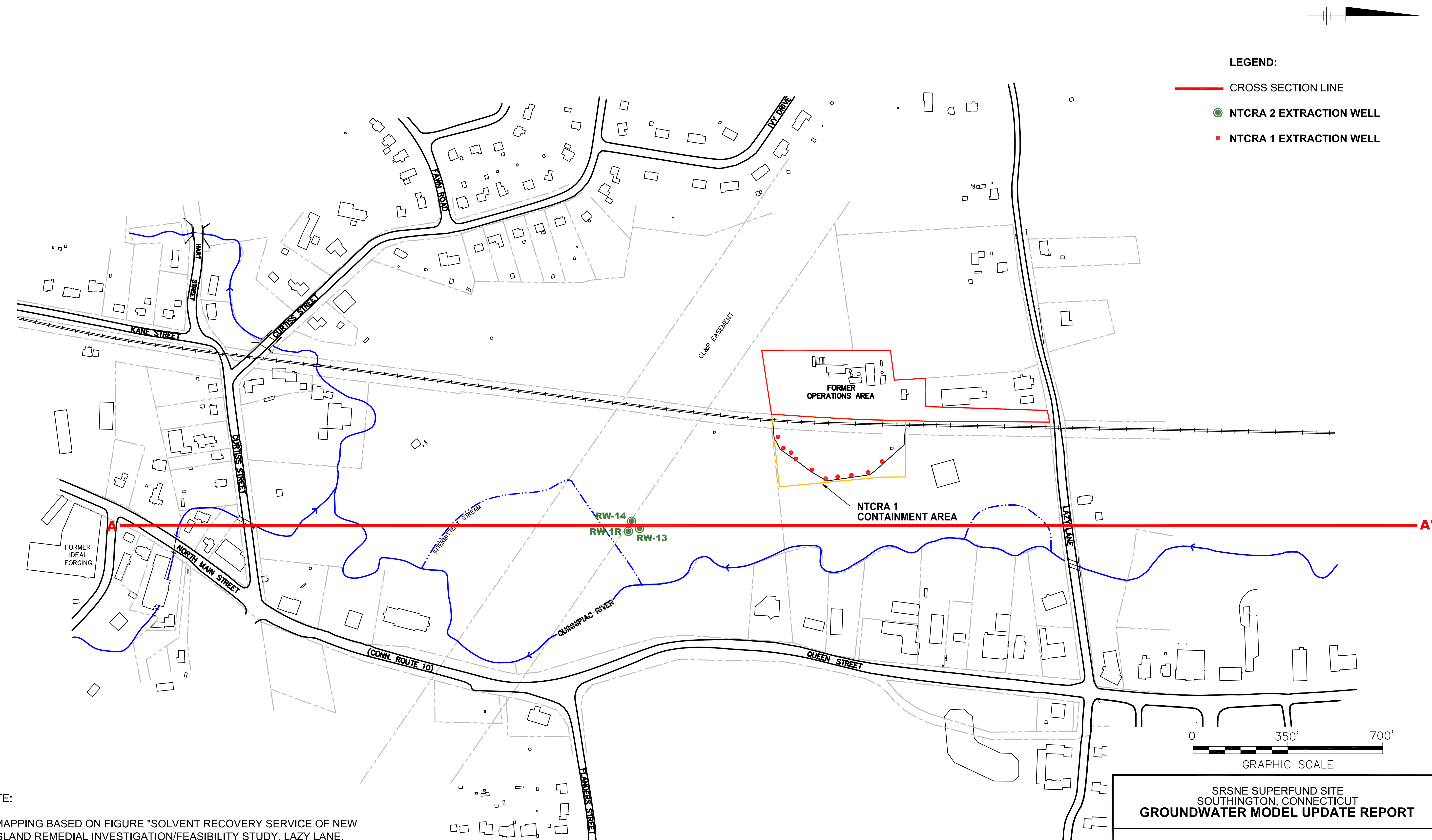
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

THICKNESS OF TILL
MODEL LAYERS 3 AND 4

ARCADIS

FIGURE
6

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L.FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 6.dwg LAYOUT: 6 SAVED: 12/20/2010 12:54 PM ACADVER: 18.0S (LMS TECH) PAGESETUP: --- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 12/30/2010 2:00 PM BY: SMALL, BRIAN



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

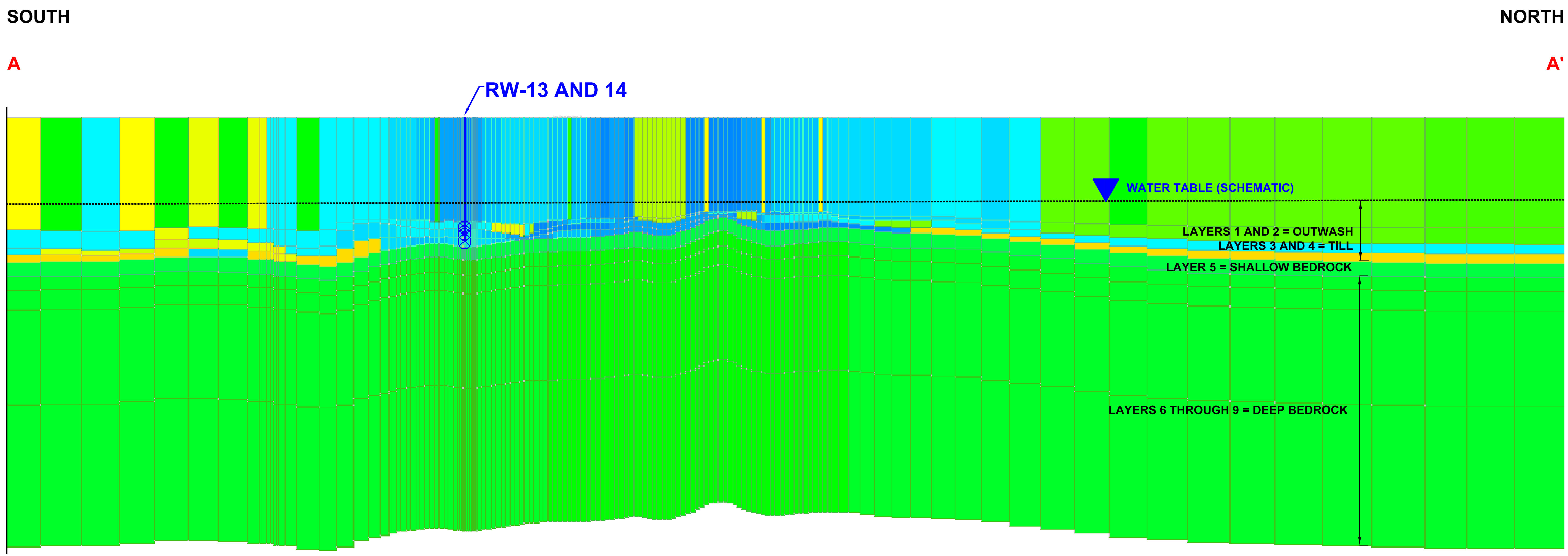
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

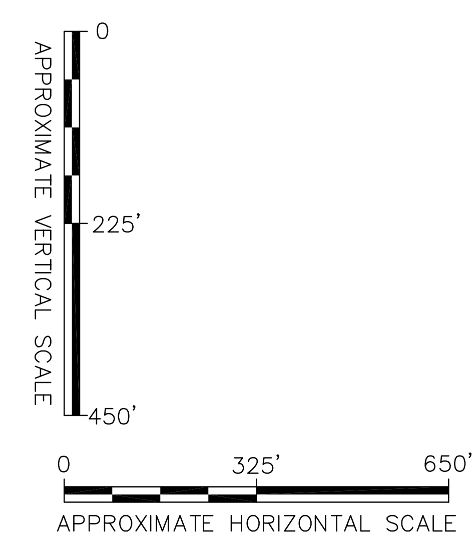
MODEL CROSS-SECTION LOCATION MAP

ARCADIS

FIGURE
7

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L. FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 7.dwg LAYOUT: 7 SAVED: 12/30/2010 2:11 PM ACADVER: 18.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 1/3/2011 12:47 PM BY: SMALL, BRIAN





NOTES:

1. CROSS-SECTION LINE TAKEN THROUGH MODEL COLUMN 56.

2. COLOR SHADING REPRESENTS VARIOUS HYDRAULIC CONDUCTIVITY ZONE ASSIGNMENTS (SEE FIGURES 9 THROUGH 14 FOR MORE DETAILS).

3. THE TOP ELEVATION OF THE MODEL GRID IS SET TO AN ARBITRARY VALUE OF 350 FEET ABOVE MEAN SEA LEVEL. THE WATER TABLE IS SHOWN SCHEMATICALLY TO ILLUSTRATE THAT THE TOP OF THE ACTIVE MODEL IS AT THE WATER TABLE ELEVATION.

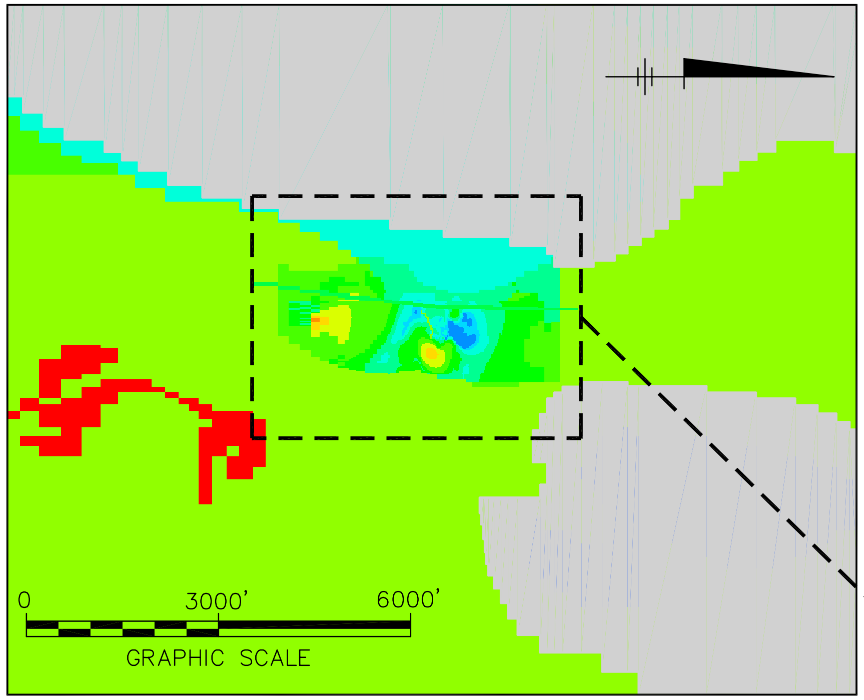
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

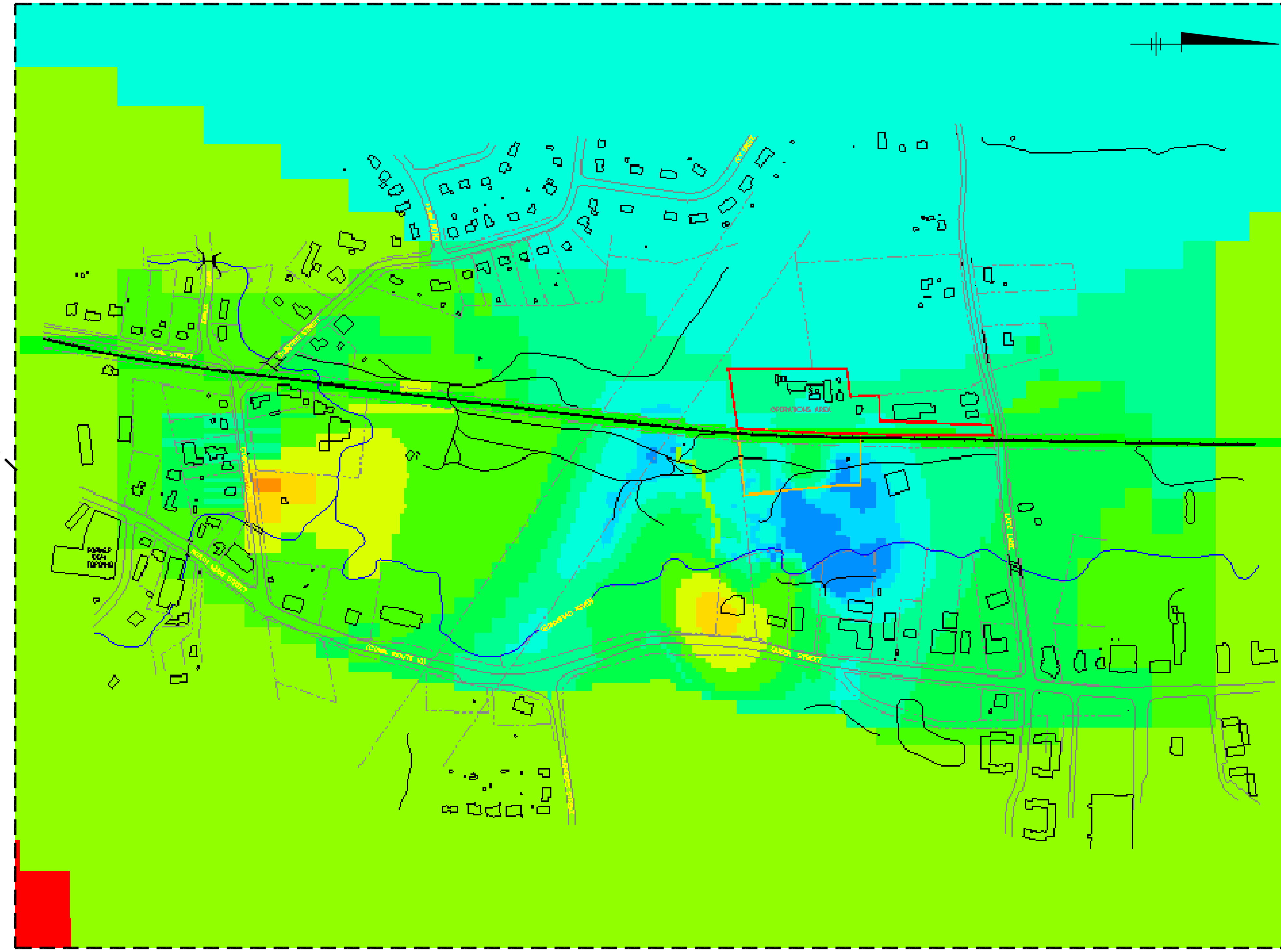
CROSS-SECTION A-A'
NORTH TO SOUTH THROUGH THE NTCRA2 AREA

ARCADIS

FIGURE
8

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L. FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 8.dwg LAYOUT: 8 SAVED: 1/3/2011 12:51 PM ACADVER: 18.0S (LMS TECH) PAGESETUP: --- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 1/3/2011 2:57 PM BY: SMALL, BRIAN





0 500' 1000'
GRAPHIC SCALE

HYDRAULIC CONDUCTIVITY, FEET PER DAY:

- 20,000.00
- 3,000.00
- 1,394.00
- 850.00
- 400.00
- 100.00
- 85.00
- 45.00
- 15.00
- 3.00
- 1.00
- 0.60
- 0.07
- NO FLOW BOUNDARY

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

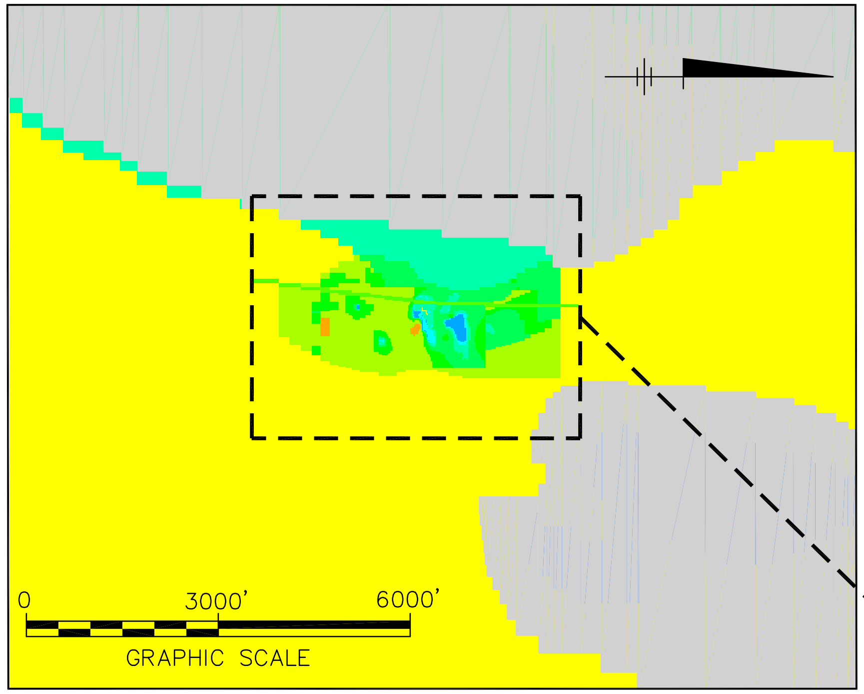
CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L.FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 9.dwg LAYOUT: 9 SAVED: 1/3/2011 9:47 AM ACADVER: 18.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 1/3/2011 12:52 PM BY: SMALL, BRIAN

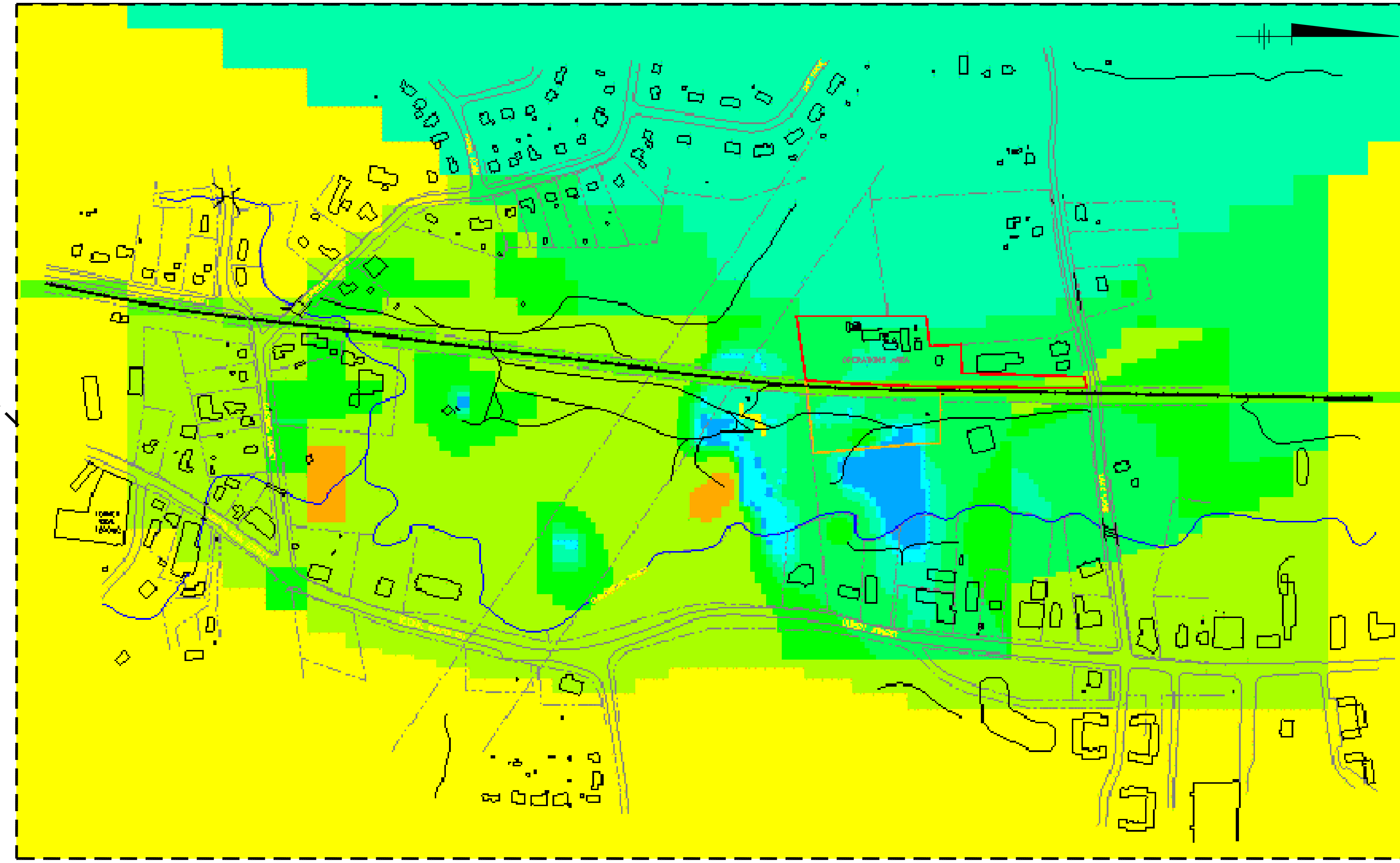
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

HYDRAULIC CONDUCTIVITY DISTRIBUTION - MODEL LAYER 1 (OUTWASH)

ARCADIS

FIGURE
9





0 500' 1000'
GRAPHIC SCALE

HYDRAULIC CONDUCTIVITY, FEET PER DAY:

- 20,000.00
- 3,000.00
- 1,394.00
- 850.00
- 400.00
- 100.00
- 85.00
- 45.00
- 15.00
- 3.00
- 1.00
- 0.60
- 0.07
- NO FLOW BOUNDARY

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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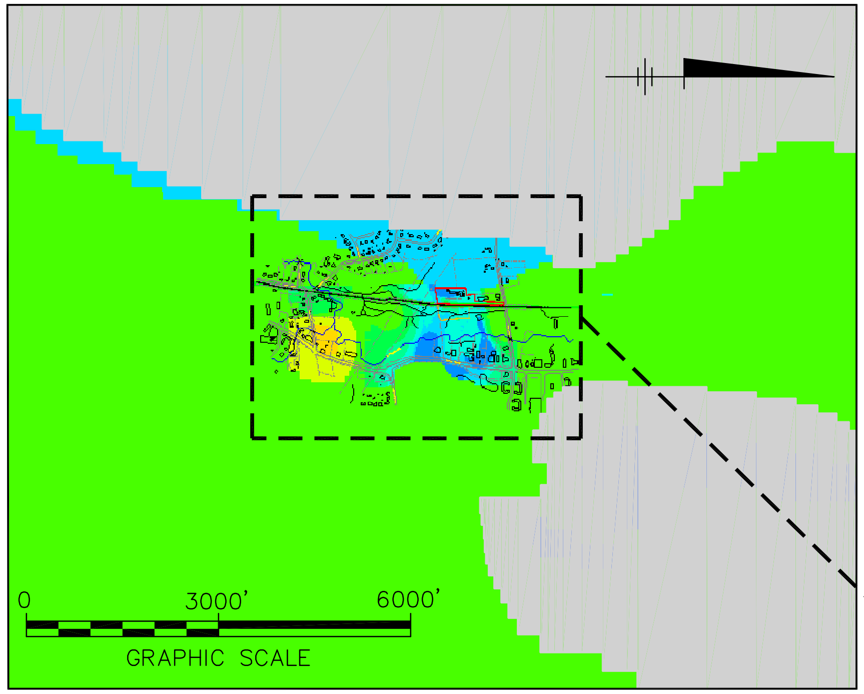
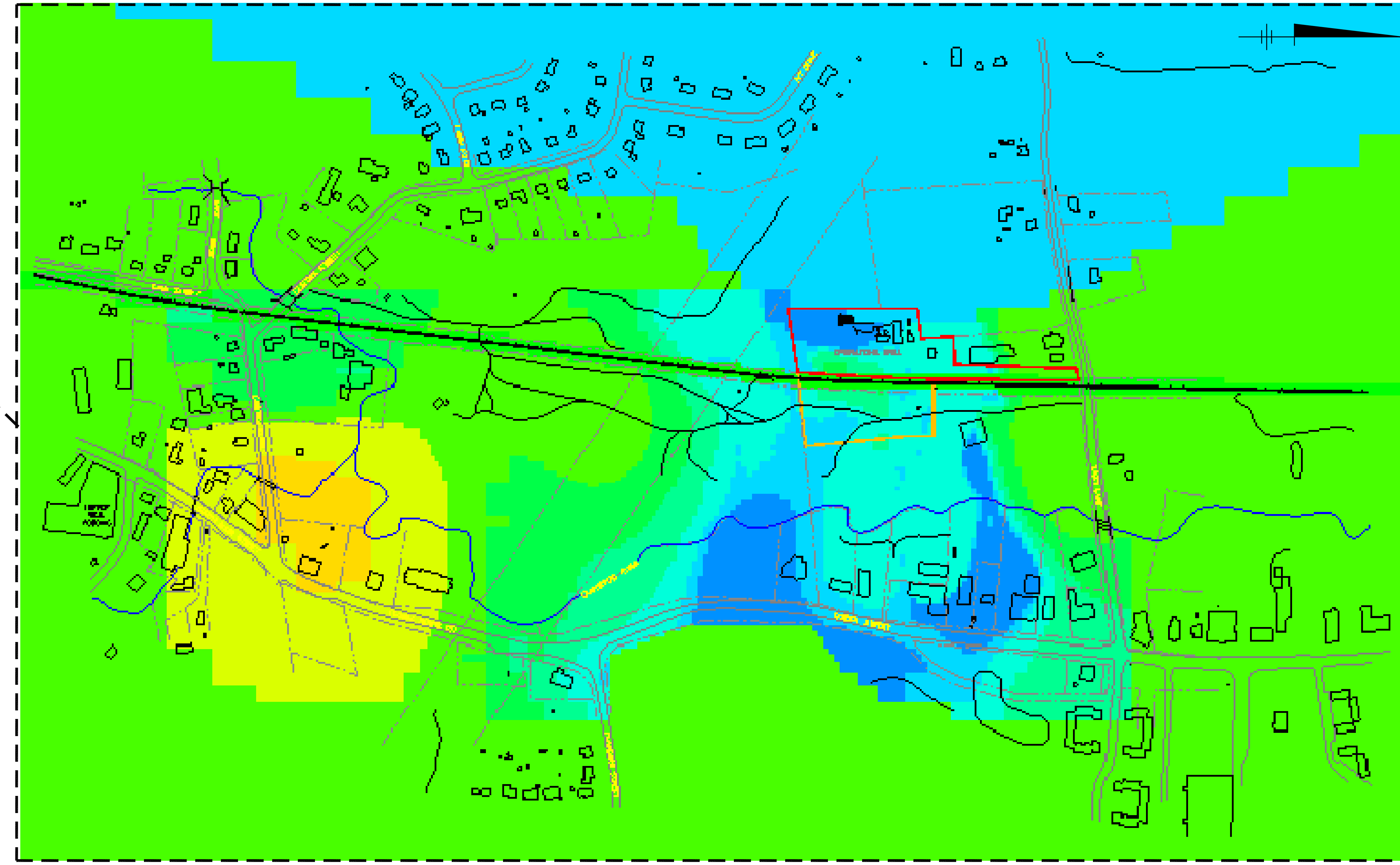
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

HYDRAULIC CONDUCTIVITY DISTRIBUTION - MODEL LAYER 2 (OUTWASH)

ARCADIS

FIGURE
10





HYDRAULIC CONDUCTIVITY, FEET PER DAY:

- 20,000.00
- 3,000.00
- 1,394.00
- 850.00
- 400.00
- 100.00
- 85.00
- 45.00
- 15.00
- 3.00
- 1.00
- 0.60
- 0.07
- NO FLOW BOUNDARY

0 500' 1000'
GRAPHIC SCALE

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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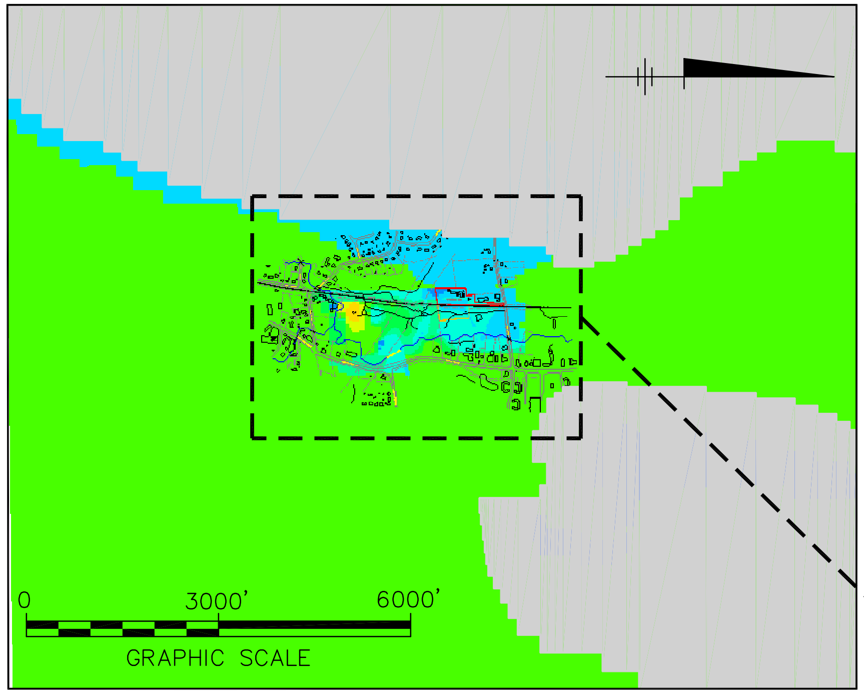
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

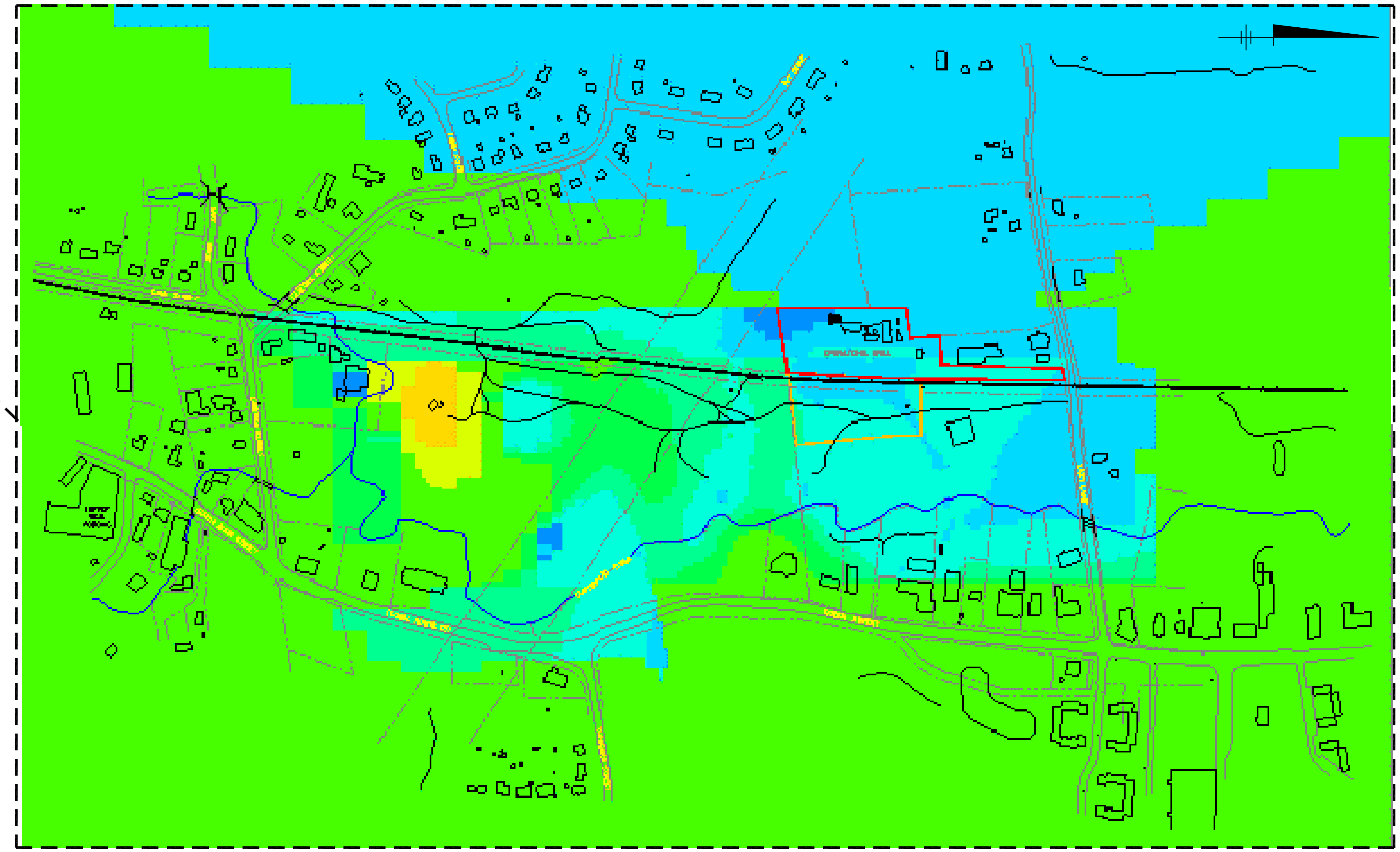
HYDRAULIC CONDUCTIVITY DISTRIBUTION - MODEL LAYER 3 (TILL)

ARCADIS

FIGURE
11

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L. FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 11.dwg LAYOUT: 11 SAVED: 1/3/2011 11:28 AM ACADVER: 18.0S (LMS TECH) PAGESETUP: --- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 1/3/2011 12:53 PM BY: SMALL, BRIAN





HYDRAULIC CONDUCTIVITY, FEET PER DAY:

- 20,000.00
- 3,000.00
- 1,394.00
- 850.00
- 400.00
- 100.00
- 85.00
- 45.00
- 15.00
- 3.00
- 1.00
- 0.60
- 0.07
- NO FLOW BOUNDARY

0 500' 1000'
GRAPHIC SCALE

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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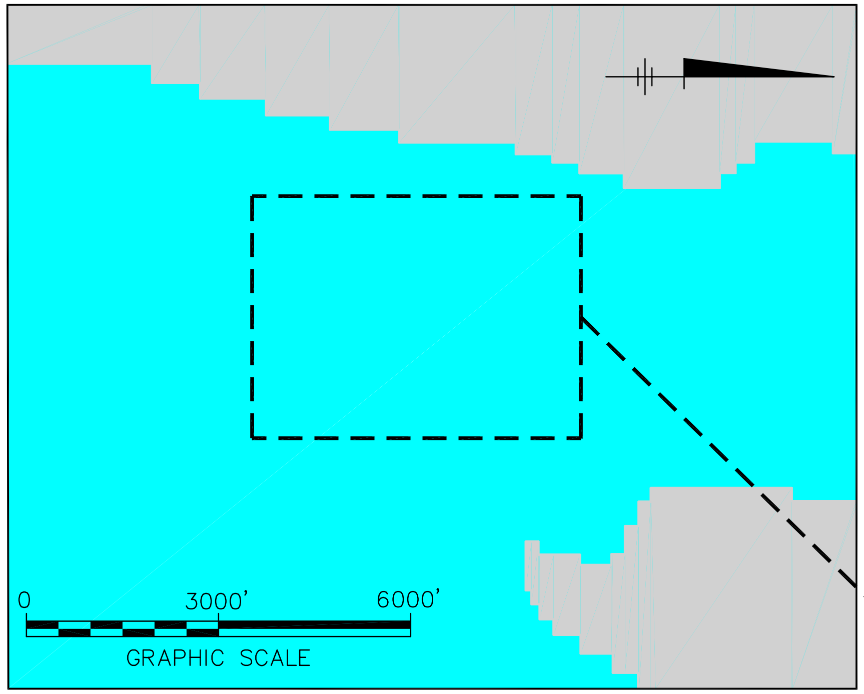
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

HYDRAULIC CONDUCTIVITY DISTRIBUTION - MODEL LAYER 4 (TILL)

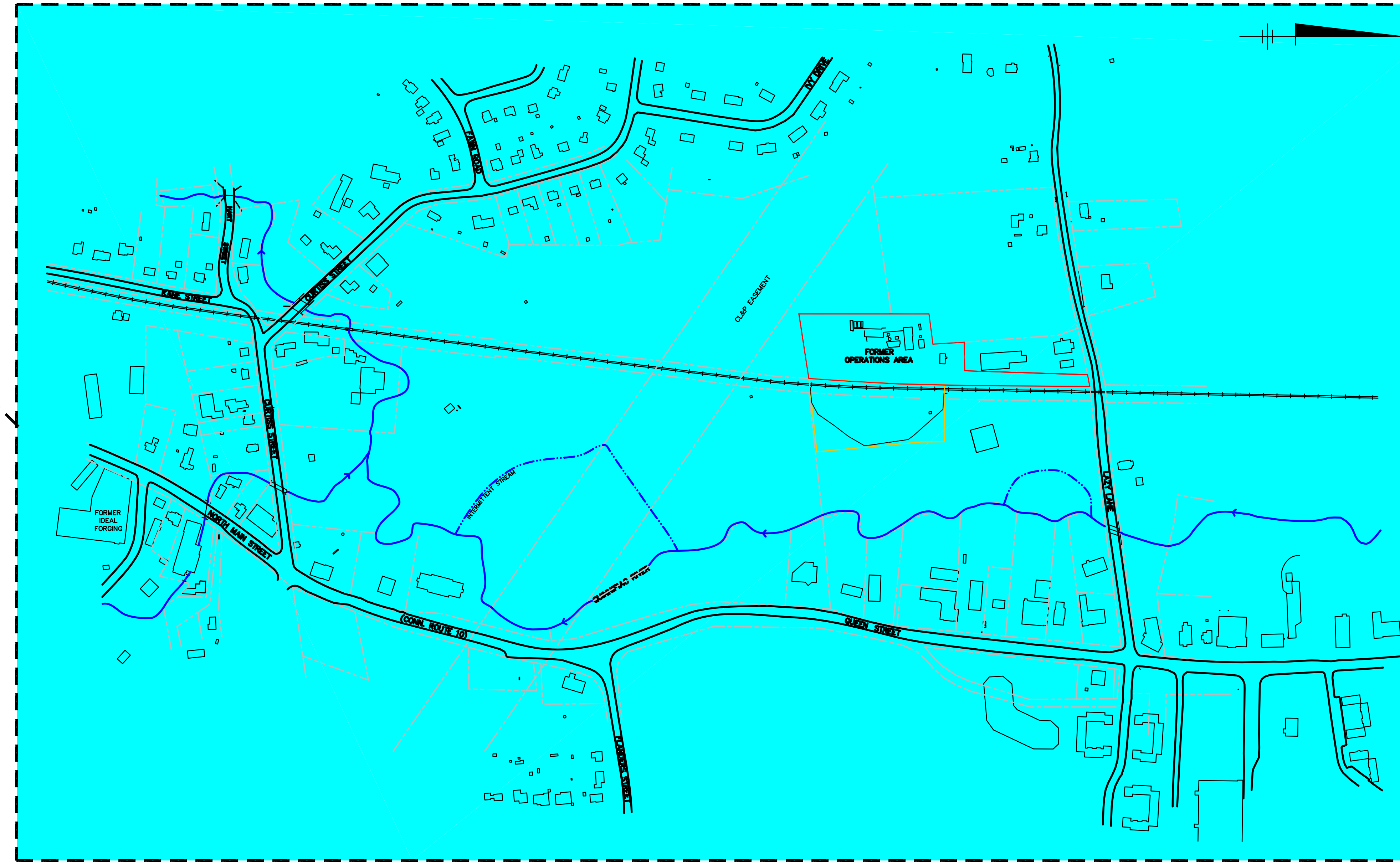
ARCADIS

FIGURE
12



HYDRAULIC CONDUCTIVITY, FEET PER DAY:

- 0.39
- NO FLOW BOUNDARY



0
500'
1000'
GRAPHIC SCALE

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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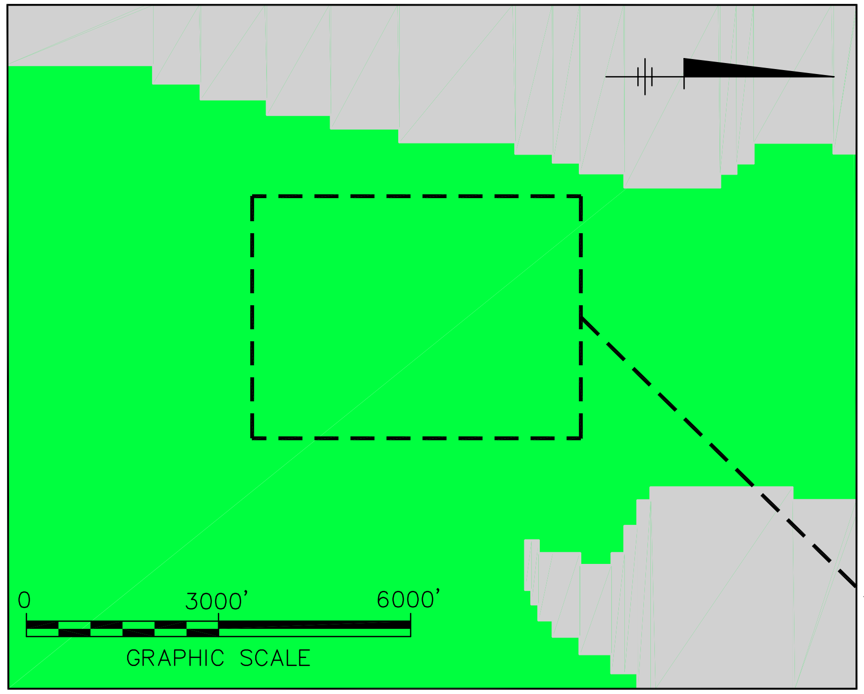
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

HYDRAULIC CONDUCTIVITY DISTRIBUTION - MODEL LAYER 5 (SHALLOW BEDROCK)

ARCADIS

FIGURE
13



HYDRAULIC CONDUCTIVITY, FEET PER DAY:

0.07

NO FLOW BOUNDARY

0
500'
1000'
GRAPHIC SCALE

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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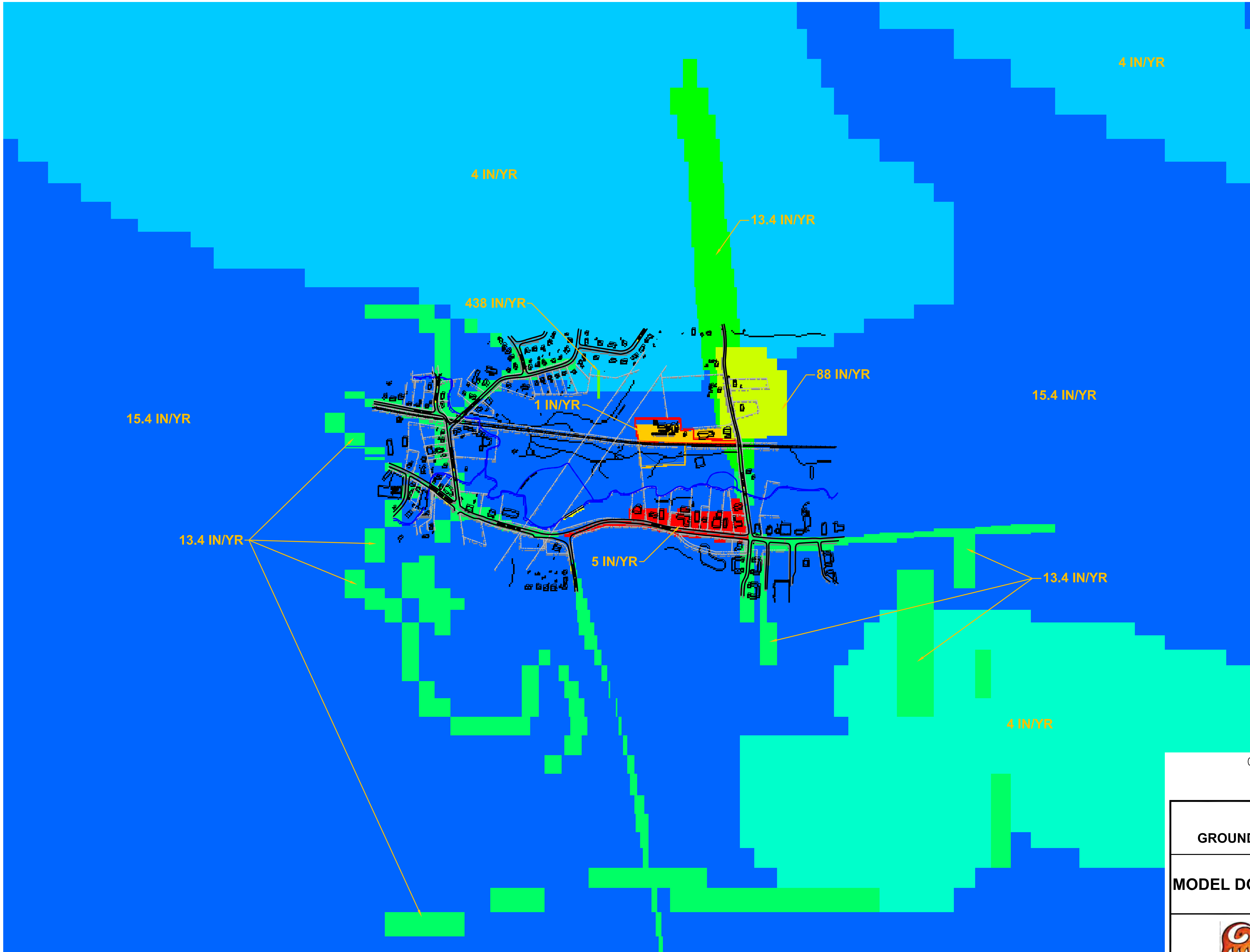
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

HYDRAULIC CONDUCTIVITY DISTRIBUTION - MODEL LAYERS 6 THROUGH 9 (DEEP BEDROCK)

ARCADIS

FIGURE
14



0 1000' 2000'
GRAPHIC SCALE

NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

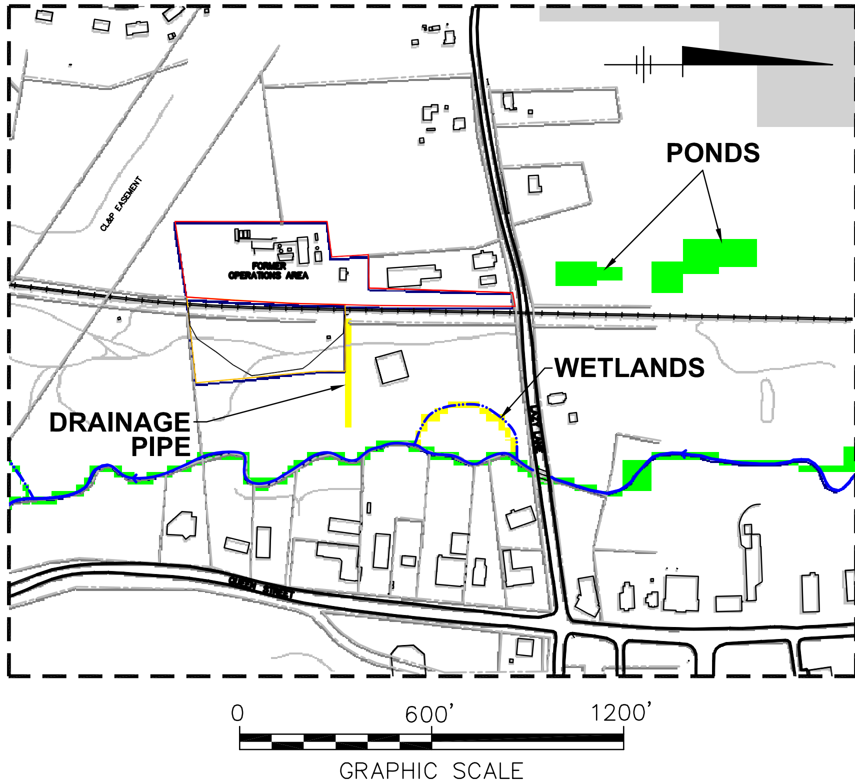
2. SEE TABLE 3 FOR A DESCRIPTION OF THE FEATURES REPRESENTED BY RECHARGE ZONES.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

MODEL DOMAIN WITH RECHARGE ZONES

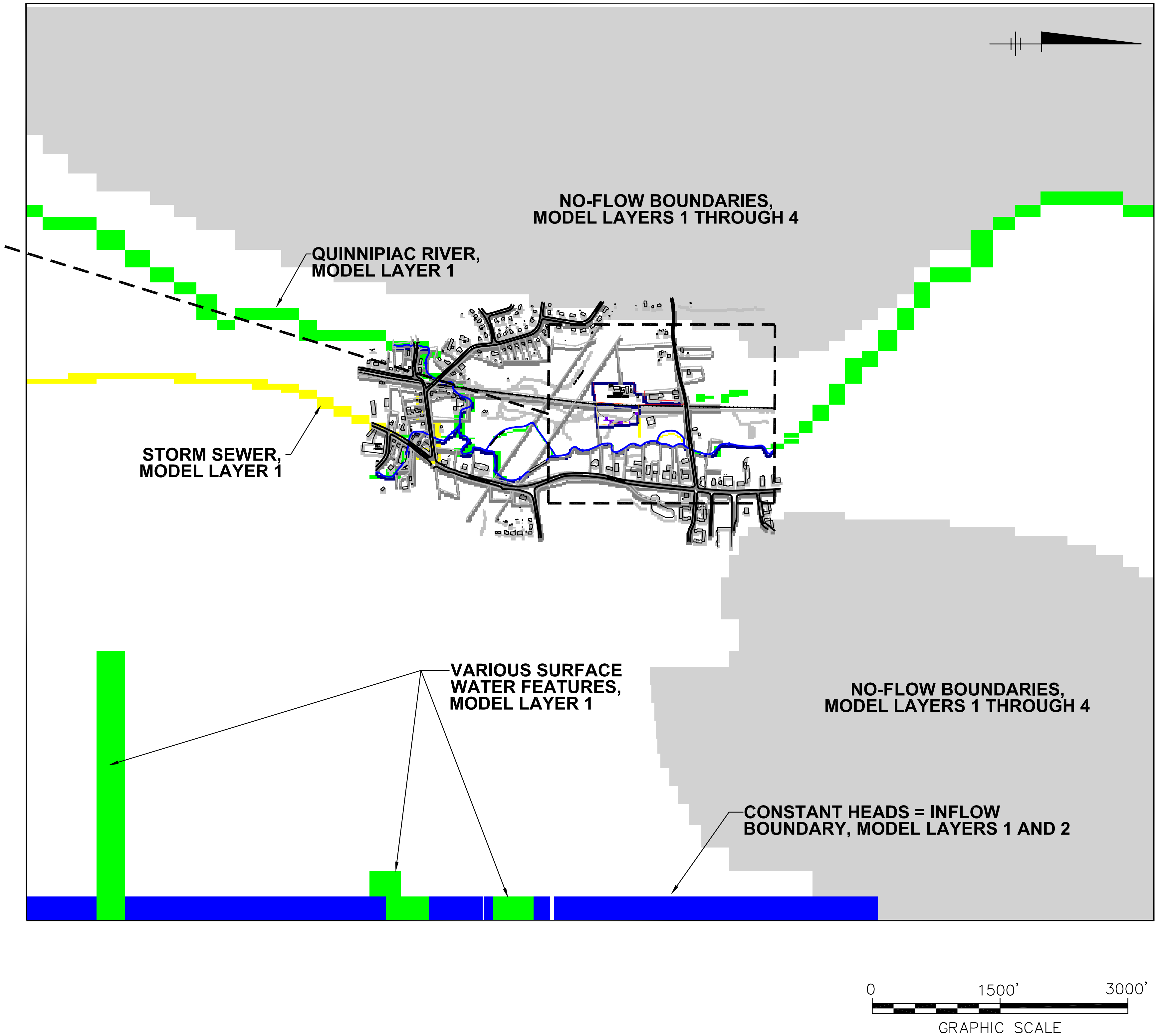
ARCADIS

FIGURE
15



BOUNDARY CONDITIONS:

- RIVER
- DRAIN
- CONSTANT HEAD
- NO-FLOW



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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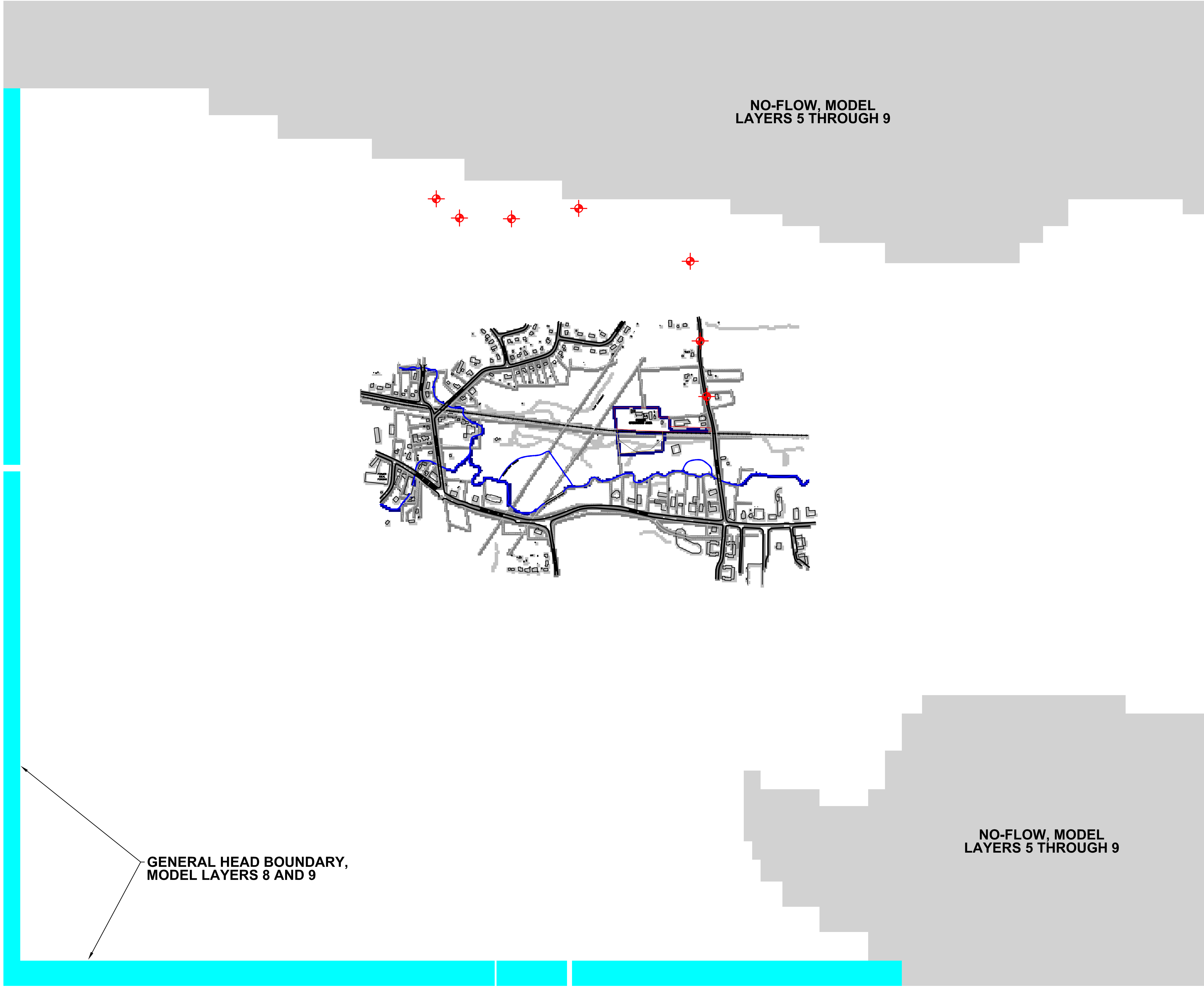
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

MODEL DOMAIN WITH BOUNDARY CONDITIONS, MODEL LAYERS 1 THROUGH 4 (OUTWASH AND TILL)

ARCADIS

FIGURE
16



BOUNDARY CONDITIONS:

- GENERAL HEAD
- NO-FLOW
- DOMESTIC WELL (MODEL LAYER 7)

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

0 1100' 2200'

GRAPHIC SCALE

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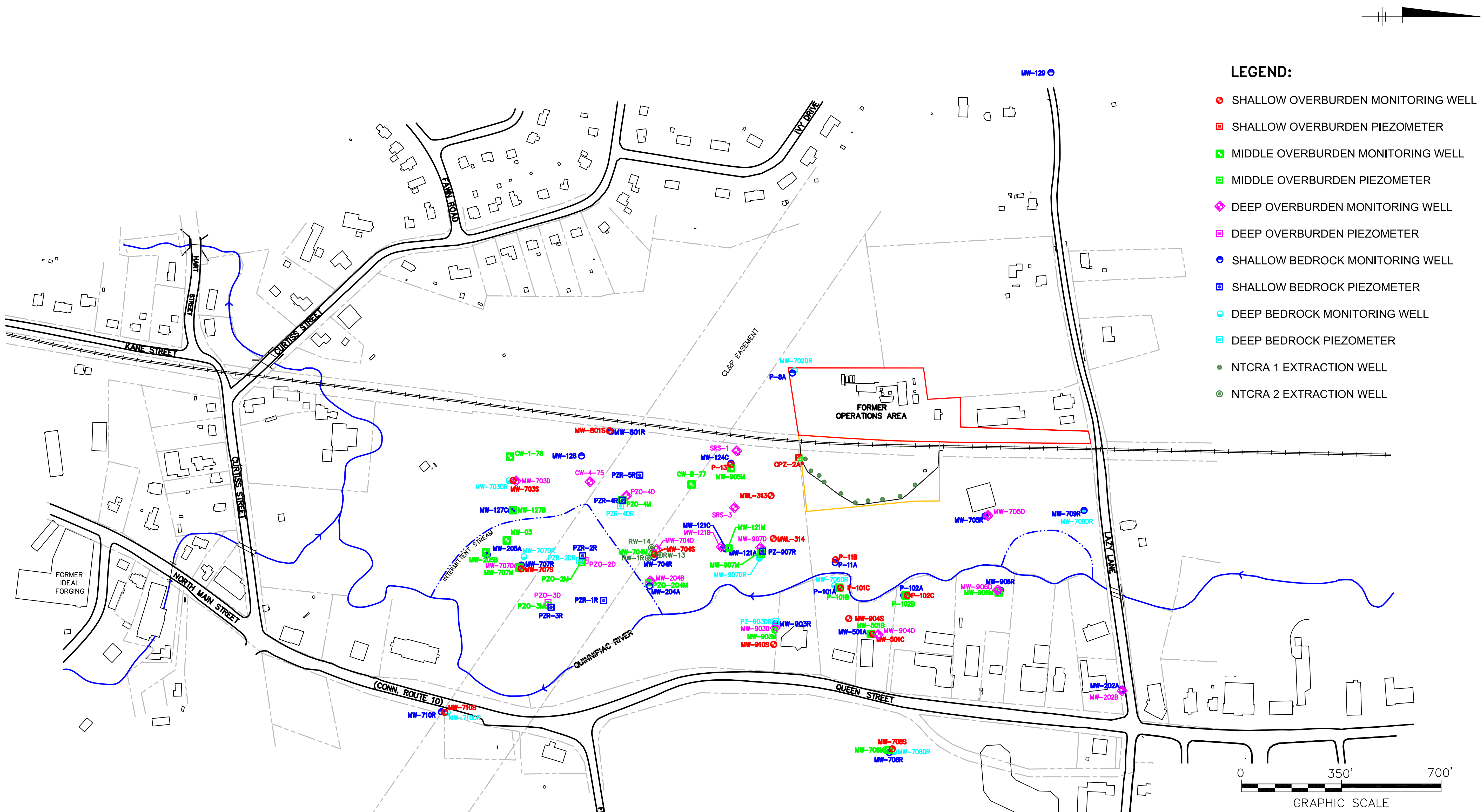
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

MODEL DOMAIN WITH BOUNDARY CONDITIONS, MODEL LAYERS 5 THROUGH 9 (BEDROCK)

ARCADIS

FIGURE
17

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L. FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 17.dwg LAYOUT: 17 SAVED: 12/30/2010 3:34 PM ACADVER: 18.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 1/3/2011 12:59 PM BY: SMALL, BRIAN



NOTES:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

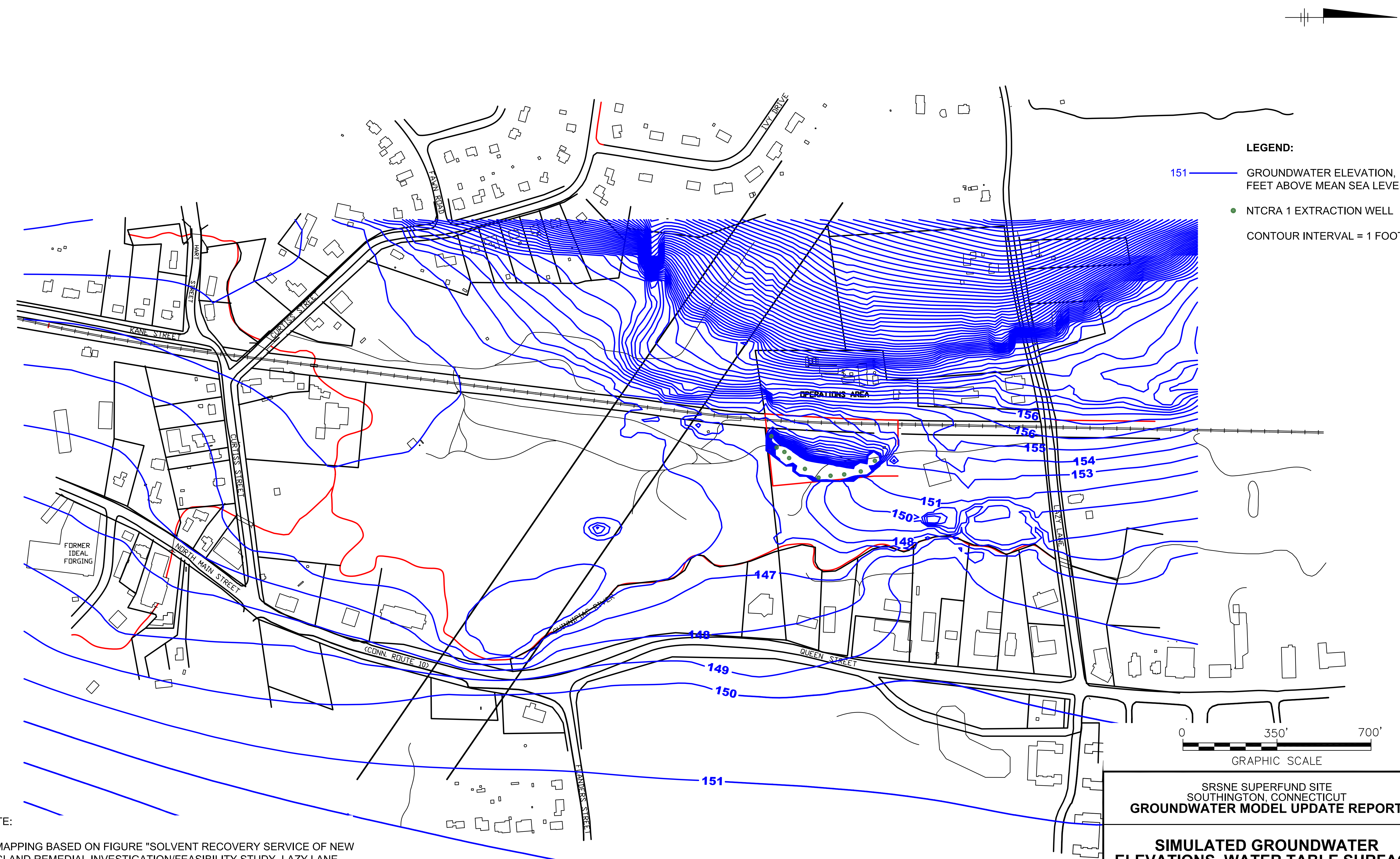
2. GROUNDWATER ELEVATIONS WERE MEASURED IN THE WELLS SHOWN ON OCTOBER 12, 2010, WITH THE EXCEPTION OF WELL MW-129. THE AVERAGE HISTORICAL GROUNDWATER ELEVATION FOR THIS WELL WAS USED IN THE CALIBRATION DATA SET.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

MODEL DOMAIN WITH CALIBRATION TARGET LOCATIONS

ARCADIS

FIGURE
18



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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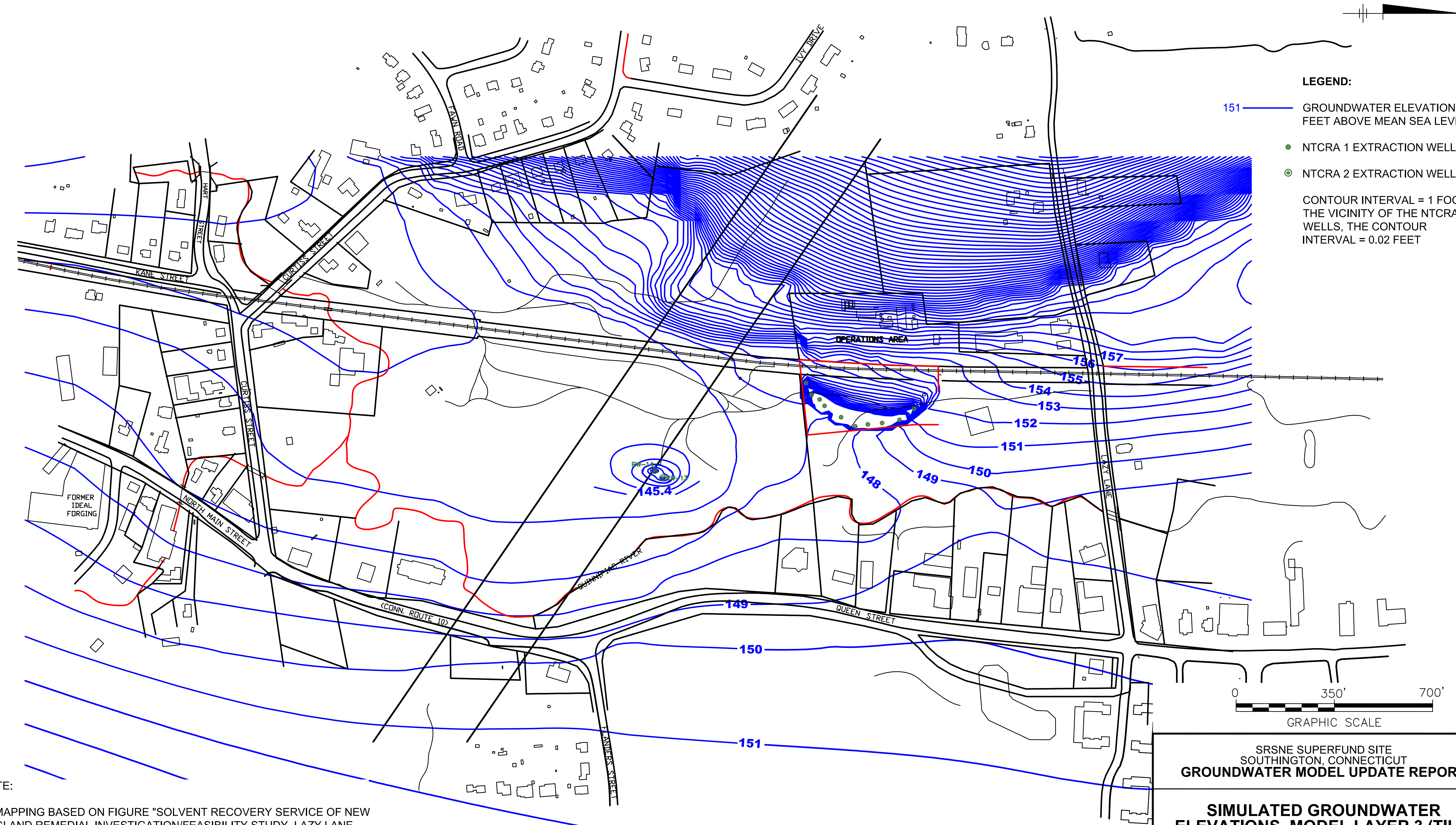
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SIMULATED GROUNDWATER ELEVATIONS, WATER TABLE SURFACE

ARCADIS

FIGURE
19

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L. FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 19.dwg LAYOUT: 19 SAVED: 12/30/2010 3:50 PM ACADVER: 18.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 1/3/2011 1:02 PM BY: SMALL, BRIAN



LEGEND:

151 —— GROUNDWATER ELEVATION, FEET ABOVE MEAN SEA LEVEL

● NTCRA 1 EXTRACTION WELL

◉ NTCRA 2 EXTRACTION WELL

CONTOUR INTERVAL = 1 FOOT; IN THE VICINITY OF THE NTCRA 2 WELLS, THE CONTOUR INTERVAL = 0.02 FEET

NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

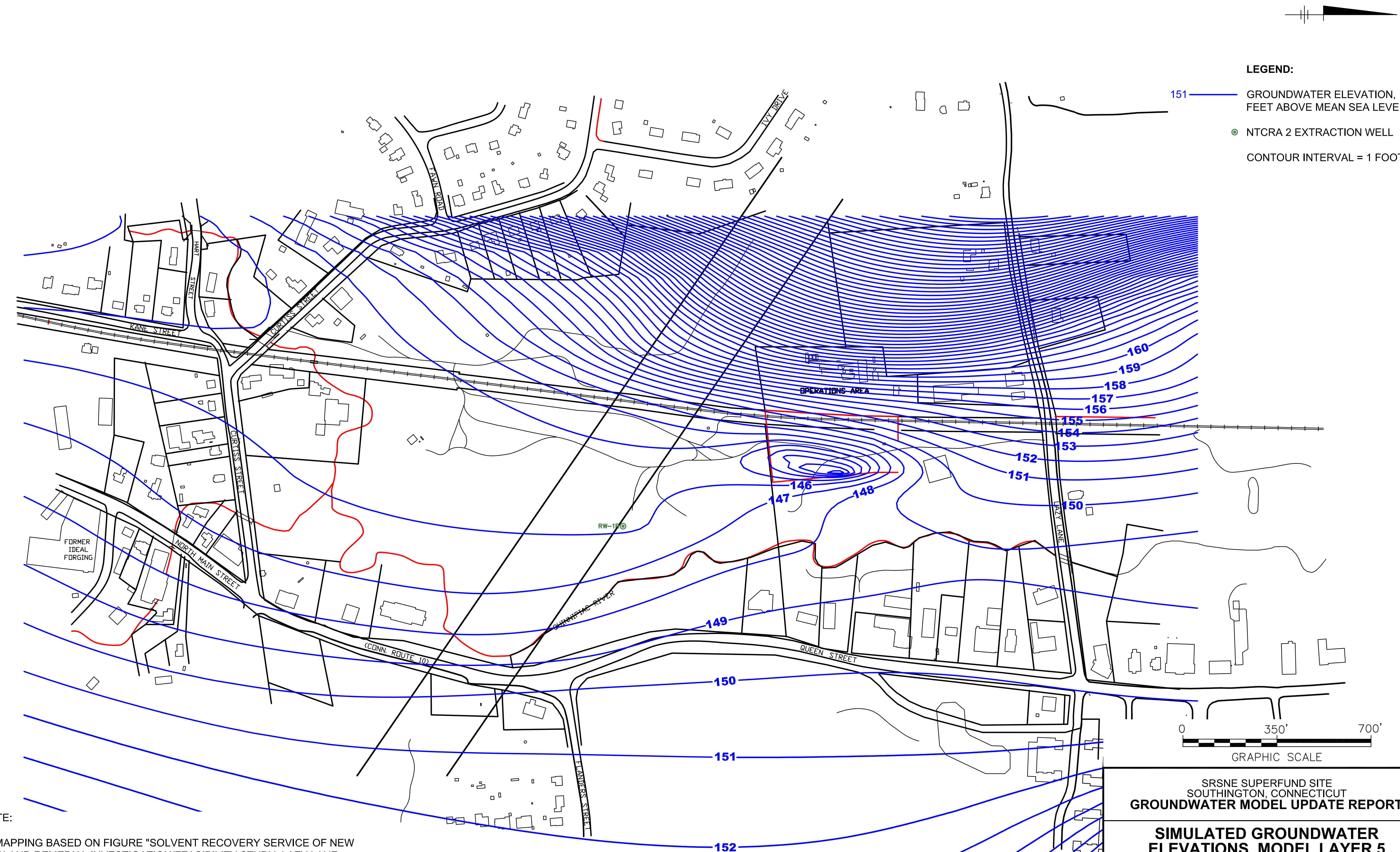
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SIMULATED GROUNDWATER ELEVATIONS, MODEL LAYER 3 (TILL)

ARCADIS

FIGURE
20

CITY: MANCHESTER, CT GROUP: ENVCAD DB: P. LISTER L.POSENAUER L.FORAKER B.SMALL PIC: G. CAMERON PM: J. HOLDEN TM: R.STEVENSON LYR: ON=*;OFF=REF
G:\ENVCAD\Manchester\ACT\B0054634\0000\02600\Figure 20.dwg LAYOUT: 20 SAVED: 1/3/2011 8:02 AM ACADVER: 18.0S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 1/3/2011 1:05 PM BY: SMALL, BRIAN



NOTE:

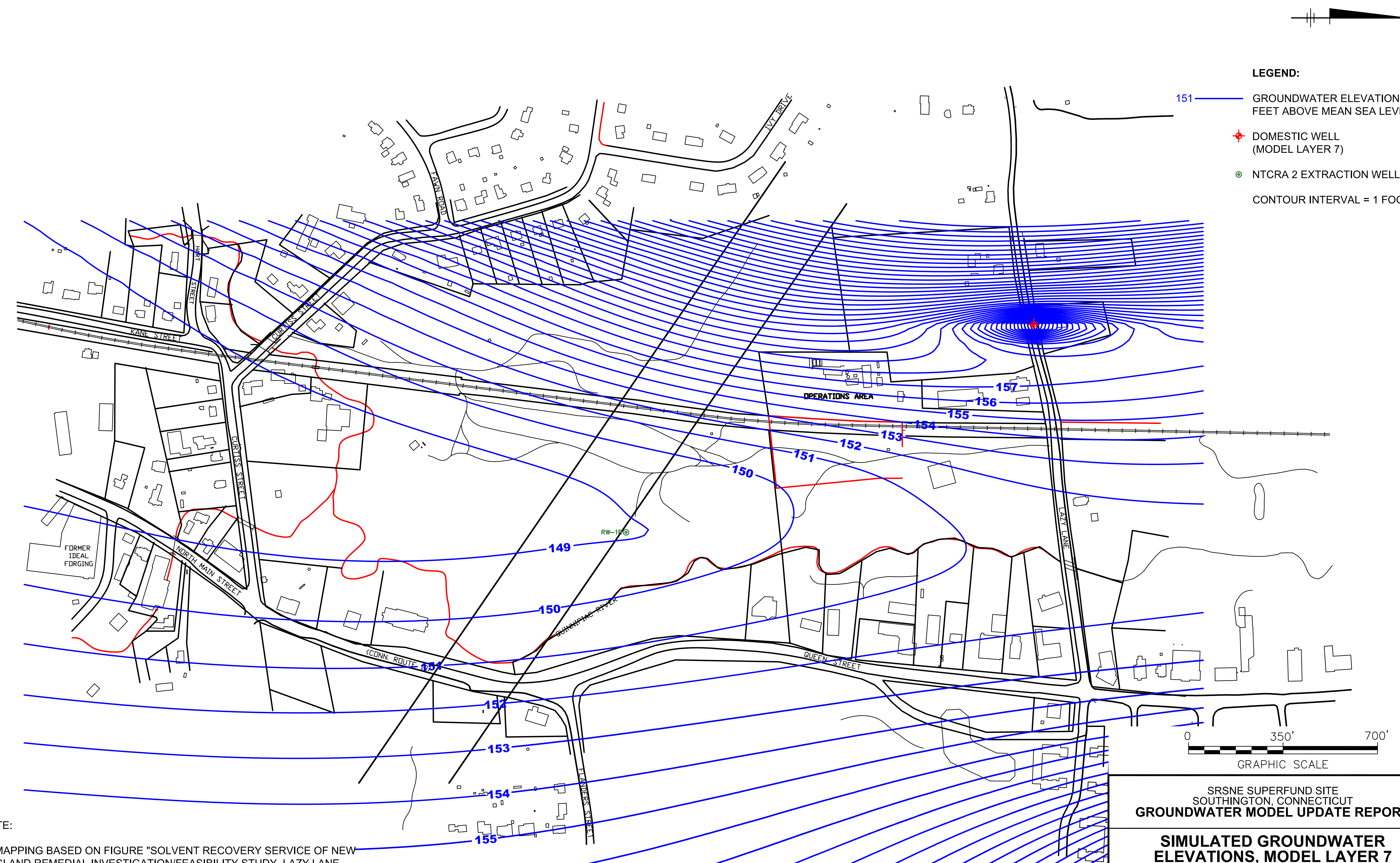
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SIMULATED GROUNDWATER ELEVATIONS, MODEL LAYER 5 (SHALLOW BEDROCK)

ARCADIS

FIGURE
21



LEGEND:

151 — GROUNDWATER ELEVATION, FEET ABOVE MEAN SEA LEVEL

DOMESTIC WELL (MODEL LAYER 7)

NTCRA 2 EXTRACTION WELL

CONTOUR INTERVAL = 1 FOOT

0 350' 700'

GRAPHIC SCALE

NOTE:

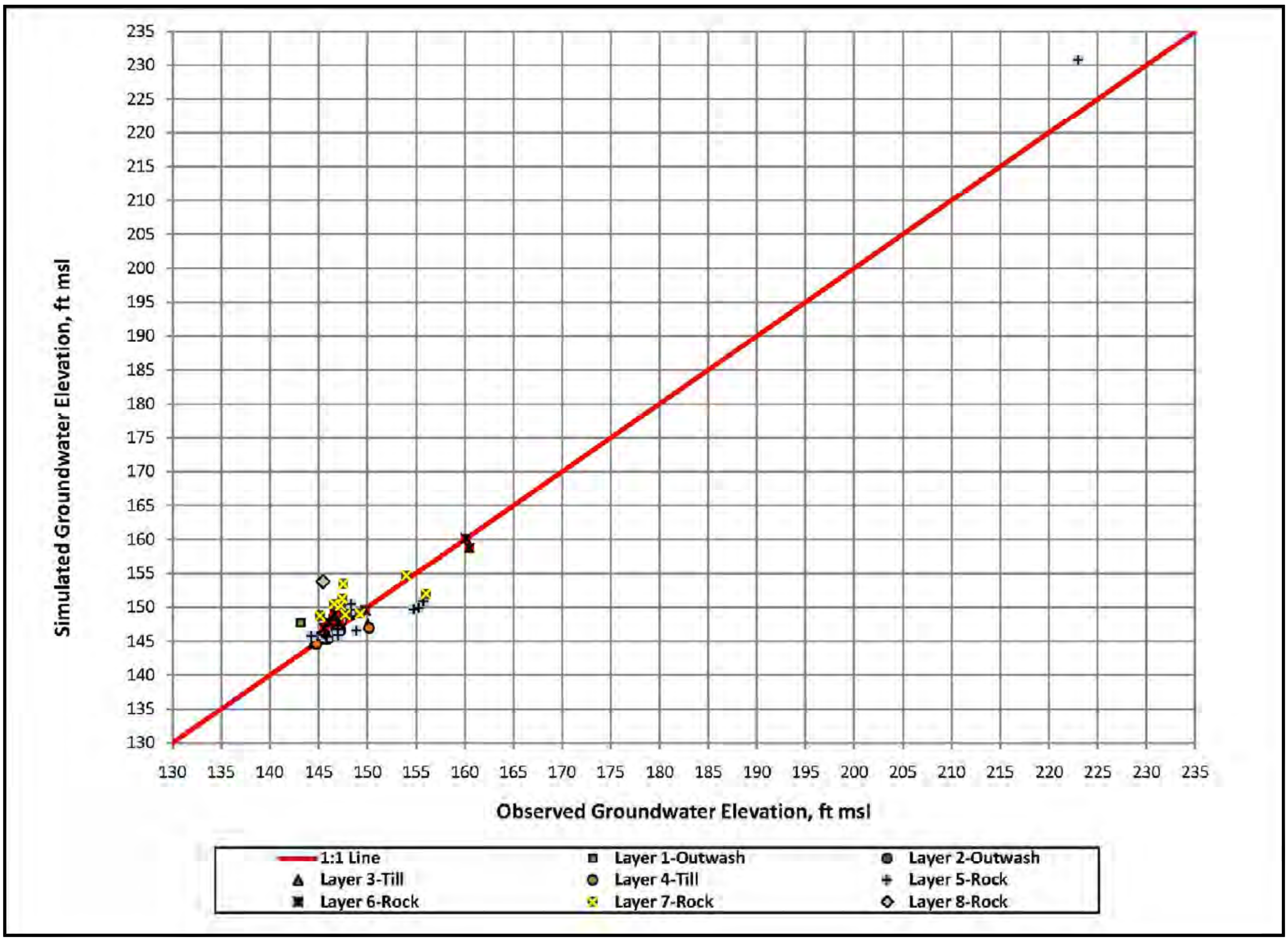
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

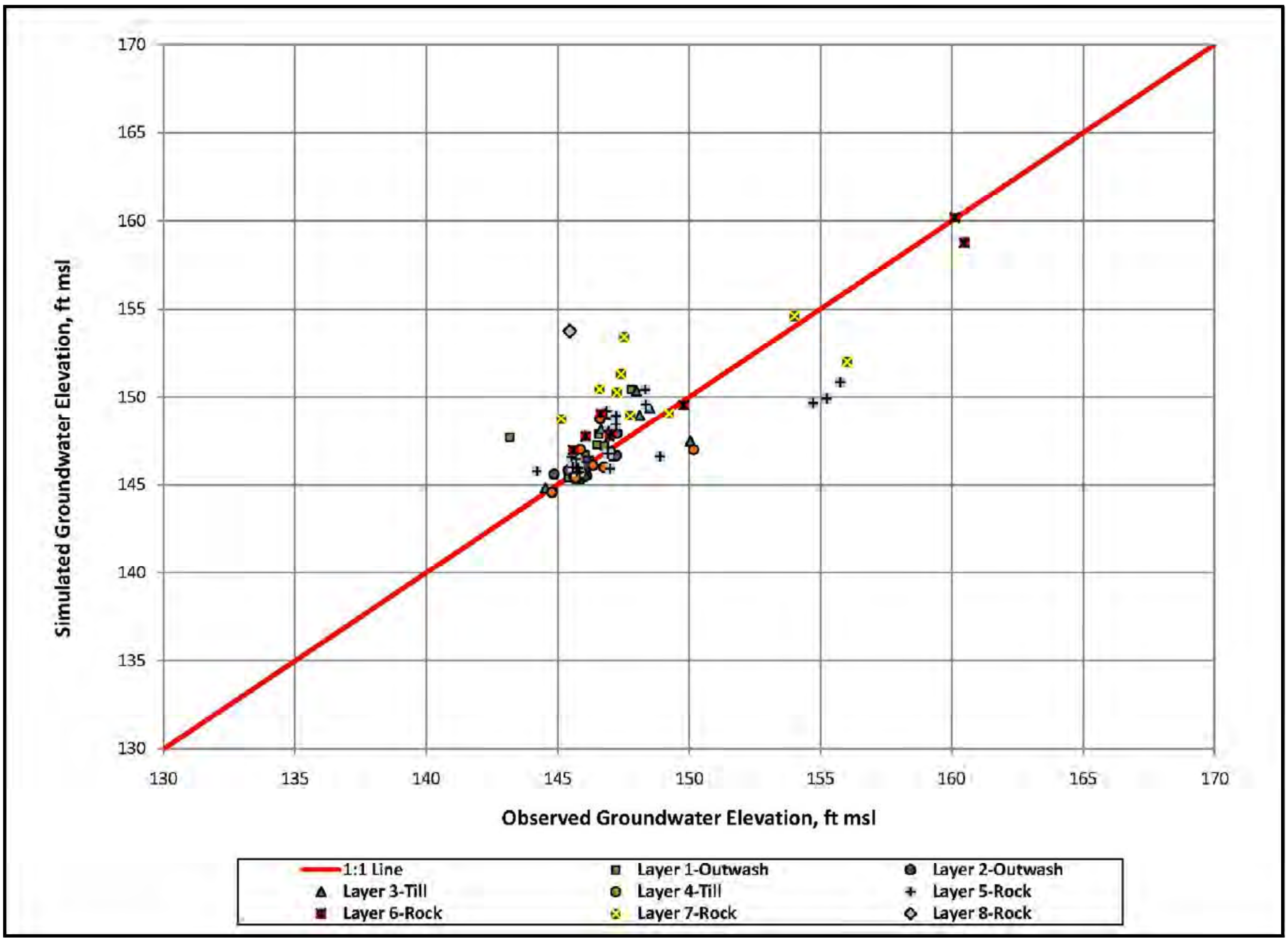
SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SIMULATED GROUNDWATER ELEVATIONS, MODEL LAYER 7 (DEEP BEDROCK)

ARCADIS

FIGURE
22



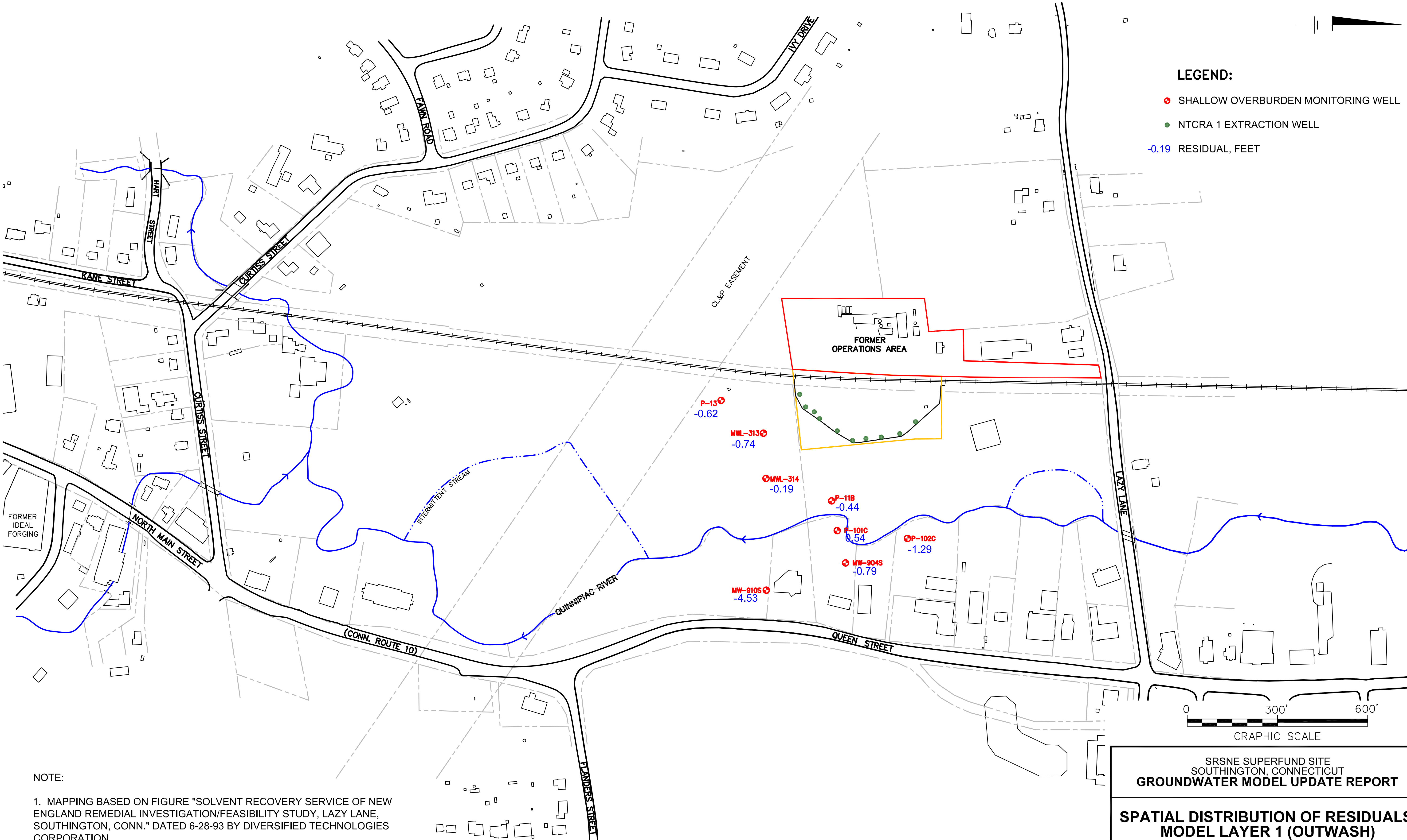


SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SIMULATED VERSUS OBSERVED GROUNDWATER ELEVATION SCATTER PLOTS

ARCADIS

FIGURE
23



NOTE:

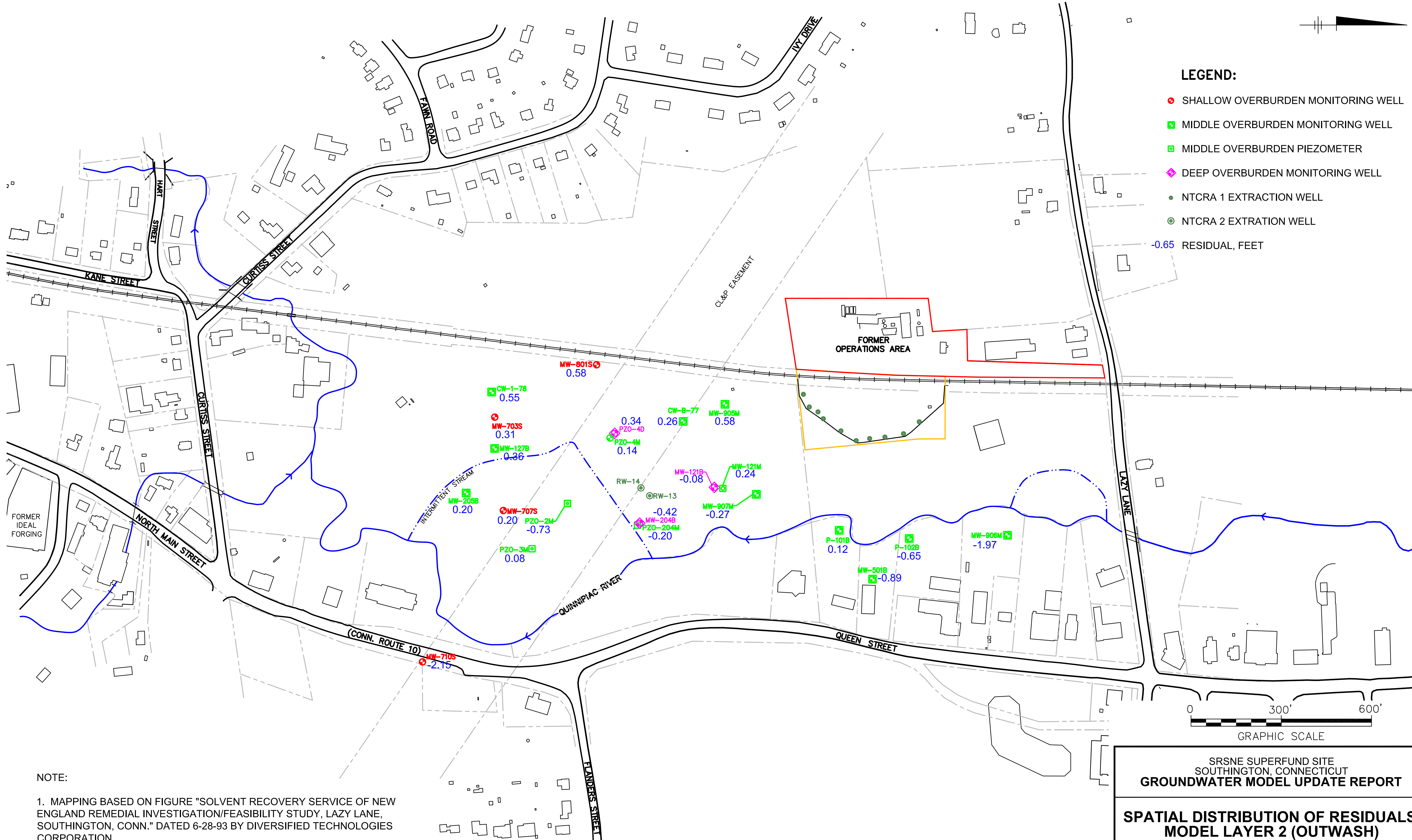
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 1 (OUTWASH)

ARCADIS

FIGURE
24



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

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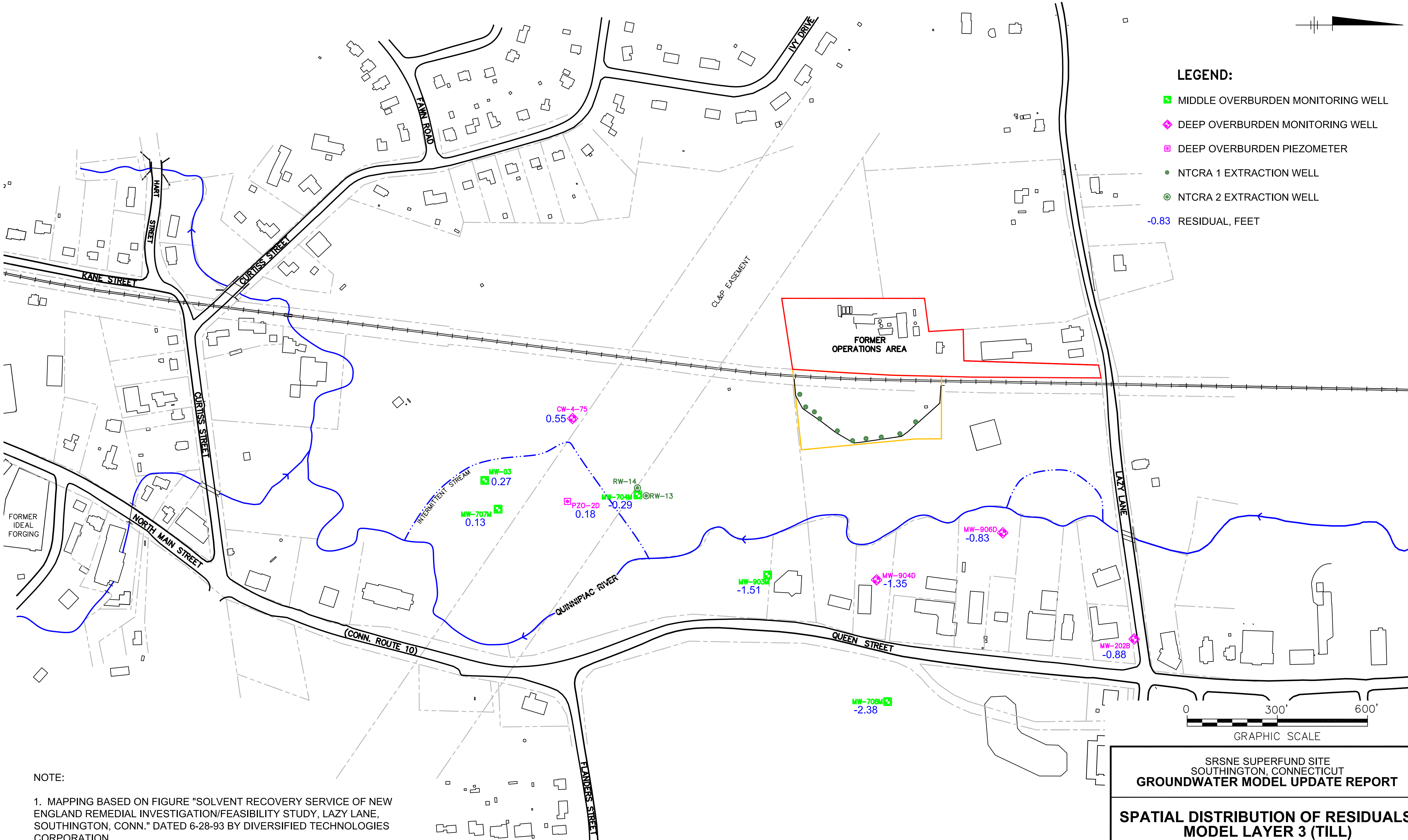
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 2 (OUTWASH)

ARCADIS

FIGURE
25



NOTE:

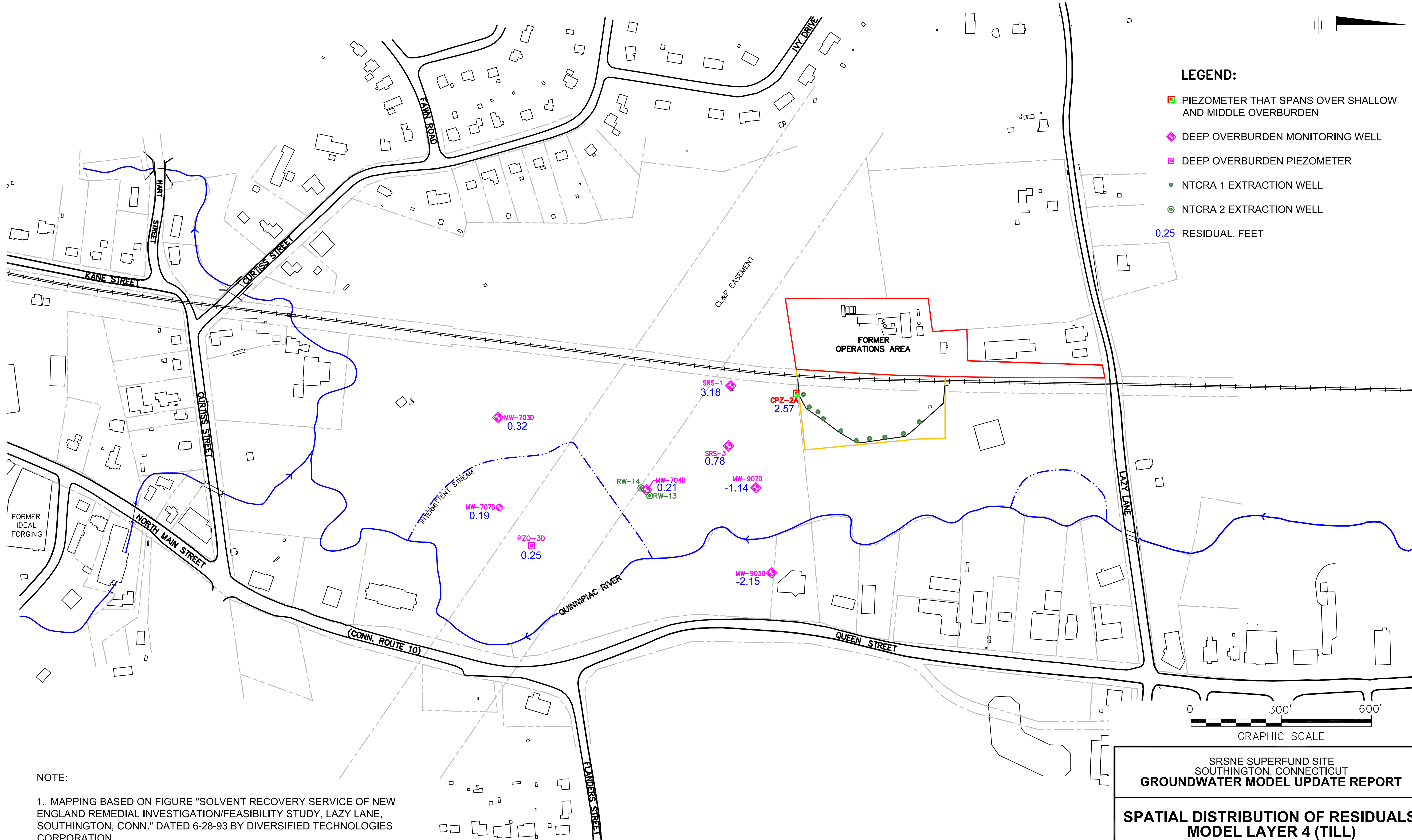
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 3 (TILL)

ARCADIS

FIGURE
26



LEGEND:

- PIEZOMETER THAT SPANS OVER SHALLOW AND MIDDLE OVERBURDEN
- DEEP OVERBURDEN MONITORING WELL
- DEEP OVERBURDEN PIEZOMETER
- NTCRA 1 EXTRACTION WELL
- NTCRA 2 EXTRACTION WELL
- 0.25 RESIDUAL, FEET

NOTE:

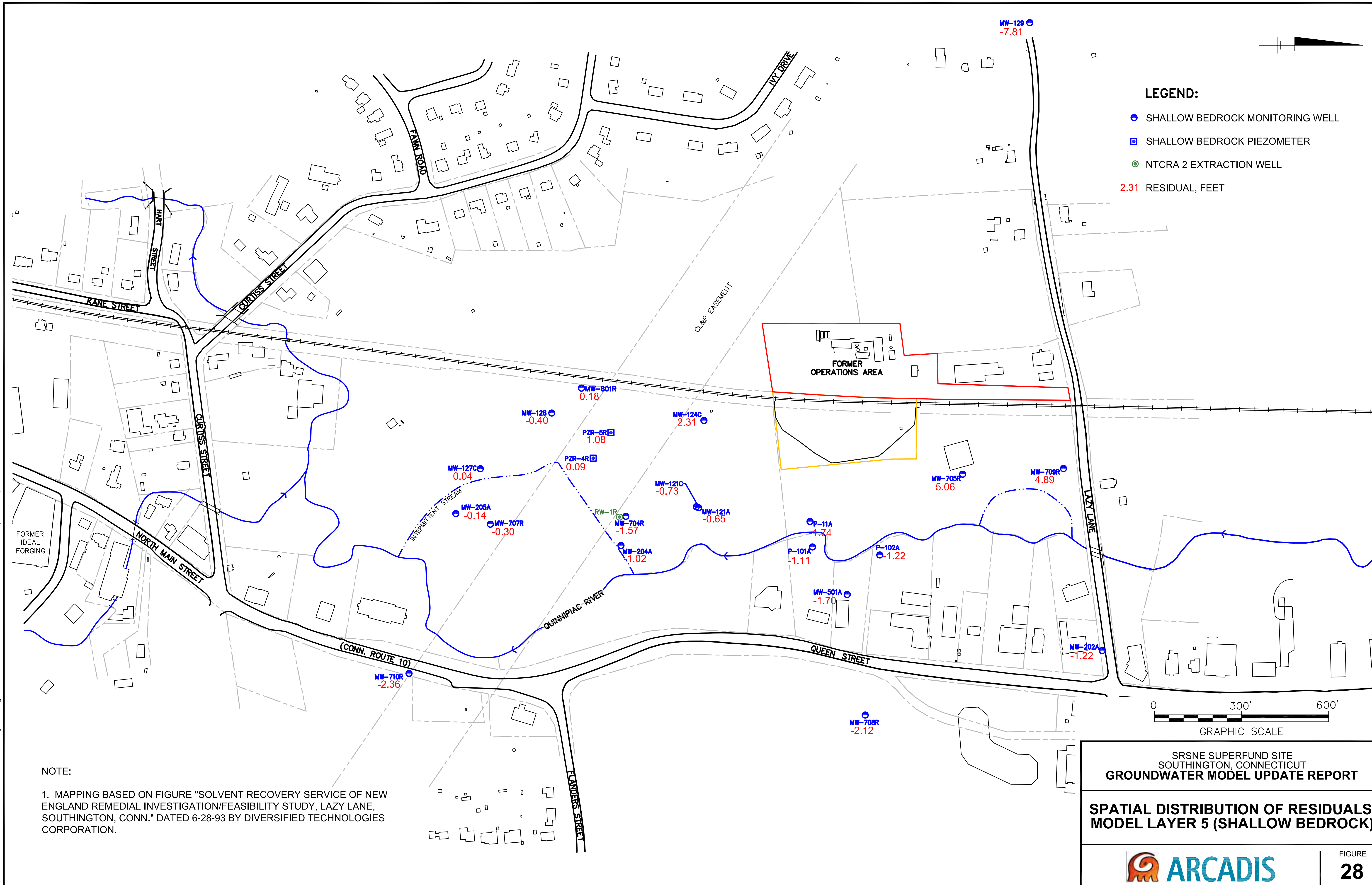
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 4 (TILL)

ARCADIS

FIGURE
27



NOTE:

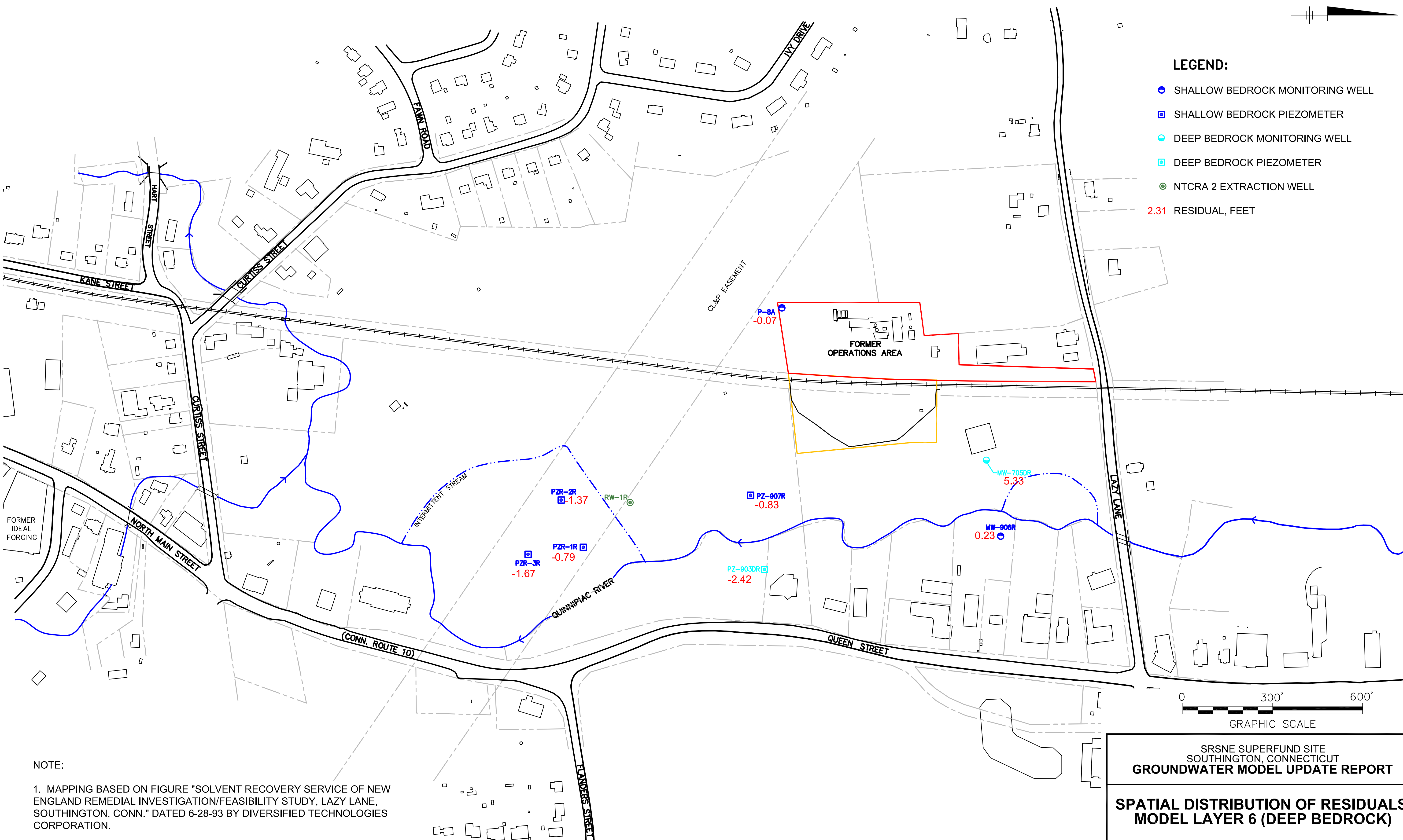
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 5 (SHALLOW BEDROCK)

ARCADIS

FIGURE
28



NOTE:

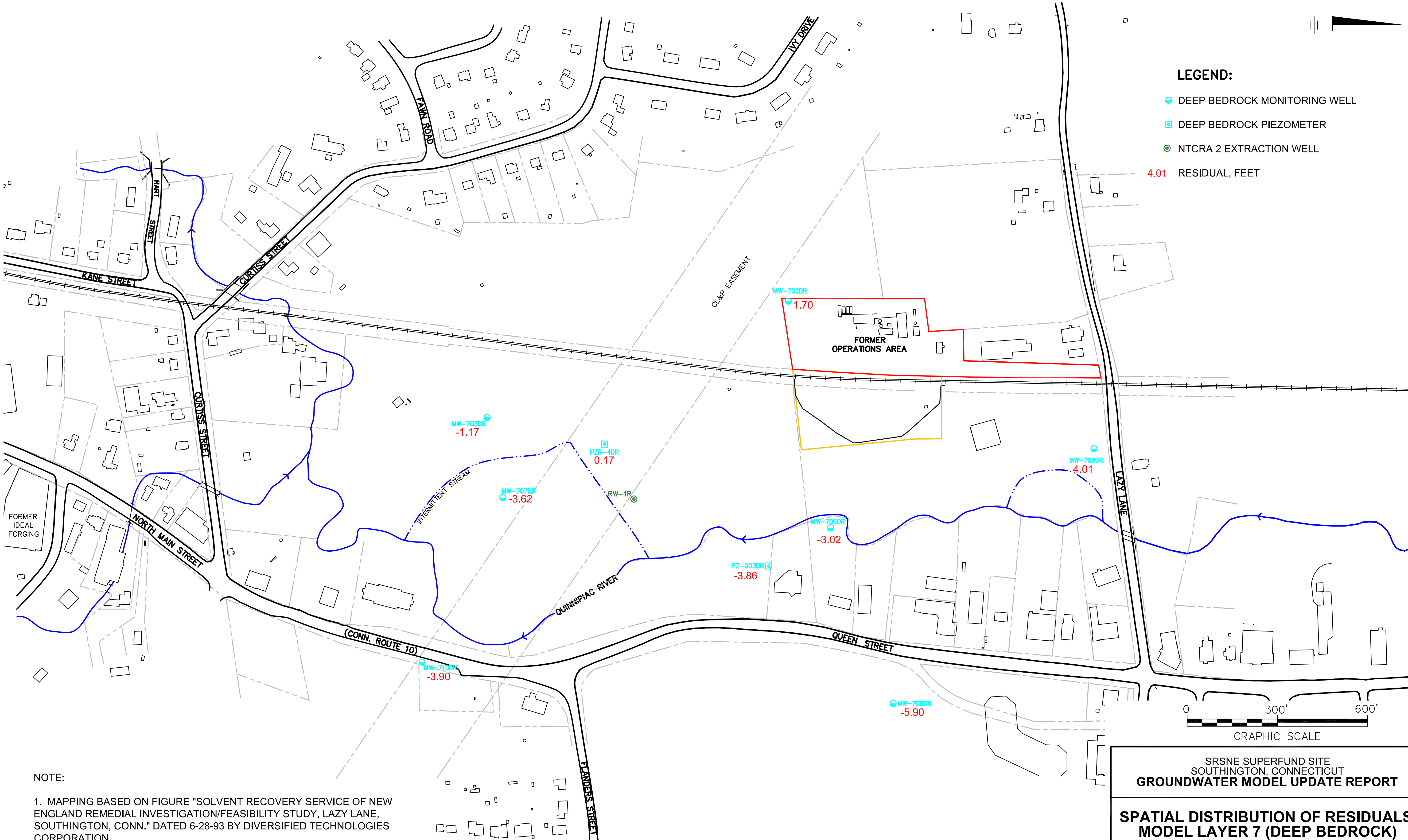
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 6 (DEEP BEDROCK)

ARCADIS

FIGURE
29



NOTE:

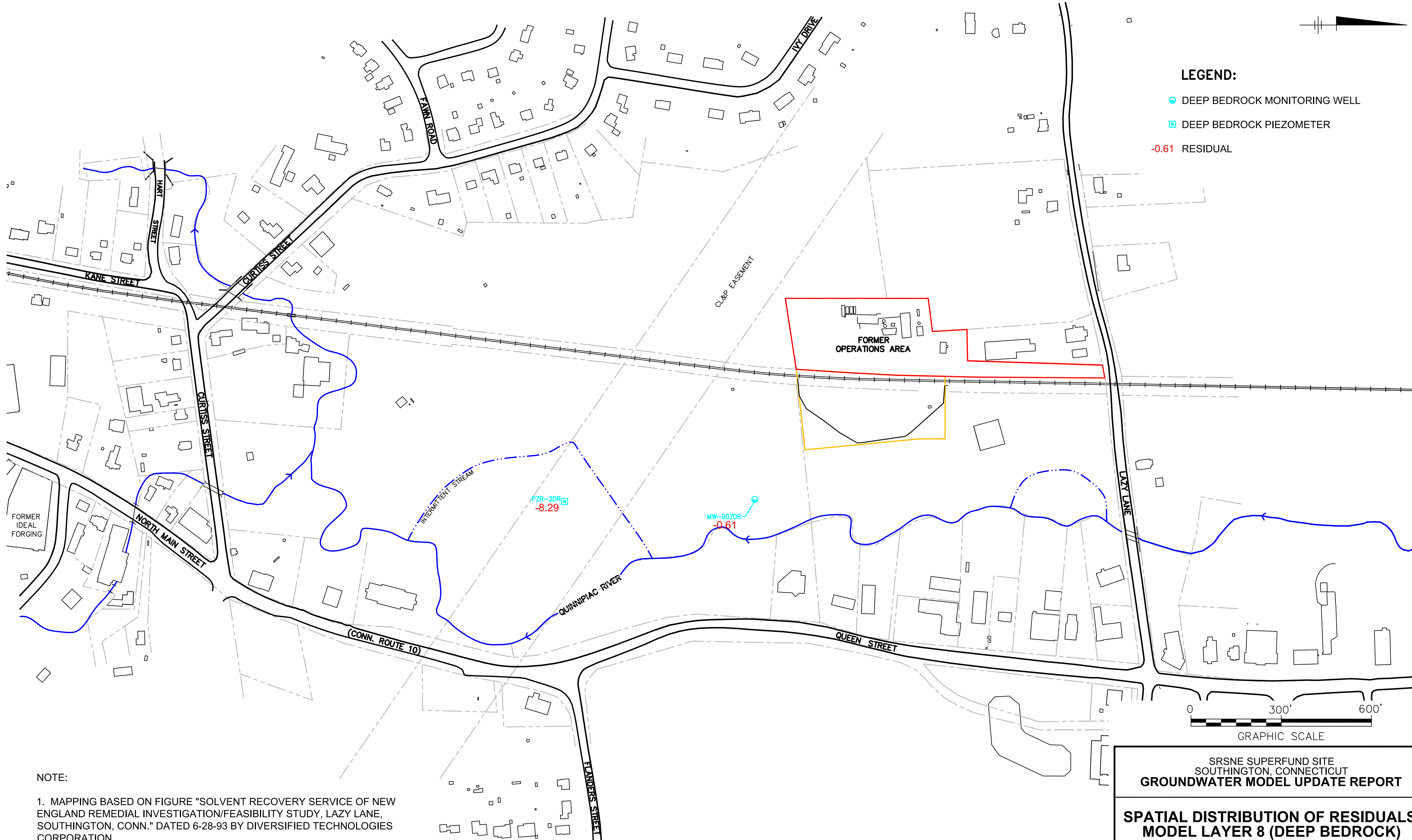
1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 7 (DEEP BEDROCK)

ARCADIS

FIGURE
30



NOTE:

1. MAPPING BASED ON FIGURE "SOLVENT RECOVERY SERVICE OF NEW ENGLAND REMEDIAL INVESTIGATION/FEASIBILITY STUDY, LAZY LANE, SOUTHINGTON, CONN." DATED 6-28-93 BY DIVERSIFIED TECHNOLOGIES CORPORATION.

SRSNE SUPERFUND SITE
SOUTHINGTON, CONNECTICUT
GROUNDWATER MODEL UPDATE REPORT

SPATIAL DISTRIBUTION OF RESIDUALS, MODEL LAYER 8 (DEEP BEDROCK)

ARCADIS

FIGURE
31