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Attachment 3

Final Project Report Groundwater Flow and Constituent Transport Modeling At The Nuclear Fuel Services Facility,

April 25, 1996

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FINAL PROJECT REPORT
GROUNDWATER FLOW AND CONSTITUENT TRANSPORT MODELING AT THE NUCLEAR FUEL SERVICES FACILITY
ERWIN, TENNESSEE

April 25, 1996

Prepared for

NUCLEAR FUEL SERVICES, INC.
Erwin, Tennessee

Prepared by

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PLATES

1.0 INTRODUCTION

Geraghty & Miller, Inc. (Geraghty & Miller) was retained by Nuclear Fuel Services (NFS) to develop a groundwater flow and constituent transport model at the NFS facility in Erwin, Tennessee. This report documents the numerical groundwater flow and solute transport models for tetrachloroethylene (PCE) and uranium developed for this site, including predictive simulations. Additionally, discussions of model assumptions and limitations, summary of the findings, and conclusions are presented. The work described in this report was based on the Conceptual Hydrogeological Model for this site (Geraghty & Miller, Inc. 1995a).

1.1 SITE LOCATION AND HISTORY

NFS is a nuclear fuel fabrication and uranium recovery facility that has been operational since the late 1950s. The NFS facility, approximately 64 acres in size, is located in the mountainous region of east Tennessee, east of the Nolichucky River and adjacent to the CSX Railroad (Figure 1-1). As shown in Figure 1-1, the NFS Erwin site, located in Unicoi County, is within the city limits of Erwin and is immediately west of the community of Banner Hill. Situated in a narrow valley surrounded by rugged mountains, the site occupies a relatively level area approximately 20 to 30 feet (ft) above the elevation of the Nolichucky River. To the west, east, and south, the mountains rise to elevations of 3,500 to 5,000 ft within a few miles of the site. A light industrial park is located opposite the site on the other (west) side of the railroad (EcoTek 1994a). Nearly 74 percent of the land within a 3-mile radius of the NFS plant is mountainous forested land. Residential, commercial, and industrial lands constitute 19 percent of the area, with about 7 percent covered by farms and suburban homes (Figure 1-2) (U.S. Nuclear Regulatory Commission 1991).

1.2 PROJECT OBJECTIVES AND SCOPE

The general objectives for the overall modeling study, including both groundwater flow and constituent transport models, at the NFS Site include the following:

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- Evaluate groundwater pathways to potential off-site receptors in the unconsolidated and bedrock aquifers;
- Establish understanding of groundwater flow conditions and estimated extent of constituent migration (current and future);
- Predict groundwater flow and the extent of contamination for uranium and PCE;
- Define the extent of the maximum potential capture zone produced by a municipal production well and determine whether this capture zone extends to the NFS Facility;
- Use the model results as a basis for installation of additional monitoring wells; and
- Develop predictive simulations to estimate the highest possible concentration of uranium at the Site (for use in a dose assessment model).

The overall scope of work for the modeling study at the NFS Site included the following tasks:

- Review and organize available data describing past and present groundwater flow conditions at the NFS Site. This task was completed and a work plan was submitted to NFS in June 1995 (Geraghty & Miller, Inc. 1995b).
- Develop a conceptual hydrogeologic model for the NFS Site based on information reviewed to satisfy the above objectives. The components of this conceptual model include a summary of the geologic framework, hydraulic properties, groundwater and surface-water interaction, hydrologic sources and sinks, water-level distributions, contaminant distributions, and groundwater flow directions and rates. This task was completed and a report was submitted to NFS in August 1995 (Geraghty & Miller, Inc. 1995a).
- Conduct a capture zone analysis study for the off-site Railroad well and submit an analysis report to NFS. This task was completed and a final letter report summarizing the findings was submitted to NFS in August 1995 (Geraghty & Miller, Inc. 1995c).

- Develop a three-dimensional numerical groundwater flow model for the NFS Site suitable for evaluating past, present, and future groundwater conditions. The conceptual model formed the basis for the construction of the numerical model. Calibration of the numerical flow model was accomplished by matching water levels simulated by the model to water levels measured in monitoring wells. The model predicts the distribution of hydraulic heads (water levels) and groundwater velocities at the Site. This task was completed and an interim draft report submitted to NFS in October 1995 (Geraghty & Miller, Inc. 1995d).

- Develop a solute transport model for uranium and PCE concentrations at the Site. The solute transport model was calibrated by matching observed uranium and PCE groundwater concentrations. This task was completed and an interim draft report submitted to NFS in December 1995 (Geraghty & Miller, Inc. 1995e).

- Develop predictive simulations to estimate the migration extent and concentration of uranium and PCE in the Site area. This task was completed and an interim draft report was submitted to NFS in January 1996 (Geraghty & Miller, Inc. 1996).

- Prepare and submit a final report to NFS documenting the entire modeling study at the Site. This document is that final report, presenting a summarization of all project tasks.

Geraghty & Miller addressed these objectives through several phases of work. The first five tasks (work plan development, the conceptual model, the development and calibration of the groundwater flow model, development and calibration of solute transport model, and Predictive Solute Transport Simulations) have been completed and submitted to NFS. The sixth task, preparation and submittal of this report completes the project tasks.

2.0 GEOLOGIC AND HYDROGEOLOGIC SETTING

2.1 GEOLOGIC FRAMEWORK

Several regional geologic studies have been published for the area of Tennessee in which the NFS Erwin plant is located. Representative references include: King and Ferguson 1960, Ordway 1959, DeBuchananne and Richardson 1956, Rodgers 1953, and EcoTek 1994a. The EcoTek 1994 report entitled, "1992/1993 Nuclear Fuel Services Hydrogeological Investigation and Monitoring Well Installation Program" is focused on geologic conditions at the NFS Site and was partially incorporated in the following discussion.

2.1.1 Bedrock

Unicoi County lies entirely within the Blue Ridge physiographic province. Its northwest boundary follows the crest of Buffalo and Looking Glass mountains while the southeast boundary extends along the crest of the Blue Ridge mountains. These mountains are underlain primarily by quartize and other clastic rocks of Cambrian and pre-Cambrian age. They project 1,000 to 2,500 ft above the adjacent lowlands. The long valley between these two lines of mountains is underlain chiefly by the Honaker dolomite, Rome formation, and Shady dolomite, all of Cambrian age (DeBuchananne and Richardson 1956).

The NFS Erwin Plant lies in the Buffalo Mountain-Cherokee Mountain area which is underlain by Cambrian and Ordovician sedimentary rocks. These rocks were folded and thrust faulted during the Appalachian Orogeny (Ordway 1959). According to Ordway, in this area, bedrock lithologic differences are reflected in the topography. The mountainous area consists mainly of sedimentary clastic rocks-pebble conglomerates, graywackes, sandstones, quartzites, siltstones, and shales-which have been thrust upon the younger rocks of the Valley and Ridge province (EcoTek 1994a).

The entire area along the Blue Ridge/Valley and Ridge transition is characterized by thrust faults and contemporaneous faults such as strike slip faults. Rodgers "Geologic Map of East Tennessee" depicts several fault contacts between the ridges on either side of the Nolichucky River Valley near Erwin. The Buffalo Mountain Fault is mapped just northwest of the NFS-Erwin site (Figure 2-1). No faults have been mapped through or adjacent to the plant site (EcoTek 1994a).

As previously discussed, mapped rock units in and along the valley occupied by the NFS facility include Rome formation, Shady dolomite, and Honaker dolomite, all of Cambrian age. The Rome is described by King and Ferguson as red, maroon, or brown shale, mostly silty and well consolidated. Outcrops on and around the NFS plant site include silty competent shale, but also softer, less competent beds of shale are present. The Shady consists of blue-gray and white dolomite, but includes small amounts of limestone and a few beds of shale. Outcrops of Shady around the NFS site include fine-grained competent dolomite, as well as weathered, soft and crumbly beds of shaley dolomite. The Honaker dolomite is described by Ordway as "dark-blue limestone with numerous distinct tan-brown silty laminae which show on weathered surfaces". Across the Nolichucky River northwest of NFS, a quarry excavated into blue-gray dolomite, is mapped as Honaker by Rodgers, 1953.

Dr. Kenneth Hasson, Professor Emeritus of Geology at East Tennessee State University, believes that this quarry outcrop is actually Shady dolomite (Hasson 1995). He describes the valley's structural setting as a large synclinal fold (Figure 2-2) with the fold axis somewhere near the CSX rail line. Therefore, the Shady should be in contact with the Rome to the northwest and southeast of the axis. The contact between the Rome and Shady is transitional with shale and dolomite interbeds as indicated by outcrops in the Nolichucky River, west of the NFS site.

Although this synclinal interpretation is possible, it does not adequately allow for the vertical to highly dipping beds of the Rome formation on-site. Less contorted, flat to low dipping beds would characterize the Rome at the site with a synclinal interpretation. Rather, coring at the site has shown clearly that the Rome is dipping at steep angles and many times is vertical. Therefore, the interpretation historically documented in literature (Figure 2-3) supports these site findings better and was used as the preferred structural geologic understanding for model construction.

The Rome formation underlies the NFS site. The bedrock is composed of mostly shales and dolomites, with a silty to sandy shale as the dominant rock type. Siltstone has also been identified at the NFS site, although this lithology is not common for the Rome in northeast Tennessee (EcoTek 1989) since the source of these clastics is well west of the

Erwin area. Locally at the NFS site, the Rome is generally dolomitic in the northern portions of the site while shales are more common in the southern portions.

2.1.2 Unconsolidated Sediments

The bedrock underlying the valley where Erwin is located has been weathered to produce a blanket of residuum. The thickest and most extensive masses of residuum overlie the Shady dolomite. Residuum is thinner over the Rome formation as it contains greater thicknesses of poorly soluble shale beds (King and Ferguson 1960).

The alluvium of the valley floors consist of stratified deposits of gravel, made up of water-rounded pebbles, cobbles, and boulders of sandstone and quartzite. Other Precambrian units from the mountains contribute to the alluvial deposits. The bases of the gravel deposits, as exposed in artificial openings, lie unconformable on the eroded surfaces of fresh bedrock, weathered bedrock or residuum (King and Ferguson 1960).

The undulating nature of the bedrock surface beneath the NFS Erwin facility is depicted in Figure 2-4. The bedrock surface mimics topography in only the most general sense as there is a perceptible westward increase in depth to bedrock toward the Nolichucky River. The depth to bedrock from the surface varies from 6.5 to 32 ft at the facility as evidenced by historical drilling activities at the site (EcoTek 1994a). Alluvial materials form the primary overburden at the site. The EcoTek 1994 study summarized much of the previous work and is therefore partially incorporated in the discussion below.

An alluvial overburden of varying thickness was found to exist across the site. This overburden consists of 2 to 4 ft of brown to dark brown, fine to medium grain clay/silt rich sand. This material is very cohesive and extends to a depth of four to six ft (in some areas the upper alluvial layer is covered by fill material of varying thickness). Below the cohesive material is a zone of medium to coarse grain, light to medium gray, micaceous sand, or orange to brown quartizitic sand. The sand extends to a depth of 10 to 15 ft. A sharp contact does not exist between the clayey unit and underlying sand, but rather the change is gradational to a coarser texture with depth. Underlying the sand is a bed of rounded pebbles coarsening with depth into cobbles and boulders (EcoTek 1994a). Thickness of the alluvium ranges from 0 ft, at an outcrop of shale (possible alluvial terrace) along the eastern plant perimeter road, to 29 ft at the northeast corner of the burial ground (EcoTek 1994a).

The coarsest material (cobbles/boulders) lies directly on the bedrock surface. Rock fragments collected from drill cuttings in boreholes consisted of both round quartz, fragments (cobbles), and shards of sandstone (boulders). The cobble/boulder zone does not occupy a consistent horizon across the site and is not laterally continuous. The origin of this material is probably channel fill brought into the valley by the Nolichucky River and its tributaries, therefore, its continuity and thickness is variable across the floodplain occupied by the NFS site (EcoTek 1994a).

The surface of the cobble/boulder zone is depicted in Figure 2-5. It depicts a variable surface with a high elevation of 1,642 ft msl to a low of 1,620 ft msl. The cobble/boulder zone is highest in the southern corner of the site with a high feature extending to the approximate center of the site. A high also is evident northeast of the burial ground. Low elevations occur along the CSX Railroad property and in the vicinity of boring 234-1. Cobbles are apparently non-existent near Building 234 and the shale outcrop below the contractors parking lot, around the Building 105 complex, along the northeastern reach of Banner Spring Branch, and in the vicinity of Wells 59 and 65 (northern corner of the fenced portion of the site) (EcoTek 1994a).

Thicknesses of the cobble/boulder zone range from 0 ft at locations described above to 16 ft at borehole SC-1, just east of the burial ground. The thickest sequences occur at the burial ground, between Wells 98A and 100A (northern site corner), and extend through the Pond 4 and 300-Area of the plant. Thin zones occur in the Building 120/131 area, the Ponds area, and in the vicinity of Building 350. At several locations where the cobble/boulder zone is non-existent, a thick bed occurs in the immediate vicinity. This indicates the erratic nature of this unit and possible presence of buried scarps or ledges.

The unconsolidated material above the cobble/boulder zone is clayier than along the southeastern site boundary. Clayey material extends from the ground surface to as deep as 15 ft. Sandy material grades from dark yellowish orange to light olive gray moving in a northeasterly direction. The remaining overburden is mostly clayey to the southeast becoming interbedded clay overlying sand to the northwest. The clayey material is medium yellowish brown, and dark yellowish orange to medium yellowish orange. The underlying sand is medium brown (EcoTek 1994a). Underlying the northern portion of the plant is a consistent sand unit that is gray in color, mostly quartizitic, but with a high mica content (20 to 30 percent) and rich in heavy minerals (5 to 10 percent). This same gray sand can be seen along the present banks of the Nolichucky River. Underlying other parts of the site, the sand becomes more quartzitic, orange to brown in color, and less micaceous (EcoTek 1994a).

Two cross sections (EcoTek 1994a) display these unconsolidsated lithologies (Plates 1 and 2). Plate 1 depicts a cross-section roughly parallel to strike and Plate 2 is perpendicular to strike.

2.2 HYDROLOGIC FRAMEWORK

The aquifer underlying the NFS site is composed of two principal hydrostratigraphic units: an unconsolidated unit and the upper Rome Formation. The water-table aquifer occurs in the unconsolidated surficial sediments at the site which are predominantly alluvial in origin. This alluvial aquifer is limited in areal extent and is found mainly in the lowland areas. The alluvial aquifer pinches out just north and south of the site due to the presence of shallow bedrock 2 to 5 ft below ground surface.

Alluvial deposits are generally very heterogeneous in sediment size, composition, and depositonal pattern, causing varying degrees of anisotropy throughout these deposits. The presence of large amounts of clay in suspended and mixed-load stream deposits commonly causes the vertical hydraulic conductivity to be orders-of-magnitude less than in a horizontal direction. Identification of low-permeability channel facies, which may result in perched water-table conditions, is also necessary to accurately describe groundwater flow. The point of auger refusal in borings may indicate the presence of either a cobble or boulder zone, or that of bedrock.

The bedrock aquifer beneath the site occurs in the Rome Formation. This shale varies from competent silty shale, to soft shale with a clay-like consistency (EcoTek 1994a). Beds are steeply dipping and contorted. Even though the alluvial aquifer is of greater permeability than the bedrock aquifer, regional groundwater flow patterns exist in the bedrock aquifer beneath the site to a depth of at least 350 ft. Groundwater originating in the upland areas such as Looking Glass Mountain and Temple Hill, flow through the Shady and Honaker Dolomite before exiting the groundwater flow system through surface water. In the dolomite formations, the rocks are competent, hard, and fine-grained. Permeability in the dolomite is due primarily to secondary porosity.

Previous investigations have determined that water in the Rome formation in the site area occurs under weak artesian (confined) conditions for the range of depths investigated. Locally, the Rome bedrock surface is shallow and intersects the water table. Based on physical and hydraulic conditions, the uppermost 10 ft of the Rome aquifer has been defined as belonging to the unconsolidated aquifer (EcoTek 1989).

2.2.1 Groundwater Usage

Wells and springs are the principal source of water supply for several communities in this region. Erwin Utilities use a combination of wells and springs for its water supply. Available well logs and groundwater withdrawal records were obtained from NFS, Erwin Utilities, and USGS Water Supply publications (Hutson and Morris 1992). To supplement existing data, searches were made to identify all groundwater users in the vicinity of the NFS site. A total of six public groundwater wells were identified within a five mile radius of the site. Table 2-1 indicates the approximate depth, yield, and use for each of the wells nearby the site. Table 2-1 also indicates the names and flow rates of springs used for water supply in the area. The on-site well (Well A) previously used for domestic water supply was not registered and is not included on Table 2-1. The nearest public water intake downstream from the NFS facility along the Nolichucky River is at Jonesborough, approximately eight miles in distance (EcoTek 1989).

For most of the wells listed in Table 2-1, average pumping rates are known, but specific pumping rates over time are not available. The average daily municipal water use for Erwin was 2.1 million gallons in 1980 and the maximum daily output was 7 million gallons (Nuclear Regulatory Commission 1991). Little is known about the usage of most of the private water wells within the 5-mile radius of the NFS site.

In relation to the NFS Site, the nearest water withdrawal well used by the Erwin Utilities Board is approximately one-half mile north of the northern NFS Facility boundary ("Railroad Well"). In addition to the Erwin Utilities Board, other users of groundwater in Unicoi County consume approximately 3 million gallons per day (EcoTek 1994a). Most public and industrial supply wells tap the fractures and solution cavities in the limestone and occasionally in the shale aquifers. Domestic water supplies generally obtain water from the alluvium and shallowest bedrock (EcoTek 1994a).

2.2.2 Water Levels

The groundwater environment in the valley around Erwin is a discharge zone as evidenced by the number of springs along the valleys and hillsides. Groundwater occurs beneath the site in both the unconsolidated alluvium and bedrock lithologies. The primary direction of groundwater flow is northwest. The water table is present in the alluvium from where it intersects the land surface to as much as 14 ft below ground surface in the southwestern area of the plant. At the NFS facility, there is a shallow component of groundwater flow associated with the permeable zones in the alluvium and a deeper component through the bedrock and the bedrock alluvium contact. Water-level data is generally limited to the site.

Monitoring wells at the NFS site are completed in three hydrostratigraphic zones; these are: 1) across the water table in the alluvium (Zone 1); 2) the deep alluvium (cobble zone) and shallow bedrock (Zone 2); and 3) in the intermediate depth bedrock (Zone 3), from 50 to 120 ft below land surface (EcoTek 1994a). Table 2-2 identifies monitoring wells by zones. A contour map (Figure 2-7) of the water table surface in Zone 1 for the month of January 1994 shows elevations ranging from 1628 to 1643 ft msl. The influence of the 3 ponds recharging the water table locally can be seen on this map. The groundwater mound or radial contours in the vicinity of the ponds indicates that the ponds are recharging the water table. Generally, groundwater flows in a northwest direction towards the Nolichucky River.

Fractures between the beds of the nearly vertically dipping dolomite probably provide the easiest pathways for water to flow. Flow through fractures across the beds may be more restrictive relative to flow through fractures along the bedding planes. This may help explain the consistent north-northwest groundwater flow directions and elliptical drawdowns (observed during Well 80 pumping test) along strike during pumping. Consequently, the primary effect of pumping is expressed asymmetrically in a northeast-southwest direction, following strike of the beds (EcoTek 1993).

Figure 2-8 depicts a water-level contour map for Zone 2, the deep alluvium and shallow bedrock. This map indicates that the general groundwater flow direction is roughly uniform except for minor influences of Banner Spring Branch. The mounding effect seen in Zone 1 contours is present but very subdued in Zone 2. This agrees well with lithologic and permeability data that suggests the hydraulic conductivity increases with depth in the alluvial materials.

There is very limited information in Zone 3, the intermediate depth bedrock zone. Only five measuring points were used to develop water-level contour maps as shown in

Figure 2-9. With these few data points it is difficult to draw contours with confidence. It is inferred that the flow directions in this zone vary slightly from north to northwest.

Table 2-3 depicts the vertical head relationships between Zone 1/Zone 2 and Zone 2/Zone 3 well clusters. Data from the well clusters indicate that consistent upward gradients exist in at least the northeast area of the site. This upward gradient is most likely due to regional discharge of groundwater (typically from the mountains) to large sinks like the Nolichucky River. Historical water level data are presented in Appendix A.

2.2.3 Hydraulic Properties

NFS has performed several aquifer tests (which include pumping tests, slug tests and packer tests) to define the hydraulic properties at the site. The subsurface lithologies have been partitioned into three distinct zones on the basis of their hydraulic properties. Aquifer tests performed in these zones provide specific data to profile hydraulic conductivity distribution beneath the site.

The alluvium (Zone 1) is fine to coarse grained unconsolidated sediments within which the hydraulic conductivity increases with depth. The slug tests conducted in the alluvial wells present a range of the hydraulic conductivity values from 0.51 feet/day (ft/d) to 114.0 ft/d (Table 2-4). Packer tests in the cobble/boulder zones (SC-1 and SC-7) yielded hydraulic conductivity estimates of 1.6 and 3.1 ft/d, respectively (Table 2-5). To validate the packer tests, the falling head was measured at the cessation of inflow for each interval tested. The falling head data were analyzed using the same methodologies as that for slug test. The results provided hydraulic conductivity estimates of 2.0 and 4.5 ft/d (Table 2-5). An aquifer test was conducted in Well 80 which resulted in an estimate of hydraulic conductivity values ranging from 6.2 to 15.9 ft/d (transmissivity ranging from 155 to 397.5 ft^2/d) and specific yield of 0.19 (EcoTek 1993). Based on the water level data collected during the last quarter of 1993 and using an average hydraulic conductivity of 22.3 ft/d, an average hydraulic gradient of 0.019 and an effective porosity of 0.30, the groundwater velocity in the alluvium can be estimated as 1.41 ft/d or 515 ft/year.

Coring across the site revealed no laterally continuous aquitard separating the bedrock from the alluvium. The groundwater in the bedrock is therefore considered to be unconfined (EcoTek 1989).

In Zone 2, packer tests were performed on discrete intervals of some shallow bedrock wells because of their apparent low permeability. Because of variability in the screened depth, differences exist between the packer test results and the slug test results. Note that well screens were placed for groundwater monitoring purposes and not in consideration of conductivity of the screened interval. Analysis of the packer and slug tests indicate that shallow bedrock displays variable hydraulic conductivity as low as 0.05 ft/d in competent dolomite and as high as 27.64 ft/d in weathered shale (EcoTek 1989). Using last quarter 1993 head data, the groundwater velocity in Zone 2 is estimated to be 1.02 ft/d for the porous fine grained bedrock. Slug test results and packer test results are provided on Tables 2-4 and 2-5, respectively.

Five wells and piezometers are screened more deeply in the bedrock at depths ranging from 50 to 120 ft (Zone 3). The deepest of these wells (Well 67) is screened from 100.0 to 120 ft. A slug test performed on this well yielded a hydraulic conductivity estimate of 33.0 ft/d, indicating the presence of a fracture or other source of higher yield. Well 82 (also in Zone 3) is screened from 60 to 100 ft in depth, and was installed as a water supply well even though it has never been used in that capacity. Well 82 will reportedly yield up to 50 gallons per minute (gpm) (EcoTek 1989). Hydraulic conductivity estimates for Zone 3 are shown on Table 2-4. Using the high end estimate for hydraulic conductivity of 33.0 ft/d, a gradient of 0.01 and an effective porosity of 0.15, the estimated groundwater velocity is 2.2 ft/d or 803 ft/year.

2.2.4 Surface Water

There are three natural surface-water bodies in the vicinity of the NFS Erwin site: Banner Spring Branch, Martin Creek, and the Nolichucky River. Banner Spring Branch is a small (1.5 to 3.0 ft wide) spring-fed stream lying entirely within the NFS Erwin plant boundaries. Banner Spring Branch originates on NFS property at Banner Spring which flows at a rate of about 300 gpm and flows toward the west and north into Martin Creek at the northwest corner of the site, about 1,200 ft from its source. Martin Creek, fed by mountain springs, groundwater, and run-off, runs nearly parallel to the northern property line of the site, crossing the property for just a few yards at the northwest corner. The width of Martin Creek varies from 8 to 15 ft, with depth varying from a few inches to pools of 3 to 4 ft deep. The flow rate varies seasonally from 1,000 to 5,000 gpm.

Banner Spring Branch currently is confined to a straight, incised channel which flows between Ponds 1, 2, and 3. Prior to creation, the Ponds area was marshy with the Banner Spring channel exiting the area along its western boundary. Banner Spring Branch is generally a gaining stream in its upper man-made reaches and is a losing stream west of the ponds area until its confluence with Martin Creek. Historically, the ponds have altered groundwater flow directions on-site. The ponds generally acted as additional recharge sources to the groundwater as indicated by observed mounding of the water table in the vicinity of the ponds. Monthly stage data for the Nolichucky River were obtained from the USGS at the gauging station near Embreeville, roughly 2.5 miles northwest of the site. The average river stage is approximately 1,515 ft msl at Embreeville.

There are several large springs in the vicinity of the NFS site. The city of Erwin relies in part upon springs for municipal supply (Johnson and Pavlicek 1991). In the southern portion of Erwin the Tennessee Wildlife Resources Agency (TWRA) operates a fish hatchery using Love Spring and several smaller springs as a source of water. Love Spring originates from the Shady Dolomite. Spring flow measurements taken at Love Spring, and a nearby unnamed spring, indicate that groundwater pumping can influence the spring flow rates and that good hydraulic communication exists in the fractured bedrock units. The three largest springs in Unicoi County include Love Spring (1.98 cubic feet per second or cfs), U.S. Fishery Spring (2.52 cfs), and Birchfield Spring (3.09 cfs). Currently, the dry season discharge from municipal springs is approximately half of the discharge rate as when they were first developed (Nuclear Regulatory Commission 1991).

The majority of springs listed in Table 2-1 exhibited quick response (within about one day) to local precipitation. In particular, many of the springs show a measurable increase in flow and the water often becomes turbid. Banner Spring water rarely has storm-related turbidity, signifying relatively deep groundwater circulation. Surface water in the Erwin area is not used for water supplies.

2.2.5 Precipitation and Groundwater Recharge

Daily precipitation values from 1985 through 1994 have been collected at the NFS site weather station. The average annual mean precipitation for Erwin is about 45.2 inches (Erwin Utilities Weather Station). It is estimated that 19 to 25 percent of the precipitation in eastern Tennessee is expected to infiltrate as groundwater recharge (Zarawski 1978).

The unconsolidated aquifer is primarily recharged by infiltration of rainfall from the ground surface as well as upward seepage of water into the unconsolidated deposits from the bedrock beneath. A secondary local source of groundwater recharge is seepage/infiltration from the ponds, marshes and streambeds. Groundwater recharge may also occur on an intermittent basis from leaking storm drains and pipelines (EcoTek 1989).

The Rome aquifer beneath the facility is primarily recharged by subsurface movement of water from beneath the adjacent upland areas. Rainfall directly infiltrates into aquifers on the upland areas and moves downgradient in the subsurface through fractures. The higher elevations of the recharge areas help to create the hydraulic head that creates the artesian pressures in the valleys. A secondary localized source of recharge to the Rome aquifer beneath the facility is downward infiltration of water from the unconsolidated aquifer into the Rome (Geraghty & Miller, Inc. 1995a).

2.3 DEVELOPMENT OF THE CONCEPTUAL MODEL

Prior to the development of the mathematical groundwater flow model, it was necessary to develop a conceptual model of subsurface conditions that described important geologic, hydrologic, and hydraulic features of the groundwater system. This conceptual model provided a framework to describe the essential input parameters required by a mathematical model. Thus, the understanding of the groundwater system developed in the conceptual model was the foundation or blueprint for the mathematical model (Geraghty & Miller, Inc. 1995a).

The development of the conceptual model began with a thorough review of available literature pertaining to the site. This review identified important features of the groundwater system. The following types of information were reviewed in the development of the conceptual model: (1) geologic framework, (2) classification of hydrogeologic units, (3) hydraulic potentials and gradients, (4) groundwater sources and sinks, (5) groundwater flow directions and rates, (6) surface water elevations and discharge rates, and (7) contaminant distributions. For the purposes of mathematical modeling, quantification of each of these elements in a conceptual model was essential.

2.4 CONTAMINANT DISTRIBUTIONS

Operations at the NFS plant are believed to have resulted in the presence of radionuclides and organic constituents in the groundwater below the facility. The prime source areas of groundwater contamination are: 1) three unlined surface impoundments (Ponds 1, 2, and 3), 2) the "Pond 4" disposal area, 3) the burial grounds, and 4) the areas associated with Buildings 111, 130, and 120/131 as shown in Figure 2-10, all of which are located in the northern portion of the NFS site. As part of this investigation, a solute transport model was developed for two types of constituents, one radioactive (uranium) and one representative chlorinated solvent (PCE). To date, none of these constituents has been detected below Zone 3 (the deep alluvial material and shallow bedrock). Figures 2-10 and 2-11 depict First Quarter 1994 PCE concentration contours in Zone 1 and Zone 2. Total uranium concentration contours are presented in Figure 2-12.

The EPA drinking water maximum contaminant levels (MCLs) were exceeded for uranium (30 pCi/L) and PCE (5 μg/L) for several wells (EcoTek 1994b). Most of the groundwater contamination exists in the vicinity of the Ponds, burial grounds (SWMU 9), Building 234, Solid Waste Management Unit (SWMU) 13/14 area, and SWMU 2, 4, and 6. Additionally, Buildings 130, 126, and 131 contribute to PCE contamination at the site. As discussed above, the consistent upward gradient observed in Zone 1 and Zone 2 reduces the potential for contamination from reaching greater depths. Vinyl chloride has also been found in the same areas as PCE and is probably the result of PCE biotransformation. The observed total uranium concentrations indicate that uranium moves very slowly in the alluvial aquifer material.

3.0 FLOW MODEL DEVELOPMENT AND RESULTS

To meet the objectives of the study, Geraghty & Miller developed a three-dimensional numerical model that simulates regional groundwater flow in the vicinity of the NFS site. This regional model provides a quantitative tool for predicting the distribution of hydraulic heads (water levels) and groundwater velocities at the site. The model also provides regional-scale estimates of the volume and direction of groundwater flow within the alluvium and bedrock and the recharge/discharge relationships of groundwater flow.

A groundwater flow model was constructed and calibrated covering nearly 38 square miles for the purpose of simulating groundwater flow on a regional scale in the two principal water-bearing units beneath the site: surficial saturated unconsolidated materials and the bedrock aquifer. The model simulates groundwater flow in a multi-unit system, consisting of the alluvium (unconsolidated material) and underlying bedrock. The bedrock aquifer system is made up of the following consolidated units: Honaker Dolomite, Rome Formation, Shady Dolomite, Hampton, Erwin, Unicoi, and Snowbird Formation.

3.1 CODE SELECTION AND DESCRIPTION

3.1.1 Code Selection

For the simulation of groundwater flow at the NFS site, Geraghty & Miller selected the code MODFLOW, a publicly available groundwater flow simulation program developed by the United States Geological Survey (McDonald and Harbaugh, 1988). MODFLOW is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted in regulatory and litigation proceedings. Given the intended use for the NFS site groundwater flow model as a decision-making tool, regulatory acceptance is vital for any code selected for this study.

In addition to its attributes of widespread use and acceptance, MODFLOW was also selected because of its versatile simulation features. MODFLOW can simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions and offers a variety of boundary conditions including specified head, areal recharge, injection or extraction wells, evapotranspiration, drains, rivers or streams, and horizontal flow barriers. Aquifers simulated by MODFLOW can be confined or unconfined, or convertible between confined and unconfined conditions. For the NFS site, which consists of a multi-unit system with variable hydrogeologic unit thickness and boundary conditions, MODFLOW's three-dimensional capability and boundary condition versatility are essential for the proper simulation of groundwater flow conditions.

MODFLOW simulates transient, three-dimensional groundwater flow through porous media described by the following partial differential equation for a constant density fluid:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right) - W = S_s\frac{\partial h}{\partial t} \qquad \text{(Eq. 1)}$$

where:

K_{xx}, K_{yy} and **K_{zz}** are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity [L/T];

h is the potentiometric head [L];

W is a volumetric flux per unit volume and represents sources and/or sinks of water [1/T];

S_s is the specific storage of the porous material [1/L]; and

t is time [T].

In Equation 1, the source/sink (W) terms may vary in both space and time, but the hydraulic parameters (i.e., K_{xx}, K_{yy}, K_{zz} and S_s) may vary in space only, not in time.

To solve the partial differential groundwater flow equation (Eq. 1) on a computer, MODFLOW uses a numerical approximation technique known as the method of finite differences. Using a block-centered finite-difference approach, MODFLOW replaces the continuous system represented in Equation 1 by a set of discrete points in space and time. This process of discretization ultimately leads to a system of simultaneous linear algebraic equations. MODFLOW solves these finite-difference equations with one of the following three iterative solution techniques: strongly implicit procedure (SIP), slice-successive over-relaxation (SSOR), or preconditioned conjugate gradients (PCG). The solution of the finite-difference equations produces time-varying values of head at each of the discrete points representing the real aquifer system. Given a sufficient number of discrete points, the simulated values of head yield close approximations of the head distributions given by exact analytical solutions to Equation 1.

3.1.2 Model Discretization

The finite-difference technique employed in MODFLOW to simulate hydraulic head distributions in multi-aquifer systems requires areal and vertical discretization or subdivision of the continuous aquifer system into a set of discrete blocks that forms a three-dimensional model grid. In the block-centered, finite-difference formulation used in MODFLOW, the center of each grid block corresponds to a computational point or node. When MODFLOW solves the set of linear algebraic finite-difference equations for the complete set of blocks, the solution yields values of hydraulic head at each node in the three-dimensional grid.

Water levels computed for each block represent an average water level over the volume of the block. Thus, adequate discretization (i.e., a sufficiently fine grid) is required to resolve features of interest, and yet not be computationally burdensome. MODFLOW allows the use of variable grid spacing such that a model may have a finer grid in areas of interest where greater accuracy is required and a coarser grid in areas requiring less detail.

The three-dimensional model grid developed for the NFS groundwater flow model, shown in Figure 3-1 and in greater detail in Plate 3, extends over an area covering approximately 38 square miles. The grid boundaries were specified to coincide with natural boundaries, when possible, and to minimize the influence of model boundaries on simulation results at the site. The model domain extends approximately 6.6 miles from the east to west boundaries and 5.7 miles from the north to south boundaries. The finite-difference grid consists of 128 columns and 100 rows with five layers for a total of 64,000 grid cells or nodes. The model grid uses a uniform 50-ft areal grid spacing in the vicinity of the site to provide increased computational detail in the area of interest and grades to larger grid spacing at greater distances from the site.

The boundaries of the finite-difference grid and the 50-ft areal grid spacing at the NFS site were selected for the purpose of accurately simulating both regional and local groundwater flow around the site and to accurately define the extent of hydraulic parameters and model structure. The extent selected for the grid ensured adequate incorporation of regional groundwater flow features that affect site conditions. The groundwater flow model was also oriented such that a principal axis of the model grid conforms to regional groundwater flow directions (north/northwest). The strike of the bedrock units is also roughly perpendicular to the average groundwater flow direction. Conveniently, the model has two axes along the column and row directions that will correspond to the directions of permeability anisotropy and groundwater flow directions (NW/SE). Shallow groundwater flow directions are typically from upland areas towards major rivers and streams such as the Nolichucky River, South Indian Creek, and smaller tributaries including Martin Creek.

The regional groundwater flow model used five layers to simulate groundwater flow in the hydrogeologic aquifer units encountered at the site. The model also used vertical hydraulic conductivity to regulate the amount of vertical flow between hydrogeologic units to represent the vertical flow of groundwater through the water-bearing units.

Geraghty & Miller relied on lithologic descriptions from on-site wells to define the structural top and bottom elevations of the shallow alluvial sediments and top of bedrock in the vicinity of the site. In more distant areas of the model domain, land surface elevation data were used to define the bottom elevations for Model Layers 1 and 2 such that the layer bottoms were a subdued reflection of topography. Model Layer 2 eventually graded to a horizontal plane in Model Layers 3 through 5. Figures 3-2 and 3-3 show structural contour maps used in the development of the vertical discretization of the regional model. Since each model layer is in direct contact with neighboring layers, only bottom elevations of model layers are shown on these figures. The bottom elevations specified for Model Layers 3, 4, and 5 are 1,525, 1,450, and 1,325 ft msl, respectively. Information from the previous investigations on the site, public water supply well logs, and published reports by USGS and other agencies were used to help define the total model depth. Table 3-1 is a generalized section of the aquifer system with corresponding model layers. Within each model layer, the hydraulic parameters represent the various lithologies found beneath the site.

Even though the site is underlain by the Rome Formation, the model domain was large enough such that the Honaker Dolomite, Shady Dolomite, Erwin, Hampton, Unicoi, and Snowbird formations were simulated. Model Layer 1 incorporates the alluvium found directly beneath the NFS site, with the bottom of this layer coinciding with the variable elevation of the top of the cobble/boulder zone. Model Layer 2 represents the cobble/boulder zone generally found just above the bedrock beneath the site. The bottom of Model Layer 2 conforms to the top of bedrock in the vicinity of the site. In areas where the alluvium pinches out, Model Layers 1 and 2 represent the first encountered bedrock unit. The lower model layers represent only the bedrock lithologies in the model domain. Multiple bedrock layers will allow for accurate simulation of vertical gradients in the bedrock and for more accurate representation of the steeply dipping bedrock units. The base of the model is defined by the low permeability regions within the bedrock units as determined mainly from municipal well yield information in the area and through numerical simulations.

3.1.3 Boundary Conditions

External model boundaries were chosen to coincide with well-defined, natural flow system boundaries where possible. MODFLOW features a variety of boundary condition options, facilitating the incorporation of natural and artificial boundaries in the model. The model uses various types of mathematical boundary conditions to represent natural boundaries: for this application, prescribed flux (including no flow) and head-dependent flux were applied. Natural boundaries simulated by the regional model include groundwater recharge from precipitation, and rivers and streams.

The model applies groundwater recharge from surface infiltration of precipitation through a prescribed flux boundary condition in the uppermost active layer of the model. A uniform precipitation recharge value (6 inches per year or in/yr) was used to represent normal infiltration conditions found in the model domain. Geraghty & Miller estimated the precipitation recharge of 6 in/yr from numerous model simulations. Greater confidence was given to slug test data during the model calibration because the initial estimated recharge (10 in/yr) contained greater uncertainty; therefore, recharge was estimated by adjusting the values to match water levels. The value of 6 in/yr is the maximum overall recharge value that the aquifer can support in the vicinity of the site. This is slightly lower than previous estimates by Zarawski 1978.

Head-dependent flux conditions represent rivers and tributary streams, such as the Nolichucky River, South and North Indian Creek, Broad Shoal Creek, Rock Creek, Martins Creek, drainage ditches, and the on-site ponds (Figure 3-1). The model simulates these head-dependent fluxes using "river and drain cells," a boundary condition option provided by MODFLOW to represent rivers and streams. River cells allow the model to compute the flow into or out of a stream as a function of the head difference between the stream elevation and the hydraulic head simulated in the aquifer. An advantage of this type of boundary condition is that the model can simulate influent or effluent conditions along different reaches of a stream depending on local head relationships between the stream and aquifer. River cells are only used in Model Layer 1 to represent larger tributary streams, the Nolichucky River, and the ponds. Minor tributaries are simulated with drain cells to allow groundwater to flow only into the tributary. If the simulated water level falls below the drain elevation, the drain becomes inactive. Springs such as Banner Spring, Erwin Spring, and Love Spring were simulated using drain cells.

The elevations of the various head-dependent boundary conditions were derived from actual field measurements or were taken from topographic maps. The Nolichucky River stage was determined from monthly stage data at the gauging station near Embreeville, roughly 2.5 miles northwest of the site. The average stage for 1994 calibration conditions is 1521.65 ft msl at Embreeville. The grade of the river was determined from topographic maps to determine the actual river stage throughout the model domain. The ponds on site were set to elevations measured during August, 1995. The elevations for Ponds 1, 2, and 3 were defined in the model as 1633.39, 1636.24, and 1638.11 ft msl, respectively. The conductance term associated with the river and drain cells was generally calculated using the current estimated hydraulic parameters of the underlying aquifer material.

A total of three groundwater supply wells and ten groundwater dewatering wells were identified within the model domain and were incorporated in the model as prescribed flux boundary conditions. Table 3-2 indicates the model grid location and average rate during the calibration period (August through December 1994) for each of the wells included in the model. Average pumping rates for the public supply wells (Railroad Well, Birchfield Well, and the O'Brien Well) were determined from Erwin Utilities pumping records. The above mentioned off-site wells did not produce any significant effects on simulated groundwater flow directions in the vicinity of the site. The average rate of the Pond 4 dewatering wells were determined by NFS personnel. The rates for individual dewatering wells were determined by calculating a uniform rate for each well. Groundwater pumping wells specified in the model that penetrate more than one model layer are termed multi-aquifer wells and are specified in the model as individual wells in each model layer they penetrate. The pumping rate allocated to each model layer is a function of the transmissivity of each model layer relative to the total transmissivity of the aquifer unit penetrated by the well.

At all other boundary locations in the model, the regional model uses prescribed no-flow boundaries to represent barriers to groundwater flow, including groundwater divides and regional groundwater flowlines. Groundwater flow divides were delineated by locating topographic highs from topographic maps in the general model area. Model extents were defined to correspond to the divides or in some cases actual grid nodes were set to no flow to better represent the actual groundwater divide.

3.1.4 Hydraulic Parameters

In constructing the NFS groundwater flow model, representative initial values for model parameters were selected based on site-specific data. These model parameters included groundwater recharge and horizontal and vertical hydraulic conductivity of unconsolidated and bedrock aquifers.

Initial values of hydraulic conductivity for the upper three model layers relied on site-specific slug test and pumping test data where available. In the upper model layers, the distribution of hydraulic conductivity is simulated to be heterogeneous to reflect the contrast between relatively high permeability alluvial material and the steeply dipping bedrock units. Vertical hydraulic conductivities in the model had a nonuniform initial distribution that corresponded exactly to the hydraulic conductivity zonation to represent various bedrock and alluvial deposits. During the calibration of the model, values of these parameters were adjusted to minimize the differences between observed and simulated groundwater elevations at target locations.

3.2 CALIBRATION TARGETS

Calibration targets are a set of field measurements, typically groundwater elevations, used to test the ability of a model to reproduce actual conditions occurring within a groundwater flow system. For the calibration of a steady-state (time-invariant) model, the goal in selecting calibration targets is to define a set of water-level measurements that represent the average elevation of the water table or potentiometric surface at locations throughout the model domain.

Based on a complete review of available water-level data for the NFS site, an average of water-level measurements was selected from August through December 1994 to calibrate the groundwater flow model. This time period was chosen to incorporate recent data and also corresponds to a period with constant pumping by the 10 on-site dewatering wells. A total of 68 monitoring wells comprise the calibration targets: 32 targets in the alluvial aquifer (Model Layer 1); 25 targets in the cobble zone (Model Layer 2); and 11 targets in the deeper bedrock aquifer (Model Layer 3). Table 3-3 lists the monitoring wells and water-level elevations chosen as targets for the calibration of the regional flow model. The following wells were not used during model calibration because they crossed multiple Model Layers: 60, 62, 77, 73, and 74. Monitor Wells SC-1 and 63 were not used because of anomalous water levels.

3.2.1 Model Calibration Procedure

For best calibration results, a model should rely on discrete measurements to produce answers free of contouring interpretations and artifacts. In the calibration of a groundwater flow model, use of point data eliminates the potential for interpretive bias that may result from attempting to match a contoured potentiometric surface (Konikow, 1978; Anderson and Woessner, 1992). In calibrating the NFS groundwater flow model, 68 water-level calibration targets were used from monitoring wells distributed in all aquifer units (Table 3-3).

As a further goal for the calibration of a model, the principle of parameter parsimony was used, which seeks to achieve an adequate calibration of a model through the use of the fewest number of model parameters. It should be noted that the use of greater numbers of model parameters during model calibration creates a situation in which many combinations of model parameter values produce equivalent calibration results. In this case, the model calibration parameters are called nonunique. Following the principle of parameter parsimony reduces the degree of nonuniqueness and results in more reliable calibrated parameter values. The information gathered for the conceptual model guides any decision to add model parameters (e.g., zones of hydraulic conductivity) to the model during the calibration process. Therefore, in the absence of hydrogeologic evidence, the simpler model is preferred.

An automatic parameter estimation procedure is routinely applied to calibrate groundwater flow models. Starting with a set of initial estimates for the model parameters, the procedure systematically updates the parameter estimates to minimize the difference between simulated and observed water levels at a set of calibration targets. Compared to trial and error procedures for model calibration, automatic parameter estimation greatly reduced the time required for model calibration and provided a better overall calibration. The general algorithm applied in conjunction with the MODFLOW code is known as the Gauss-Newton Method and is described in greater detail by Duffield et al. (1990) and Hill (1992).

The primary criterion for evaluating the calibration of a groundwater flow model is the difference between simulated and observed water levels at a set of calibration targets. A residual or model error, e_i, is defined as the difference between the observed and simulated hydraulic head measured at a target location:

$$e_i = h_i - \hat{h}_i \qquad \text{(Eq. 2)}$$

where h_i is the measured value of hydraulic head and $\hat{h}_i$ is the simulated value at the *i*th target location. A residual with a negative sign indicates overprediction by the model (i.e., the simulated head is higher than the measured value). Conversely, a positive residual indicates underprediction.

The automatic parameter estimation procedure seeks to minimize an objective function defined by the residual sum of squares (RSS):

$$RSS = \sum_{i=1}^{n} (h_i - \hat{h}_i)^2 \qquad \text{(Eq. 3)}$$

where n is the total number of calibration targets. The RSS is the primary measure of model fit. The residual standard deviation (RSTD), which normalizes the RSS by the number of calibration targets and number of estimated parameters (p), is defined as follows:

$$RSTD = \sqrt{\frac{RSS}{n-p}} \qquad \text{(Eq. 4)}$$

The RSTD is useful for comparing model calibrations with different numbers of calibration targets and estimated parameters. Another calibration measure is the mean of all residuals ($\bar{e}$):

$$\bar{e} = \frac{1}{n} \sum_{i=1}^{n} e_i \qquad \text{(Eq. 5)}$$

A mean residual significantly different from zero indicates model bias. The Gauss-Newton parameter estimation procedure produces a near zero mean residual at the minimum RSS.

3.2.2 Calibration Results

The calibration of the regional groundwater flow model required over 100 individual MODFLOW simulations using both trial-and-error adjustments of the model parameters and the automatic parameter estimation code. During the calibration process, Geraghty & Miller altered model values of groundwater recharge, horizontal and vertical hydraulic conductivity, and boundary conditions within measured or realistic ranges, to obtain a satisfactory match between simulated and observed water levels.

Using the 68 water-level targets selected for the calibration of the NFS groundwater flow model, calibration of the model was evaluated through the analysis of (1) simulated hydraulic head distributions in all of the water-bearing hydrogeologic units, (2) estimated hydraulic properties, and (3) residual statistics.

3.2.2.1 Simulated Hydraulic Heads and Hydraulic Properties in Model Layers 1 and 2

The water-table occurs in the unconsolidated surficial sediments at the site, which are predominantly alluvial in origin, and in various bedrock units in the highland areas north and south of the NFS site. This surficial alluvium is limited in areal extent. The surficial alluvium is roughly bounded by the Nolichucky River to the west. The alluvium also pinches out just south of the site as is demonstrated by the presence of the Rome Formation a few feet below ground surface.

The estimated hydraulic conductivities in Model Layers 1 and 2 of the groundwater flow model reflect the various lithologies comprising these layers (Figures 3-4 and 3-5). A total of six hydraulic conductivity zones (Parameter Zones), with horizontal hydraulic conductivities ranging from 0.02 to 25 ft/d, represent bedrock and unconsolidated surficial sediments in Model Layer 1. Model Layer 2 contains a similar hydraulic conductivity distribution as Model Layer 1, except it has a uniform hydraulic conductivity of 15 ft/d in the alluvial materials that primarily represent the cobble zone (Figure 3-5). Hydraulic conductivities in Layer 2 for the bedrock units remain unchanged from Model Layer 1. Generally, the alluvium (Model Layer 1) consists of fine to coarse grained unconsolidated sediments. The slug tests conducted in the alluvial wells present a range of hydraulic conductivity values from 0.51 ft/d to 114.0 ft/d (Table 2-4). Closer examination of the data on Table 3-4 suggests that at least two permeability zones exist in the shallow alluvium: a low permeability region in the vicinity of the ponds and a higher permeability region beneath the building area of the site. These two permeability zones correspond to Parameter Zones 5 (5 ft/d) and 6 (25 ft/d) presented on Figure 3-4. Calibration trials also supported the existence of two permeability zones in the alluvial materials. Zone 5 was used in most areas in the model domain where it is assumed that alluvial materials exist. The hydraulic conductivity for cobble zone materials (Figure 3-5; Zone 5) was estimated during the model calibration. The estimated value (15 ft/d) is considered to be a reasonable hydraulic conductivity for cobble/boulder material. The value is slightly higher than slug-derived values in the cobble zone.

The bedrock hydraulic conductivity zonation was entered into the model directly from published geologic maps. During the model calibration, it was found that three of the rock formations contained different hydraulic properties (Rome Formation, Shady Dolomite, and the Honaker Dolomite) but that the Hampton, Erwin, Unicoi, and Snowbird Formations are hydraulically similar. Thus the latter four formations were simulated as a combined hydraulic zone in the model. Descriptions of groundwater flow from USGS literature (DeBuchananne and Richardson 1956) support the model finding that these units have similar flow characteristics. In general, it was found that the more resistant bedrock units contained a higher degree of anisotropy, a 2:1 ratio between strike direction hydraulic conductivity and perpendicular to strike hydraulic conductivity, and that the more permeable bedrock units like the Rome Formation (Zone 1) have a lesser degree of anisotropy (1.5:1). The estimated average horizontal hydraulic conductivity for the Rome Formation is 9.8 ft/d. Pumping test data from highly weathered portions of the formation revealed permeability of approximately 11.75 ft/d (EcoTek 1989). There were insufficient data to justify the introduction of variable permeability zones within the Rome Formation, therefore, in this case, the simpler model with uniform properties is preferred. The value for the Rome Formation was estimated during calibration and is very close to the value determined from the aquifer test. The values estimated by the model represent an average hydraulic conductivity for the unit that best matches observed water levels. The aquifer test results, while providing accurate estimates of transmissivity in vicinity of the well, do not necessarily provide large scale estimates of average transmissivity.

The more resistant rocks that form the highlands in the Erwin area (Zone 4) were estimated to have a mean horizontal hydraulic conductivity of 0.014 ft/d. The low hydraulic conductivity value results in simulated groundwater levels closely mimicking topography. Hydraulic conductivity of Zones 2 and 3, which represent the Honaker and Shady Dolomites, have estimated horizontal hydraulic conductivities of 5.7 and 2.83 ft/d, respectively. Both are reasonable values for their lithologies and both units are able to support high groundwater withdrawals of the municipal supply wells. Other researchers in similar geologic settings have found that low anisotropy ratios of 2.6:1 result in improved model calibration when using the porous media approach to simulate fractured aquifer units (Lee, et.al 1992). The low hydraulic conductivities in Zones 2, 3, and 4 were estimated by the model and have greater uncertainty since no site-specific measured values were used to guide the calibration. Many aquifer descriptions were reviewed in these low permeability areas, such as drillers logs and reported well yields. All information corroborated extremely low hydraulic conductivities in the lowland areas near the site, and good estimates of precipitation recharge provided enough constraints on the system to enable estimation of these hydraulic conductivities.

The model regulates the vertical flow of groundwater between Model Layers 1 and 2 through vertical hydraulic conductivity values that correspond precisely to the hydraulic conductivity zonation. Thus, units having lower vertical hydraulic conductivity allow less vertical flow of groundwater. The distribution of leakance coefficients simulated for the bedrock and alluvial materials in Model Layers 1 and 2 are shown on Figures 3-4 and 3-5. The simulated vertical hydraulic conductivities range from 0.02 to 2.5 ft/d. Generally, the highest leakance values occur in the alluvial aquifer units. A 10:1 ratio exists between the highest horizontal hydraulic conductivity (along strike), and the vertical hydraulic conductivity in Zones 1 through 3 (alluvial materials/higher conductivity bedrock). In the low conductivity bedrock units, only a 2:1 ratio exists between the strike direction hydraulic conductivity and the vertical hydraulic conductivity, which is quite typical in fractured rock settings.

The simulated hydraulic head surface for Model Layer 1 shows regional water levels declining from all areas surrounding the NFS site toward the Nolichucky River and Indian Creeks (Figures 3-6 and 3-7). The simulated hydraulic heads in Model Layer 2 depict a similar but more subdued reflection of the uppermost model layer (Figures 3-8 and 3-9). The water table significantly flattens in the higher permeability units, specifically the alluvial and cobble zones and in the Rome Formation along the Nolichucky and Indian Creeks. Groundwater flow conditions in the vicinity of the site are northwest towards the Nolichucky River (Figures 3-7 and 3-9). Slight inflections are noticed in the water table due to influences from the drainage ditch, Banner Spring, and the ponds. Beneath the ponds, slight downward gradients are produced from Model Layer 1 to Model Layer 2, but these gradients reverse closer to the river.

Generally, there is a downward hydraulic gradient in the highland areas of the model. Gradients tend to be upward near discharge points such as springs and the Nolichucky River. Across the site, gradients are predominately horizontal with increasing upward vertical flow components in the vicinity of the Nolichucky River.

3.2.2.2 Simulated Hydraulic Heads and Hydraulic Properties in Model Layers 3 Through 5

A total of four hydraulic conductivity zones, with horizontal hydraulic conductivities ranging from 0.02 to 12 ft/d, represent the deeper bedrock units. The zonation of the lower three layers of the model is nearly identical to Model Layers 1 and 2, except that the alluvial materials are absent (Figures 3-10 through 3-12). Consistent horizontal and vertical hydraulic conductivities were used for the bedrock hydrogeologic units in all model layers. Simulated hydraulic head contours for Model Layers 3 through 5 are depicted in Figures 3-13 through 3-18.

Basically, the simulated heads in the lower bedrock layers reflect those in the shallow zone. In the upland areas decreasing hydraulic heads are simulated with depth. This indicates downward flow of recharge in the upland areas. Groundwater originating in the highland areas ultimately flows towards the valleys, exiting the groundwater system via the rivers. In the lowland areas, beneath the rivers, upward hydraulic gradients are simulated by the model. Simulated head contours in the bedrock beneath the site indicate a northwest groundwater flow direction towards the Nolichucky River.

3.3 ANALYSIS OF MODEL RESIDUALS

The calibration objective for the NFS groundwater flow model was to minimize the residual sum of squares (Eq. 3) computed for the 68 water-level calibration targets. Table 3-4 lists the simulated water elevations and model residuals for each calibration target. The maps of simulated hydraulic head (Figures 3-7, 3-9, and 3-14) show the spatial distribution of the residuals in each of the calibrated model layers.

The largest computed residual for the entire set of targets is -5.00 ft; however, only 13 residuals out of the 68 targets exceed ±2 ft. Greater than 71 percent of the targets have residuals of ±1.5 ft or less. Overall, the model shows a very good match to the measured water levels given the complex geologic conditions encountered in the unconsolidated and bedrock aquifers at the site.

Residual statistics for the calibrated groundwater flow model also indicate good agreement between simulated and measured groundwater elevations. The mean is close to zero (-0.002) and the residual standard deviation (1.5 ft) is less than 0.1 percent of the range of simulated water-level elevations for the entire model domain and less than 7 percent of the range found on-site.

3.4 SENSITIVITY ANALYSIS

Sensitivity analysis was performed to examine the effects of uncertainties in each of the hydraulic parameters in the model. In a sensitivity analysis, a single parameter is varied from its calibrated value while holding all others constant. The parameters investigated in the sensitivity analysis for the NFS regional groundwater flow model included the horizontal hydraulic conductivity of each zone, vertical hydraulic conductivity of each model layer, and precipitation recharge. Because many hydraulic parameters in the regional model are distributed in multiple zones, individual zonal parameter values were varied by a uniform percentage during the sensitivity analysis. For example, to evaluate the sensitivity of hydraulic conductivity of zone 1 (Rome Formation), the parameter variation applied to all five model layers.

For each hydraulic parameter except recharge, the sensitivity analysis investigated four discrete parameter variations as follows: -80 percent, -40 percent, +40 percent and +80 percent. Only three hydraulic conductivity zones exhibited a significant change in the residual sum of squares (RSS) calibration statistic as shown in Figure 3-19. Only the Rome formation (Zone 1), the Honaker Formation (Zone 2), and the cobble zone (Zone 3) were mildly sensitive to parameter changes. Generally, the model was much more sensitive to parameter decreases than increases. All other horizontal hydraulic conductivity parameter zones were not very sensitive to parameter changes. Even though some of the hydraulic parameter zones were insensitive to the calibration statistic, the parameter changes resulted in significantly different groundwater flow conditions. In some cases, production wells would go dry or the water table computed in the highland areas was significantly underpredicted or overpredicted. A slight increase in the Rome Formation vertical hydraulic conductivity (Zone 1) resulted in minimally better statistical match (Figure 3-20), but it was felt that the resultant permeability value would have been unreasonably high.

Vertical hydraulic conductivities were most sensitive to decreases in the Rome Formation (Layer 1) and the Honaker and Shady Dolomite units (Layers 2 and 3) (Figure 3-20). The vertical hydraulic conductivities were virtually insensitive to increases. The values used in the model were the lowest possible to achieve calibration that bordered the inflection point of parameter insensitivity. Figure 3-21 depicts the recharge sensitivity plot. Recharge, the source of all water in the model, is an extremely sensitive parameter. Slight increases and decreases in the parameter generally affect the model calibration symmetrically.

3.5 CAPTURE ZONE FOR THE RAILROAD WELL

The capture zone of the Railroad Well was evaluated with the MODFLOW groundwater flow model described in the preceding sections. The Railroad Well was included in the model calibration simulations and the effects of this well and the capture zone produced by the well were automatically calculated by the model. Therefore, a separate capture zone analysis for the Railroad Well was unnecessary. This analysis replaces the earlier Capture Zone Analysis Report prepared and submitted to NFS on August 4, 1995, for this site (Geraghty & Miller, Inc. 1995c). That report was based on limited information using simple analytical techniques to determine the capture zone of the Railroad Well for screening purposes only. The major assumptions of the previous capture zone analysis included uniform hydraulic properties (vertically and areally) in the subsurface near the well, only two-dimensional flow conditions, uniform groundwater flow directions and rates, and influence of surface water boundaries. The accuracy of the predicted capture zone was limited by these assumptions. All of these assumptions were eliminated in the present analysis. The current groundwater flow model contains all of the known hydrogeologic complexities of the aquifer system, resulting in a more accurate depiction of the Railroad Well capture zone.

The capture zone was delineated from the MODFLOW results by using a particle-tracking (pathline) analysis. The MODPATH code (Pollock 1989) was used in conjunction with MODFLOW to perform the pathline analysis. Pathline analysis is a simple, cost-effective form of contaminant transport analysis which ignores the effects of dispersion, retardation and chemical reactions. In effect, the particles represent the motion of groundwater in the model. The MODPATH code uses the flow terms and velocities computed by MODFLOW for use in the calculations. Figure 3-22 depicts the simulated capture zone for the Railroad Well in the model domain. Actual particle tracks or pathlines were not shown in Figure 3-22, but the shaded area depicting the capture zone was drawn by outlining particle tracks that enter the well. The capture zone analysis indicates that the Railroad Well receives all of its water from the Rome Formation. Groundwater flows along strike in the Rome Formation from the eastern portion of the model domain to the Railroad Well. Groundwater flow directions and rates on-site are generally unaffected by the operation of the Railroad Well.

4.0 SOLUTE TRANSPORT MODEL ANALYSIS

Operations at the NFS plant site are believed to have resulted in the presence of radionuclides and organic constituents in the groundwater beneath the facility. The prime source areas of groundwater contamination are: 1) three unlined surface impoundments (ponds); 2) the "Pond 4" disposal area; 3) the burial grounds, which are located in the northern portion of the NFS Site; and 4) various areas in the vicinity of plant buildings. As part of this evaluation, solute transport models were developed for two constituents; uranium and PCE. To date, neither of these constituents has been detected below the deep alluvial material and shallow bedrock. This hydrostratographic unit is referred to as Zone 2 (EcoTek, Inc. 1989). A consistent upward gradient observed in Zone 1 and Zone 2 appears to have prevented contamination from reaching greater depths. Vinyl chloride and 1, 2 DCE have also been found in the same areas as PCE and are probably the result of PCE biodegradation.

Figures 4-1 and 4-2 depict 1993 PCE concentration contours in Zone 1 and Zone 2. Total uranium concentration contours for a portion of the Site are presented in Figure 4-3 and 4-4. The U.S. Environmental Protection Agency (EPA) drinking water MCLs were exceeded for uranium and PCE in several wells (Advanced Recovery Systems, Inc. 1994a). Most of the groundwater contamination appears to exist in the vicinity of the ponds, burial grounds, Building 234, SWMU 13/14 area and SWMU 2, 4, and 6 area (uranium and PCE). Historically, the Building 130 scale pit and the areas adjacent to Buildings 130 and 120/131 may have contributed to PCE contamination at the Site. Source areas used in the solute transport model are shown in Figure 4-5.

4.1 WASTE SOURCES

The following subsections describe the primary sources of groundwater contamination at the NFS Site that were simulated with the solute transport model.

4.1.1 Three Unlined Impoundments (SWMU 1) and Area of Concern (AOC) 5

SWMU 1 and AOC 5 are located north of plant production facilities and include Ponds 1, 2, and 3 which were built from 1957 to 1963; both received process waste waters associated with the production of nuclear materials. These ponds received fluids until 1978, when a waste water treatment plant was built to handle waste water. The three ponds contained approximately 91,000 cubic feet (ft^3) of waste material. The predominant radiological waste contaminants were isotopes of uranium and thorium. PCE was also detected among other contaminants in the waste samples. Waste from Pond 2 was also identified as characteristically hazardous for PCE and cadmium (Advanced Recovery Systems, Inc. 1994b).

Waste removal began in August 1991 at Pond 3 with dredging to remove most of the contaminated sediments. Removal of waste from Ponds 1, 2, and 3 was completed in September 1993, August 1994, and May 1994, respectively (Advanced Recovery Systems, Inc. 1994b). Waste from Pond 2 was treated to reduce PCE and cadmium concentrations below TCLP regulatory levels in an onsite treatment unit prior to disposal.

The historical discharge rates of contaminated water to the ponds was calculated using the NFS Lagoon Historical Data Report (Nuclear Fuel Services, Inc. 1985). Table 4-1 provides information on various buildings at the facility, the chemical processes for which these buildings were used, operating periods, and quantities of waste water discharged (flow rates) to the ponds. These flow rates were calculated for appropriate time stress periods, defined in Section 4.2, and incorporated into the solute transport model.

The present channel of Banner Spring Branch is designated as AOC 5 and has no known unregulated releases; however, it was a receptor of supernatant from the ponds prior to 1978.

4.1.2 Pond 4 (SWMU 2)

SWMU 2 (Pond 4) was originally a marshy or low lying area located in the western portion of the facility (west of the ponds) and received waste material (Figure 4-5). The types and forms of materials placed in the Pond 4 area have been identified as the following: press cake, incinerator ash, sludges, drums (empty), buckets, (empty), conduit, pipes, old equipment, and general trash. No records of these materials and disposal activities are available. SWMU 2 has been identified as a potential source for uranium and PCE (EcoTek, Inc. 1994b).

4.1.3 Banner Spring's Abandoned Stream Bed Channel (SWMU 6)

SWMU 6 designates the abandoned channel of Banner Spring Branch which received supernatant from the three NFS impoundments (Figure 4-5). This channel is located north of the main Plant facilities in the Pond 4 area. Stream sediments were contaminated with isotopes of uranium and thorium. In 1967, the channel of Banner Spring Branch was relocated approximately 200 ft upstream leaving the existing channel abandoned. Sediments from this portion of the abandoned channel were left in place and then backfilled. SWMU 6 is located within the boundary of SWMU 2 and has been identified as a potential source for uranium only (EcoTek, Inc. 1994b).

4.1.4 Building 130 Scale Pit (SWMU 20) and Adjoining Buildings 131 & 120

Building 130 was constructed in the late 1950s. Operations in the 130 Building include thorium processing, HEU processing, and cleaning uranium hexaflouride cylinders. Potential contaminants may include uranium, PCE, and TCE. Building 120 was constructed in the late 1950s. Building 131 was constructed in the early 1960s adjacent to Building 120. The Building 120/131 area has been used for maintenance, product storage, and as a pilot plant. Currently, the Building 120/131 complex houses the maintenance department and a research and development laboratory. Chlorinated solvents were thought to have been used and stored in the vicinity of Buildings 120 and 131 (Nuclear Fuel Services, Inc. 1995d).

4.1.5 Radiological Waste Burial Ground (SWMU 9)

NFS disposed of low-level radioactive waste onsite in a shallow burial ground referred to as the radiological waste burial ground (SWMU 9) (Figure 4-5). The waste included contaminated equipment, construction debris, laboratory waste, and process waste. The waste was buried in units 120 to 160 ft long, 25 to 26 ft wide, and no greater that 10 ft deep with 3 to 6 ft of overburden. This SWMU was active from 1966 to 1977, and is a potential source for both uranium and PCE contamination (Nuclear Fuel Services, Inc. 1995a).

4.1.6 Bulk Chemical Storage Area at Building 111 (SWMU 13)

Building 111 was used as a storage area for processed chemical products, operating from 1957 to 1979 (Figure 4-5). This building is thought to be a potential source for both uranium and PCE (Nuclear Fuel Services, Inc. 1995b).

In addition to the above described sources, Buildings 234a, 234c, 233, 110A through

110D, 302, 303, 304, and 309 were also identified as potential source areas for uranium and PCE contamination at the Site.

4.2 HISTORICAL PUMPING SCHEDULES

After a careful review of the waste disposal history at the Site and of the production history of Erwin Utility supply wells, the model was divided into six stress periods. Furthermore, it is assumed that NFS began discharging process waste water to the three ponds in January 1957 and continued until December 1978. The pumping schedules for the supply wells have been used to define the stress periods presented below:

- **Stress Period 1:** This first stress period covers the time period extending from January 1957 through December 1970. During this period, only two supply wells within the model domain, the Birchfield Well and the O'Brien Well, were actively pumping. The Birchfield Well is screened in Model Layers 3, 4, and 5, while the O'Brien Well is screened only in Model Layer 3. The daily average pumping rates were calculated from recorded monthly pumping totals. Additionally, effluent was discharged to the three impoundments during this period from plant operations which was simulated by 20 (number of model cells encompassing ponds) injection wells continuously discharging into the ponds at a constant rate of 132.35 ft^3/day/well. Table 4-1 shows the daily discharge information used to calculate the discharge into the ponds.

- **Stress Period 2:** The second stress period extends from January 1971 through December 1975. This period uses the same pumping wells and average rates used in stress period 1, except that the injection rate of processed waste water effluent sent to the impoundments was reduced to 49.47 ft^3/day/well. Table 4-1 shows the daily discharge information used to calculate the discharge into the ponds.

- **Stress Period 3:** This stress period extends from January 1976 through December 1978 and was included in the model to simulate an increase in pumping rates for the Birchfield and O'Brien Wells. This period maintained the injection rate of processed waste water effluent sent to the impoundments as used in stress period 2.

- **Stress Period 4:** The fourth stress period extends from January 1979 through December 1985, and was included to account for additional pumping rate increases at both the Birchfield and O'Brien Wells. This period was also modified to remove waste water effluent entering the impoundments as effluent to the ponds was stopped in 1978.

- **Stress Period 5:** The fifth stress period extends from January 1986 through December 1990. During this time, the Railroad Well started pumping in addition to the other wells. The Railroad Well withdraws all its water from Model Layers 3, 4, and 5.

- **Stress Period 6:** The last stress period extends from January 1991 through December 1993. This stress period incorporates changes in the pumping rates of the three supply wells in the model domain.

The flow rates, as presented in Table 4-2, are a conservative estimate of actual flow rates during any one operational time period.

4.3 COMPUTER CODE SELECTION

To perform the solute transport modeling at the NFS Site, Geraghty & Miller used MT3D, a three-dimensional solute transport program developed for EPA (Zheng 1990). MT3D functions in conjunction with MODFLOW, thereby providing a seamless transition from the groundwater flow modeling to solute transport modeling. Developed in the public domain, MT3D is thoroughly documented, extensively tested, and benchmarked against analytical solutions. MT3D can simulate the migration of dissolved constituents using the Methods of Characteristics or an explicit finite-difference scheme to solve the transport equation. The code is fully three-dimensional, simulates transport in confined or unconfined aquifers, and includes hydrodynamic dispersion, adsorption assuming a linear isotherm, and decay in the solute transport calculations. The MT3D code uses the flow terms (including sources) and velocities computed by MODFLOW (McDonald and Harbaugh 1988) for use in the transport calculations.

4.4 TRANSPORT PARAMETERS

The NFS solute transport model required the following additional data components prior to the model runs: the description of the flow field (Darcy velocity distribution), effective porosity, dispersion coefficient, partition coefficient (adsorption), decay parameter, source area, source concentration, and release timing. Both PCE and uranium, the two constituents for which the model was run, are adsorbed by the geologic materials during transport; therefore, a partition coefficient (K_d) was assigned for each constituent for the calibration. Adsorption of constituents onto aquifer materials causes the constituent plume center of mass to migrate at a slower rate than groundwater. For selected parameters, representative values were chosen based on site-specific data. The partition coefficients calculated for uranium and PCE are 175 and 0.2 milliliter/gram (ml/g), respectively. The partition coefficient for PCE was calculated from the octonal carbon partition coefficient (K_{oc}) value of 333 ml/g and a site measurement of fraction organic carbon (K_{foc}) of 0.0006. The value of 333 was obtained by averaging 302 and 363. The values 302 and 363 were recommended by Dr. Bill Doucette, Utah State University (Dr. Bill Doucette 1995). Given a site bulk density of 1.6 grams per cubic centimeters (g/cm^3), and a total porosity of 41 percent, the calculated retardation factors for uranium and PCE are 684 and 1.78, respectively (Nuclear Fuel Services, Inc. 1995c).

Decay parameters were also used for both species. The radiological decay rate for uranium is 6.3×10^8 years. PCE also undergoes decay by microbial activity at the Site as indicated from the presence of daughter products such as vinyl chloride. The biodecay rate for PCE can range from 6 months to 2 years (Howard et al. 1991). During the model calibration, the biodecay rate was varied within this range, with a 9-month half life representing the best fit. The fast decay rate used in the model is within the literature range in values and was empirically estimated with the model. The estimated decay rate used in the model is the best suited value given the extent of information the model is based on. Additional downgradient monitor wells may be needed to confirm the extent of the PCE plume which will help to refine the estimated PCE decay rate. Other bioactivity parameters can also be collected in the subsurface to confirm the decay rate. Values for the most uncertain parameters, biodecay rate and source strength, were varied extensively during model calibration in order to calibrate the model.

4.5 EFFECTIVE POROSITY

Literature values of effective porosity for materials hydrogeologically similar to those at the NFS Site range from 25 to 40 percent for gravels, 35 to 50 percent for silts, and 0 to 10 percent for shales (includes fractured rock) (Freeze & Cherry 1979). Since most constituents at the NFS Site occur in the alluvial materials, the effective porosity used in the model was assumed to be in the higher range, more representative of the sandy materials. The estimated effective porosity in the calibrated transport models is 25 percent, which fits within the range suggested in the literature. The total porosity measured at the Site is 41 percent (Nuclear Fuel Services, 1995c). The effective porosity is the net pore space through which groundwater flows and is smaller than the total porosity because it excludes pores which are not interconnected. The effective porosity is typically estimated to be equal to a factor of about 1.5 below the measured total porosity (de Marsily 1986).

4.6 DISPERSIVITY

Two primary processes are simulated in the transport model: advection and dispersion. Advection defines the process of contaminant migration due to the movement of groundwater. The advective transport term is computed using velocities determined by the flow model. Dispersion describes the mixing of a contaminant in the subsurface due to tortuous, non-linear flow paths in the aquifer medium. Dispersion is simulated using a coefficient known as dispersivity. The dispersivity values are multiplied by the velocity terms to develop dispersive flux terms which are added to the advective flux terms. Dispersive fluxes are a function of groundwater velocity not grid size. Dispersivity was estimated during calibration to improve the calibrations over pure advection. The dispersivity term is very small in comparison to the advective terms.

A longitudinal dispersivity of 10 ft was estimated through model calibration at the NFS Site. Longitudinal dispersivity applies to the local direction of groundwater flow within a grid cell, and the transverse value of dispersivity applies to dispersion perpendicular (right angles) to the flow direction. The transverse dispersivity was estimated to be 1 ft.

Generally, the transverse dispersivity is within a factor of 5 to 20 of the longitudinal dispersivity and is usually estimated empirically through the use of groundwater models (Freeze and Cherry 1979). Gelhar et al. (1992) also cites evidence from tracer tests that dispersivities should be on the order of 3 to 30 ft for the scale of transport. These dispersivities can be an order of magnitude greater if the geologic material is fractured (Gelhar et al., 1992). Gelhar et al. (1992) found that in many tracer tests the transverse dispersivities are commonly one to two orders of magnitude less than longitudinal dispersivities. Gelhar et al. (1992) also cite evidence that dispersivities generally increase, possibly indefinitely with scale. Reilly (1990) states that:

> "the more closely we represent the actual permeability distribution of an aquifer; the more closely our calculation of advective transport will match reality. The finer the scale of simulation, the greater will be the opportunity to match natural permeability variations. In most situations, however, when both data collection and computational accuracy have been extended to their practical limits, calculations of advective transport will fail to match field observation. To the extent that scale variations represent random deviation from the velocity used in the advective transport calculation, and to the extent that they occur on a scale which is significantly smaller than the size of the region used for advective calculation, dispersion theory may adequately describe the differences between advective calculation and field observation. Determination of the dispersion coefficients are usually approached empirically (for example, through model calibration)."

4.7 SOLUTE TRANSPORT CALIBRATION

From the aquifer and constituent data compiled for this study, a conceptual model (Geraghty & Miller, Inc. 1995a) was formed as a basis for constructing the transport model. The conceptual model of the system identified important physical features of the aquifer system and waste source. It also identified important processes operating within the system that controlled the flow of groundwater, introduction of contaminants from the various source areas to the aquifer, and transport of contaminants within the subsurface flow system. Finally, it identified nominal or most likely values for each parameter with which to begin model calibration from the range of measured or estimated values.

To judge the success of transport model calibration, and to provide information on the magnitude and direction of parameter changes required during calibration, target values of concentration at various locations within the aquifer were identified against which to match concentration values computed by the model.

The monitoring well data used for the uranium and PCE calibrations were those concentrations measured during December 1993. This data provided the best site coverage (most data points) for uranium and PCE. Tables 4-3 and 4-4 list the uranium and PCE concentration data used for calibration targets. There are no guidelines or general rules to follow regarding solute transport calibration statistics. One reason for this is that small scale heterogeneities can influence the migration of contaminants and may not noticeably affect hydraulic heads. Another complicating factor is that transport parameters such as retardation and decay (in the case of PCE) may be spatially variable. Also, there may be some significant variability in the constituent concentrations with depth and time. Since, the model computes concentrations which represent an average over the entire grid cell, the computed concentrations may not closely match the observed concentration at a particular well. These factors along with uncertainties regarding the source distribution and strength make it extremely difficult to match observed constituent concentrations as closely as hydraulic heads. Therefore, residual statistics were not used to describe the transport calibrations. Rather, a more qualitative calibration was performed. Observed constituent concentrations are posted on the model together with computed concentration distributions to allow for quick determination of the quality of the fit between observed and computed values. Model adjustments were performed to minimize, to the extent possible, the difference between computed and observed constituent concentrations.

Solute transport calibration was achieved by systematically varying transport model parameters to obtain an acceptable match between model calculated constituent concentrations at each target location and observed values. Similar to the flow model calibration, the transport model was calibrated to specific point data to eliminate interpretive bias introduced when attempting to interpolate contours on isopleth maps. In addition, the number of transport parameters varied during calibration was minimized to ensure model uniqueness.

In contrast to flow model calibration, automatic techniques for solute transport model calibration are not generally available because of the difficulty in obtaining stable solutions with unique values for all the model calibration parameters. Therefore, the transport calibration was carried out through trial and error by manually varying model calibration parameters before each computer run. Transport model calibration consisted of the following steps: 1) run the model; 2) examine calculated constituent concentrations and residuals; and 3) adjust parameters and run the model again if the simulated concentrations at most target values is not close.

Because the mass of contaminants released from each source area is uncertain, the constituent source concentration was varied during the transport model calibration process in order to match the observed constituent concentrations. The calibrated source area concentration values for uranium and PCE are shown in Figures 4-6 and 4-7, respectively. A source term in the model is a mass loading rate applied over designated grid cells in Model Layer 1. The mass loading rate is calculated by taking the assumed concentrations of the source multiplied by the injection rate in the model. The injection rate can be the recharge rate or the pond infiltration rate. This mass loading rate is applied to the right hand side of the advection/dispersion equation. Turning off the source means no mass loading rate is set in the model and no contributions (supply) of mass occurs in the model. Any previous concentrations in the groundwater are simply advected and dispersed in the model.

4.8 CALIBRATION TRIALS

During the initial calibration all known potential sources were simulated with the model. Pond sources were simulated by assigning concentrations to the river cells in the model. Most source areas were assumed to start at the beginning of the model simulations (1957) and remained active through the end of the simulations in December 1993. As the calibration proceeded, starting and ending times for sources were adjusted to better reflect plant operations and remedial activities. The PCE sources in the ponds were also altered over time. Most building sources began in 1962 and have continued to the present. These include Building 111, 120, and 131. Building 234 and SWMU 20 began in 1966.

Beginning in August 1991, the PCE source was significantly reduced (source material removed) in the model in Pond 3, and the source concentration in Pond 2 was reduced to half of its previous concentration. Solute transport parameters that were varied during the calibration included the source distribution and concentration level, effective porosity, and the PCE biodecay rate. Initial simulations also assumed pure advection with no dispersivity. As the calibration proceeded, a small amount of dispersive flux was added to improve the quality of the calibration. The main focus of the model adjustments was toward estimating the source extents and concentrations. For each simulation the source concentration would remain fixed over time. Table 4-5 presents information on source concentrations used in the solute transport model.

Results from preliminary simulations showed that the lateral extent of the plume matched the observed plume extent, but the concentration gradients in the direction of flow within the plume required some adjustments. Several trials were conducted in which the source concentrations were varied in magnitude and aerial extent in an attempt to match the steep concentration gradients inferred from the field data.

4.9 URANIUM SOURCE DISTRIBUTION

The final source distribution for uranium is depicted on Figure 4-6 and generally corresponds to the discussion in Section 4.1. Source adjustments involved establishing the highest source concentration in the vicinity of Building 234a (eastern portion of facility), because of recent increases in observed dissolved uranium concentrations directly downgradient of this building. Excluding this building, the remaining source areas range in concentration from 600 to 2,600 picocuries per liter (pCi/L) (Figure 4-6). The extent and magnitude of these source areas were initially governed by the conceptual model, but these source areas were refined empirically with the model during the model calibration.

The model assumes that most building and landfill source areas contribute contaminants to the groundwater system at the recharge infiltration rate (6 in/yr). Therefore, the source mass loading rate is basically the source concentration multiplied by the recharge infiltration rate. In reality, soil contaminants may enter the system at a faster or slower rate.

Since the flux rate was fixed in the model, the estimated source concentration represents a long term average source concentration. Since the uranium migrates in the groundwater system at an extremely low rate, downgradient dissolved uranium concentrations were predominantly used to help determine source concentrations. It was also found that pond sources (1, 2 and 3) were probably at lower concentrations than in building areas. The Building 110 area (chemical lab) was assumed to be a minor source of uranium.

4.10 PCE SOURCE DISTRIBUTION

The final source distribution for PCE is depicted on Figure 4-7 and, similarly to the uranium calibration, the source areas were determined empirically with the model and are based on a thorough review of site investigation reports to determine actual areas where PCE was used or disposed (Section 4.1). Source area locations were also refined based on verbal information provided by NFS staff. In many instances, the source areas for uranium and PCE are somewhat different because of plant operations and disposal techniques. The source concentrations for PCE generally range from 0.1 to 105 milligrams per liter (mg/L). The highest source concentrations were estimated to exist in the Buildings 120/131 area which agrees with NFS knowledge of operations in this area. Monitoring Wells 102A and 103A, just downgradient of Building 120, have consistently shown the highest dissolved concentrations of PCE. Source concentrations set in the Building 131 vicinity had the second highest concentration (50 mg/L). Source areas designated over the remainder of the facility ranged from 0.1 to 1.5 mg/L. The source concentrations in the ponds (1, 2 and 3) was estimated to be 0.9 mg/L. As previously stated, the pond source concentrations were significantly diminished with time to reflect source removal. After August 1991, the Pond 2 and Pond 3 source concentrations were set to 0.46 mg/L and 0.05 mg/L to simulate a minor amount of residual PCE still present in soils beneath the ponds. This source distribution resulted in the best match against observed PCE concentration data.

4.11 SIMULATED URANIUM CONCENTRATION DISTRIBUTION

The final calibrated uranium plume is shown in Figures 4-8 through 4-10. The contour maps represent the concentration distribution predicted in December 1993. The model only calculated concentration distributions in the upper three layers of the model. No significant concentrations were simulated in the lower model layers (4 and 5).

The uranium plume (delineated by the simulated 0.1 pCi/L uranium contour) typically extends about 100 to 150 ft in the downgradient direction from the source areas in Model Layer 1 (Figure 4-8). In the lower model layers the plume scarcely extends beyond the source areas and is computed to have significantly lower concentrations (Figures 4-9 and 4-10). The highest simulated and observed groundwater concentrations are in the direct vicinity of the ponds.

4.12 SIMULATED PCE CONCENTRATION DISTRIBUTION

The final calibrated PCE plume is shown in Figures 4-11 through 4-13. The contour maps represent the concentration distribution predicted in December 1993. The model only calculated concentration distributions in the upper three layers of the model. The upward vertical gradient in the vicinity of the Site reduces the potential for downward migration of dissolved phase contaminates. As these constituents migrate from the Site towards the Backwash area, the upward flow potential increases. No significant concentrations were simulated in the lower model layers (4 and 5).

The PCE plume (delineated by the simulated 5.0 micrograms per liter [µg/L] PCE contour) extends significantly further than the uranium plume. This is due to the greater mobility of PCE in the groundwater system. Low PCE concentrations are actually simulated as reaching the Backwash area (Figure 4-11). The maximum extent of the PCE plume is approximately 725 ft northwest of the NFS property boundary in Model Layer 1 (Figure 4-11). The PCE plume does not migrate as far from the Site in the lower model layers (Figures 4-12 and 4-13). The highest simulated and observed groundwater concentrations are in the direct vicinity of Building 120.

4.13 COMPARISON WITH FIELD DATA

As a check on the model calibration, the observed uranium and PCE concentrations measured in monitoring wells at the NFS Site in December of 1993 were compared with the concentrations computed at the model grid cell containing the observation well (Tables 4-3 and 4-4).

The well summary shows agreement between uranium and PCE concentrations predicted by the model and observed values. The model excels in the vicinity of the ponds where it appears to match high concentrations very well. The model underpredicts uranium and PCE concentrations at some monitoring wells, along the western perimeter of the Site (including monitor wells include 105A and 106A). The absence of simulated concentrations near Monitoring Wells 105A and 106A for both uranium and PCE is due to the absence of a source term for these wells in the model. It was determined during model calibrations and through discussions with NFS personnel that no significant sources were thought to remain upgradient of these monitoring wells at the facility and were ignored in the modeling. The model also had difficulty simulating uranium and PCE concentrations in monitoring wells upgradient of SWMU 10, near Monitoring Wells 55, 55A, 63, and 63A. The low uranium concentration observations in these wells remains unexplained. The apparent underprediction of constituent concentrations in Model Layer 3 also remains unexplained since the groundwater flow model accurately simulates vertical hydraulic gradient in the vicinity of the site. Additional water levels and sampling data may be necessary to improve the model's ability to simulate observed concentrations in Model Layer 3.

Even though the model may have overpredicted or underpredicted concentrations at some monitoring wells, especially those on the fringes of the plume, the model simulates the distribution of both plumes and concentration gradients very well over the 37-year time span.

5.0 PREDICTIVE SIMULATIONS

Operations at the NFS Site are believed to have resulted in the presence of radionuclides and organic constituents in groundwater beneath the facility. As part of this task, solute transport models were developed and calibrated for two constituents: uranium and the chlorinated solvent PCE. Both solute transport models were calibrated to observed constituent concentrations determined from groundwater samples collected in December 1993. The solute transport model calibration resulted in an excellent match to observed concentrations as illustrated in Figures 4-8 through 4-13 for both uranium and PCE for three different model layers (Layer 1, Layer 2, and Layer 3). These figures depict simulated isopleths and observed constituent concentrations for the December 1993 sampling event. The solute transport model also provided an estimate of constituent (uranium and PCE) migration and effective source concentration levels. Predictive simulations were performed to continue the simulation into the future. The simulated December 1993 uranium and PCE distributions were used to set initial concentration distributions in the model for predictive purposes. Adjustments to the models for predictive purposes included definition of continuing sources in the model or the discontinuing of sources after some period of time and changes in groundwater withdrawals in the model domain over time.

5.1 CURRENT AND FUTURE PUMPING SCHEDULES

After a careful review of the current and future pumping schedules and the waste disposal history at the Site, the model was divided into three future stress periods based on a calibration date of December 1993. The following is a description of the future pumping stresses simulated in the model:

- **Stress Period 1:** This first stress period covers the time period extending from January 1994 through July 1994. During this period, only three supply wells within the model domain, the Birchfield Well, the O'Brien Well, and the Railroad Well, were actively pumping. As with the historical simulations presented in the solute transport calibration report (Geraghty & Miller, Inc. 1995e), the daily average pumping rates were calculated from recorded monthly pumping totals.

- **Stress Period 2:** The second stress period extends from August 1994 through December 1996. This period uses the same pumping wells and average rates used in stress period 1, except that the Pond 4 dewatering wells are in operation. The Pond 4 dewatering system consists of 10 wells pumping a total of about 6 gpm.

- **Stress Period 3:** This stress period extends from January 1997 to 1,000 years into the future. During this period the Pond 4 dewatering wells are inactivated and the new Ambrose Well is assumed to be brought into service at 1,000 gpm. The Ambrose Well, a municipal water supply well, is located along the eastern model domain boundary near Rock Creek.

5.2 SOURCE DISTRIBUTIONS

The future source areas for uranium and PCE were defined in the model in a similar manner as for the solute transport model calibrations. For Building and Burial Grounds source areas, it is assumed that the sources contribute contaminants to the groundwater system under the influence of a recharge infiltration rate of 6 inches per year. Therefore, the source mass loading rate is basically the source concentration multiplied by the recharge infiltration rate. For both uranium and PCE, it was assumed that the Ponds no longer contribute contaminant mass to the groundwater system and were therefore excluded as a source from the predictive simulations. It was also assumed that all other historical sources of contamination defined during the uranium and PCE solute transport model calibrations will remain as sources into the future. An additional uranium simulation was performed assuming that the Burial Grounds will not be a continuing source of uranium. Because of future remedial actions, natural attenuation through biodecay, volatilization, and flushing, it was assumed that all remaining PCE source areas would not be a major contributor of PCE into the groundwater system for time periods after 10 years. Future source area distributions for uranium and PCE are shown in Figures 4-6 and 4-7. All source concentration values were kept the same as those estimated during the solute transport model calibrations (Geraghty & Miller 1995e).

5.3 SIMULATED FUTURE URANIUM CONCENTRATION DISTRIBUTION

Simulated future uranium concentrations after 500 years are depicted in Figures 5-1 through 5-3 for Model Layers 1, 2, and 3, respectively. These results include the effect of a continuing source at the Burial Grounds. The extent of the simulated plume is indicated by the 0.1 pCi/L contour line. The predicted uranium plume in Model Layer 1 reaches the Backwash area after 500 years but not at concentrations greater than 5 pCi/L. In onsite areas, the predicted uranium plume still displays concentrations centered in the vicinity of known source areas.

Figures 5-4 through 5-9 depict the uranium plume after 1,000 years. After 1,000 years, the highest concentration in groundwater is 1,200 pCi/L, northeast of the plant near SWMU 6 in Model Layer 1, and the highest concentration of groundwater entering the Backwash area is 10 pCi/L. The model also has shown that even after 1,000 years of transport no significant uranium concentrations are predicted to occur at depth (Model Layers 4 and 5). The uranium concentration distribution in the three upper model layers are summarized below:

- Simulated uranium concentration distribution in Model Layer 1 after 500 years indicates that the uranium plume will migrate off-site and reach the Backwash area. Simulated uranium concentrations for 1,000 years show a gradual increase in concentration and extent, and indicate changes from that of 500 year simulations (Figures 5-1 and 5-4).

- Simulated uranium concentration distribution in Model Layer 2 after 500 years indicates an increase in the areal extent of the plume (Figures 4-9 and 5-5) demonstrating the downward movement of uranium in the site area. Slight changes were noticed in areal extent of the plume in 1,000 year simulations versus 500 year simulation plumes (Figures 5-2 and 5-5). The rate of migration in lower model layers is much less than in Model Layer 1 due to the variation in hydraulic conductivity in the model. There is greater transport in Model Layer 1, thus, long term changes in concentration are more noticeable. The maximum concentrations after 1,000 years in Model Layer 2 is 245 pCi/L.

- Simulated uranium concentration distribution in Model Layer 3 after 500 and 1,000 years indicates an increase in areal extent of the plume with time, but no significant increase in concentrations as compared to that of December 1993 (Figures 4-10 and 5-6). The maximum concentrations after 1,000 years in Model Layer 3 are 1.5 pCi/L.

A second simulation was performed to predict the effects of the Burial Grounds source area by eliminating the source in the model. These simulated results, after 1,000 years, are shown in Figures 5-7 through 5-9. The Burial Grounds source area only appears to affect groundwater concentrations in the direct vicinity of the source and does not appear to significantly effect downgradient groundwater concentrations. Groundwater concentrations in the vicinity of the Burial Grounds after 1,000 years for Model Layer 1 are on the order of

5 pCi/L as opposed to concentrations over 100 pCi/L with the source active (comparison of Figures 5-4 and 5-7).

5.4 SIMULATED FUTURE PCE CONCENTRATION DISTRIBUTION

The predictive simulation time period for PCE was much shorter than for uranium due to its greater mobility in the groundwater system and relatively fast biodecay rate. The simulated future concentrations of PCE after 10, 13, and 15 years are shown on Figures 5-10 through 5-15. After 10 years of predictive transport (Figures 5-10 through 5-12 for Model Layers 1, 2, and 3, respectively), the areas beneath the Ponds is predicted to be virtually free of PCE, with other areas appearing to have reached steady-state conditions with active sources. After the discontinuing of the remaining sources, the dissolved phase concentrations simply migrate towards the river and attenuate in the aquifer through mixing and biodecay. Biodecay in the model actually represents the transformation of PCE into other daughter products not simulated by the model.

The highest simulated groundwater concentrations and extent of contamination is in the direct vicinity of Building 120. Figures 5-13 through 5-15 indicate that the plume is significantly diminished after 13 years of transport. The PCE plume is almost completely diminished after 17 years when the highest simulated concentration in Model Layer 1 is about 5 µg/L. The plume actually diminished faster in Model Layer 2 where the highest concentration after 15 years is only about 3 µg/L. The highest simulated PCE concentration reaching the Backwash area is approximately 20 µg/L after 13 years.

6.0 DISCUSSION OF MODEL ASSUMPTIONS AND LIMITATIONS

Because of the relatively long history of development and use of saturated continuum flow models, the issues surrounding their application to modern decision making problems are generally not conceptual or theoretical, but are practical. The physical processes controlling saturated flow are well understood and the mathematical models describing these processes have been studied extensively. The challenges posed by practical application arise in situations where it is not feasible to model a flow system at spatial and/or temporal scale appropriate to conceptual or mathematical understanding. Saturated continuum flow models rest on fluid mechanical principles and laboratory column validation of Darcy's law. Field application at this scale is not possible; therefore, successful application of groundwater flow models rests on the skill and art of the hydrogeologist in understanding when, where, and how to simplify and respond to a lack of information.

Generally, the greatest source of uncertainty in model prediction lies in supplying values of those site-specific parameters that control the flow system which are difficult to measure or vary spatially. Generally, the results of a model application are dependent on the quality of the data used as input for the model. Errors can be introduced into the model by incorrectly specifying boundary conditions, hydraulic properties, and/or the hydrogeologic framework (structure). There is a range of capability in modeling fluid flow in geologic media. Modeling saturated flow in porous media is straightforward with few conceptual or numerical problems. At the present time, conceptual issues and/or problems in obtaining data on parameter values limit the reliability and therefore the applicability of flow models involving some media.

The NFS groundwater flow and solute transport models assume that the fractured media can be represented as an equivalent porous medium by replacing the primary and secondary porosity and hydraulic conductivity with a continuous porous medium having equivalent hydraulic properties. Aquifer test analysis in the bedrock at the site has confirmed that in the vicinity of the site the flow patterns are similar to the flow pattern in the fractured system. Simulation of flow in this fractured system using this conceptual model required definition of effective values for hydraulic conductivity and porosity. Typically, these values are estimated from aquifer tests, water balances, inverse model calibration, and field descriptions. The equivalent porous medium approach adequately represents the behavior of a regional flow system, but may poorly reproduce local conditions. The model has been tested in the vicinity of the site and appears to accurately simulate flow directions and rates. In other areas of the model, far away from the site, the model may not accurately simulate local flow conditions. This can not be evaluated at this time due to a lack of detailed hydraulic information in those areas. The model may also be less reliable in these areas because of the scale of individual grid cells. The uncertainty in model parameters was addressed through a detailed sensitivity analysis. It established the extent to which uncertainty in a given parameter contributes to uncertainty in the model.

The NFS models were developed with consideration to regional flow conditions. To simplify boundary condition specification and to add flexibility to the model, the limits of the model were extended to regional groundwater flow divides or discharge points. By doing this, specification of artificial boundaries was unnecessary. The use of artificial boundaries to constrain regional flow patterns can lead to inaccuracy and insensitivity in the model. The model boundaries are set far enough away from the site, such that the model without further alteration can be used to simulate the effects of pumping wells in the vicinity of the site without boundary condition effects. While the model is well suited for this study it may not be usable for regional water-resource evaluation. This is only because of the current extents of the model. Municipal pumping exists on both sides of the regional discharge boundary (Rock Creek). A few of the supply wells within the model domain are located fairly close to the model boundary which may limit the models accuracy in those areas.

The model also contains a sufficient level of discretization horizontally and vertically to represent the gradient of hydraulic heads in the vicinity of the site even in areas with large contrasts in hydraulic conductivity. It was determined through calibration of two solute transport models that model predictions of groundwater velocity are representative of site conditions. Additional downgradient monitoring wells may be necessary to enhance the model's predictive ability. These additional wells will fill data gaps identified during the solute transport calibrations and would serve as additional constraints for estimating unknowns such as decay rates and source loading values.

It should be noted that even though the estimated biodecay rate of 9-months was the best suited value determined during the model calibration, it may overestimate the actual rate of biotransformation at the Site. To more accurately determine the effective decay rate in the subsurface, additional bioactivity parameters can be collected at the Site to reduce model uncertainties.

The accuracy of the NFS flow model was determined statistically by comparing the simulated results with real world values. This does not necessarily indicate that the model will perform with the same level of accuracy for predictive use. The predictive simulations discussed in this report contain similar flow system stresses as for the calibration period. Thus, the predictions should be as reliable as the calibrated flow model. Predictive simulations involving significant stresses, such as extraction wells in the vicinity of the site, should be validated against actual field measurements to evaluate the accuracy of the model predictions.

7.0 SUMMARY AND CONCLUSIONS

- Geraghty & Miller developed and calibrated a regional groundwater flow model for the NFS site that simulates groundwater flow in an unconsolidated and bedrock aquifer system. The model makes use of detailed geologic interpretations of the thickness, and extent and heterogeneity of the lithologic units in the vicinity of the site. Calibration of the steady-state flow model used 68 water-level measurements from monitoring wells, distributed in all simulated aquifer units near the NFS site.

- A capture zone analysis performed at the Railroad Well indicated that its area of capture does not include the NFS site. The Railroad Well derives all of its water from the Rome Formation.

- In order to effectively build the solute transport model, a thorough understanding of both uranium and PCE primary source areas was developed and incorporated into the model. These source areas are represented by three unlined surface impoundment ponds, the "Pond 4" disposal area, the burial grounds, and various areas in the vicinity of plant particularly Buildings 130, 120, and 131. Additionally, model simulation incorporated the production history of nearby Erwin Utility supply wells and infiltration at the ponds to define six individual aquifer stress periods.

- The solute transport model calibration resulted in an excellent match to the observed uranium and PCE concentrations over time, and the calibrated solute transport parameters exhibited good agreement with field measured and accepted transport parameter values. The model also provided an estimate of constituent (PCE and uranium) migration and effective source concentration levels. Through the calibration process, significant confidence has been added to the model and model parameters that were then used for predictive simulations.

- The predictive simulations were performed for uranium and PCE constituents observed at the site. A maximum time period of 1,000 years for uranium and 25 years for PCE was used for these simulations into the future. The result of solute transport model calibrations for both constituents were used as starting conditions for predictive purposes. The future pumping stresses were simulated as three individual stress periods which were defined based on the current and future pumping schedules and the waste disposal history.

- The simulated uranium concentrations indicated that in Model Layers 1 and 2, the areal extent of the uranium plume increased at a 500 and 1,000-year time period when compared to 1993 simulated data. No major changes in concentrations or areal extent of uranium were noted for Model Layer 3 and the model did not predict any significant uranium concentrations in Model Layers 4 and 5. Additionally, when the Burial Grounds are removed as a source area, it is observed that concentrations decrease by two orders of magnitude in that area of the site. The model also indicated that simulated PCE concentrations and areal extent of the predicted PCE plumes extend to the Backwash area but decrease and become insignificant after 15 years into the future. However, much of this is due to biodecay of PCE into its daughter products, not modeled in this report.

- The ability of the model to perform predictive simulations has helped to predict the current and future extent of contamination at the Site and it can be a powerful tool to evaluate the effectiveness of proposed remedial systems, for risk assessment, and to develop a cost-effective monitoring well program. The models are a tool that can be updated periodically as new site information is gathered. Model updates can be performed easily and can enhance the models' ability to provide accurate predictions.

8.0 RECOMMENDATIONS

After completing the modeling analysis of groundwater conditions at the NFS Site, Geraghty & Miller proposes that the following activities be conducted at the NFS facility:

Installation of Downgradient Monitoring Wells: Geraghty & Miller recommends installation of 12 monitoring wells (nine wells for Zone 1, and 3 wells for Zone 2), to be drilled and sampled for target analytes. These wells will be used to collect additional data to define the downgradient extent of the PCE plume. These wells are placed as such to cover most of the off site area downgradient of suspected on-site source areas. Geraghty & Miller recommends that NFS uses a phased approach by first installing the interior wells closer to the site. These initial monitoring wells should be screened only in the upper residuum (Zone 1). Three wells are recommended for Zone 2 and should be installed and screened as such. The locations of the proposed wells are shown on the attached Figures 8-1 and 8-2. Data obtained from these wells can be used for confirming the model assumptions, predictions, and to refine the model. Dependent on the results from these new monitoring wells, the solute transport calibrations may require some refinement.

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Table 2-1. Public and Private Groundwater Supplies in the Unicoi County Area

Nuclear Fuel Services, Inc. Erwin, Tennessee

Public Groundwater Supplies in Unicoi County

Source	Geologic Horizon[1]	Depth (ft)	Potential Yield (gpm)	Location in Relation to NFS
Erwin Utility District				
Anderson-McInturff Spring	Cu/Chk	—	450	Approx. 3.8 mi. NE of NFS
Birchfield Well and Spring	Cu/Chk/Cs	222	1,500	Approx 1.5 mi. N or NFS
O'Brien Well and Spring	Ce (spring)	606	630	Approx 1.3 mi. NE of NFS
Railroad Well	Cr/Chk	240	315	Approx 3,500 ft NE of NFS
Plassco Well	Chk	350	—	Approx 2.5 mi. ENE of NFS
Elk's Club Well	Chk	305	1,200	Approx 1.6 mi. NE of NFS
Ambrose Well	Chk	270	1,100	Approx 1.5 mi. N of NFS
Johnson City Water Department				
Unicoi Springs (3)	Cu	—	2,500	Approx. 6 mi. NE of NFS

SOURCE: First Tennessee Development District, March 1987 and Bradfield Environmental Services, Inc.

Private Groundwater Supplies Within a 5-mile Radius of NFS

Owner and/or Name	Geologic Horizon[1]	Depth (ft)	Potential Yield (gpm)[3]	Use
Crystal Ice, Coal & Laudry (well)	Chk	135	75	Industrial
Love Spring	Cs	—	500	—
Grady Ledford (well)	Ce	122	N/A	Domestic
Sam Tipton (well)	Ce	80	N/A	Domestic
E.L. Lewis (spring)	Ce	—	5	Domestic
Unaka Springs	Cu	—	N/A	Domestic
U.S. Dept. of the Interior (spring)	Chk	—	916	Industrial
Fess Radford (well)	Chk	30	N/A	Domestic
Kelley Rice (well)	Cs	24	N/A	Domestic
Charles Erwin (well)	Chk	323	N/A	Domestic
Yates Spring	Cu	—	10	Domestic
W.B. Walker	Ch	N/A	3	Domestic

NOTES:

1. Chk – Honaker Dolomite Cs – Shady Dolomite Ce – Erwin Formation
   Cu – Unicoi Formation Cr – Rome Formation Ch – Hampton Formation
2. Banner Spring was listed as a potential water supply source in the Survey of Public Groundwater Supplies published by the First Tennessee Development District in March 1987. Banner Spring is owned by Nuclear Fuel Services, Inc. and is not a water supply.
3. N/A – Not Available

SOURCE: EcoTek Inc., Hydrogeologic Characterization Study of NFS Facility, Vol. I, March 1989

Table 2-2. Monitoring Wells by Zone

Nuclear Fuel Services, Inc. Erwin, Tennessee

Zone 1		Zone 2	Zone 3
Well 5	Well 68	Well 30	Well 67
Well 10	Well 72	Well 41	Well 82
Well 24	Well 75	Well 60B	SC-1
Well 25	Well 78	Well 63B	SC-3
Well 26	Well 80	Well 65	SC-4
Well 27	Well 91	Well 67B	
Well 28	Well 92	Well 66	
Well 29	Well 93	Well 71	
Well 31	Well 94	Well 76	
Well 32	Well 95A	Well 77	
Well 33	Well 96A	Well 79	
Well 34	Well 97A	Well 81	
Well 35	Well 98A	Well 100B	
Well 36	Well 99A	Well 107B	
Well 38	Well 100A		
Well 39	Well 101A		
Well 40	Well 102A		
Well 52	Well 103A		
Well 55	Well 104A		
Well 55A	Well 105A		
Well 56	Well 106A		
Well 57	Well 107A		
Well 58	Well LD-1A		
Well 59	Well LD-2A		
Well 60	Well 234-2		
Well 62	Well 234-3		
Well 63	SC-6		
Well 63A	SC-7		
Well 70A	SC-8		
Well 64			

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Table 2-3. Vertical Hydraulic Gradients

Nuclear Fuel Services, Inc.   Erwin, Tennessee

October 1993

Zone 1 to Zone 2

Well No.	h_1	l_1	Well No.	h_2	l_2	*d*h	*d*l	*d*h/*d*l
60	1633.68	1634.31	60B	1633.71	1615.73	-0.03	18.58	-0.002
63A	1640.67	1640.66	63B	1640.39	1620.73	0.28	19.93	0.014
100A	1629.10	1629.70	100B	1628.47	1605.21	0.63	24.49	0.026
107A	1632.16	1633.40	107B	1631.82	1616.76	0.34	16.64	0.020
72	1632.11	1628.90	71	1631.64	1612.95	0.47	15.95	0.029
68	1629.51	1629.88	66	1629.76	1611.01	-0.25	18.87	-0.013
59	1628.92	1628.63	65	1629.80	1609.37	-0.88	19.26	-0.046
64	1634.51	1635.12	67B	1634.94	1608.88	-0.43	26.24	-0.016

Zone 2 to Zone 3

Well No.	h_1	l_1	Well No.	h_2	l_2	*d*h	*d*l	*d*h/*d*l
67B	1634.94	1608.88	67	1635.17	1530.26	-0.23	78.62	-0.003

November 1993

Zone 1 to Zone 2

Well No.	h_1	l_1	Well No.	h_2	l_2	*d*h	*d*l	*d*h/*d*l
60	1633.77	1634.31	60B	1633.79	1615.73	-0.02	18.58	-0.001
63A	1640.81	1640.66	63B	1640.40	1620.73	0.41	19.93	0.021
100A	1629.20	1629.70	100B	1628.54	1605.21	0.66	24.49	0.027
107A	1632.06	1633.40	107B	1631.78	1616.76	0.28	16.64	0.017
72	1633.67	1628.90	71	1634.94	1612.95	-1.27	15.95	-0.080
68	1629.66	1629.88	66	1629.83	1611.01	-0.17	18.87	-0.009
59	1629.11	1628.63	65	1630.02	1609.37	-0.91	19.26	-0.047
64	1634.58	1635.12	67B	1634.98	1608.88	-0.4	26.24	-0.015

Zone 2 to Zone 3

Well No.	h_1	l_1	Well No.	h_2	l_2	*d*h	*d*l	*d*h/*d*l
67B	1634.98	1608.88	67	1635.23	1530.23	-0.25	78.65	-0.003

December 1993

Zone 1 to Zone 2

Well No.	h_1	l_1	Well No.	h_2	l_2	*d*h	*d*l	*d*h/*d*l
60	1633.84	1634.31	60B	1633.87	1615.73	-0.03	18.58	-0.002
63A	1640.73	1640.66	63B	1640.40	1620.73	0.33	19.93	0.017
100A	1628.92	1629.70	100B	1628.32	1605.21	0.6	24.49	0.024
107A	1632.24	1633.40	107B	1631.97	1616.76	0.27	16.64	0.016
72	1632.71	1628.90	71	1631.92	1612.95	0.79	15.95	0.050
68	1629.72	1629.88	66	1629.66	1611.01	0.06	18.87	0.003
59	1627.86	1628.63	65	1630.47	1609.37	-2.61	19.26	-0.136
64	1634.07	1635.12	67B	1634.97	1608.88	-0.9	26.24	-0.034

Zone 2 to Zone 3

Well No.	h_1	l_1	Well No.	h_2	l_2	*d*h	*d*l	*d*h/*d*l
67	1634.97	1608.88	67B	1635.26	1530.23	-0.29	78.65	-0.004

NOTES:

h = hydraulic head
l = screen midpoint elevation
*d*h = difference in head, well to well
*d*l = length of vertical flow path (screen midpoint to screen midpoint or water table to screen midpoint)
*d*h/*d*l = vertical hydraulic gradient
h_1 and h_2 = water elevations from fourth quarter 1993 data

Table 2-4. Slug Test Results

Nuclear Fuel Services, Inc. Erwin, Tennessee

EcoTek 1992/1993

Zone 1

Well No.	K (cm\sec.)	K (ft\day)
55A	1.14E-03	3.23
63A	1.80E-04	0.51
70A	1.12E-03	3.18
95A	3.37E-03	9.50
96A	8.67E-03	24.60
97A	4.60E-03	13.02
98A	2.49E-02	70.61
99A	5.49E-04	1.56
100A	1.34E-02	38.02
101A	1.37E-03	3.88
102A	1.41E-02	40.10
103A	9.53E-03	27.00
104A	3.20E-03	10.27
105A	1.28E-03	3.64
106A	7.45E-04	2.11
107A	4.05E-02	114.00
LD-1A	4.04E-04	1.15
LD-2A	1.29E-02	36.57

Zone 2

Well No.	K (cm\sec.)	K (ft\day)
60B	1.82E-03	5.14
63B	9.76E-03	27.64
67B	2.39E-03	6.78
100B	4.14E-03	11.75

OHM-1990

Zone 1

Well No.	K (cm\sec.)	K (ft\day)
91	1.49E-03	4.21
92	1.19E-03	3.36
94	1.70E-03	4.81

EcoTek 1989

Zone 1

Well No.	K (cm\sec.)	K (ft\day)
52	4.54E-03	13.00
55	7.53E-03	21.50
56	2.15E-03	6.10
57	4.43E-03	12.70
58	1.91E-03	5.50
59	3.61E-03	10.30
60	4.82E-03	13.80
62	1.94E-03	5.50
63	5.33E-03	15.20
64	4.86E-03	13.90
68	2.57E-03	7.30
72	8.43E-04	2.40
73	9.92E-04	2.80

Zone 2

65	7.21E-04	2.10
66	1.99E-03	5.70
71	3.92E-03	11.20
79	4.67E-03	12.80
81	2.25E-03	6.40

Zone 3

67	1.16E-02	33.00
82	1.72E-03	4.90

TLG-1987

Zone 1

Well No.	K (cm\sec.)	K (ft\day)
29	6.90E-04	1.95
31	1.40E-03	3.23
33	3.22E-04	0.91
36	1.31E-03	3.71
39	3.66E-04	1.00

Zone 2

30	9.45E-05	0.27

12JUL95 SB

cm - centimeter

sec - second

Table 2-5. Corehole Packer Test Results

Nuclear Fuel Services, Inc. Erwin, Tennessee

Location	Interval (ft/bgl)	Water Pressure at Swivel (psi)	K		Falling Head Results K		Average K per Zone (from Packer Test Data)	
			(ft/day)	(cm/sec)	(ft/day)	(cm/sec)	(ft/day)	(cm/sec)
SC-1	22.0-31.0	5	1.8	6.3E-04				
		10	4	1.4E-03				
		15	3.7	1.3E-03	4.47	1.6E-03	3.1	1.1E-03
	35.0-44.0	10	3.7	1.3E-03				
		20	3.1	1.1E-03				
		30	2.6	9.1E-04	0.26	9.0E-05	3.1	1.1E-03
	61.0-69.0	20	1.9	6.7E-04				
		30	1.6	5.6E-04				
		40	1.7	6.1E-04	4.23	1.5E-03	1.8	6.2E-04
SC-3	17.5-26.5	10	0.82	2.9E-04				
		20	0.79	2.8E-04	1.04	3.7E-04	0.82	2.9E-04
	34.5-43.5	10	0.04	1.4E-05				
		20	0.12	4.2E-05				
		30	0.14	4.8E-05	0.22	7.6E-05	0.1	3.5E-05
	51.0-60.0	20	0.14	4.8E-05				
		30	0.14	4.8E-05				
		40	0.14	4.8E-05	0.68	2.4E-04	0.14	4.8E-05
SC-6	19.5-28.0	20	0.62	2.2E-04				
		10	0.48	1.7E-04	0.27	9.5E-05	0.54	1.9E-04
	42.5-51.0	25	0.14	4.9E-05				
		34	0.18	6.4E-05	0.086	3.0E-05	0.16	5.7E-05
	62.5-71.0	20	0.25	8.8E-05				
		40	0.48	1.7E-04	1.04	3.7E-04	0.37	1.3E-04
SC-7	12.5-21.5	10	1.9	6.7E-04				
		15	1.3	4.7E-04	1.99	7.0E-04	1.6	5.7E-04
	45.0-54.0	10	0.54	1.9E-04				
		20	1.1	4.0E-04				
		30	1.6	5.8E-04	1.12	4.0E-04	1.1	3.9E-04
	55.0-64.0	10	0.51	1.8E-04				
		15	0.99	3.5E-04				
		20	1.2	4.3E-04	1.5	5.2E-04	0.91	3.2E-04
SC-8	27.0-36.0	5	0.71	2.5E-04	0.19	6.7E-05	0.71	2.5E-04
	46.0-55.0	10	0.43	1.5E-04				
		15	0.21	7.3E-05				
		20	0.25	8.8E-05	0.22	7.6E-05	0.28	1.0E-04
	60.5-69.5	20	0.01	3.5E-06				
		30	0.05	1.9E-05				
		40	0.08	2.7E-05	0.17	6.1E-05	0.05	1.6E-05

22FEB96 SB

cm - centimeter
psi - per square inch
sec - second
ft - feet
bgl - below ground level

Table 3-1. Hydrogeologic Units and Numerical Model Equivalents

Nuclear Fuel Services, Inc. Erwin, Tennessee

HYDROGEOLOGIC UNIT	NAME OF ROCK UNIT	DESCRIPTION	MODEL LAYER*
Alluvium (Zone 1)	Alluvium	Medium sandy, etc.	1
Cobbles and Boulders Zone (Zone 2)	Cobbles and Boulders Zone	-same-	2
Shallow Zone Bedrock Aquifer (Zone 3)	Shady Dolomite	Blue grey dolomite	1, 2, 3, 4, & 5
	Rome Formation	Shale, siltstone and some dolomite	
	Honaker Dolomite	Dolomite and limestone	
	Erwin	Quartzite, shale and siltstone	
	Unicoi	Quartzite, conglomerate and shale	
	Snowbird Formation		

* all bedrock units occur in each model layer

Table 3-2. Summary of Withdrawal Wells

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Well	Layer	Row	Column	Rate (gpm)
Railroad Well	3,4,5	40	116	270.4
Birchfield Well	3,4,5	12	122	552.7
O'Brien Well	3	7	123	241.5
PW-1	1	55	92	0.6
PW-2	1	54	92	0.6
PW-3	1	53	91	0.6
PW-4	1	52	90	0.6
PW-5	1	53	89	0.6
PW-6	1	53	88	0.6
PW-7	1	54	89	0.6
PW-8	1	55	89	0.6
PW-9	1	56	90	0.6
PW-10	1	56	91	0.6

gpm - gallons per minute

Table 3-3. Calibration Targets for the Groundwater Flow Model
Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Row	Column	Layer	Observed Water-Level
5	52	99	1	1632.5
10	51	94	1	1630.4
26	53	91	1	1630.73
28	53	89	1	1629.79
29	60	91	2	1633.76
31	58	94	2	1634.59
32	62	95	2	1634.48
33	59	91	1	1634.28
34	54	94	1	1633.24
35	62	91	2	1634.43
36	56	94	1	1634.13
38	59	89	2	1633.46
39	61	89	1	1633.85
40	65	91	1	1636.19
52	67	91	1	1636.86
55	65	98	1	1638.57
55A	68	97	1	1638.12
56	60	103	1	1637.94
57	55	101	1	1632.35
58	51	101	1	1630.73
59	50	96	2	1629.48
63A	68	102	1	1640.95
64	60	96	1	1634.97
68	49	100	1	1630.33
70A	62	85	2	1633.32
75	56	87	1	1633.35
91	56	85	2	1633.41
92	56	85	2	1633.82
93	54	86	2	1633.5
94	52	86	2	1633.53
95A	57	100	1	1634.74
96A	58	103	1	1636.2
97A	56	83	2	1634.05

ft - feet
msl - mean sea level

Table 3-3. Calibration Targets for the Groundwater Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Row	Column	Layer	Observed Water-Level
98A	48	101	1	1628.27
99A	48	99	1	1628.92
100A	49	94	2	1629.69
101A	49	91	1	1629.76
102A	50	88	2	1629.98
103A	50	85	1	1630.04
104A	51	80	1	1631.41
105A	52	74	1	1632.11
106A	54	68	1	1632.91
107A	58	73	1	1633.85
LD-1A	48	72	2	1633.57
LD-2A	59	84	2	1633.85
234-2	65	87	1	1634.33
234-3	64	88	1	1634.64
SC-6	65	64	1	1638.2
SC-7	62	67	2	1633.63
SC-8	56	65	2	1633.06
30	59	94	2	1634.16
41	65	93	2	1636.42
60B	57	99	3	1634.47
63B	68	102	2	1640.9
65	51	96	2	1630.31
66	50	100	2	1630.1
67B	59	97	3	1635.59
71	53	85	3	1632.39
76	57	94	3	1633.44
77	59	94	3	1634.3
79	56	91	2	1633.41
81	52	92	2	1630.61
100B	49	94	3	1629.3
107B	64	79	3	1633.35
67	60	97	3	1635.93
82	57	63	3	1630.58
SC-3	67	89	3	1637.49
SC-4	64	83	3	1634.65

ft - feet

msl - mean sea level

Table 3-4. Observed and Simulated Water Levels for the Calibrated Groundwater Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Row	Column	Layer	Observed Water-Level (ft msl)	Simulated Water-Level (ft msl)	Residual (ft)
5	52	99	1	1632.5	1628.346	4.15
10	51	94	1	1630.4	1630.304	9.56E-02
26	53	91	1	1630.73	1631.138	-0.408
28	53	89	1	1629.79	1631.066	-1.28
29	60	91	2	1633.76	1634.855	-1.1
31	58	94	2	1634.59	1634.136	0.454
32	62	95	2	1634.48	1636.061	-1.58
33	59	91	1	1634.28	1633.706	0.574
34	54	94	1	1633.24	1630.441	2.8
35	62	91	2	1634.43	1635.558	-1.13
36	56	94	1	1634.13	1632.74	1.39
38	59	89	2	1633.46	1634.266	-0.806
39	61	89	1	1633.85	1635.259	-1.41
40	65	91	1	1636.19	1634.766	1.42
52	67	91	1	1636.86	1635.28	1.58
55	65	98	1	1638.57	1637.82	0.75
55A	68	97	1	1638.12	1639.042	-0.922
56	60	103	1	1637.94	1636.194	1.75
57	55	101	1	1632.35	1631.832	0.518
58	51	101	1	1630.73	1628.098	2.63
59	50	96	2	1629.48	1629.817	-0.337
63A	68	102	1	1640.95	1640.765	0.185
64	60	96	1	1634.97	1635.397	-0.427
68	49	100	1	1630.33	1628.152	2.18
70A	62	85	2	1633.32	1635.942	-2.62
75	56	87	1	1633.35	1633.532	-1.82E-01
91	56	85	2	1633.41	1633.365	4.49E-02
92	56	85	2	1633.82	1633.769	5.13E-02
93	54	86	2	1633.5	1632.198	1.3
94	52	86	2	1633.53	1631.037	2.49
95A	57	100	1	1634.74	1633.407	1.33
96A	58	103	1	1636.2	1634.168	2.03
97A	56	83	2	1634.05	1633.907	0.143
98A	48	101	1	1628.27	1626.238	2.03
99A	48	99	1	1628.92	1628.443	0.477
100A	49	94	2	1629.69	1629.506	0.184
101A	49	91	1	1629.76	1629.895	-0.135

ft - feet
msl - mean sea level

Table 3-4. Observed and Simulated Water Levels for the Calibrated Groundwater Flow Model
Nuclear Fuel Services, Inc.   Erwin, Tennessee

Well	Row	Column	Layer	Observed Water-Level (ft msl)	Simulated Water-Level (ft msl)	Residual (ft)
102A	50	88	2	1629.98	1630.207	-2.27E-01
103A	50	85	1	1630.04	1630.57	-0.53
104A	51	80	1	1631.41	1631.401	8.965E-03
105A	52	74	1	1632.11	1631.879	0.231
106A	54	68	1	1632.91	1632.797	0.113
107A	58	73	1	1633.85	1634.92	-1.07
LD-1A	48	72	2	1633.57	1631.954	1.62
LD-2A	59	84	2	1633.85	1635.068	-1.22
234-2	65	87	1	1634.33	1636.624	-2.29
234-3	64	88	1	1634.64	1636.389	-1.75
SC-6	65	64	1	1638.2	1638.089	0.111
SC-7	62	67	2	1633.63	1637.036	-3.41
SC-8	56	65	2	1633.06	1635.04	-1.98
30	59	94	2	1634.16	1634.462	-0.302
41	65	93	2	1636.42	1635.734	0.686
60B	57	99	3	1634.47	1634.05	0.42
63B	68	102	2	1640.9	1640.734	0.166
65	51	96	2	1630.31	1630.224	8.56E-02
66	50	100	2	1630.1	1628.795	1.31
67B	59	97	3	1635.59	1635.008	0.582
71	53	85	3	1632.39	1632.084	0.306
76	57	94	3	1633.44	1633.847	-0.407
77	59	94	3	1634.3	1634.588	-0.288
79	56	91	2	1633.41	1632.596	0.814
81	52	92	2	1630.61	1631.02	-0.41
100B	49	94	3	1629.3	1629.655	-3.55E-01
107B	64	79	3	1633.35	1636.962	-3.61
67	60	97	3	1635.93	1635.211	0.719
82	57	63	3	1630.58	1635.588	-5.01
SC-3	67	89	3	1637.49	1638.057	-0.567
SC-4	64	83	3	1634.65	1636.743	-2.09

ft - feet
msl - mean sea level

Table 4-1. Volume of Solutions Discharged to Ponds from 1957 - 1978

Nuclear Fuel Services, Inc. Erwin, Tennessee

		Operation Years		Operation		Total	Average
Building	**Process**	**From**	**To**	**Days**	(gallons/day)	**Gallons**	(ft^3 /day)
110A	H.E. UO_2 Production	1957	1967	3,650	500	1,825,000	66.84
110B	L.E. UO_2 Production	1957	1967	3,650	800	2,920,000	106.95
111	H.E. U Scrap Recovery	1960	1965	1,825	700	1,277,500	93.58
111	Thorium Metal Production	1962	1969	2,555	10,800	27,594,000	1443.85
301	L.E. UO_2 Production	1964	1970	2,190	2,000	4,380,000	267.38
233	H.E. U Scrap Recovery	1962	1970	2,920	2,600	7,592,000	347.59
302	H.E. Fuel Manufacturing	1966	1970	1,460	2,400	3,504,000	320.86
	Total Processed:	**1957**	**1970**	4,745	**19,800**	93,951,000	**2,647.06**
233	H.E. U Scrap Recovery	1970	1978	2,920	2,600	7,592,000	347.59
302	H.E. Fuel Manufacturing	1970	1978	2,920	2,400	7,008,000	320.86
303	H.E. Fuel Manufacturing	1970	1978	2,920	2,400	7,008,000	320.86
	Total Processed:	**1970**	**1978**	2,920	**7,400**	21,608,000	**989.30**

SOURCE: Nuclear Fuel Services, Inc. 1985.

Table 4-2. Water Supply Pumping History, 1957 through 1993

Nuclear Fuel Services, Inc. Erwin, Tennessee

		Birchfield Well		O'Brien Well		Railroad Well	
		mg/year	ft^3/day	mg/year	ft^3/day	mg/year	ft^3/day
Stress Period 1 Jan. 1957 - Dec. 1970	1957 - 1970	220.79	81991.98	249.14	92520.42	—	—
Stress Period 2 Jan. 1971 - Dec. 1975	1971 - 1975	220.79	81991.98	249.14	92520.42	—	—
Stress Period 3	1976	220.79	81991.98	249.14	92520.42	—	—
Jan. 1976 - Dec. 1978	1977	251.22	93293.97	262.68	97548.28	—	—
	1978	255.96	95053.48	262.12	97341.80	—	—
	Average:	**242.66**	**90113.14**	**257.98**	**95803.50**	—	—
Stress Period 4	1979	284.27	105565.58	272.80	101307.56	—	—
Jan. 1979 - Dec. 1985	1980	223.08	82841.28	255.29	94803.92	—	—
	1981	224.94	83533.13	257.77	95723.78	—	—
	1982	269.76	100179.00	288.08	106980.84	—	—
	1983	253.36	94087.20	291.69	108322.56	—	—
	1984	274.34	101877.60	260.81	96854.95	—	—
	1985	240.65	89367.57	222.10	82478.46	—	—
	Average:	**252.91**	**93921.62**	**264.08**	**98067.44**	—	—
Stress Period 5	1986	223.68	83064.84	228.46	84841.06	12.77	4742.28
Jan. 1986 - Dec. 1990	1987	192.13	71350.64	227.61	84526.89	70.92	26338.38
	1988	157.70	58561.72	156.18	57999.48	159.27	59146.61
	1989	236.19	87711.30	210.74	78260.18	39.71	14748.22
	1990	241.11	89539.88	240.07	89151.81	57.32	21287.14
	Average:	**210.16**	**78045.68**	**212.61**	**78955.88**	**68.00**	**25252.53**
Stress Period 6	1991	205.03	76139.71	199.65	74142.16	160.65	59659.09
Jan. 1991 - Nov. 1993	1992	221.99	82439.10	142.14	52785.20	172.40	64021.46
	1993	229.15	85097.30	164.35	61032.38	159.07	59070.86
	Average:	**218.72**	**81225.37**	**168.71**	**62653.25**	**164.04**	**60917.14**

Source: NFS correspondence dated August 8, 1995.

Note: Average was calculated for the stress periods.

mg/year: Million gallons per year.

Table 4-3. Observed and Simulated Uranium Concentrations for the Calibrated Solute Transport Model

Nuclear Fuel Service, Inc. Erwin, Tennessee

Well ID	Layer	Row	Column	Observed Uranium Concentration (pCi/L)	Model Calculated Concentration (pCi/L)
29	2	60	91	33.8	1.0199
30	1	59	94	406	530.02002
35	1	62	91	400	536.45996
38	1	59	89	120	7.90764
39	1	61	89	70.7	56.6206
55	1	65	98	0.381	0.00000
56	1	60	103	0.184	0.01641
57	1	55	101	0.293	0.19799
58	1	51	101	0.294	0.0231
59	2	50	96	0.281	0.02848
62	2	56	96	0.293	0.00003
63	1	64	103	0.194	0.00000
65	2	51	96	0.431	0.06543
66	1	50	100	4.71	14.12620
68	1	49	100	7.71	28.3710
55A	1	68	97	0.208	0.00000
60B	3	57	99	147	0.00006
63A	1	68	102	0.939	0.00000
63B	2	68	102	0.284	0.00000
67B	3	59	97	0.359	0.00000
70A	1	62	85	0.274	0.00252
95A	1	57	100	15.6	5.84396
96A	1	58	103	2.01	0.25572
97A	2	56	83	1.94	0.00027
98A	1	48	101	5.28	0.42236
99A	1	48	99	1.67	0.0214
100A	1	49	94	27.8	5.56458
100B	3	49	94	0.234	0.00006
101A	1	49	91	9.08	10.17112
102A	1	50	88	6.19	5.92006
103A	1	50	85	1.36	0.00006
104A	1	51	80	0.467	0.00000
105A	1	52	74	7.54	0.00000
106A	1	54	68	3.08	0.00000
107A	1	58	73	5.13	0.00000
107B	3	64	79	14.3	0.00000
234-2	1	65	87	307	33.2694
234-3	1	64	88	18.3	27.7008
LD-1A	2	48	72	0.667	0.00000
LD-2A	1	59	84	45.8	48.6412

NOTE: Observed uranium concentrations from December 1993 Quarterly Sampling
pCi/L - picocuries per liter

Table 4-4. Observed and Simulated PCE Concentrations for the Calibrated Solute Transport Model

Nuclear Fuel Service, Inc. Erwin, Tennessee

Well ID	Layer	Row	Column	Observed PCE Concentration (ug/L)	Model Calculated Concentration (ug/L)
29	2	60	91	5	70.74140
30	1	59	94	1	42.00390
31	2	58	94	15	21.83520
32	2	62	95	25	11.56990
35	1	62	91	181	459.22000
38	1	59	89	248	107.55000
39	1	61	89	330	222.36000
52	1	67	91	15	0.43707
62	2	56	96	5	2.72410
63	1	64	103	25	14.55200
64	1	60	96	5	11.69640
65	2	51	96	20	3.42945
66	2	50	100	7	0.29213
68	1	49	100	2	0.17380
77	3	59	94	27	1.15045
79	2	56	91	191	79.89880
95A	1	57	100	12	17.76660
96A	1	58	103	2	2.12992
98A	1	48	101	9	0.06684
99A	1	48	99	5	0.17382
100A	2	49	94	2	3.72635
100B	3	49	94	21	1.33075
101A	1	49	91	114	107.03000
102A	1	50	88	2,960	2310.19995
103A	1	50	85	2,840	2314.50000
104A	1	51	80	5	1.11944
105A	1	52	74	5	0.00000
106A	1	54	68	5	0.00000

NOTE: Observed PCE concentrations from December 1993 Quarterly Sampling
µg/L - micrograms per liter

Table 4-5. Source Concentrations used in the Solute Transport Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sources	Initial Concentrations	
	PCE (mg/L)	Uranium (pCi/L)
Burial Grounds	0.2	2,000
Pond #1	0.9	1,200
Pond #2	0.9	1,200
Pond #3	0.9	1,200
Pond #4	2.0	2,600
Stockpile Soil	—	1,600
Building 130 Area	1.0	1,600
Building 111 Area	1.0	1,600
Building 120	50	—
Building 131	105	—
Building 110 Area	—	600
Building 234 A	1.0	3,000
Building 234 C	—	2,000
Building 302, 304 and 306 Area	—	1,600
Building 303 Area	—	1,600
Building 309 Area	—	1,600

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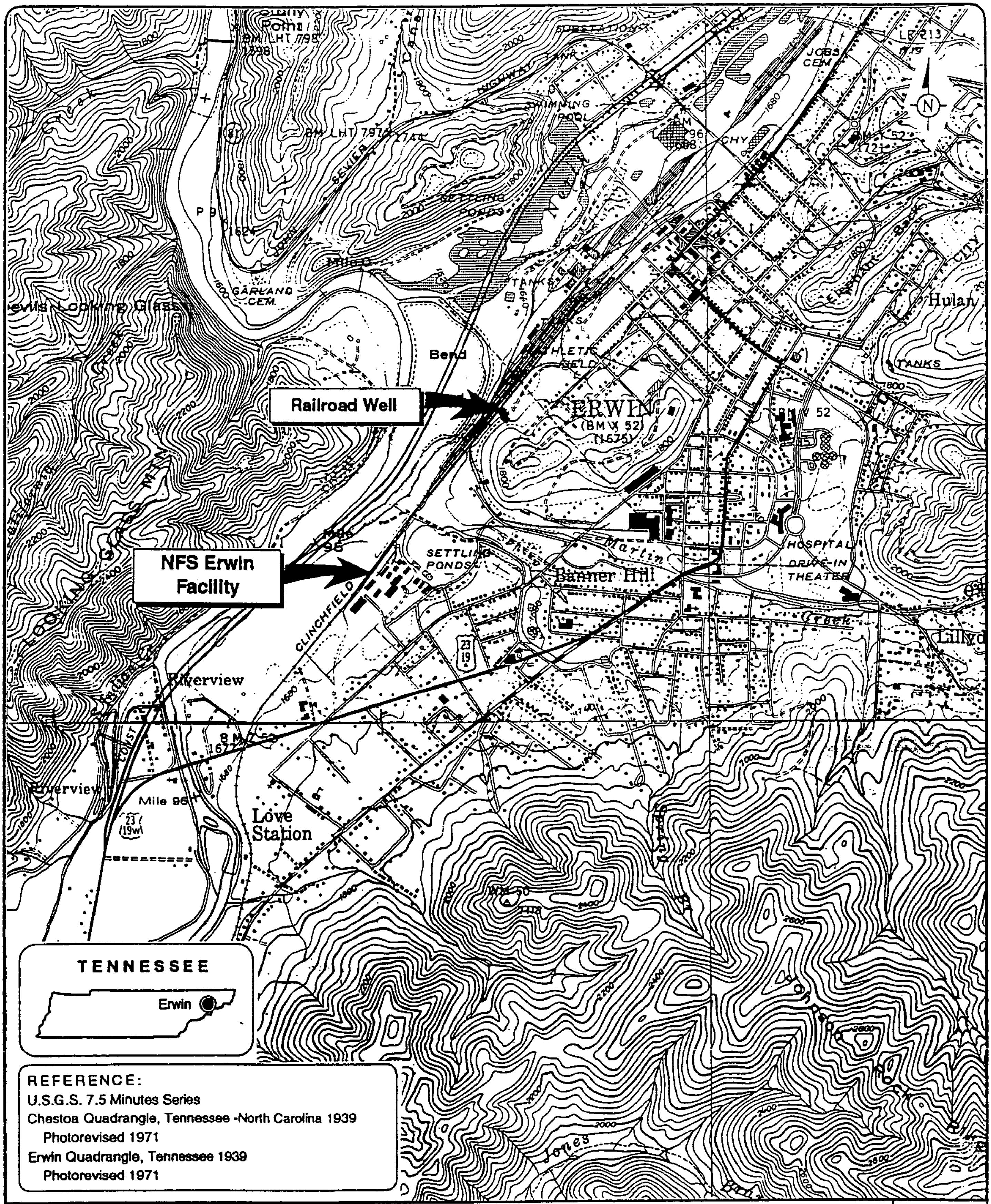
mg/L - Milligrams per Liter
pCi/L - Picocuries per Liter



REFERENCE:
U.S.G.S. 7.5 Minutes Series
Chestoa Quadrangle, Tennessee -North Carolina 1939
Photorevised 1971
Erwin Quadrangle, Tennessee 1939
Photorevised 1971

GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

0 2,000 ft

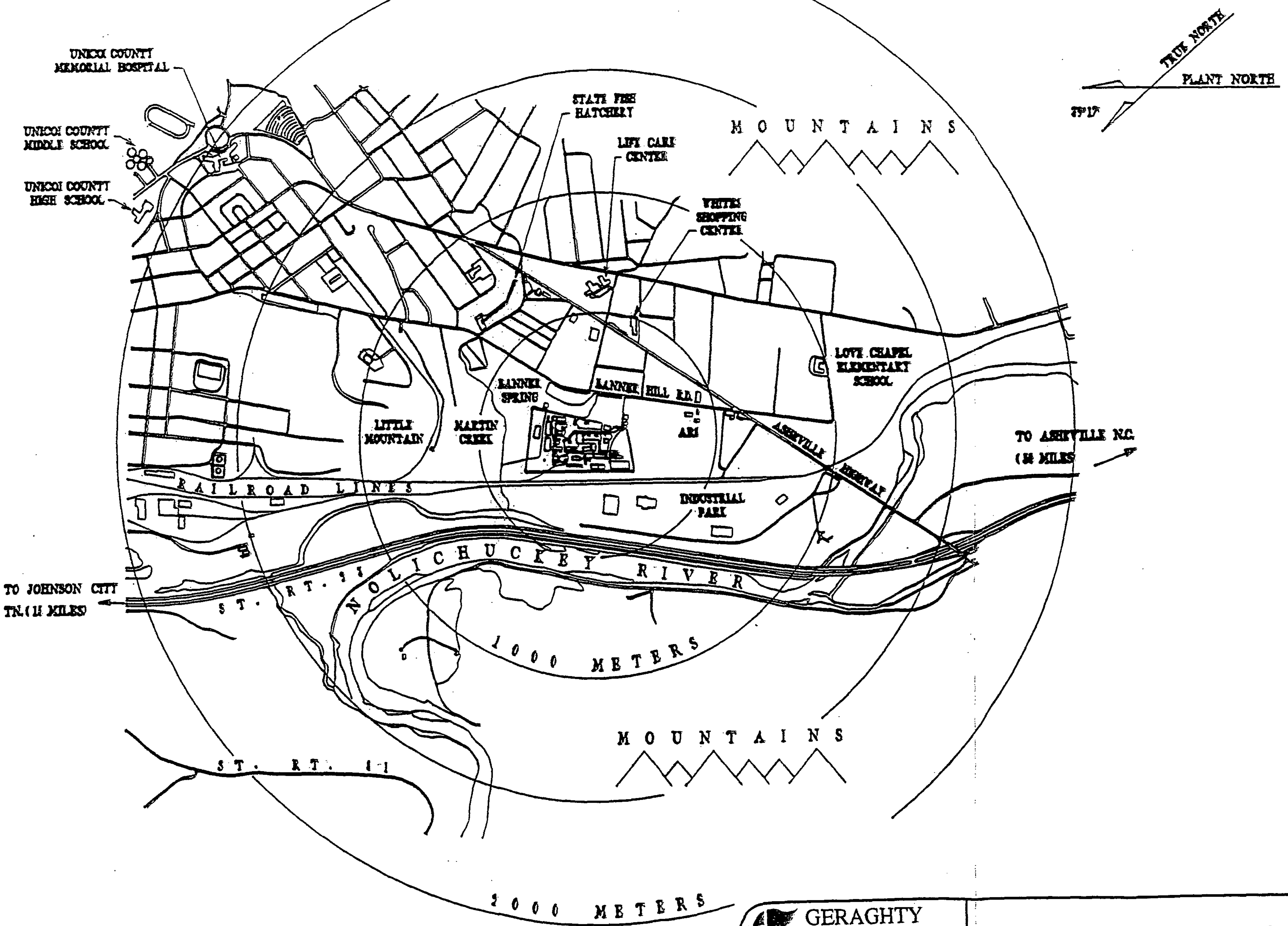
Regional Location Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
1-1

/ DRAWING NO.: 6-30139 / DRAWING DATE: 23FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /

/ DRAWING NO.: 0795-17843 a / DRAWING DATE: 12JUL95 SB / FILE NAME: CONCEPTUAL MODEL / PROJECT NO.: TN0333.001 / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

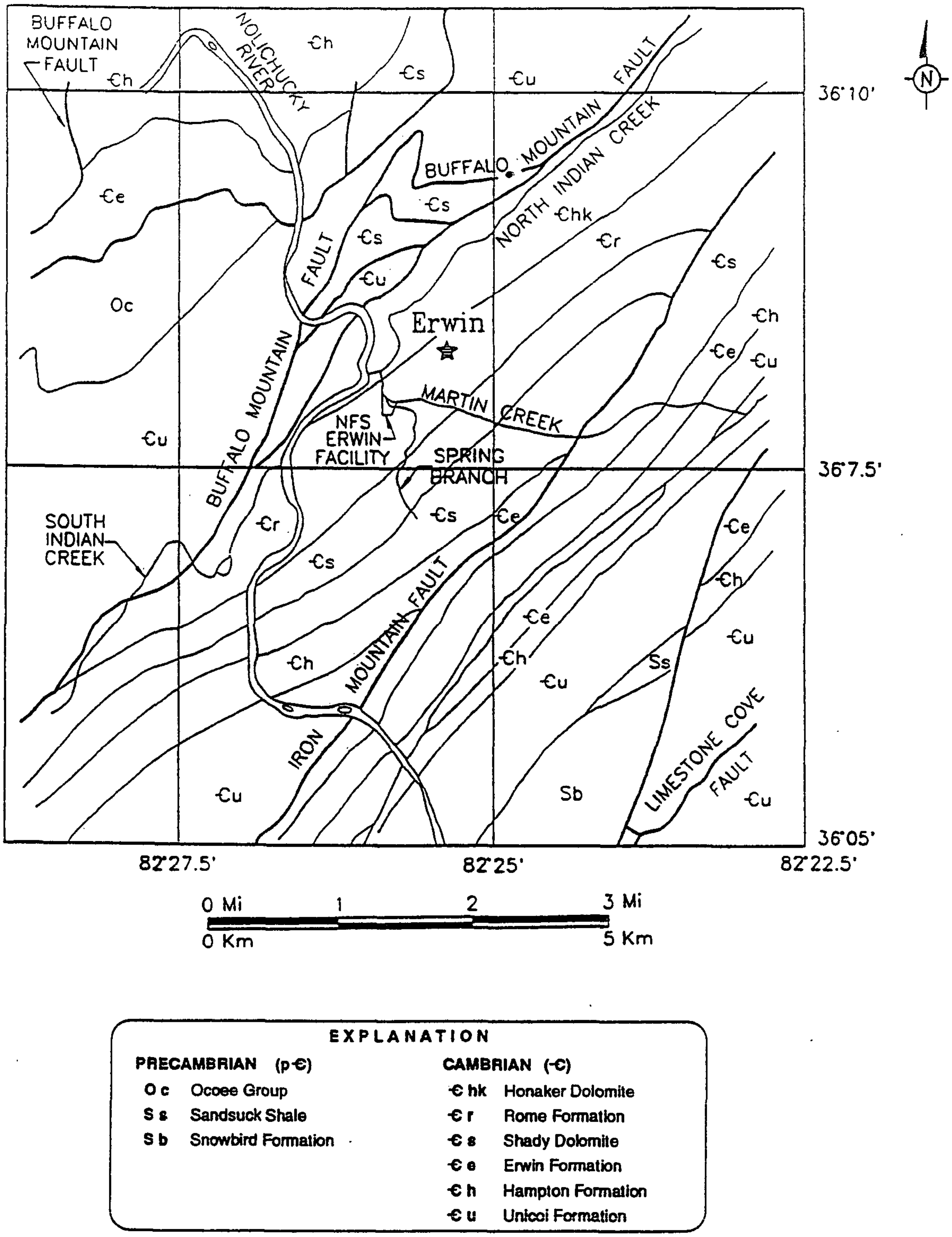
SCALE 0 50 meters

Plant and Area Map

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE
1-2

REFERENCE: ECOTEK, Inc. 1992/1993 Nuclear Fuel Services Hydrogeologic Investigation and Monitoring Well Installation Program, June 30, 1994



REFERENCE: J. Rodgers, Compiler, Geologic Map of East Tennessee, open file Sheet 199, Tennessee Division of Geology, Knoxville, Tennessee.

/ DRAWING NO.: 0295-30130 / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /

GERAGHTY & MILLER, INC.
Environmental Services
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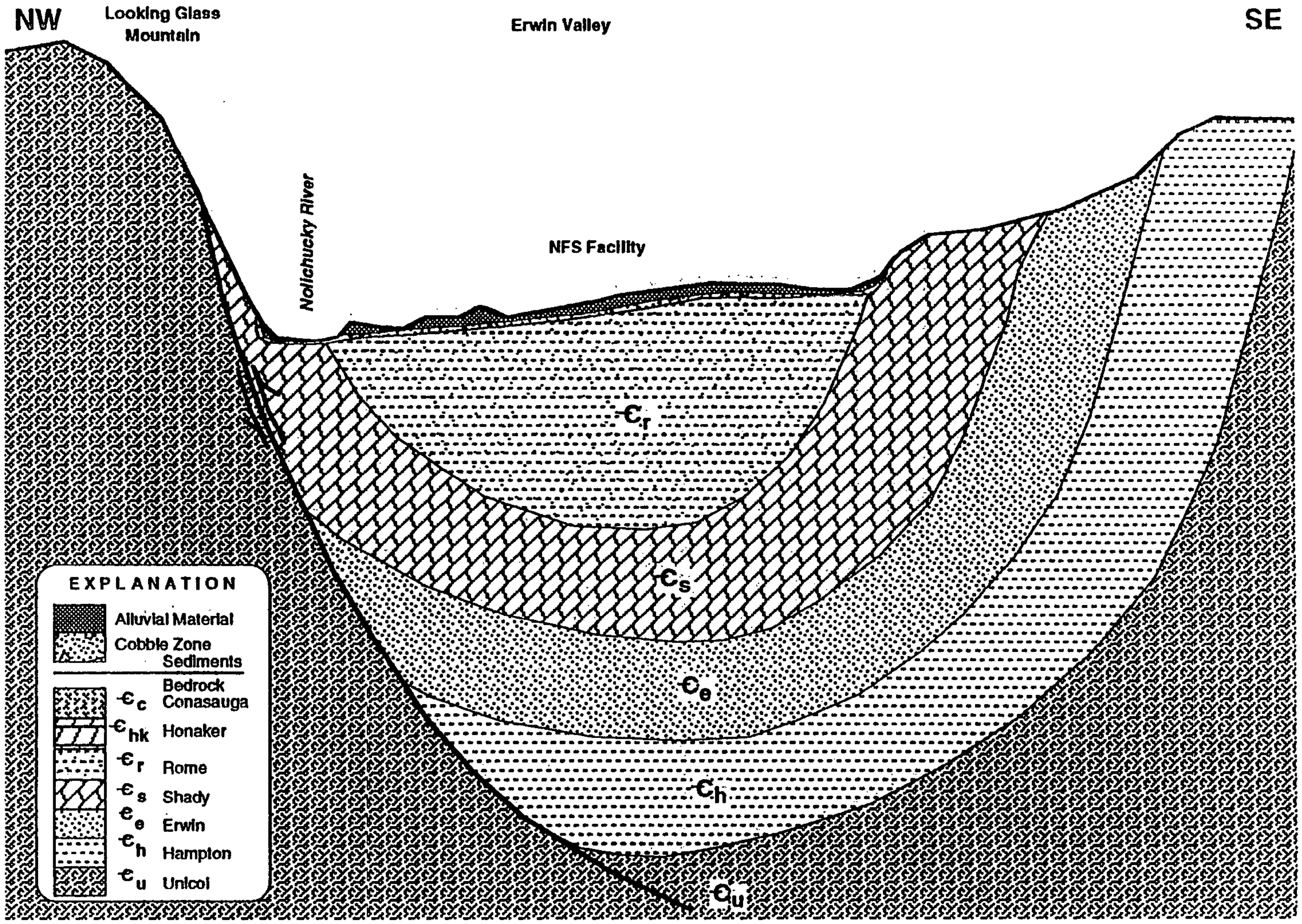
Geologic Map of the Erwin Region

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-1

/ DRAWING NO.: 30131 / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / JECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



GERAGHTY
& MILLER, INC.
Environmental Services
A **Heidemij** company

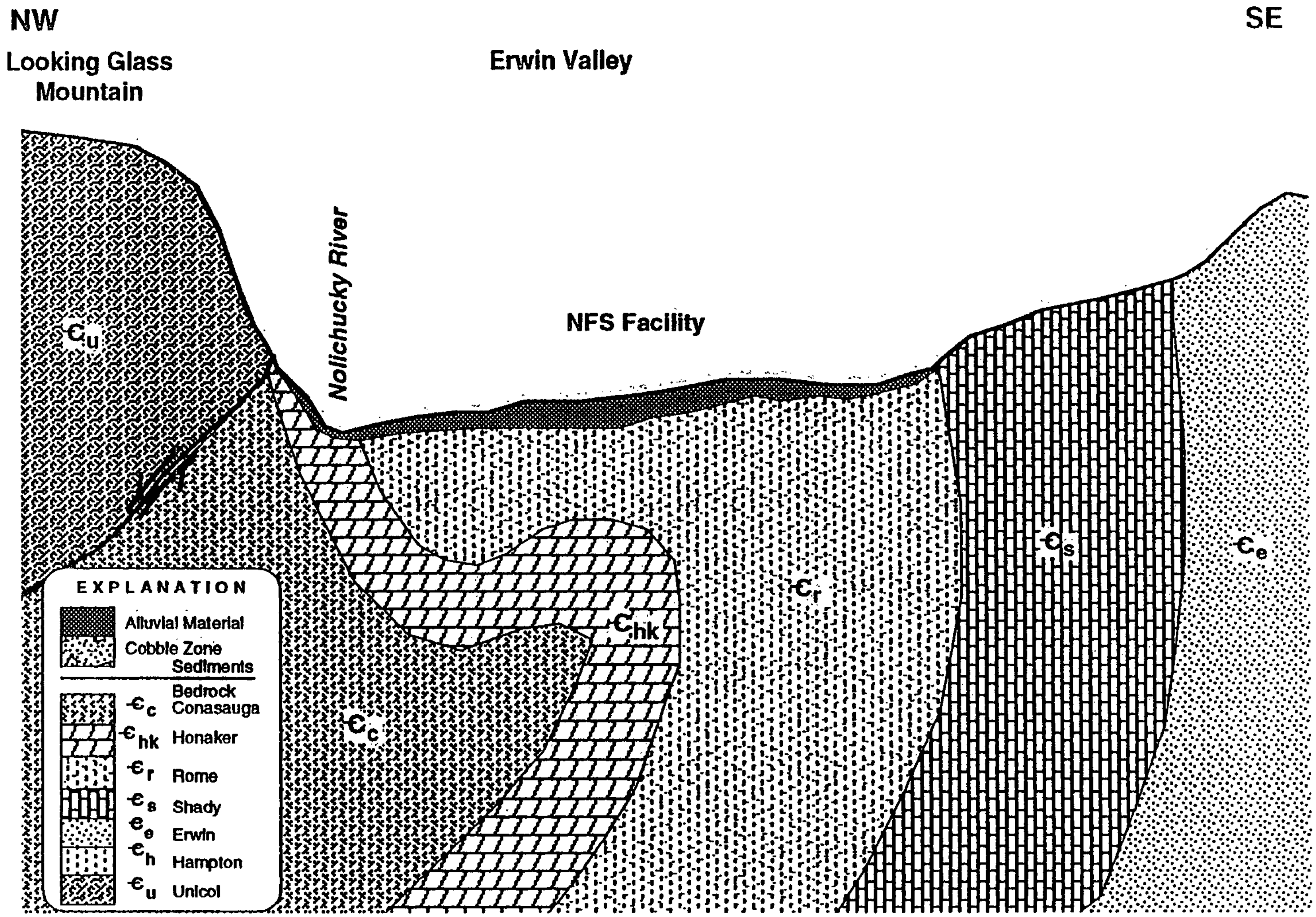
NOT TO SCALE

**Generalized Geologic Cross-Section,
Synclinal Interpretation**

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-2

/ DRAWING NO.. ·30134 / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN JECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

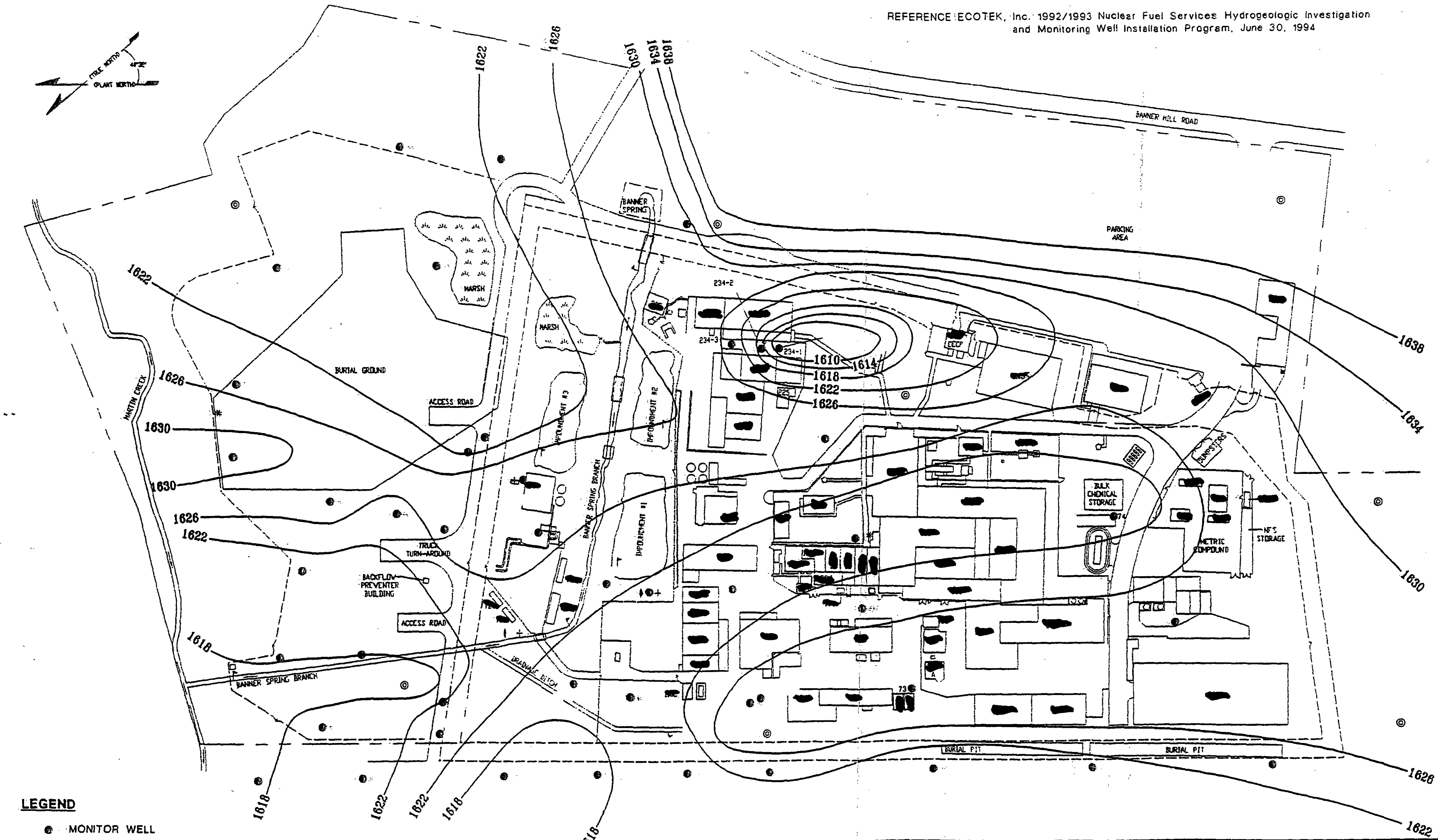
NOT TO SCALE

Generalized Geologic Cross-Section, Literature Interpretation

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-3

REFERENCE: ECOTEK, Inc. 1992/1993 Nuclear Fuel Services Hydrogeologic Investigation and Monitoring Well Installation Program, June 30, 1994



LEGEND

● MONITOR WELL

◎ PIEZOMETER LOCATION

CONTOUR LINE (FT, MSL)

0 160 ft
SCALE

GERAGHTY
& MILLER, INC.
Environmental Services
A Heidemij company

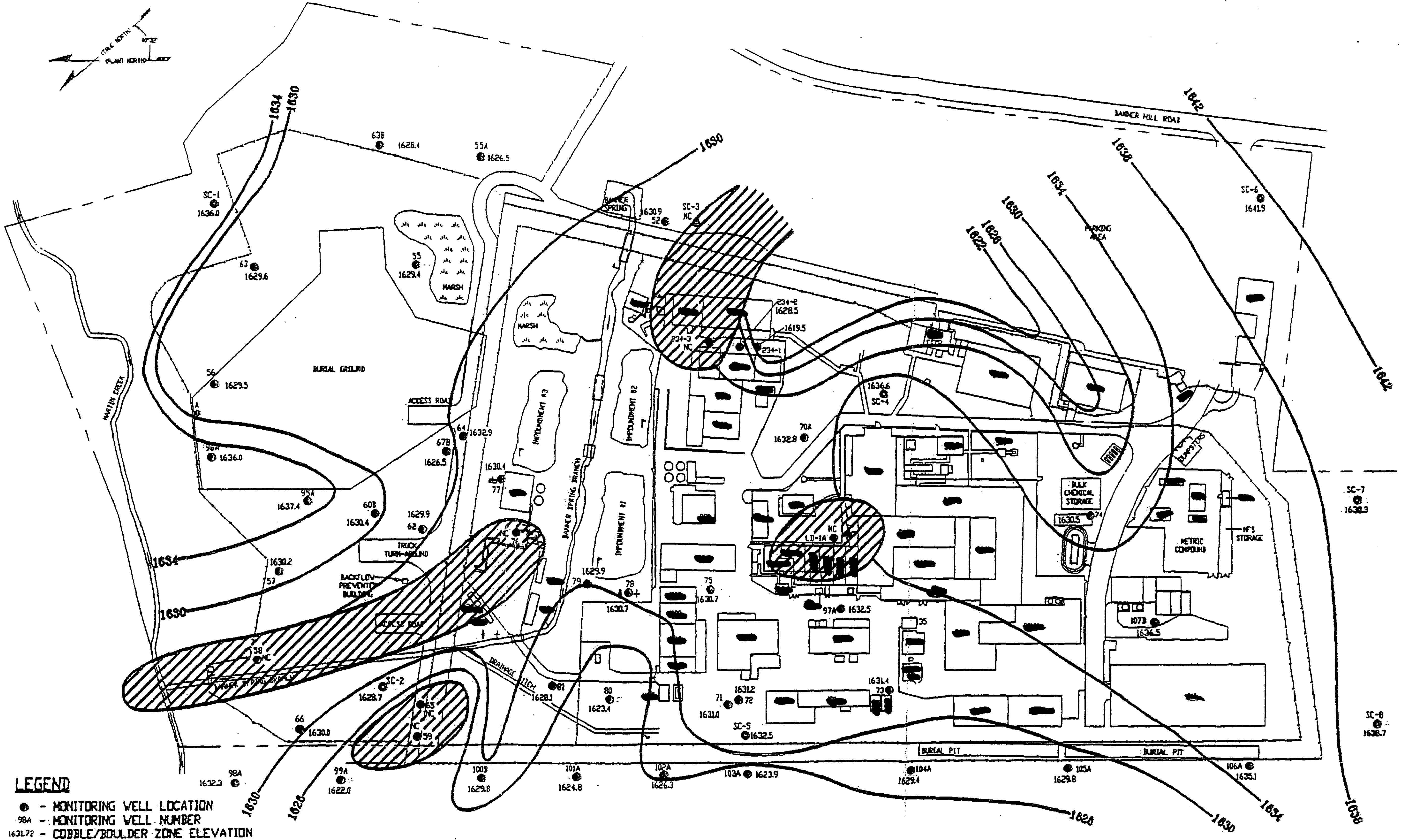
Bedrock Surface

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-4

DRAFTER: B. ALTOM
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30134.DWG
FILE: CONC. MODEL
PROJ. NO.: TN0333.001
DWG DATE: 22FEB96 SB

/ DRAWING NO.: 0795-30135a / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



LEGEND

- ● - MONITORING WELL LOCATION
- 98A - MONITORING WELL NUMBER
- 1631.72 - COBBLE/BOULDER ZONE ELEVATION
- ⌒ - COBBLE/BOULDER ZONE ELEVATION CONTOUR
- NC - NO COBBLE
- ▨ - ZONE OF NO COBBLE

CONTOUR INTERVAL = 4 FEET

REFERENCE: Advanced Recovery Systems First Quarter 1994 Nuclear Fuel Services Groundwater Monitoring Report, July 22, 1994

GERAGHTY & MILLER, INC.
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SCALE 0 160 ft

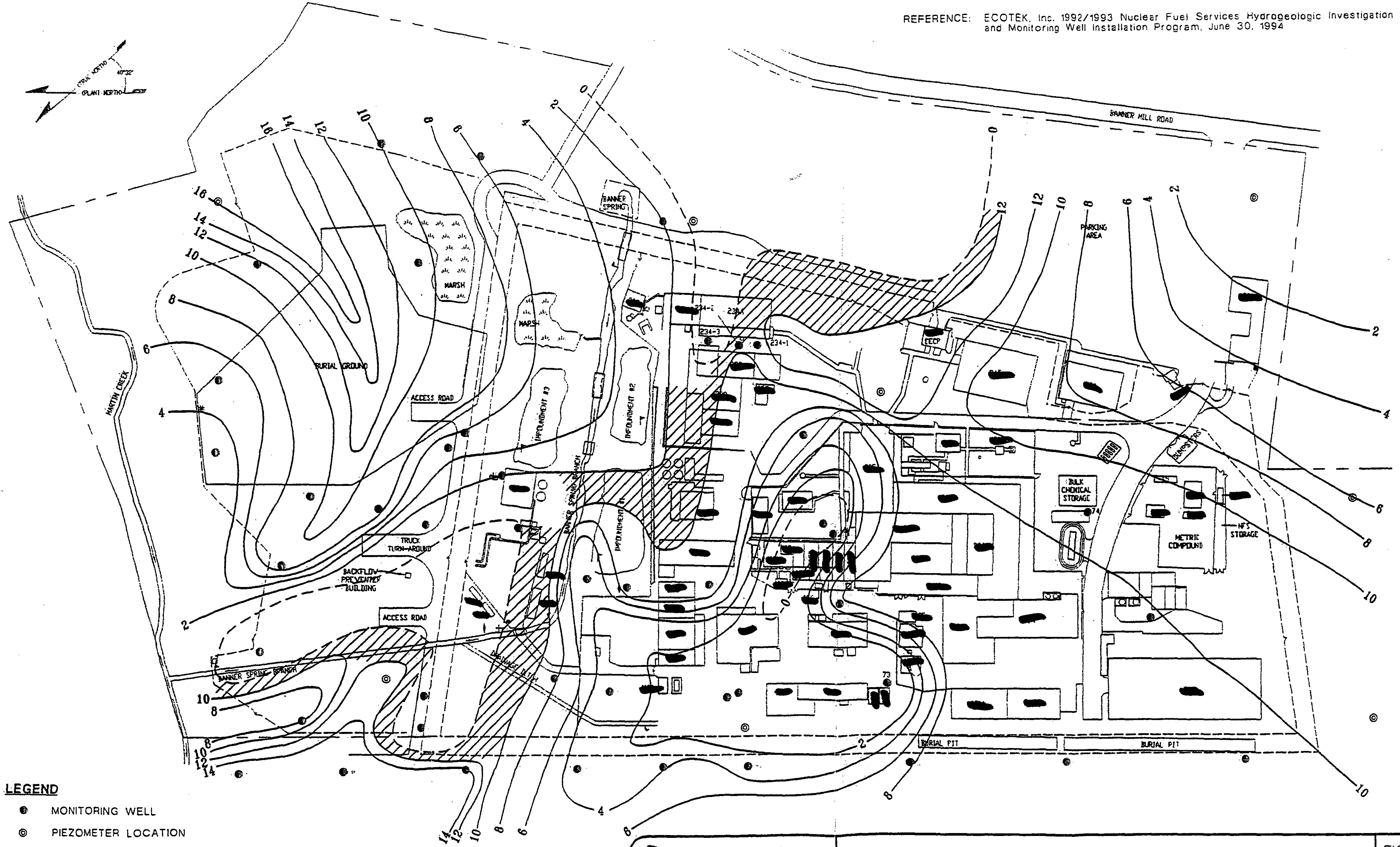
Cobble/Boulder Zone Surface

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE
2-5

DRAFTER: B. ALTOM | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30137.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 22FEB96 SB

REFERENCE: ECOTEK, Inc. 1992/1993 Nuclear Fuel Services Hydrogeologic Investigation and Monitoring Well Installation Program, June 30, 1994



LEGEND

- ● MONITORING WELL
- ◎ PIEZOMETER LOCATION
- ⁀ THICKNESS CONTOUR (FT)
- ▨ POTENTIAL SCARP OR LEDGE

0 160 ft
SCALE

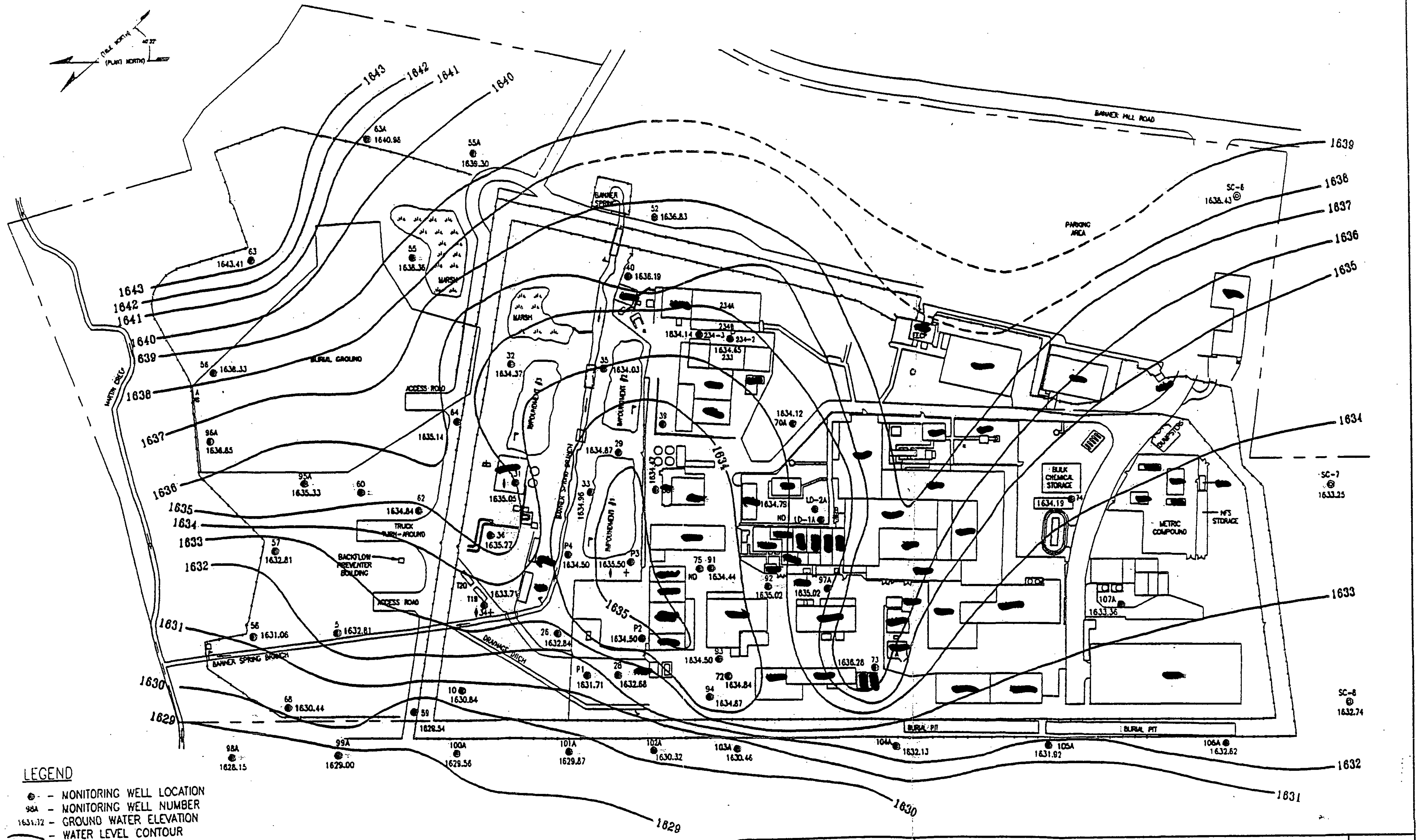
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Cobble/Boulder Zone Isopach Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 2-6

/ DRAWING NO.: 0795-30138 d / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



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[redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted]

REFERENCE: Advanced Recovery Systems First Quarter 1994 Nuclear Fuel Services Groundwater Monitoring Report, July 22, 1994

GERAGHTY & MILLER, INC.
Environmental Services
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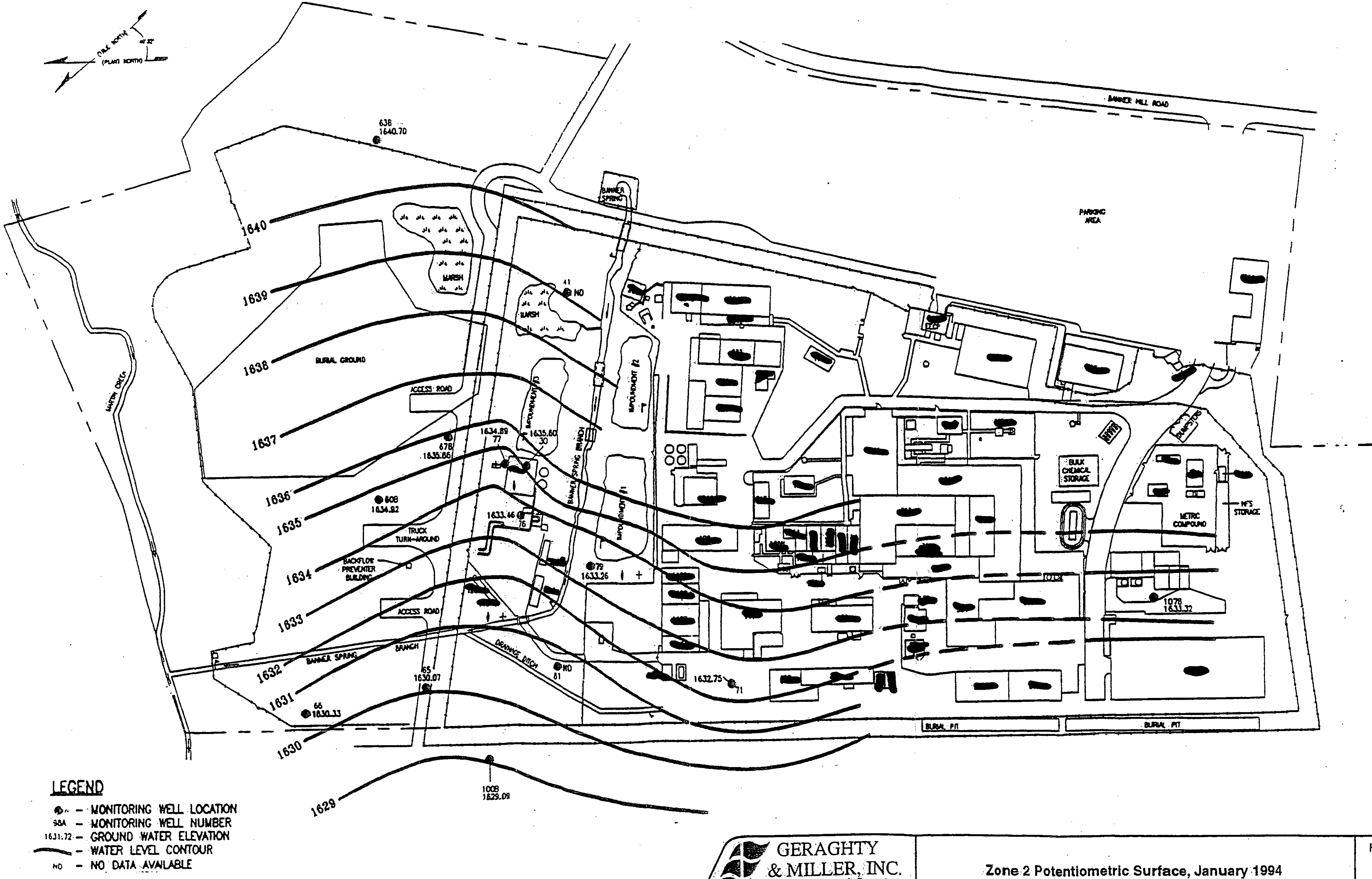
SCALE 0 160 ft

Zone 1 Water-Table Surface, January 1994

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE
2-7



REFERENCE: Advanced Recovery Systems First Quarter 1994 Nuclear Fuel Services Groundwater Monitoring Report, July 22, 1994

GERAGHTY & MILLER, INC.
Environmental Services
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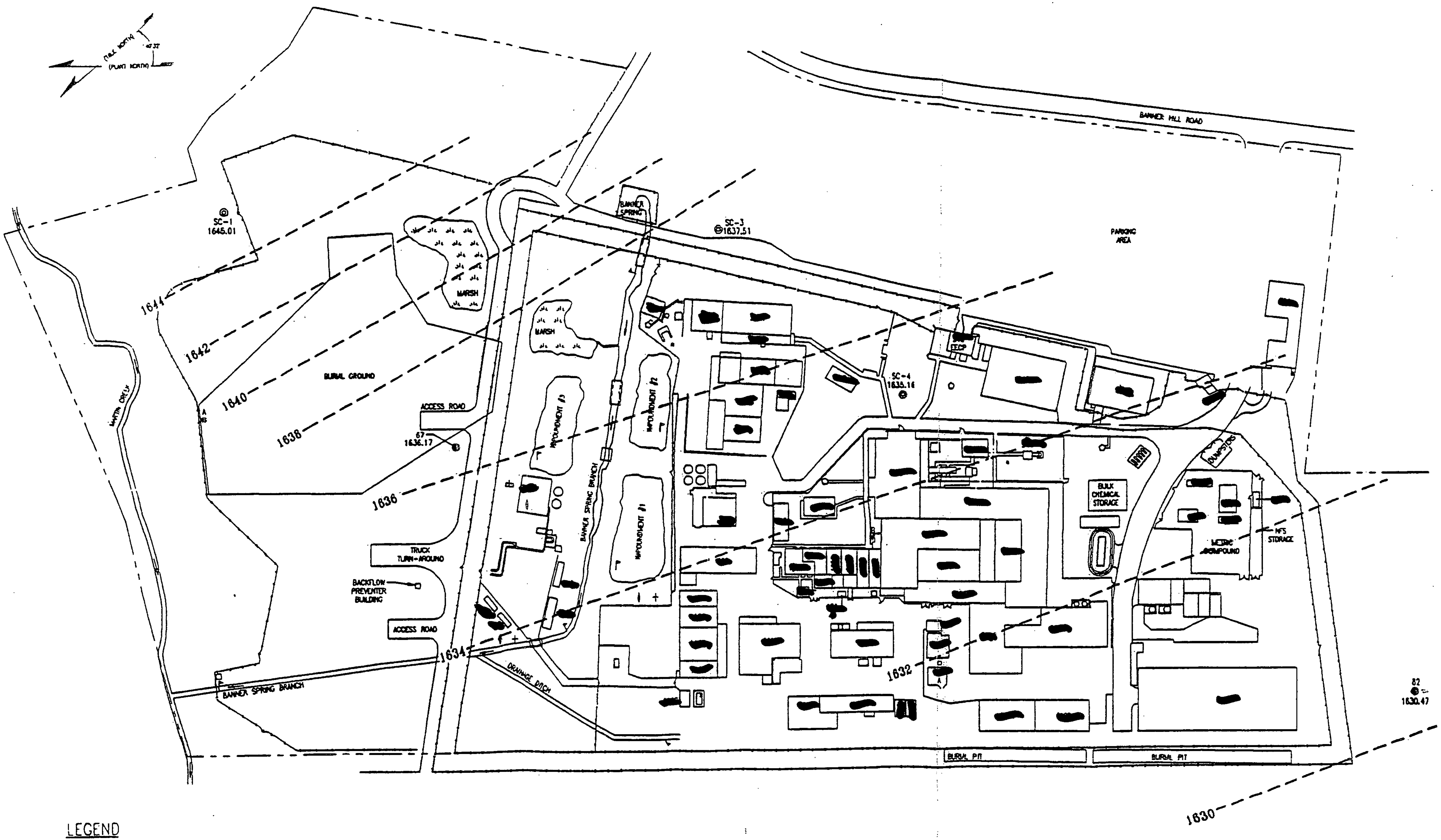
SCALE 0 160 ft

Zone 2 Potentiometric Surface, January 1994

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE
2-8

/ DRAWING NO.: 0795-30136 / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



[redacted]

LEGEND

●	MONITORING WELL LOCATION
98A	MONITORING WELL NUMBER
1631.72	GROUND WATER ELEVATION
———	WATER LEVEL CONTOUR

REFERENCE: Advanced Recovery Systems First Quarter 1994 Nuclear Fuel Services
Groundwater Monitoring Report, July 22, 1994

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

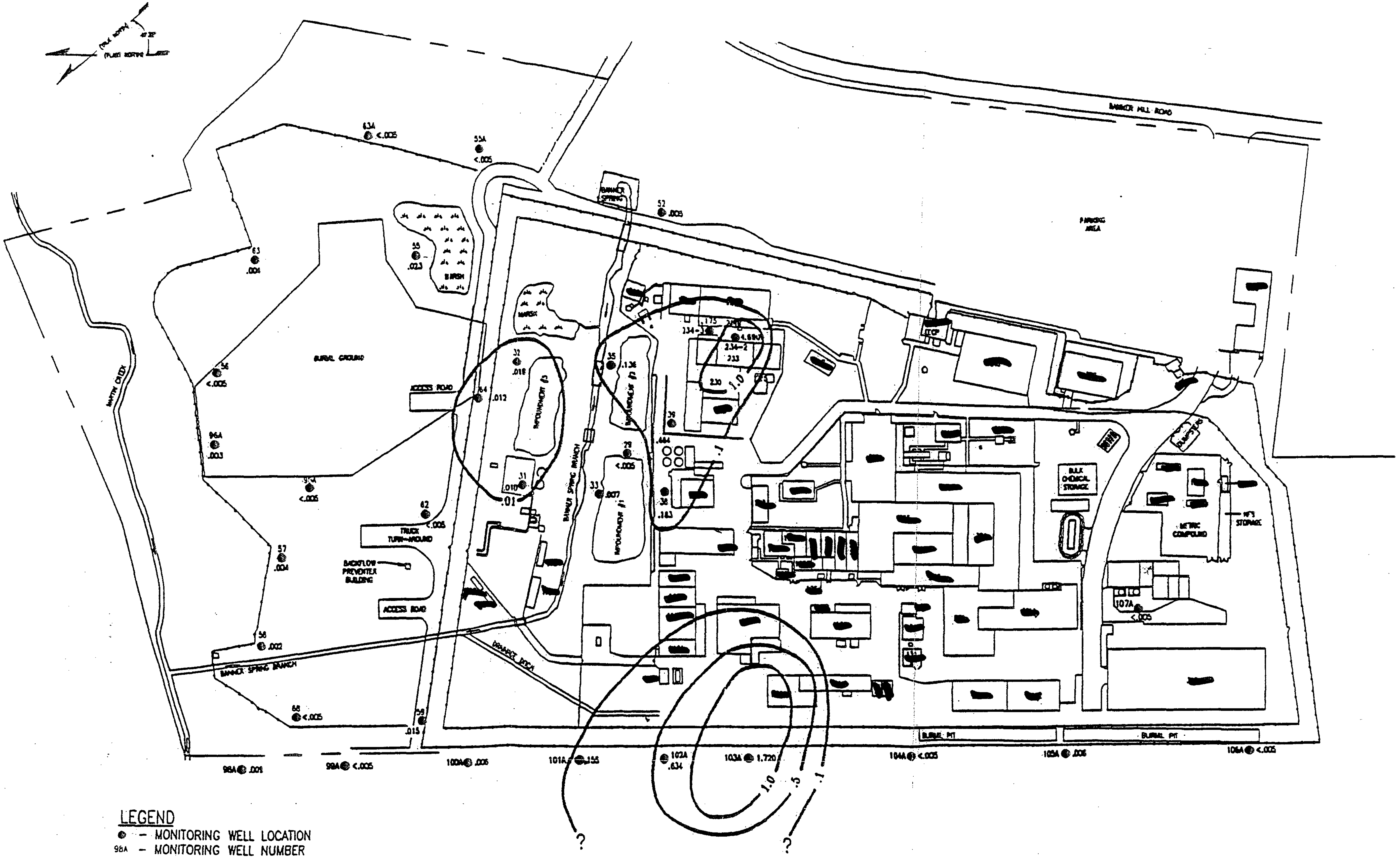
SCALE 0 160 ft

Zone 3 Potentiometric Surface, January 1994

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE
2-9

/ DRAWING NO.: 0785-301361 / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



LEGEND

● – MONITORING WELL LOCATION
98A – MONITORING WELL NUMBER
1.72 – CONCENTRATION
— – ISOCONCENTRATION CONTOUR
MCL = 0.005 mg/L

REFERENCE: Advanced Recovery Systems First Quarter 1994 Nuclear Fuel Services
Groundwater Monitoring Report, July 22, 1994

DRAWING NO.: 0795-30136 b / DRAWING DATE: 22FEB96 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /

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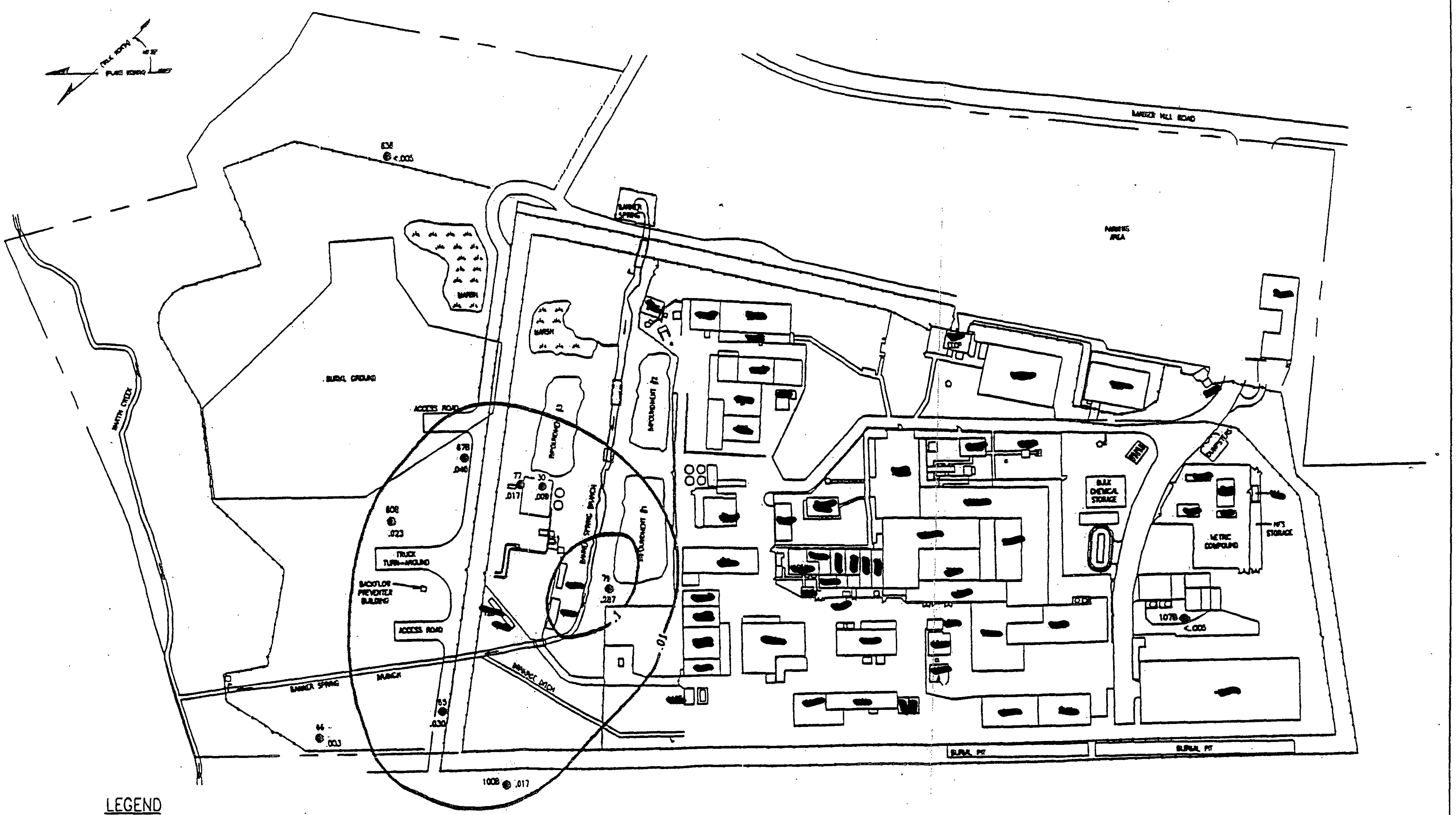
SCALE 0 160 ft

1st Quarter 1994 Tetrachloroethylene (PCE) (mg/L)
Zone 1

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE
2-10

/ DRAWING NO.: 0795-30136c / DRAWING DATE: 22FEB9614JUL95 SB / FILE NAME: GW MODEL / PROJECT NO.: 000050.0TN / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



LEGEND

- ● – MONITORING WELL LOCATION
- 98A – MONITORING WELL NUMBER
- .003 – CONCENTRATION
- ⁀ – ISOCONCENTRATION CONTOUR

MCL = 0.005 mg/L

REFERENCE: Advanced Recovery Systems First Quarter 1994 Nuclear Fuel Services Groundwater Monitoring Report, July 22, 1994

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

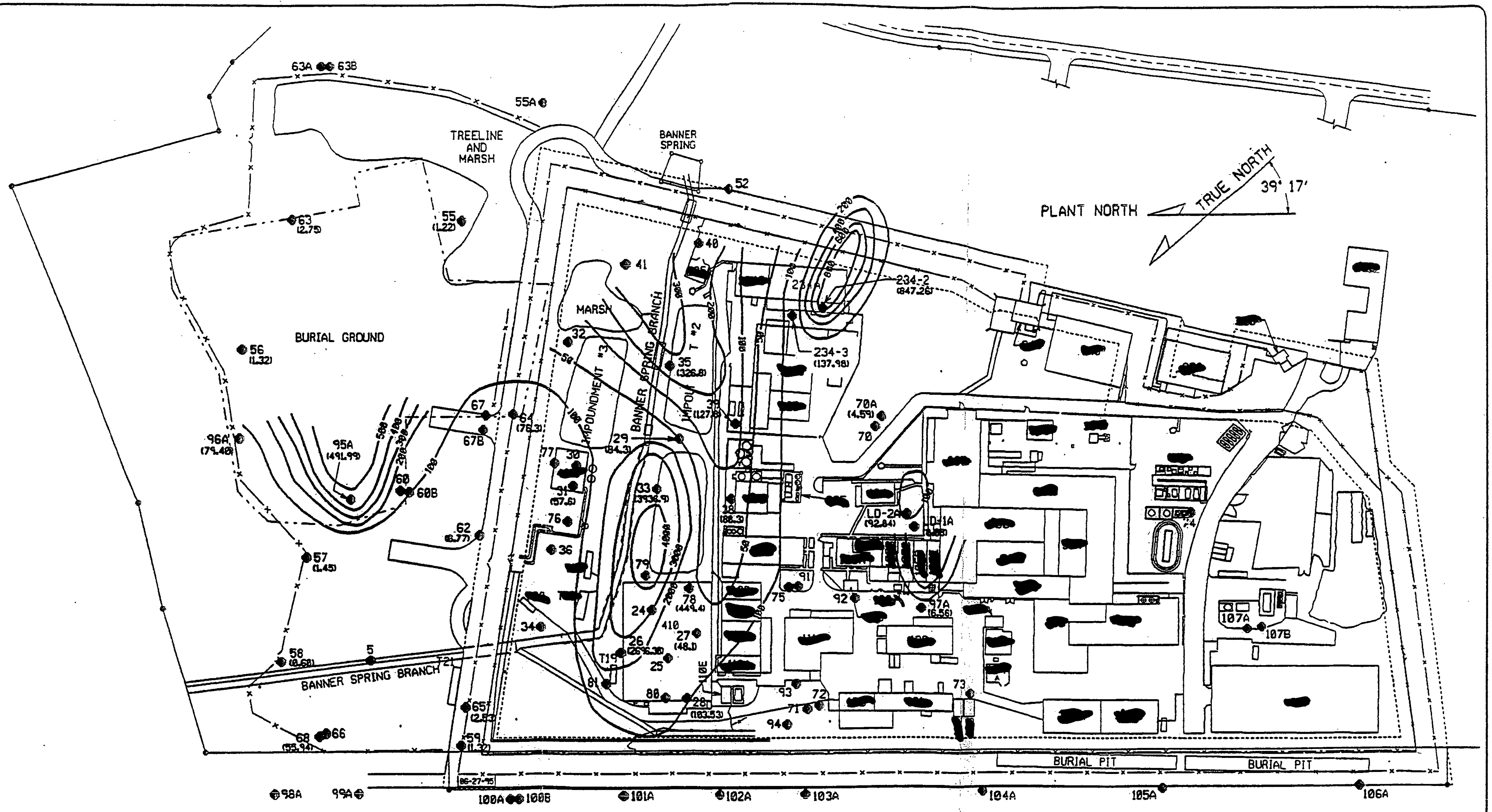
SCALE 0 160 ft

1st Quarter 1994 Tetrachloroethylene (PCE) (mg/L)
Zone 2

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE 2-11

/ DRAWING NO.: 0785-30138R a / DRAWING DATE: 12JUL95 SB / FILE NAME: CONCEPTUAL MODEL / PROJECT NO.: TN0333.001 / / PROJECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



LEGEND

● - MONITORING WELL LOCATION

REFERENCE: ECOTEK, Inc., RCRA Facility Investigation Report for SWMUs 2, 4, and 6 at Nuclear Fuel Services, Inc. Erwin, Tennessee March 29, 1994

GERAGHTY & MILLER, INC.
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SCALE 0 150 feet

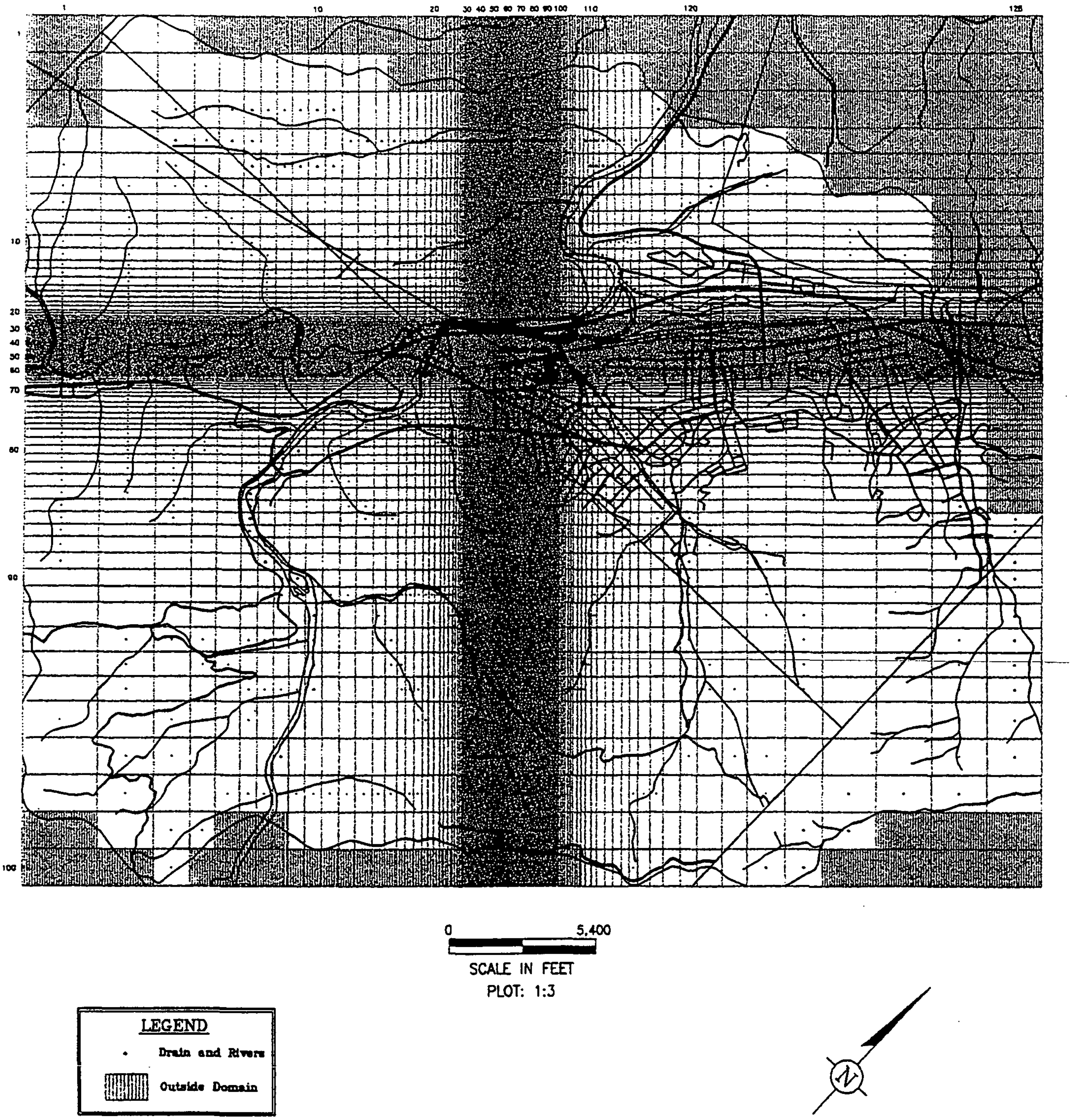
Total Uranium Concentrations (Filtered) in SWMUs 2, 4, and 6

Nuclear Fuel Sevices, Inc. Erwin, Tennessee

FIGURE

2-12

DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30139.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 10CT95 SB



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Environmental Services
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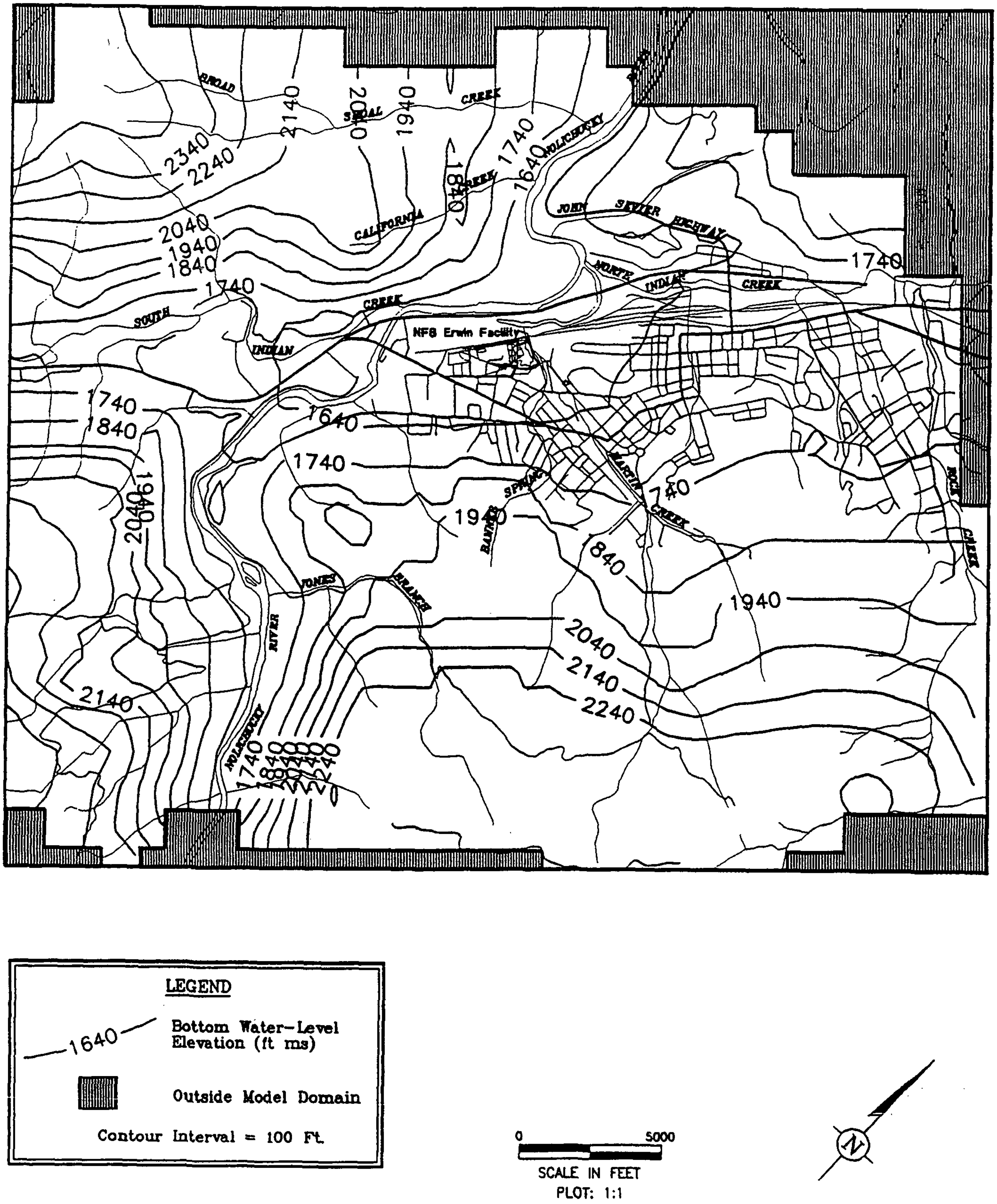
Finite Difference Mesh and Boundary Conditions

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-1



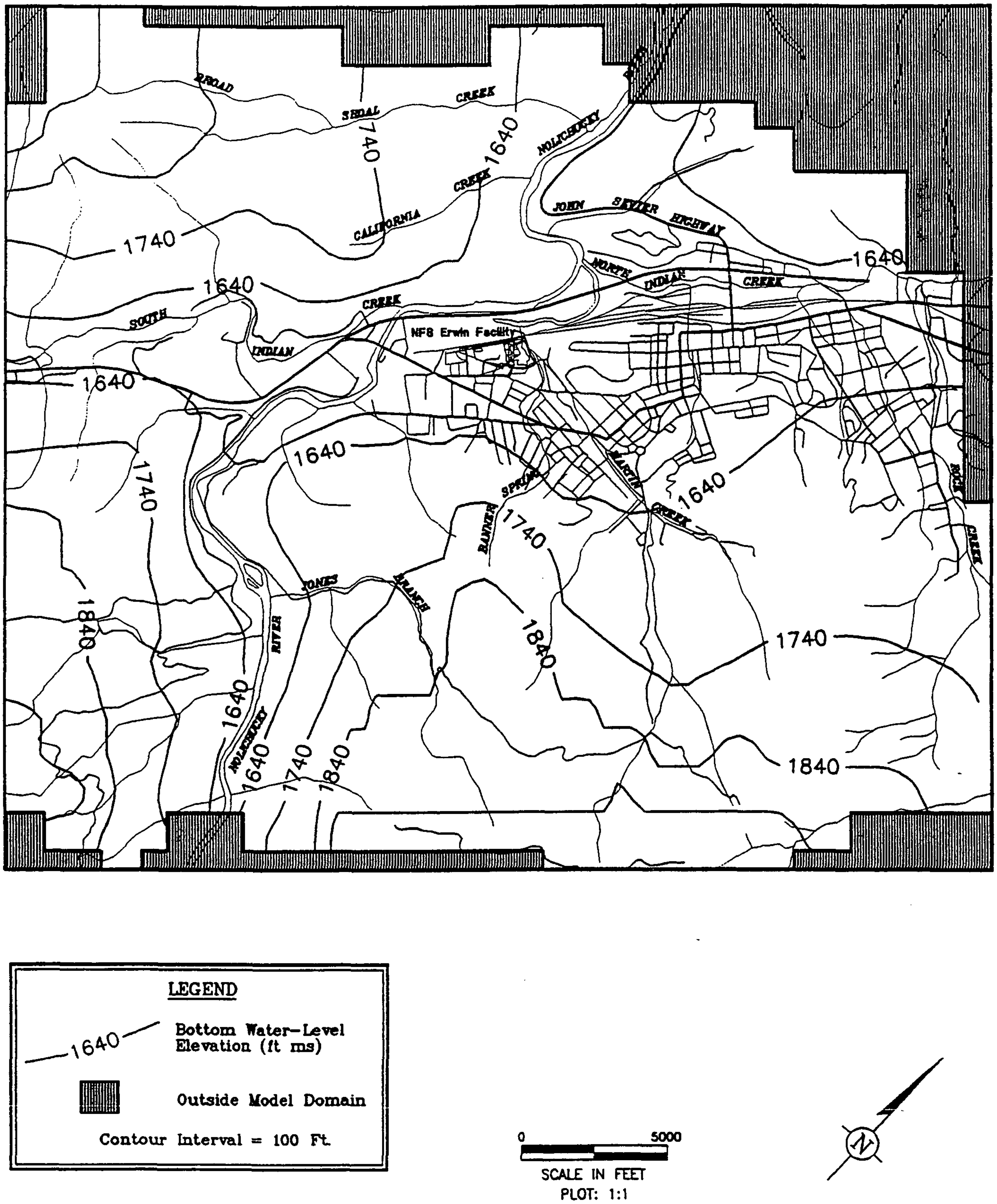
DRAFTER: J. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30130.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 22FEB96 SB

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Contour Map of Bottom Elevations for Model Layer 1

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 3-2



DRAFTER: J. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D3013...DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 2..EB96 SB

GERAGHTY & MILLER, INC.
Environmental Services
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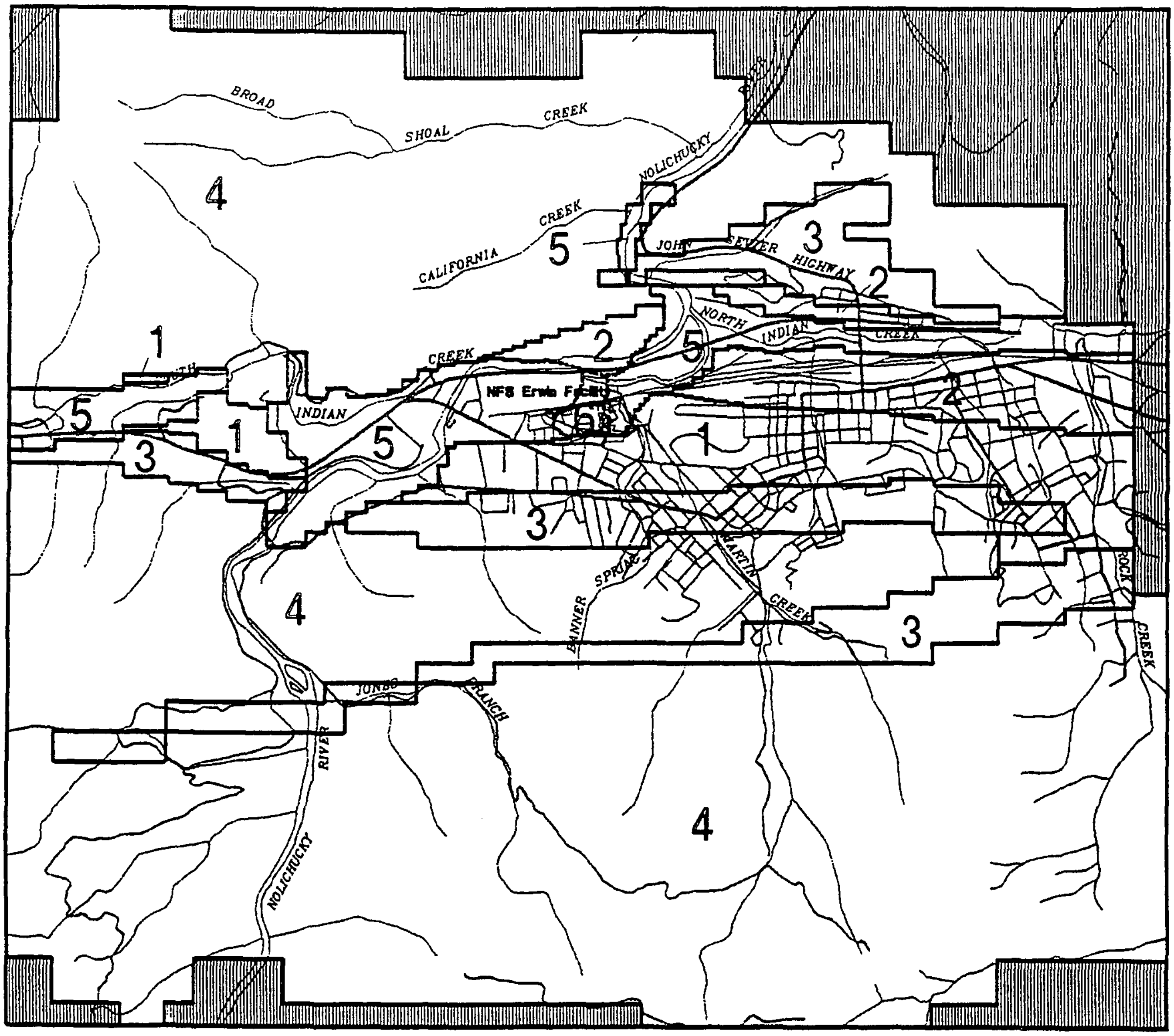
Contour Map of Bottom Elevations for Model Layer 2

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-3



LEGEND

Zone	K_X (ft/d)	K_Y (ft/d)	K_Z (ft/d)	Formation
1	12	8	1	Rome
2	8	4	.8	Honaker
3	4	2	.2	Shady
4	.04	.02	.02	Erwin, Hampton, Unicoi, Snowbird
5	5	5	.5	Zone 1 Alluvium
6	25	25	2.5	Zone 1 Alluvium
▨	Outside Model Domain			

0 5000

SCALE IN FEET

PLOT: 1:1

N

GERAGHTY & MILLER, INC.

Environmental Services

A Heidemij company

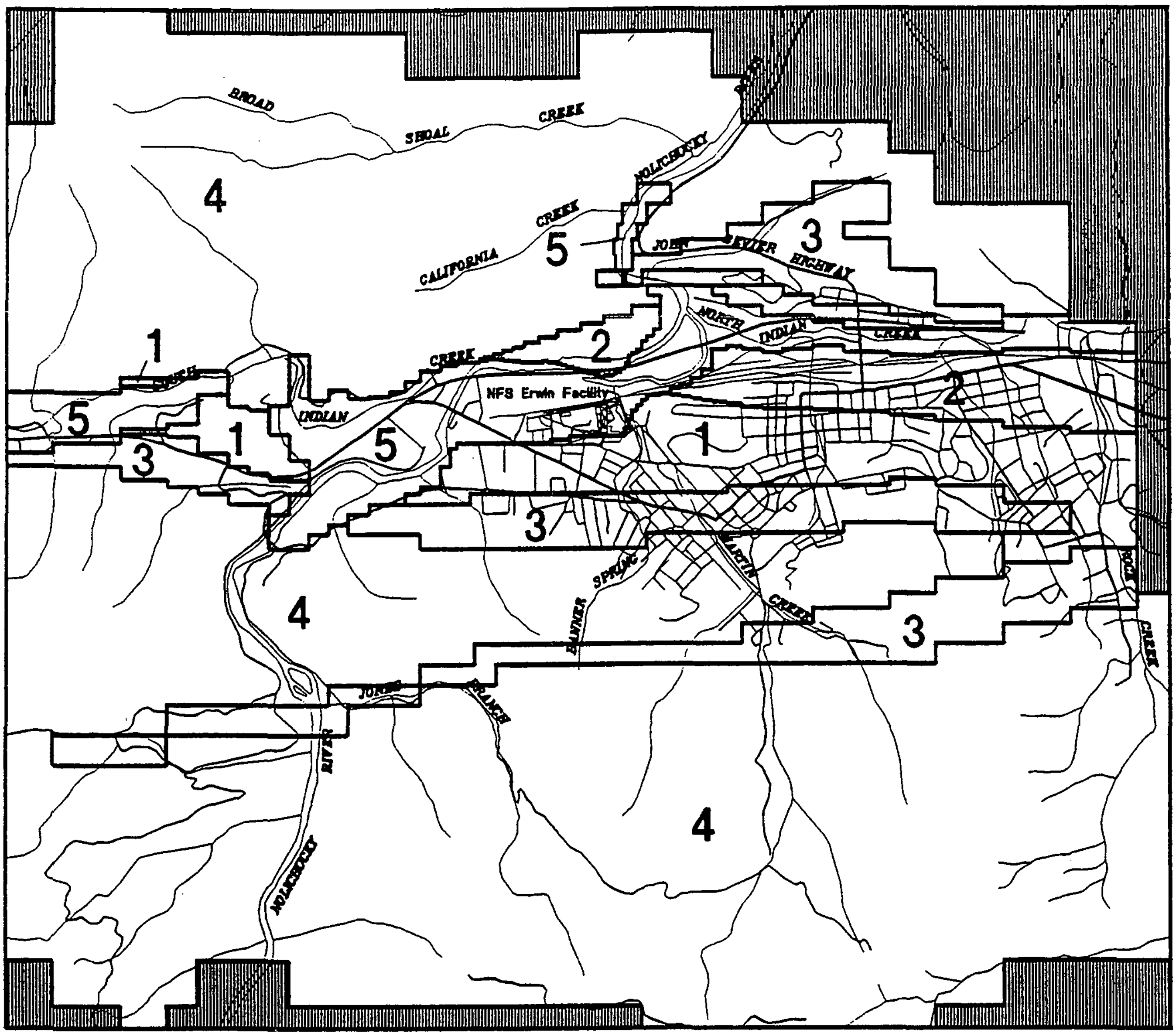
Hydraulic Conductivity Zonation for Model Layer 1

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 3-4

DWG DATE: 27FEB96 SB | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30130c.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: J. BAKER

DWG DATE: 23FEB96 SB | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30130a.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: S. BAKER



LEGEND

Zone	K_X (ft/d)	K_Y (ft/d)	K_Z (ft/d)	Formation
1	12	8	1	Rome
2	8	4	.8	Honaker
3	4	2	.2	Shady
4	.04	.02	.02	Erwin, Hampton, Unicoi, Snowbird
5	15	15	1.5	Cobble Zone
▨				Outside Model Domain

0 5000
SCALE IN FEET
PLOT: 1:1

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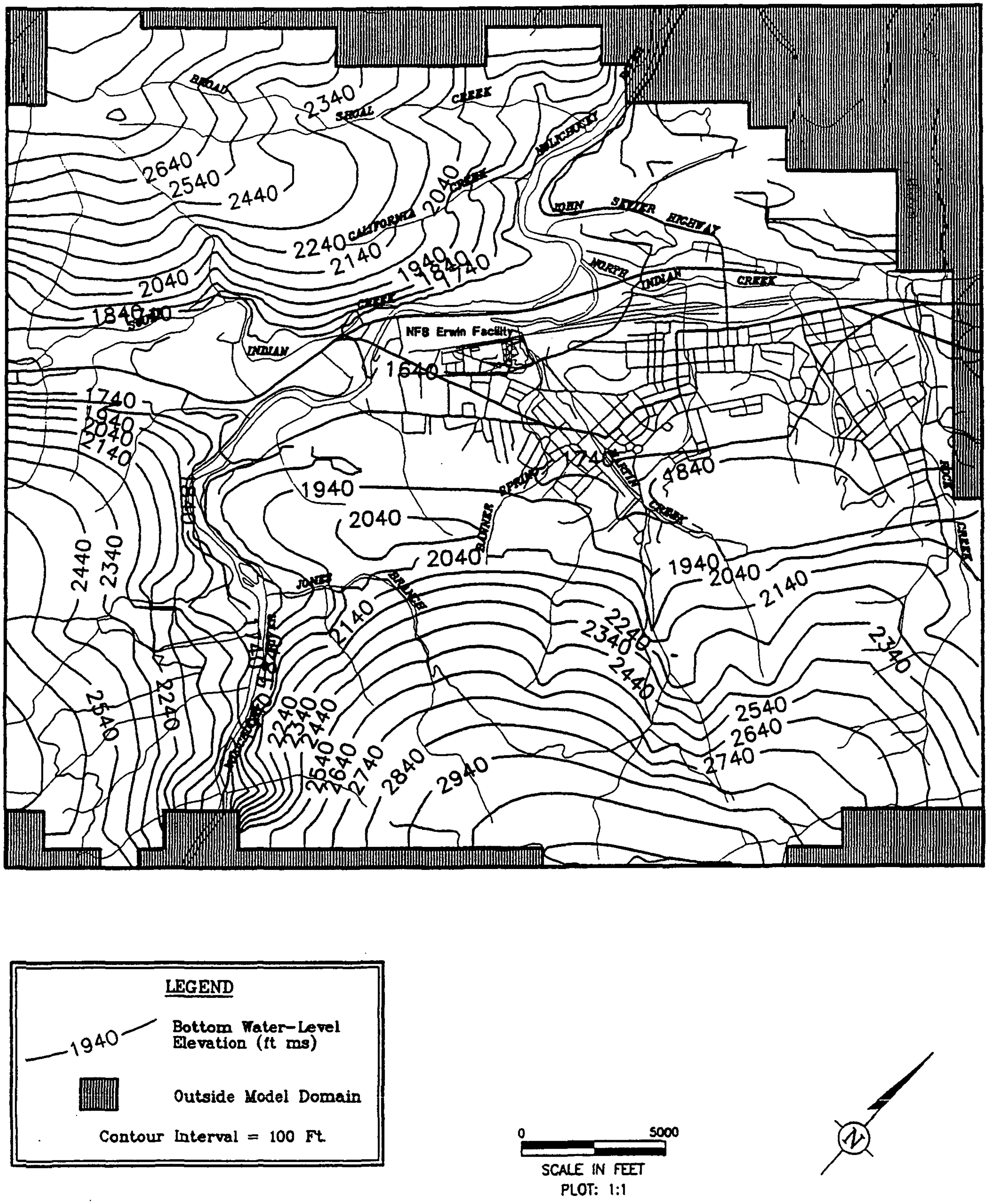
A **Heidemij** company

Hydraulic Conductivity Zonation for Model Layer 2

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-5

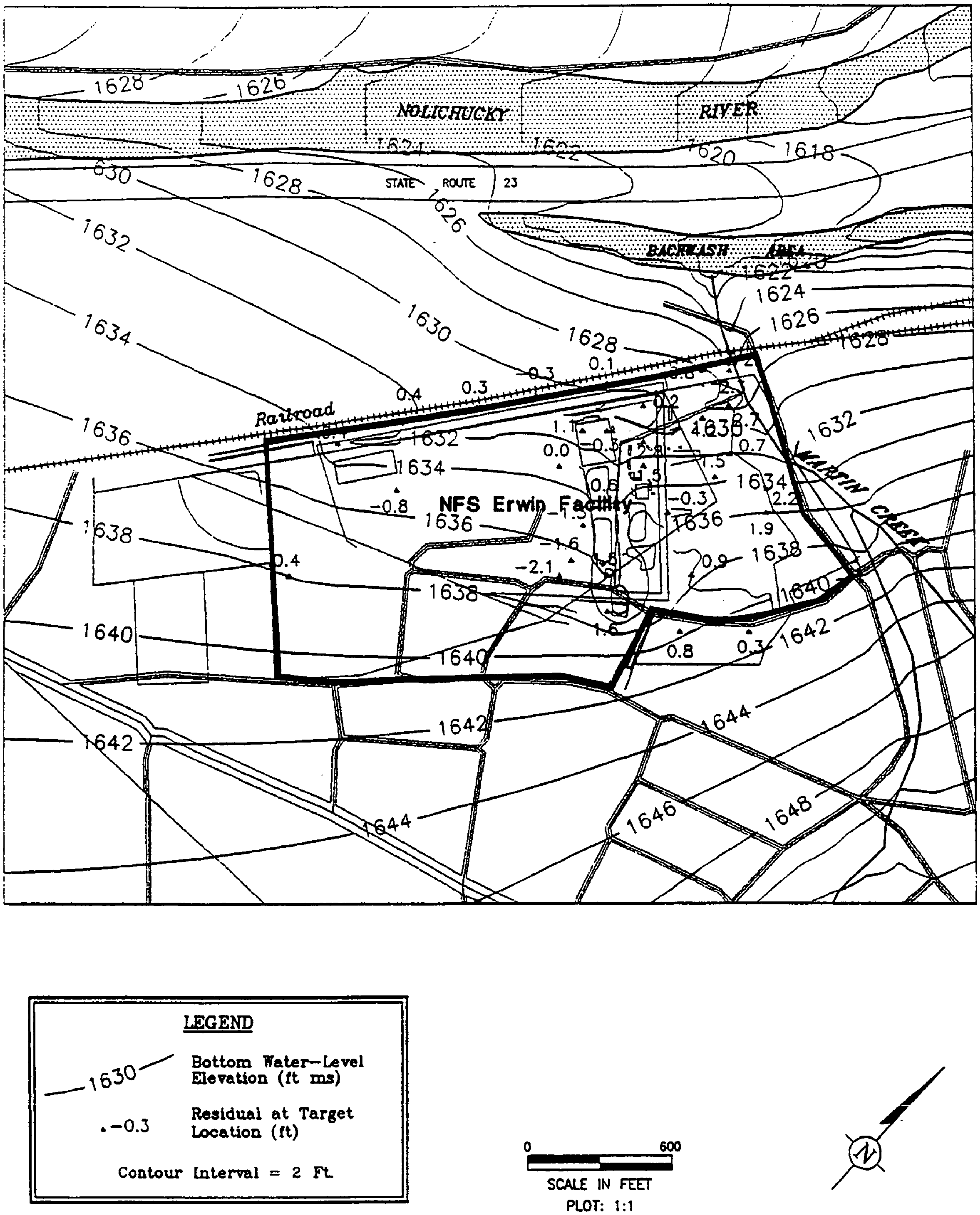


GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Simulated Hydraulic Head Distribution for Model Layer 1

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 3-6



NOTE: New Nolichucky River location digitized from aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

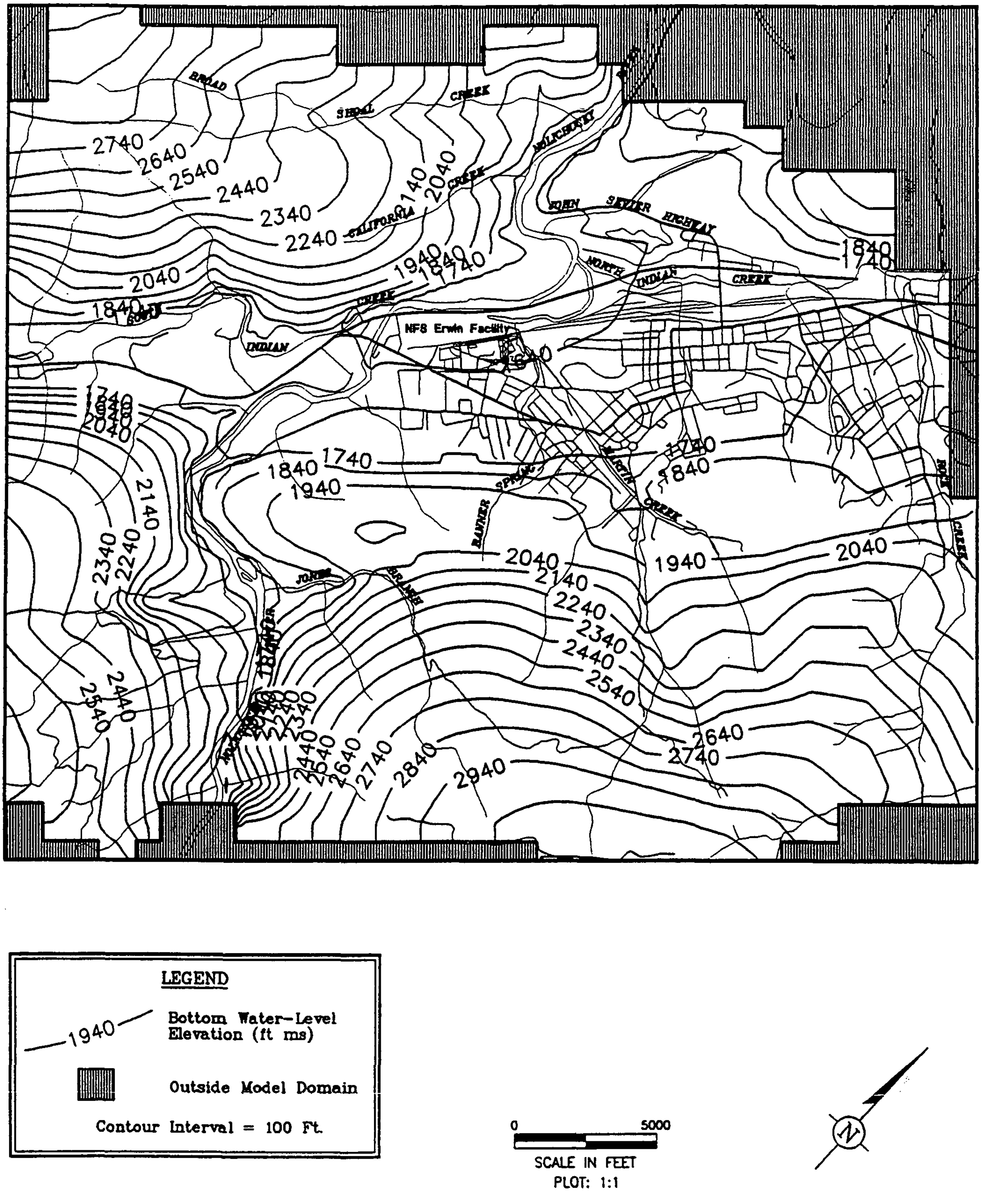
Simulated Hydraulic Head Distribution and Residuals for Model Layer 1

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-7

DWG DATE: 25FEB96 Ba | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30096a.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: S. BAKER

DWG DATE: EB96 SB | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D3013..JWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: J. BAKER



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& MILLER, INC.
Environmental Services
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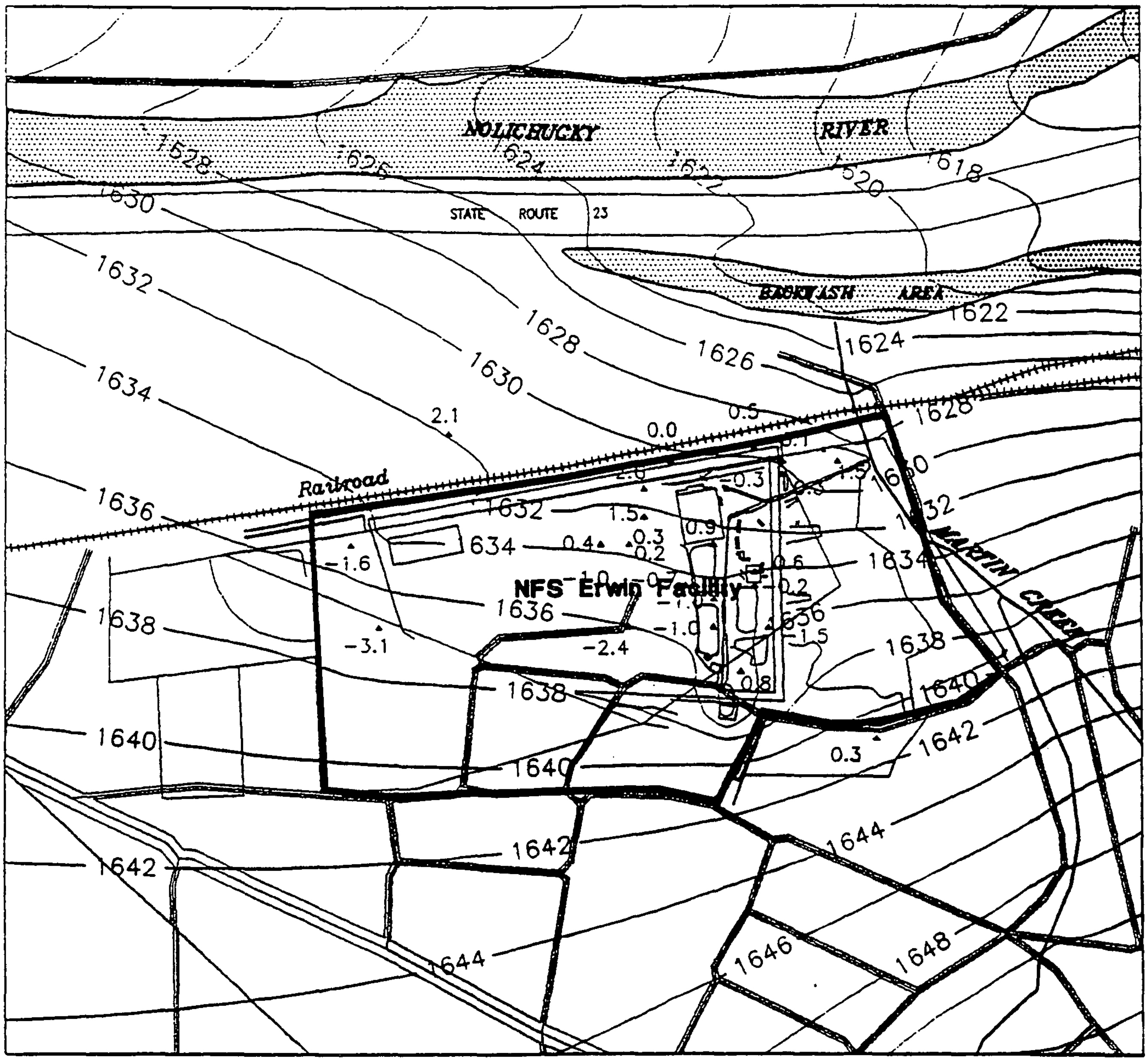
Simulated Hydraulic Head Distribution for Model Layer 2

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-8

DRAFTER: J. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30096b.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 25FEB96 Ba



LEGEND

1630 Bottom Water-Level Elevation (ft ms)

• −0.3 Residual at Target Location (ft)

Contour Interval = 2 Ft.

0 600

SCALE IN FEET

PLOT: 1:1

NOTE: New Nolichucky River location digitized from aerial photograph, 1990.

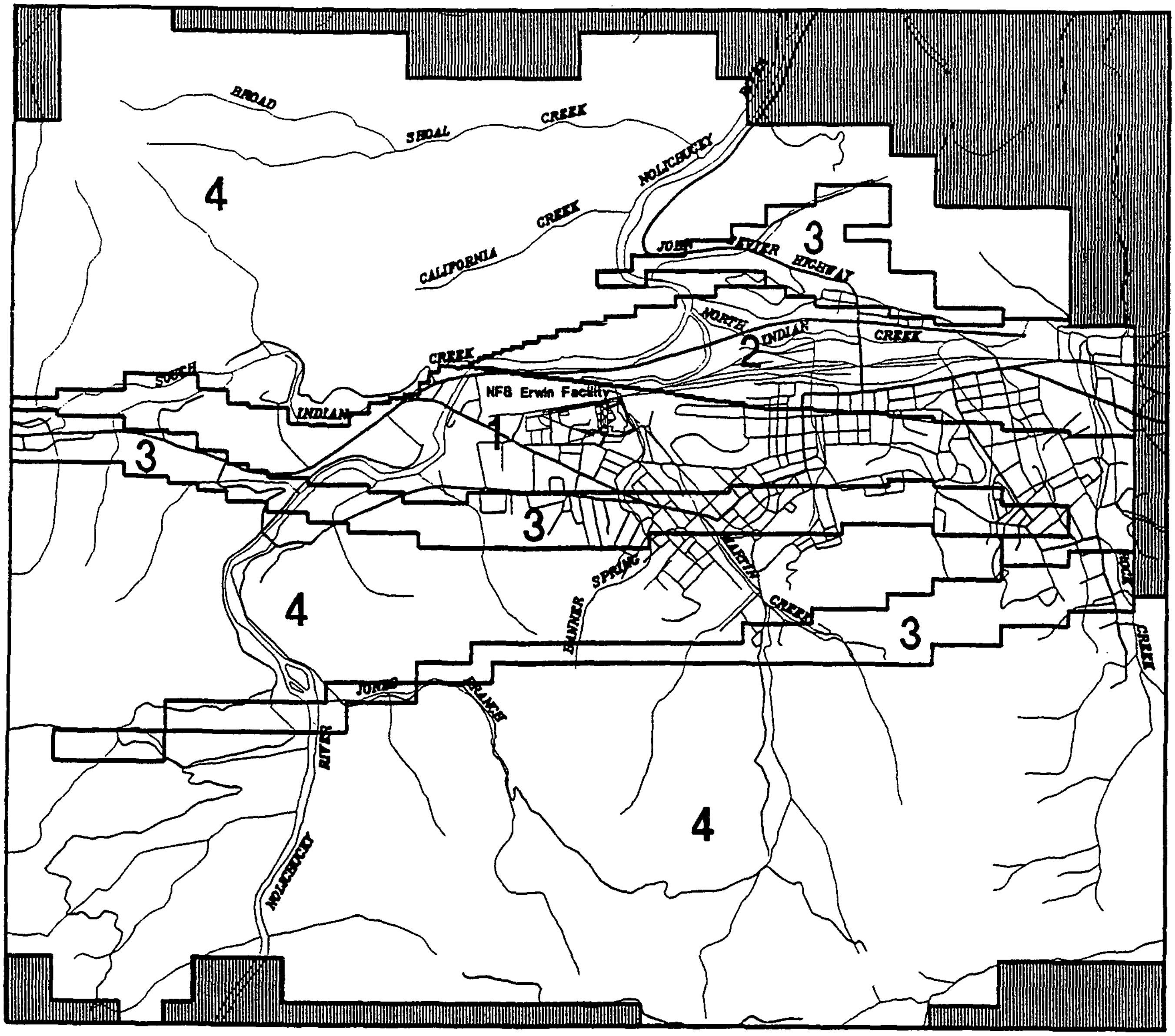
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Hydraulic Head Distribution and Residuals for Model Layer 2

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 3-9

DWG DATE: 23FEB96 SB | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30130g.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: S. BAKER



LEGEND

Zone	K_X (ft/d)	K_Y (ft/d)	K_Z (ft/d)	Formation
1	12	8	1	Rome
2	8	4	.8	Honaker
3	4	2	.2	Shady
4	.04	.02	.02	Erwin, Hampton, Unicoi, Snowbird
▨	Outside Model Domain			

0 5000
SCALE IN FEET
PLOT: 1:1

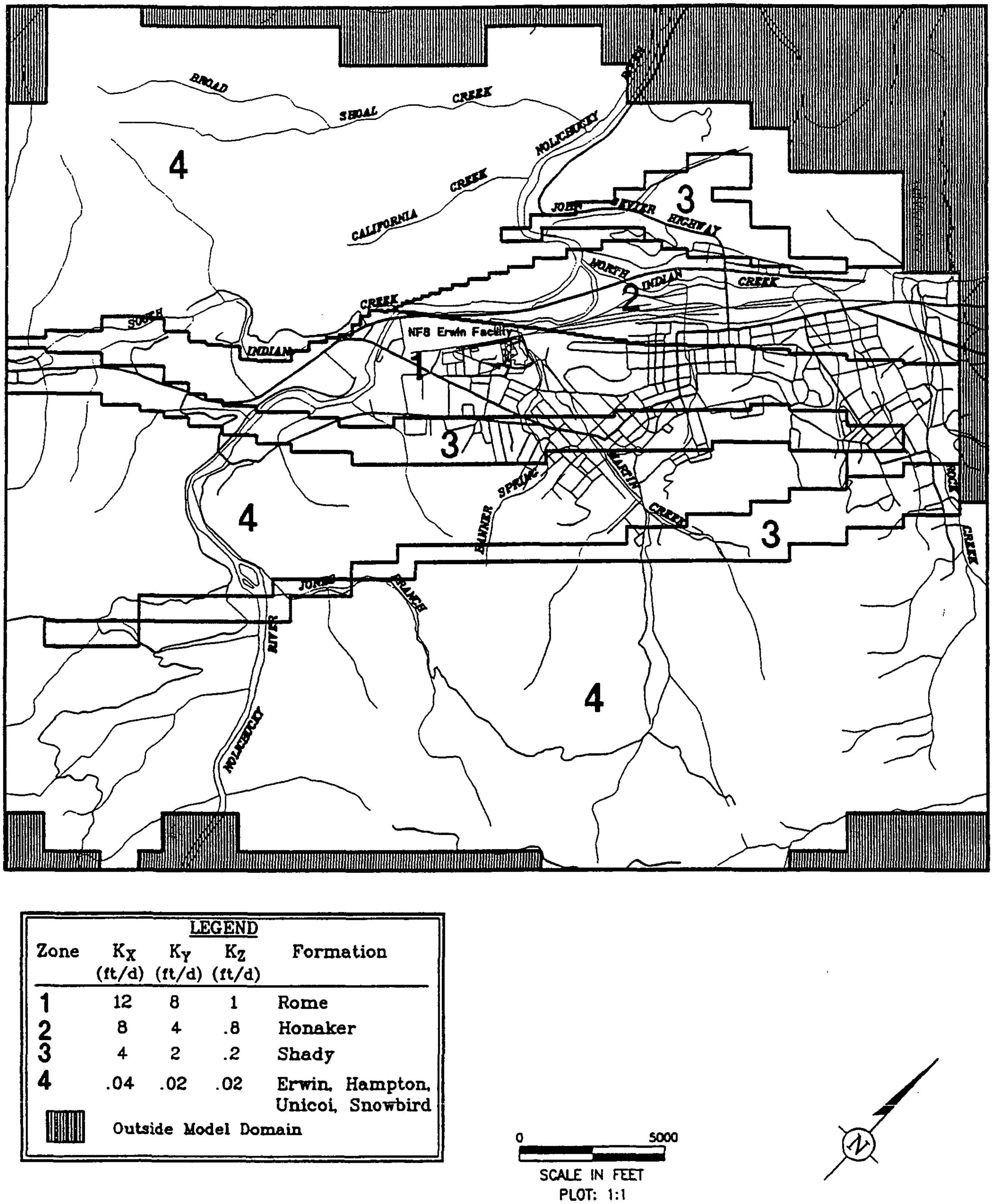
N

GERAGHTY
& MILLER, INC.
Environmental Services
A Heidemij company

Hydraulic Conductivity Zonation for Model Layer 3

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-10



LEGEND

Zone	K_X (ft/d)	K_Y (ft/d)	K_Z (ft/d)	Formation
1	12	8	1	Rome
2	8	4	.8	Honaker
3	4	2	.2	Shady
4	.04	.02	.02	Erwin, Hampton, Unicoi, Snowbird
▥				Outside Model Domain

DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D3013[illegible].DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: [illegible]FEB96 SB

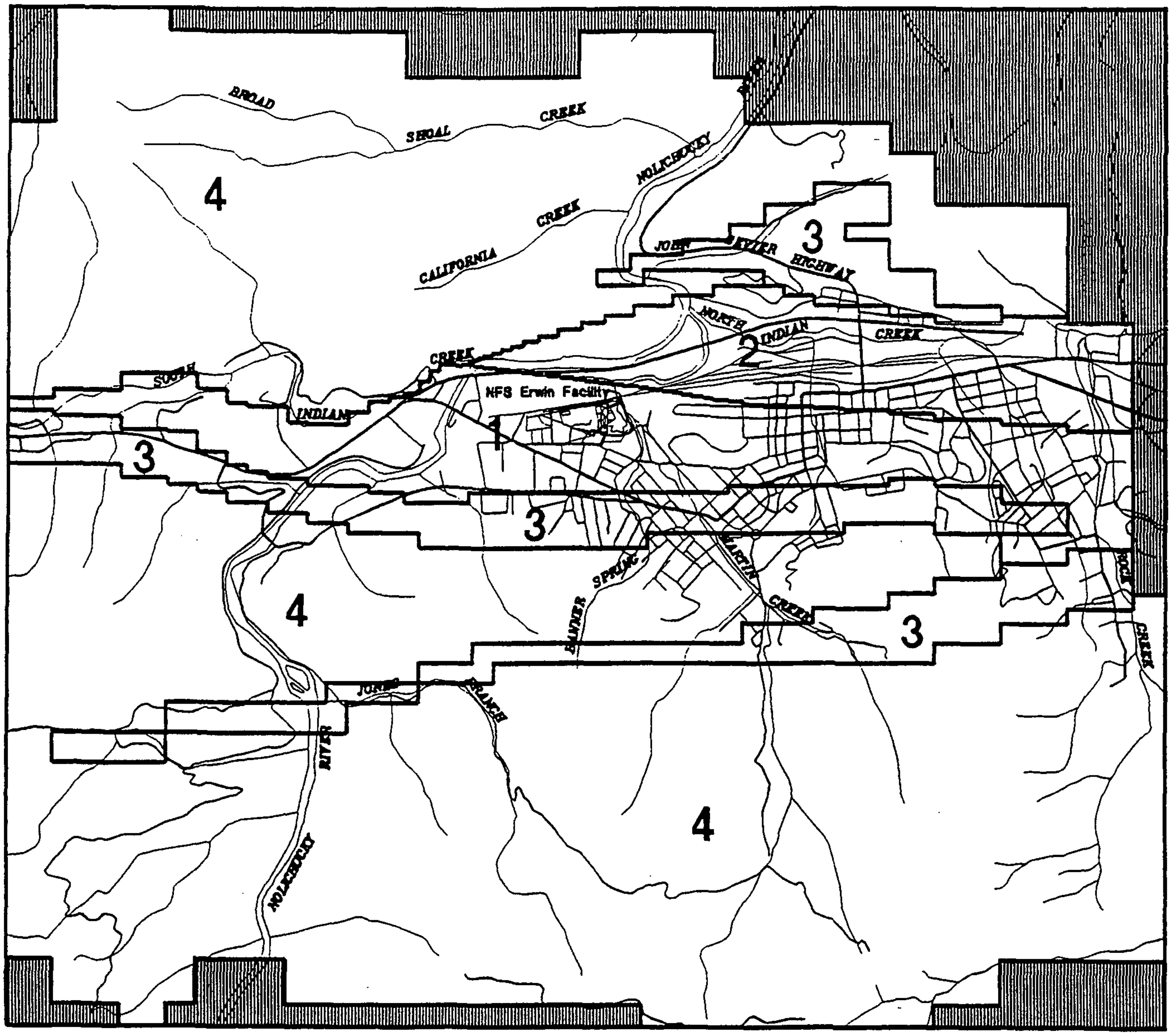
GERAGHTY
& MILLER, INC.
Environmental Services
A **Heidemij** company

Hydraulic Conductivity Zonation for Model Layer 4

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-11

DRAFTER: S. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30130h.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 23FEB96 SB



LEGEND

Zone	K_X (ft/d)	K_Y (ft/d)	K_Z (ft/d)	Formation
1	12	8	1	Rome
2	8	4	.8	Honaker
3	4	2	.2	Shady
4	.04	.02	.02	Erwin, Hampton, Unicoi, Snowbird
▥				Outside Model Domain

0 5000
SCALE IN FEET
PLOT: 1:1

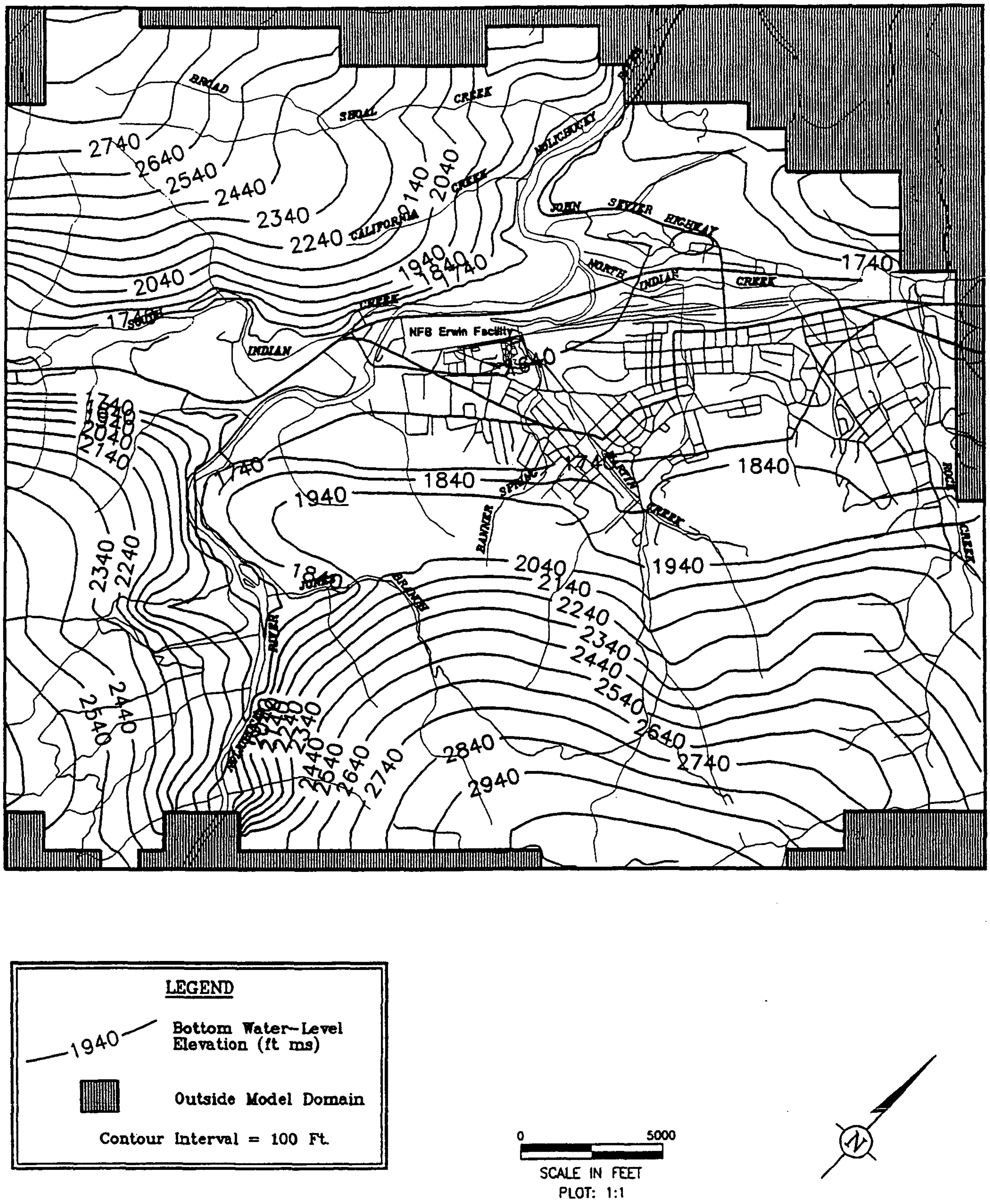
GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Hydraulic Conductivity Zonation for Model Layer 5

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-12

DRAWING: D30130I.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 22FEB96 SB | DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN



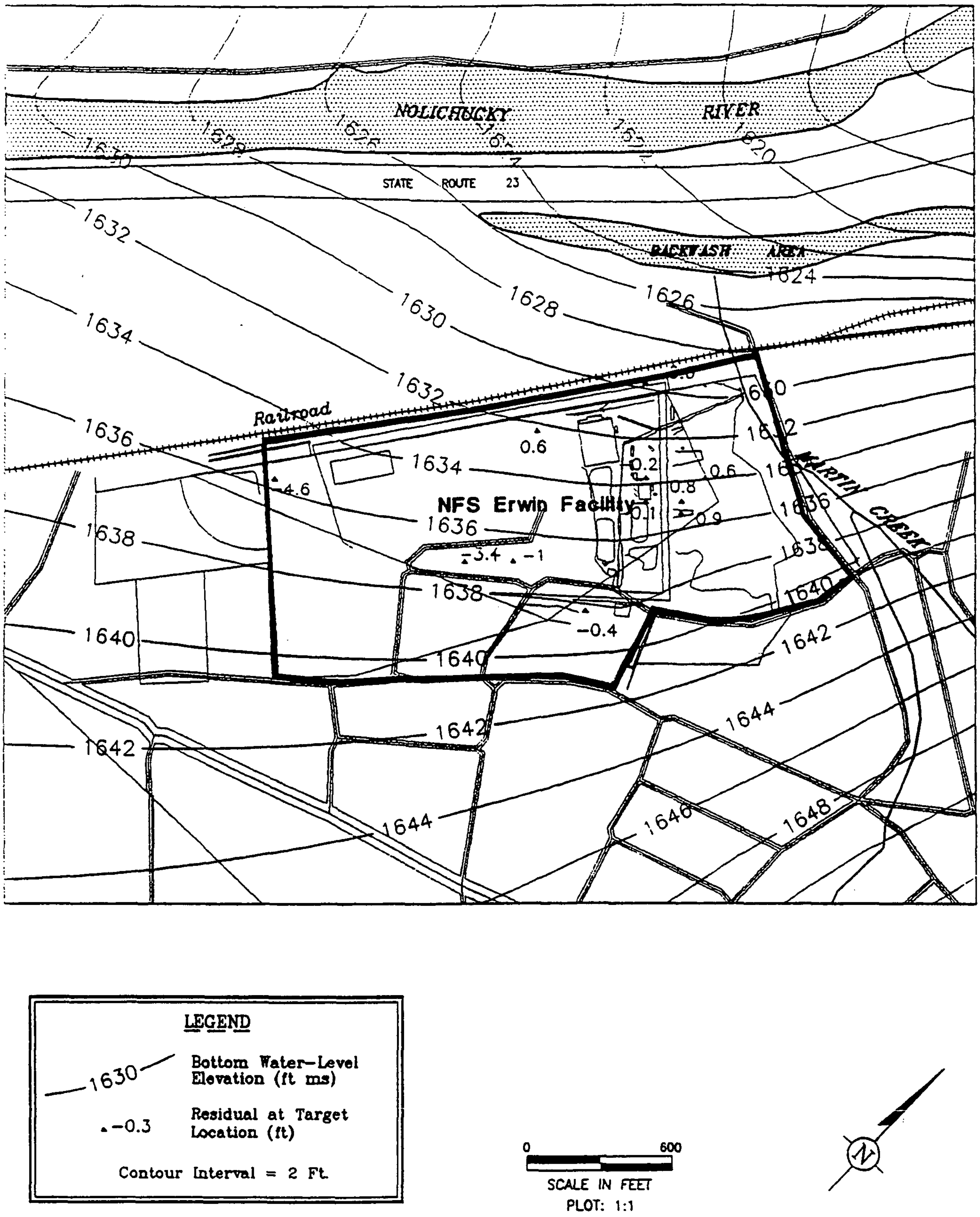
GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Simulated Hydraulic Head Distribution for Model Layer 3

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-13

DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30096c.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 25FEB96 Ba



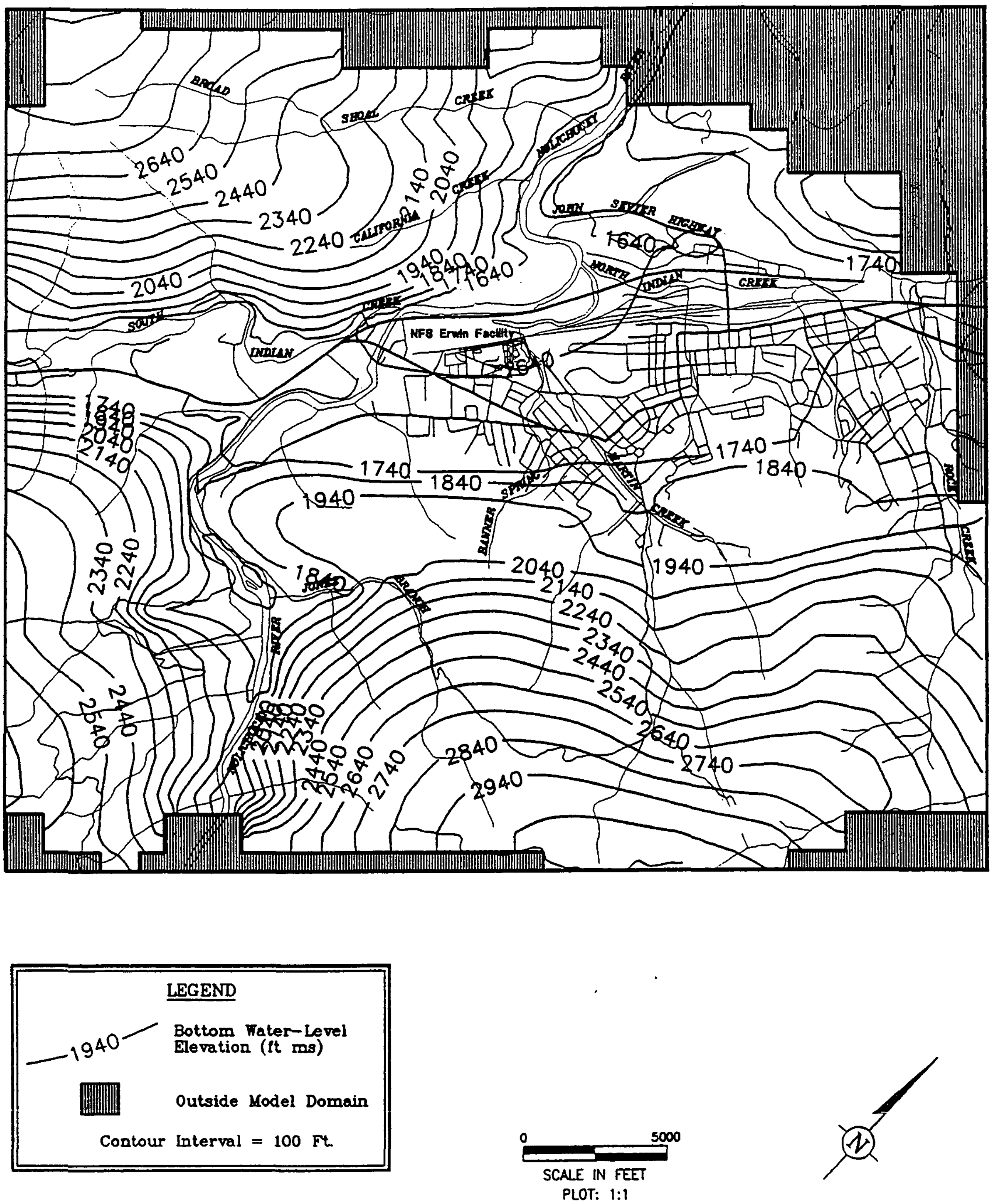
NOTE: New Nolichucky River location digitized from aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Hydraulic Head Distribution and Residuals for Model Layer 3

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-14



DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30130J.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 22FEB96 SB

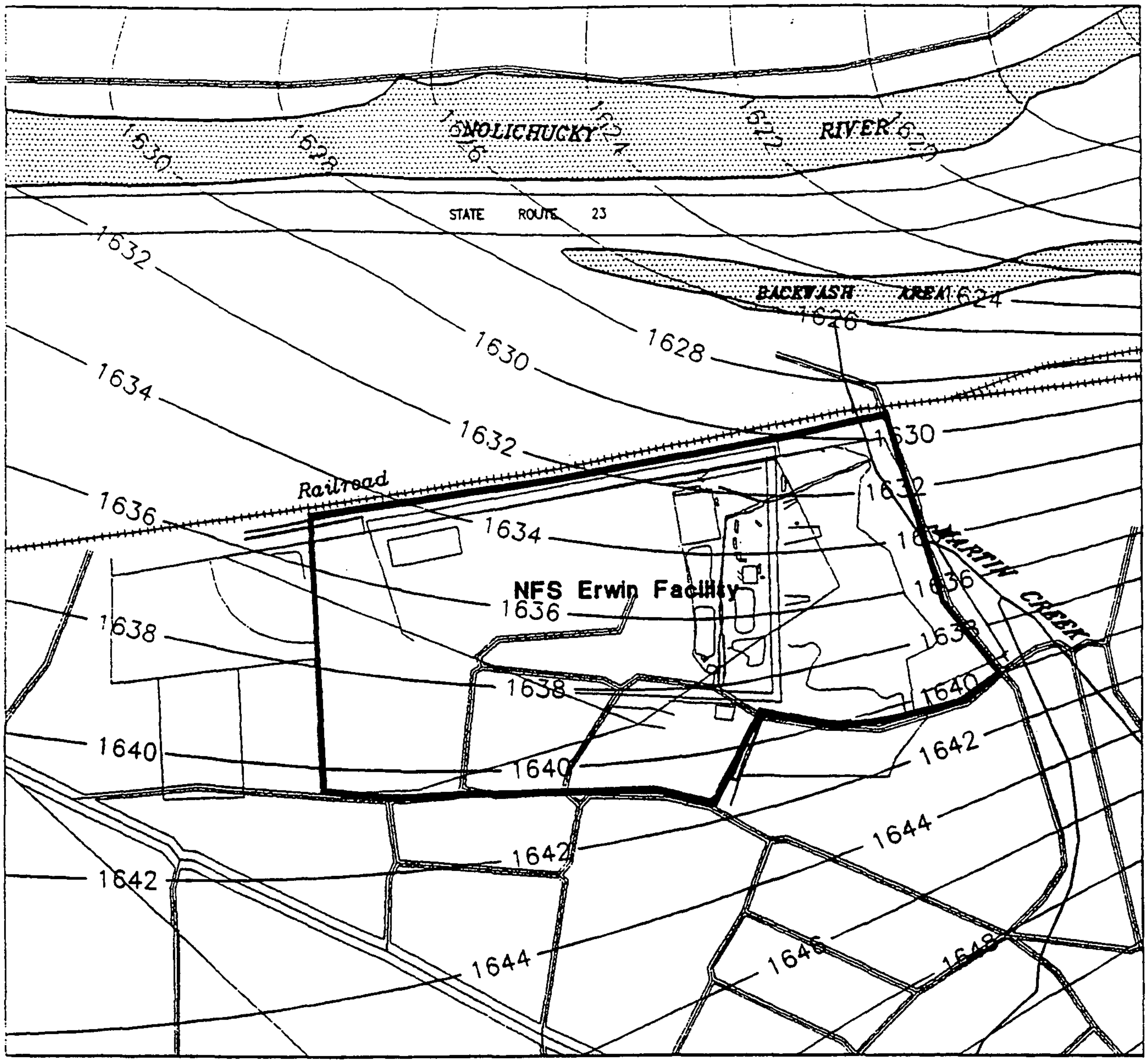
GERAGHTY
& MILLER, INC.
Environmental Services
A **Heidemij** company

Simulated Hydraulic Head Distribution for Model Layer 4

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-15

DRAFTER: . BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30096[illegible].DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 25FEB96 Ba



LEGEND

1630 Bottom Water-Level Elevation (ft ms)

Contour Interval = 2 Ft.

0 600
SCALE IN FEET
PLOT: 1:1

N

NOTE: New Nolichucky River location digitized from aerial photograph, 1990.

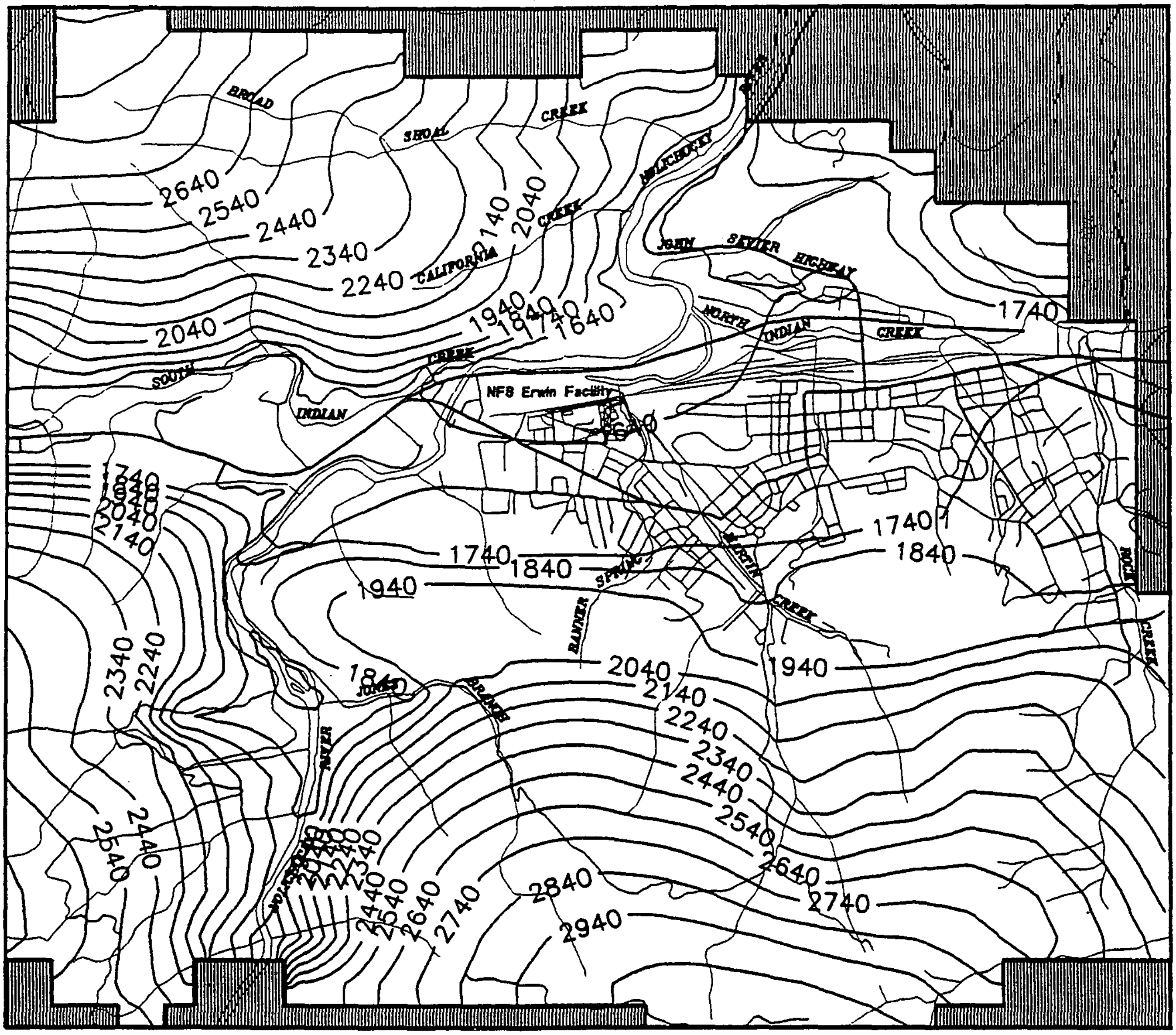
GERAGHTY
& MILLER, INC.
Environmental Services
A Heidemij company

Simulated Hydraulic Head Distribution and Residuals for Model Layer 4

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-16

DWG DATE: 22FEB96 SB | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30130K.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: BAKER



LEGEND

1940 — Bottom Water-Level Elevation (ft ms)

▨ Outside Model Domain

Contour Interval = 100 Ft.

0 5000

SCALE IN FEET
PLOT: 1:1

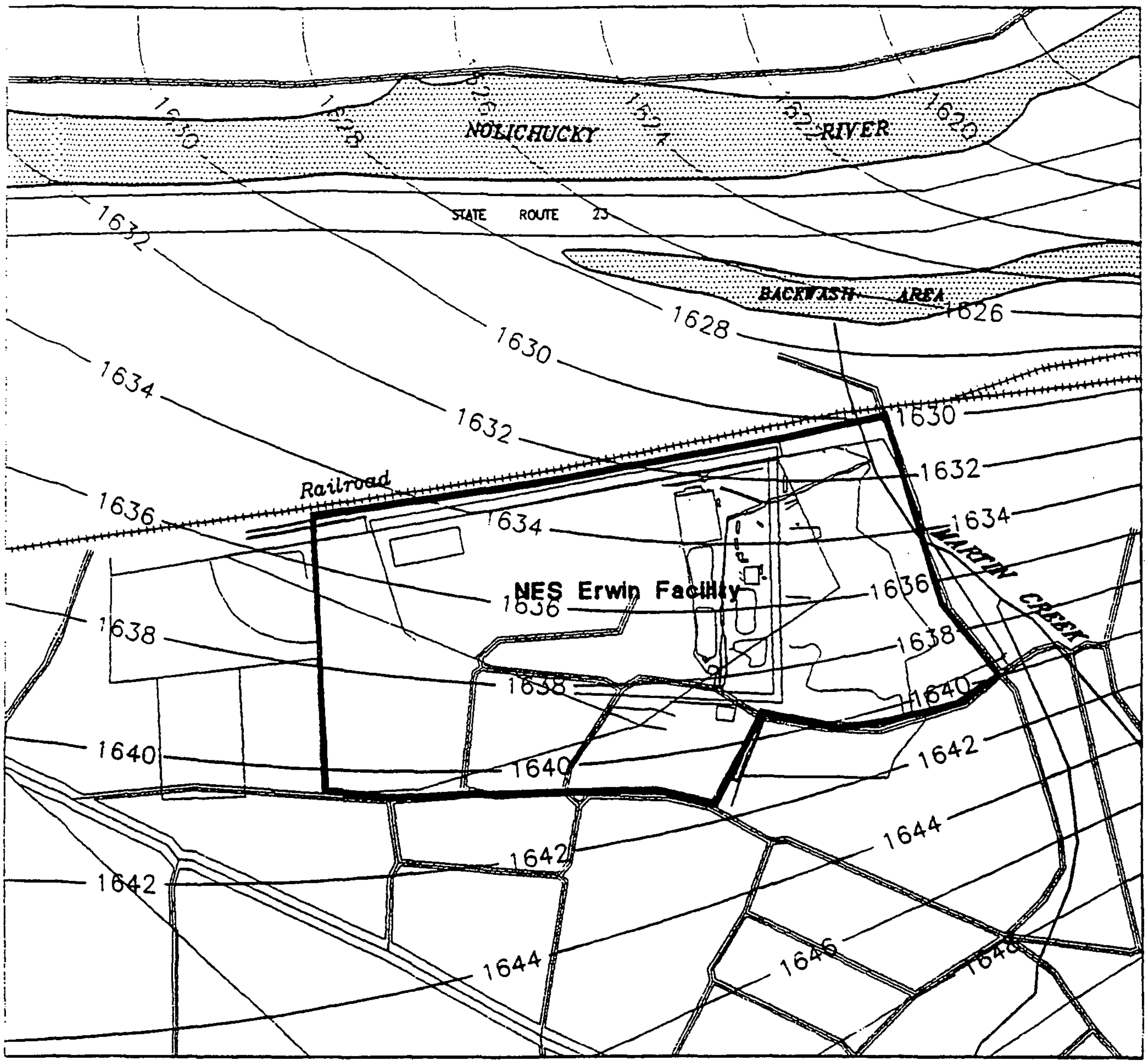
N

GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Simulated Hydraulic Head Distribution for Model Layer 5

Nuclear Fuel Service, Inc. Erwin, Tennessee

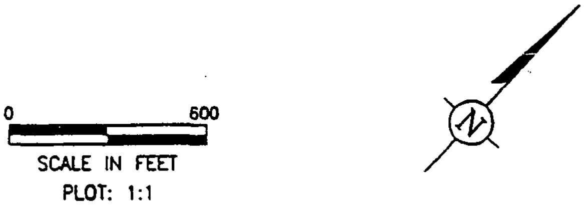
FIGURE
3-17



LEGEND

1630 Bottom Water-Level Elevation (ft ms)

Contour Interval = 2 Ft.



NOTE: New Nolichucky River location digitized from aerial photograph, 1990.

DRAFTER: [illegible] BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30096e.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 25FEB96 Ba

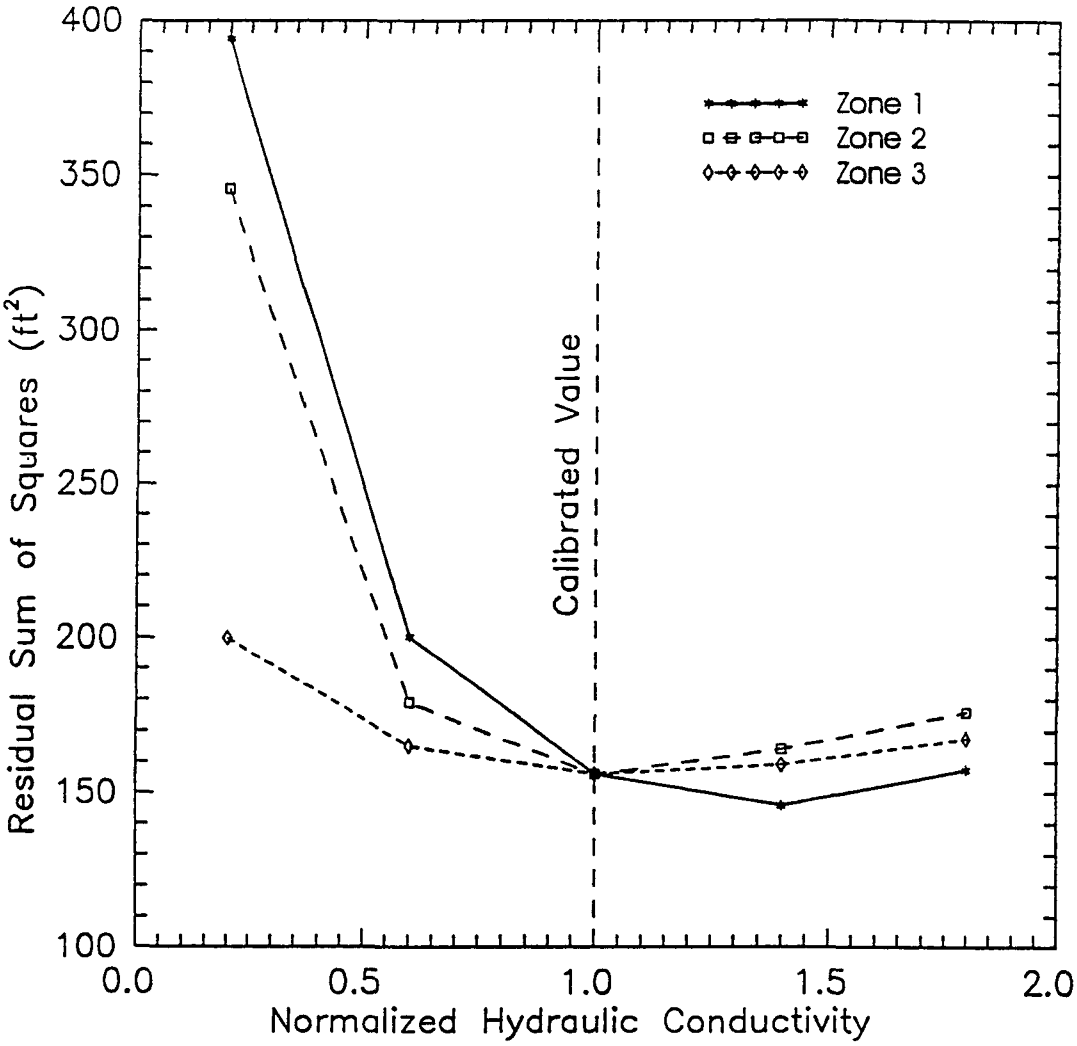
GERAGHTY
& MILLER, INC.
Environmental Services
A Heidemij company

Simulated Hydraulic Head Distribution and Residuals for Model Layer 5

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-18

DRAFTER: BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D20192.[illegible]
FILE: MODEL REPT
PROJ. NO.: TN0333.001
DWG DATE: 18[illegible]T95 SB



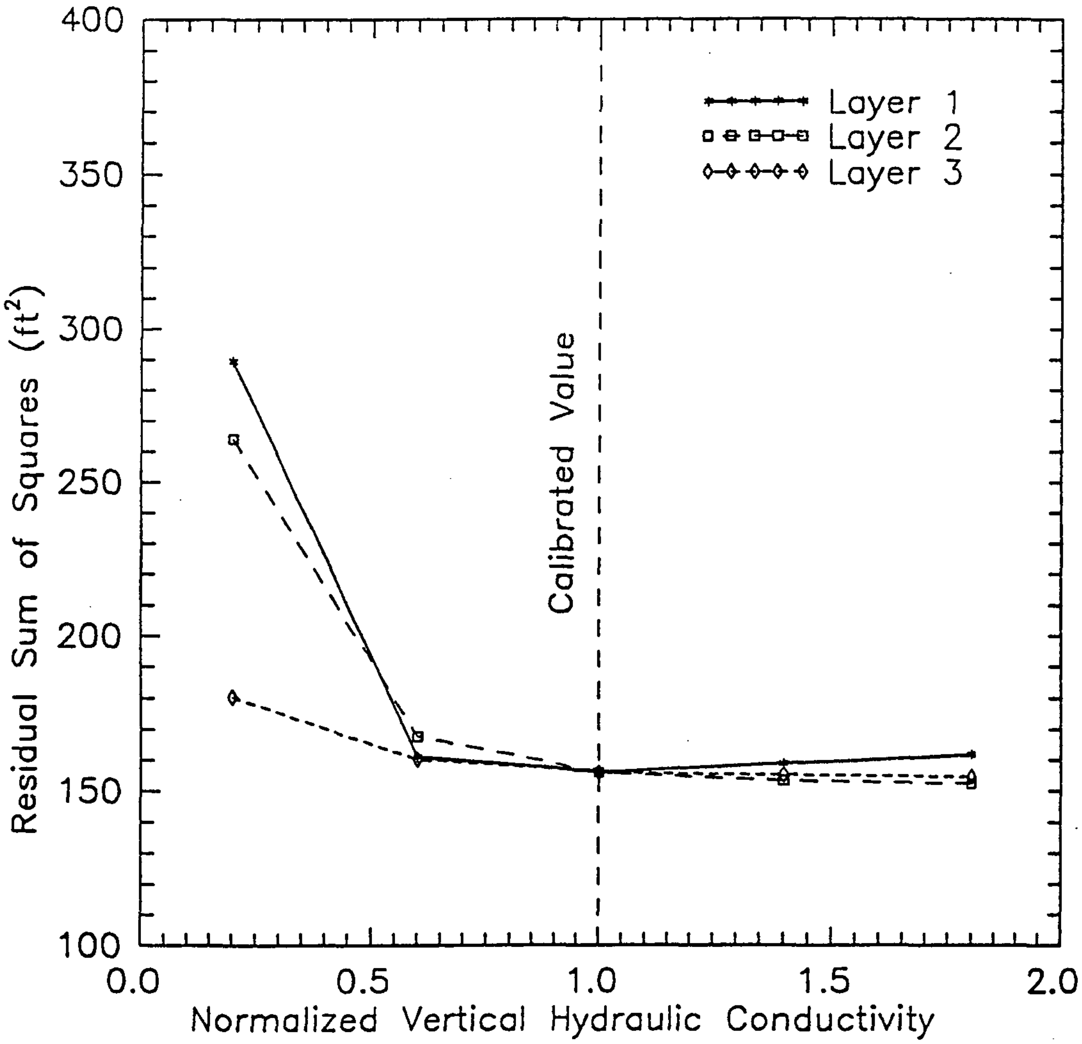
GERAGHTY
& MILLER, INC.
Environmental Services
A **Heidemij** company

Sensitivity Analysis of Hydraulic Conductivities

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-19

DWG DATE: 18OCT95 SB | PROJ. NO.: TN0333.001 | FILE: MODEL REPT | DRAWING: D20190.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: BAKER



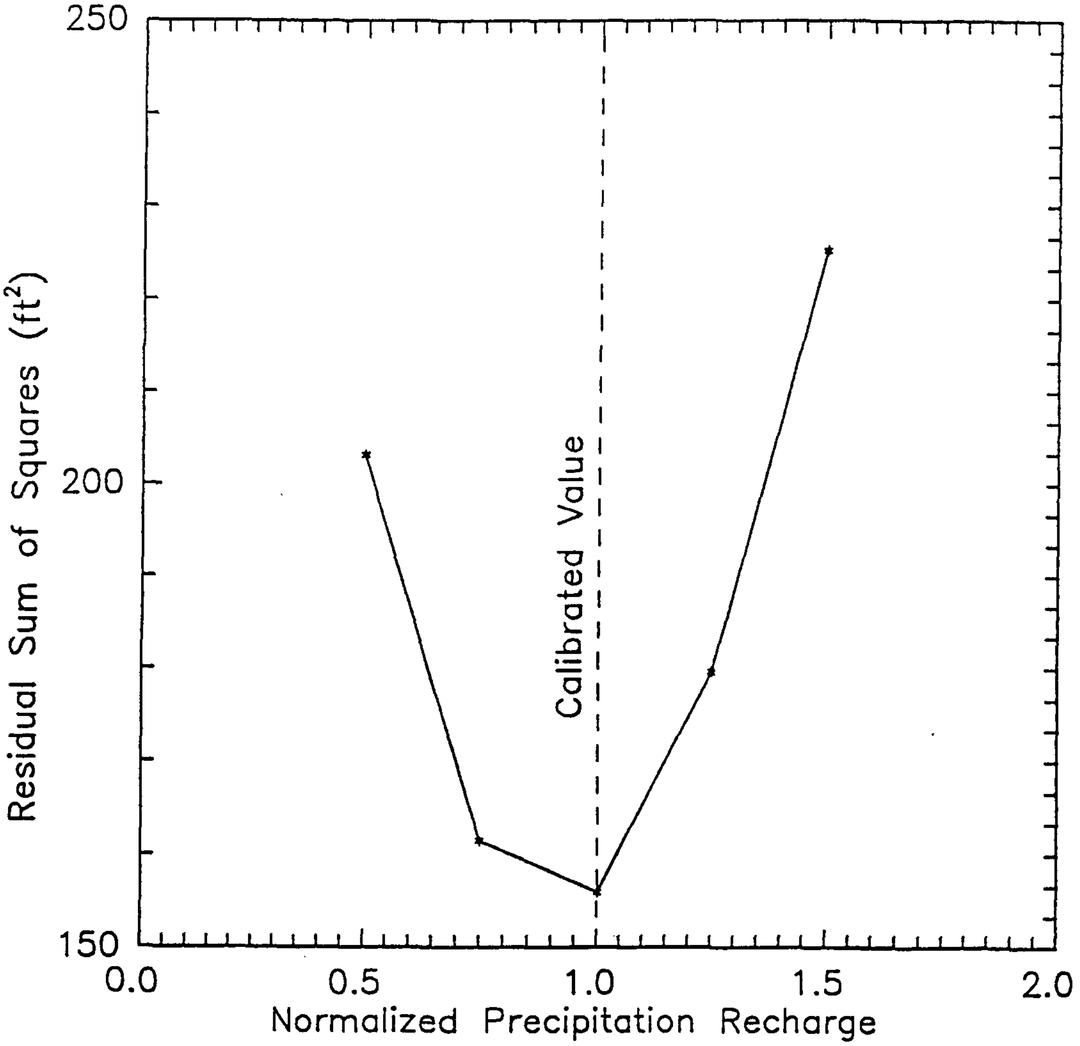
GERAGHTY
& MILLER, INC.
Environmental Services
A **Heidemij** company

Sensitivity Analysis of Vertical Hydraulic Conductivities

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-20

DWG DATE: 1_CT95 SB | PROJ. NO.: TN0333.001 | FILE: MODEL REPT | DRAWING: D2019_WG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTE_ _. BAKER



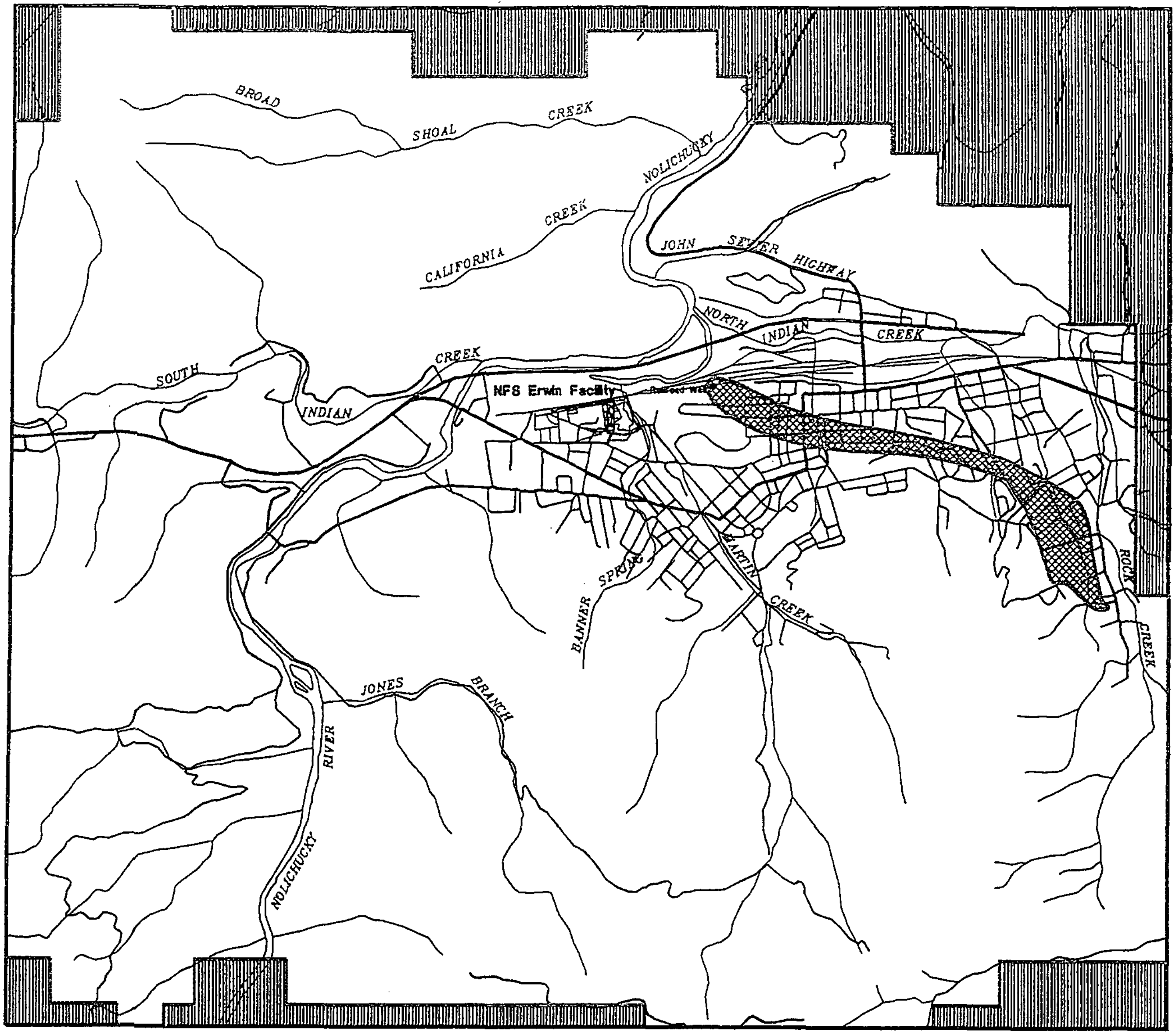
GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Sensitivity Analysis of Recharge in Groundwater Model

Nuclear Fuel Service, Inc.   Erwin, Tennessee

FIGURE
3-21

DRAFTER: J. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D3013[illegible].DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: [illegible]MAR96 Ba



LEGEND

▥	Outside Model Domain
▩	Capture Zone Extent

0 5000

SCALE IN FEET

PLOT: 1:1

N

GERAGHTY & MILLER, INC.

Environmental Services

A Heidemij company

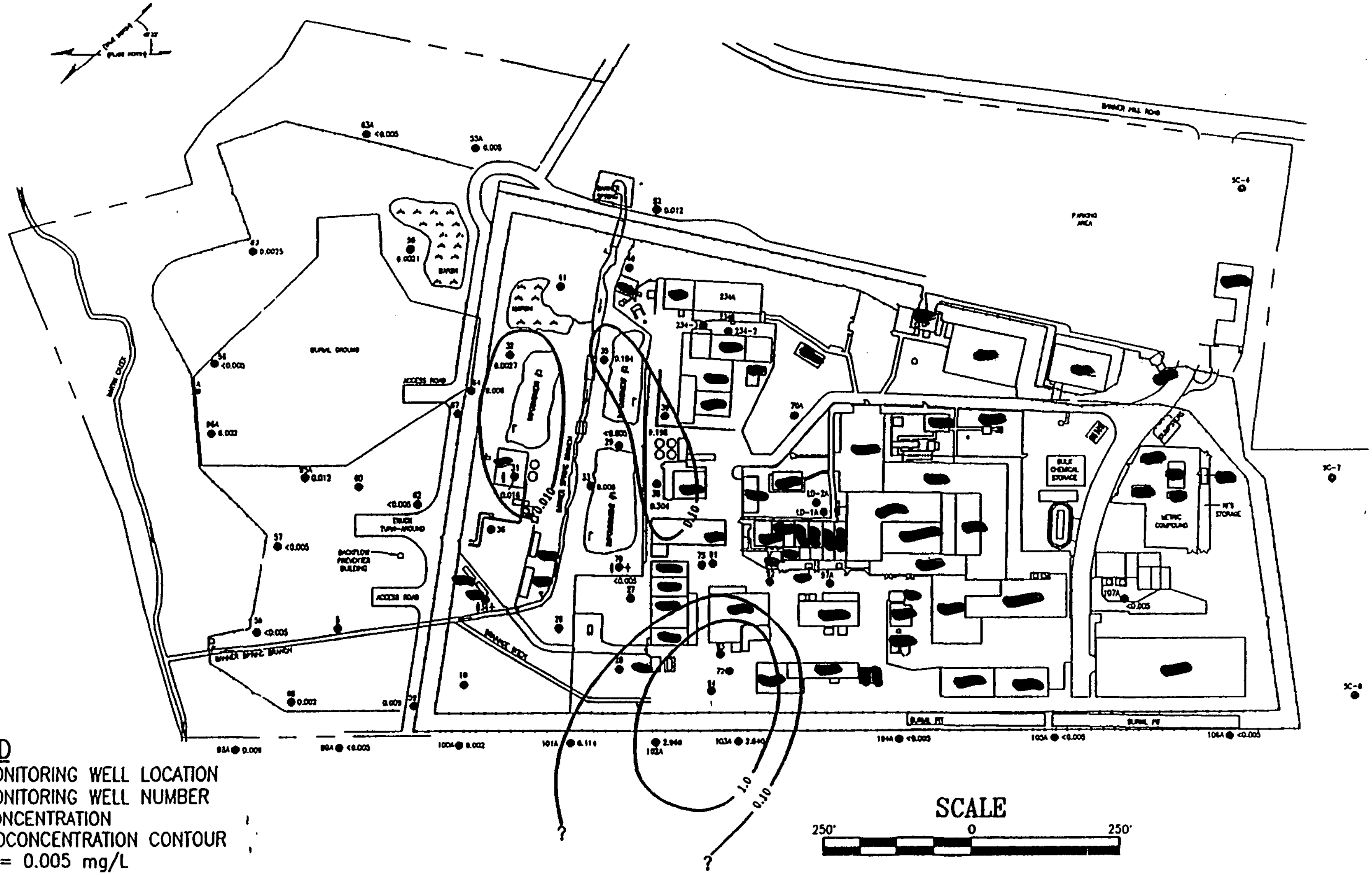
Simulated Capture Zone of the Railroad Well

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE

3-22

/ DRAWING NO.: ·5-20461 / DRAWING DATE: 15DEC95 SB / FILE NAME: MODEL / PROJECT NO.: TN0333.001 / ːCT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



LEGEND
- ● – MONITORING WELL LOCATION
- 98A – MONITORING WELL NUMBER
- 1.72 – CONCENTRATION
- ⁀ – ISOCONCENTRATION CONTOUR

MCL = 0.005 mg/L

SOURCE: Advanced Recovery Systems, Inc. Fourth Quarter 1993 Nuclear Fuel Services Groundwater Monitoring Report.

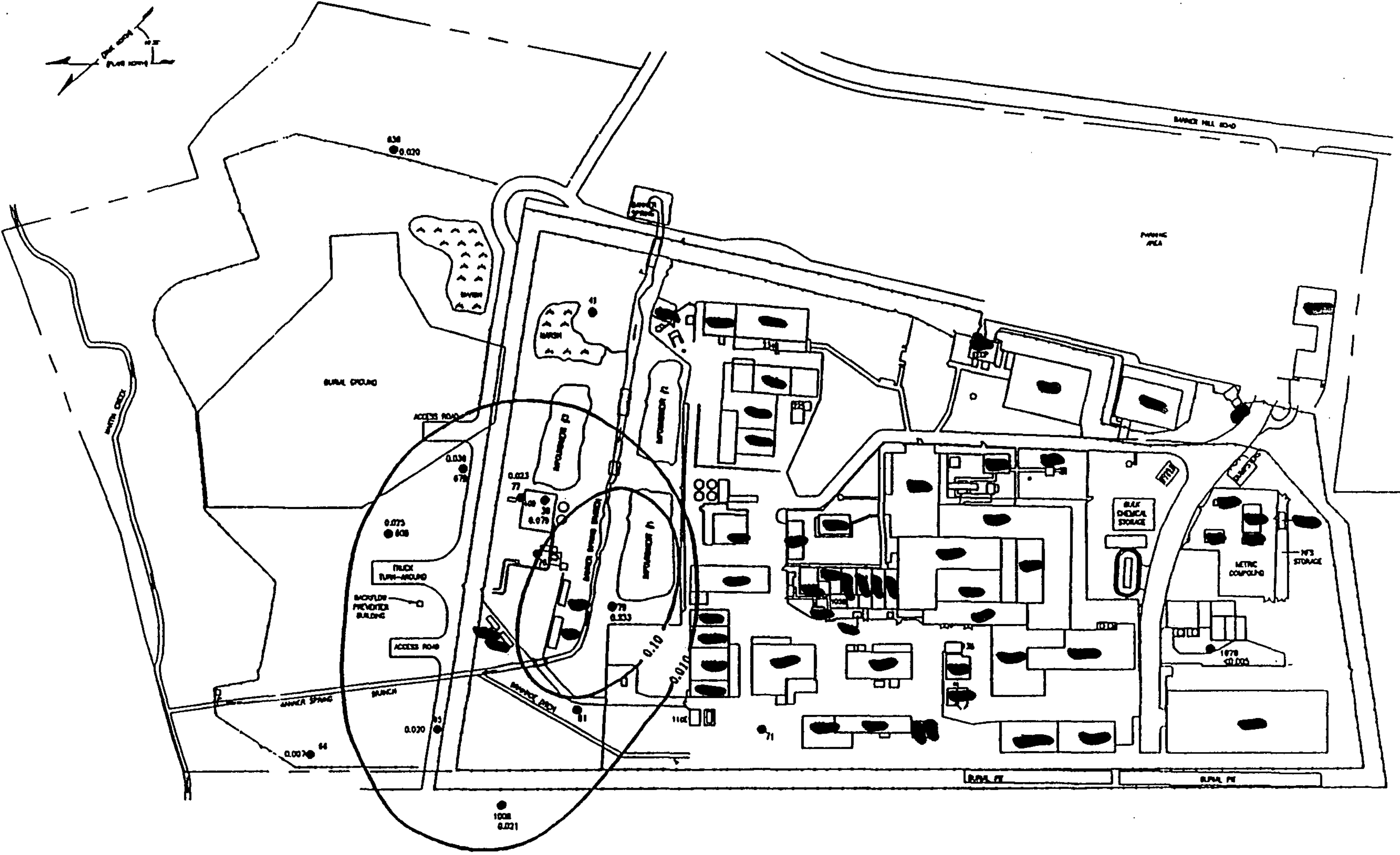
GERAGHTY
& MILLER, INC.
Environmental Services
A Heidemij company

Fourth Quarter 1993 PCE (mg/L) Concentrations in Zone 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
4-1

/ DRAWING NO. ‑20462 / DRAWING DATE: 15DEC95 SB / FILE NAME: MODEL / PROJECT NO.: TN0333.001 / CT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



LEGEND

- ● – MONITORING WELL LOCATION
- 98A – MONITORING WELL NUMBER
- 1631.72 – CONCENTRATION
- ISOCONCENTRATION CONTOUR

MCL = 0.005 mg/L

SCALE

250' 0 250'

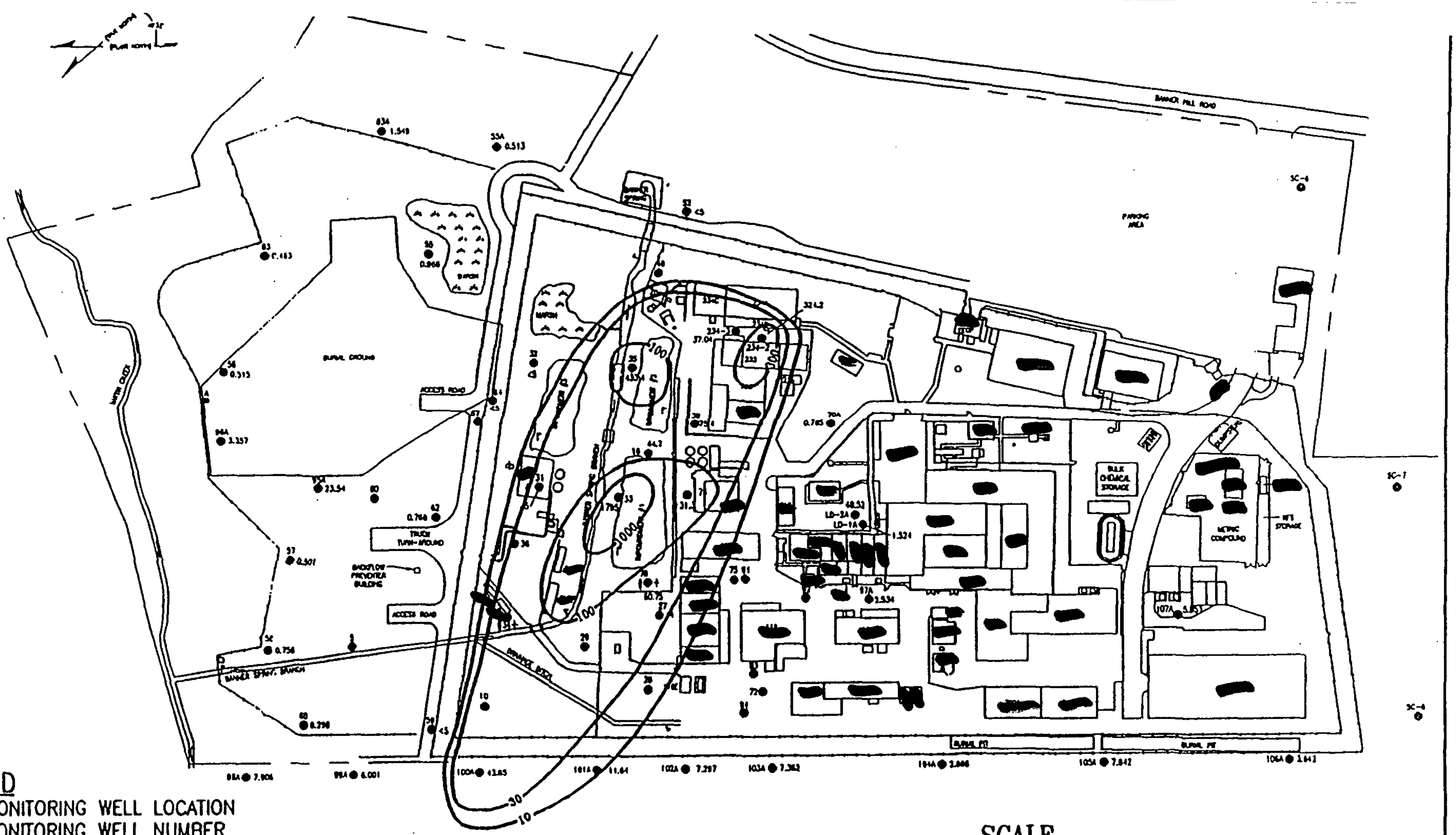
SOURCE: Advanced Recovery Systems, Inc. Fourth Quarter 1993 Nuclear Fuel Services Groundwater Monitoring Report.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Fourth Quarter 1993 PCE (mg/L) Concentrations in Zone 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 4-2



[redacted] [redacted]

LEGEND

● – MONITORING WELL LOCATION
98A – MONITORING WELL NUMBER
1631.72 – CONCENTRATION
—— – ISOCONCENTRATION CONTOUR
MCL = 30 pCi/L

SOURCE: Advanced Recovery Systems, Inc. Fourth Quarter 1993 Nuclear Fuel Services Groundwater Monitoring Report.

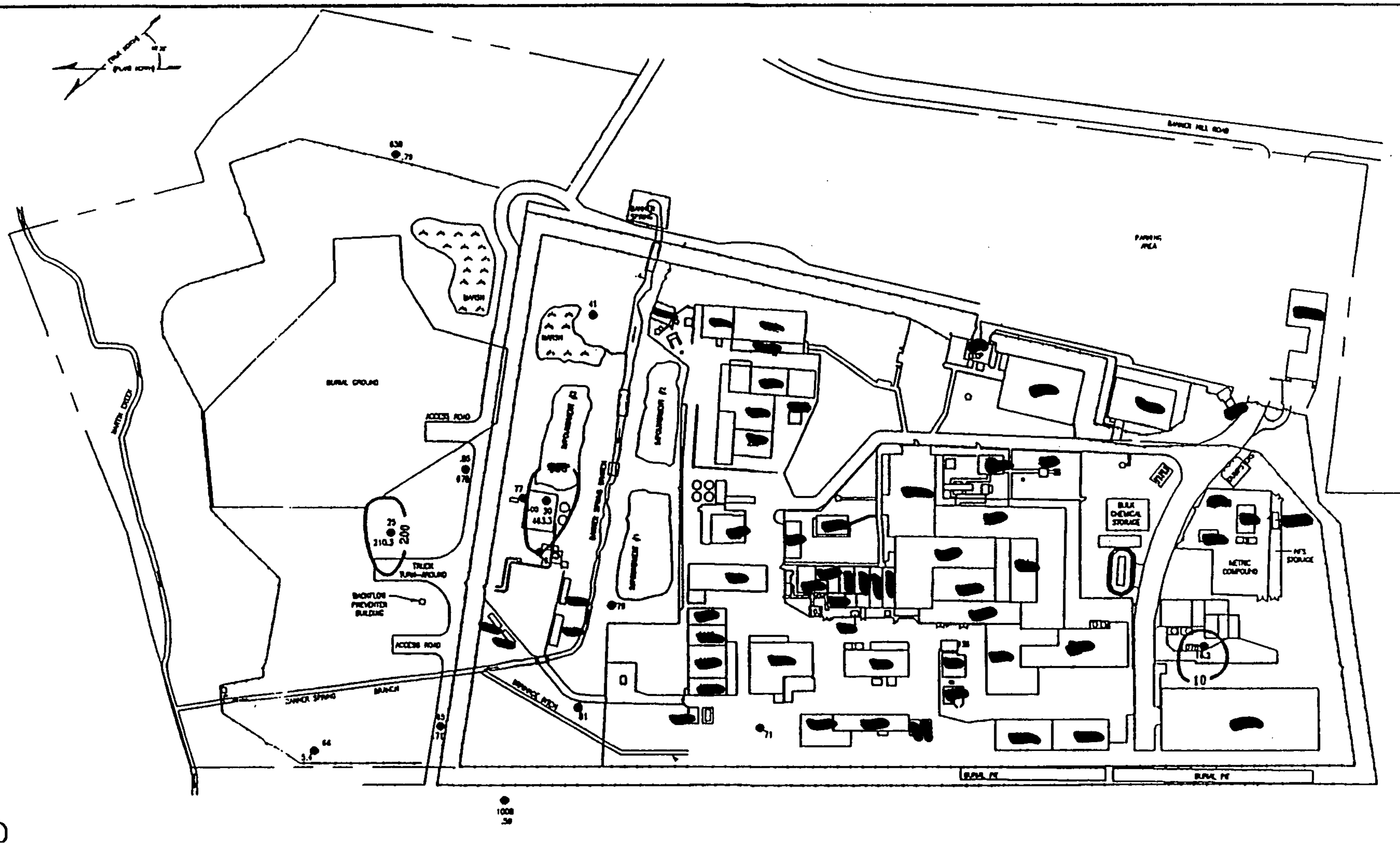
GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Fourth Quarter 1993 Total Uranium (pCi/L) Concentrations in Zone 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
4-3

/ DRAWING NO.. ..35-20464 / DRAWING DATE: 15DEC95 SB / FILE NAME: MODEL / PROJECT NO.: TN0333.001 / ..JECT MANAGER: T. KHAN / PROJECT OFFICER: B. ILGNER / DRAFTER: S. BAKER /



LEGEND

- ● – MONITORING WELL LOCATION
- 98A – MONITORING WELL NUMBER
- 1.72 – CONCENTRATION
- ⁀ – ISOCONCENTRATION CONTOUR

MCL = 30 pCi/L

SCALE

250' 0 250'

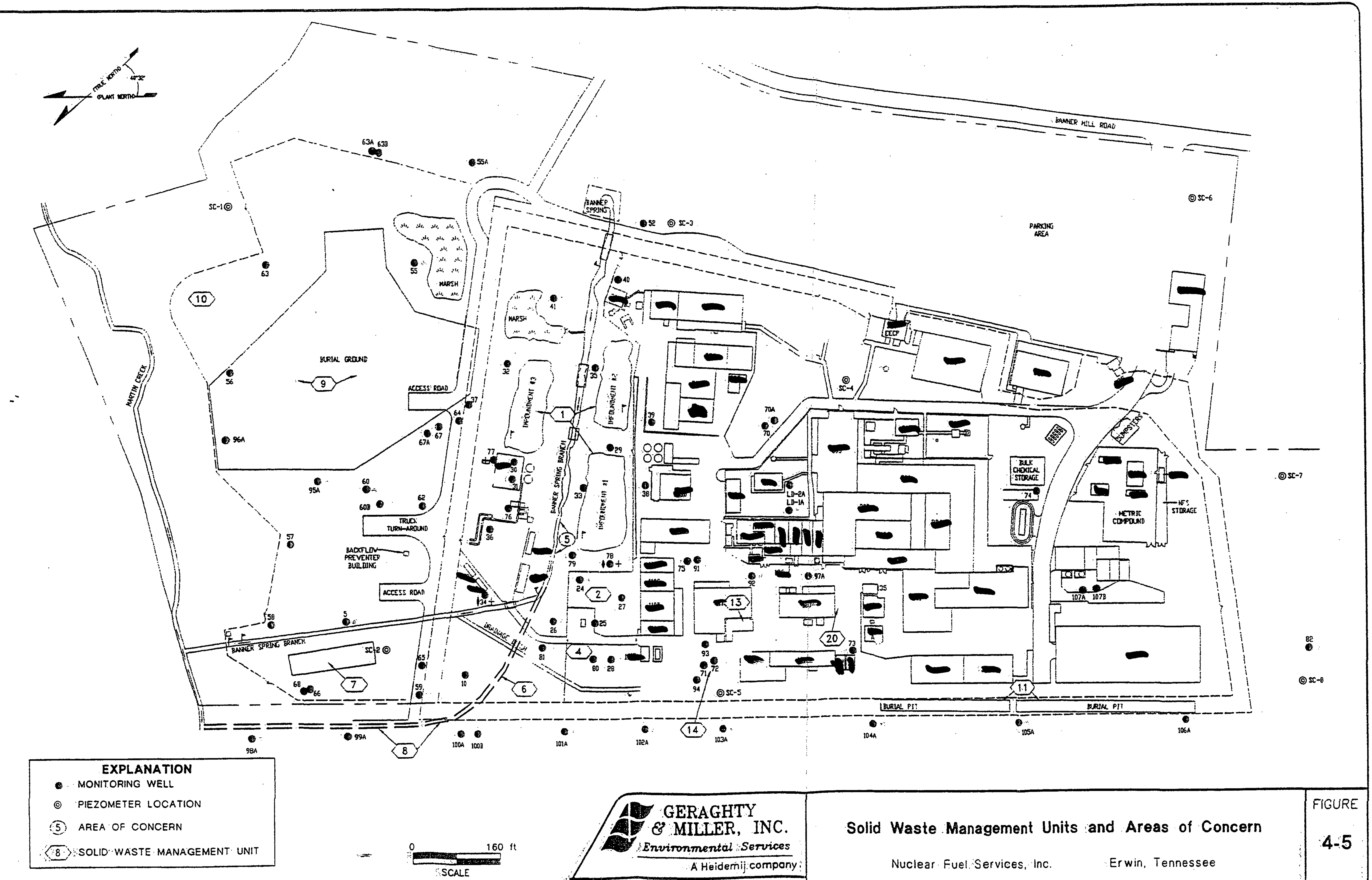
SOURCE: Advanced Recovery Systems, Inc. Fourth Quarter 1993 Nuclear Fuel Services Groundwater Monitoring Report.

GERAGHTY
& MILLER, INC.
Environmental Services
A Heidemij company

Fourth Quarter 1993 Total Uranium (pCi/L) Concentrations in Zone 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
4-4



GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

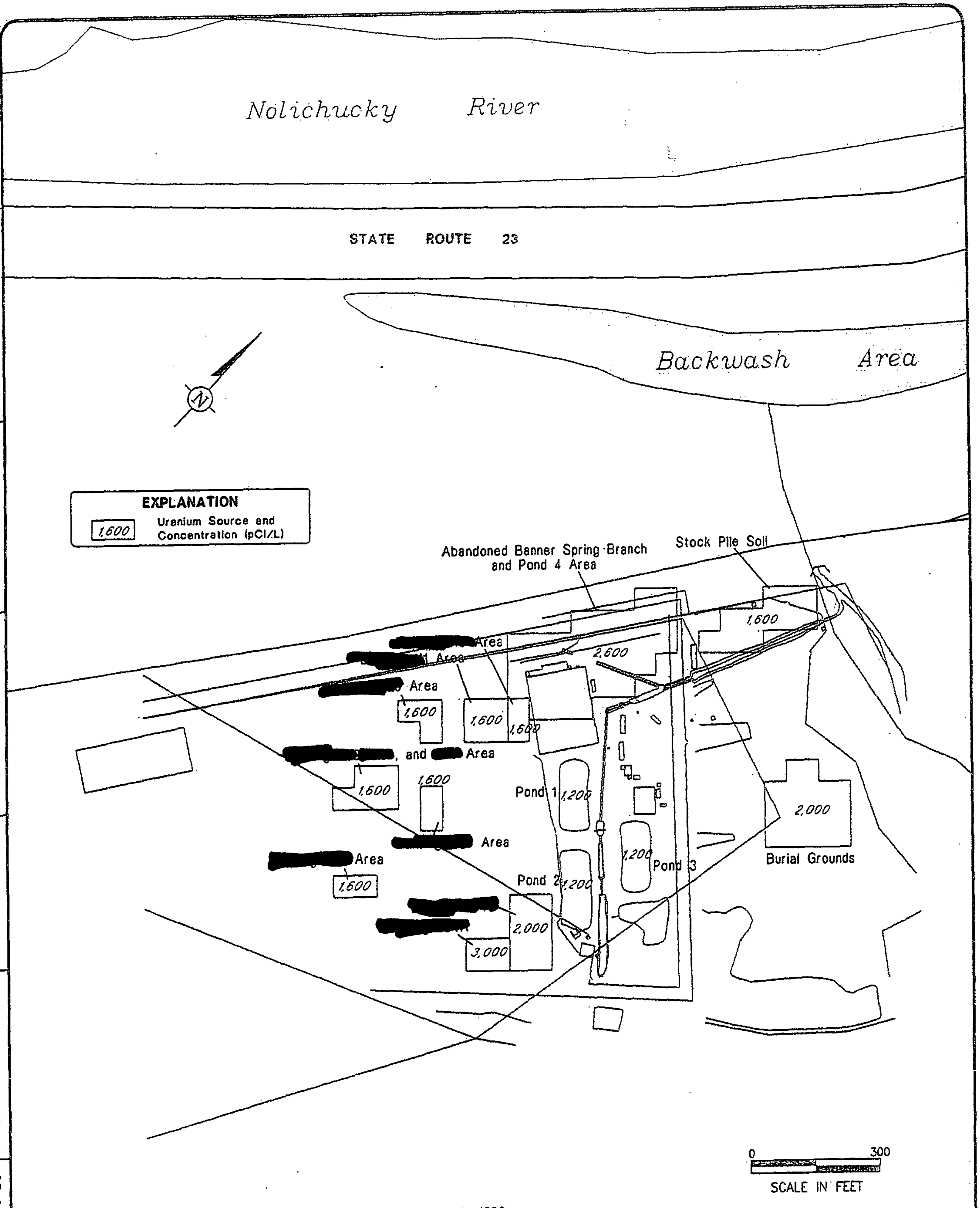
Solid Waste Management Units and Areas of Concern

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
4-5

DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30140d.DWG | FILE: MODEL REPORT | PROJ. NO.: TN0333.001 | DWG DATE: 22FEB96 SB

DRAFTER: S. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30092G2.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 25FEB96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

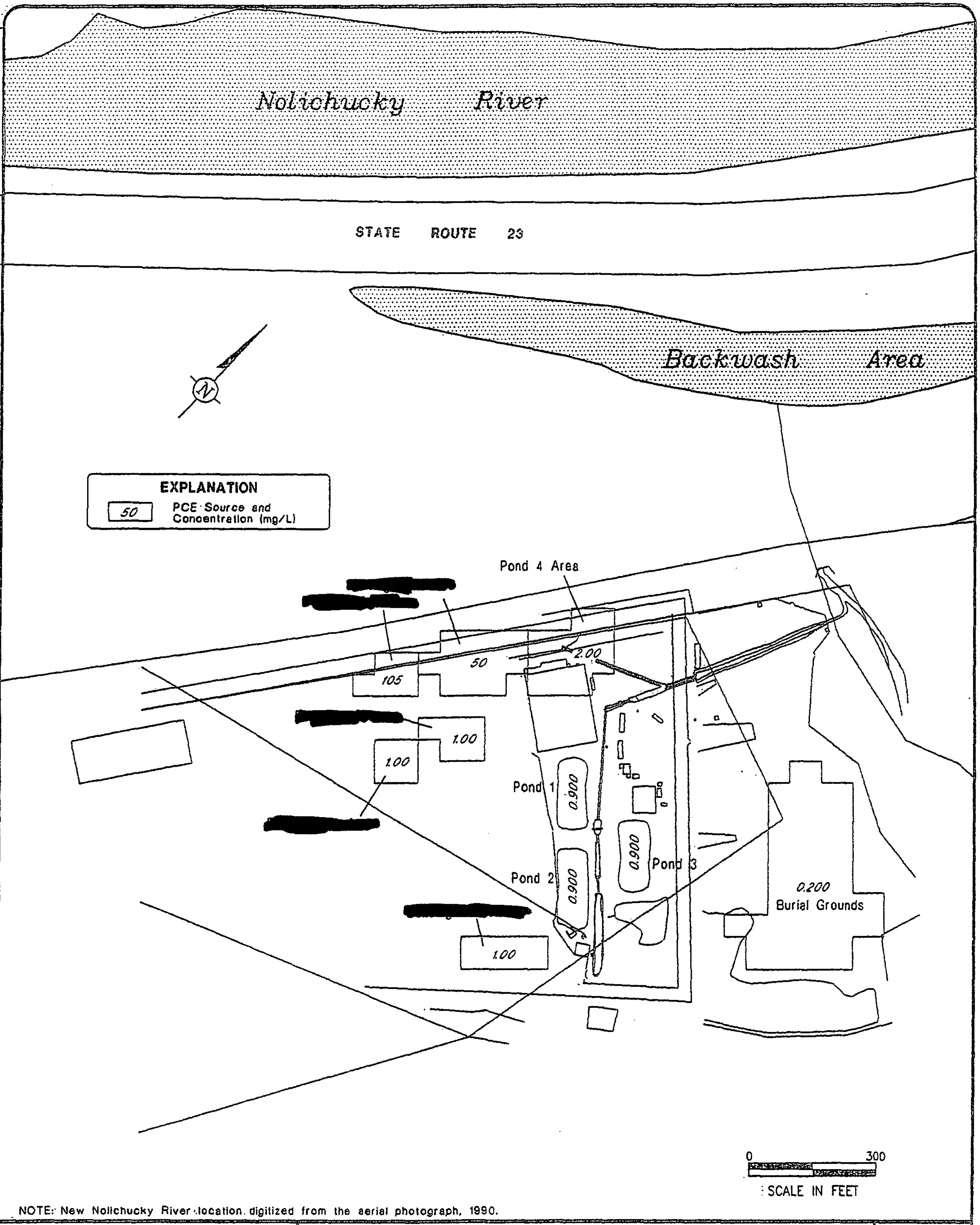
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Source Locations and Concentrations

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
4-6

DRAFTER: J. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D3009222.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 31MAR96 Ba



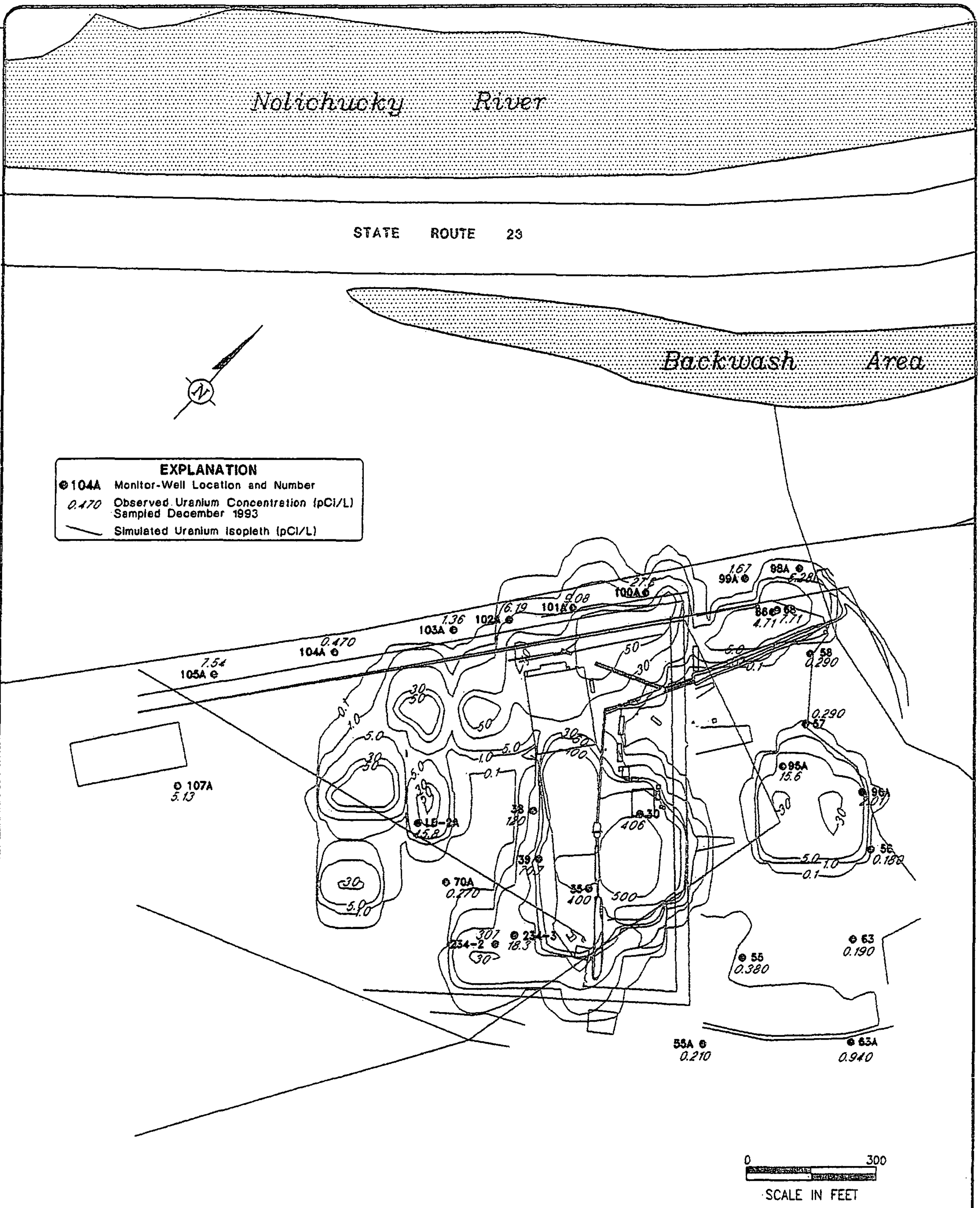
NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated PCE Source Locations and Concentrations

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 4-7



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

DRAFTER: S. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30092D.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 31MAR96 Ba

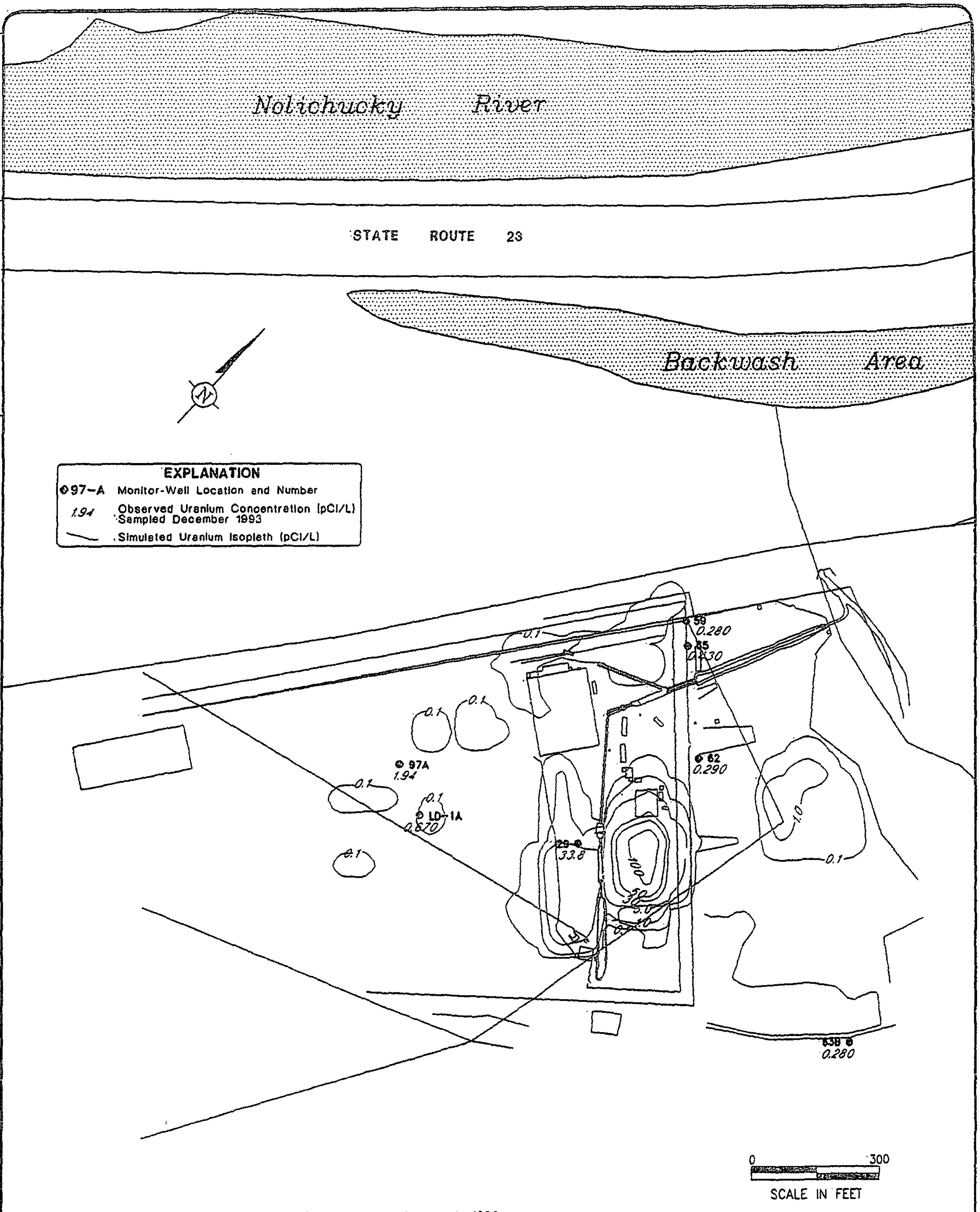
GERAGHTY & MILLER, INC.
Environmental Services
A **Heidemij** company

Simulated 1993 Uranium Concentration Distribution in Model Layer 1

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
4-8

DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30092E.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 31MAR96 Bo



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated 1993 Uranium Concentration Distribution in Model Layer 2

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 4-9

DRAFTER: S. BAKER

PROJ. OFFICER: B. ILGNER

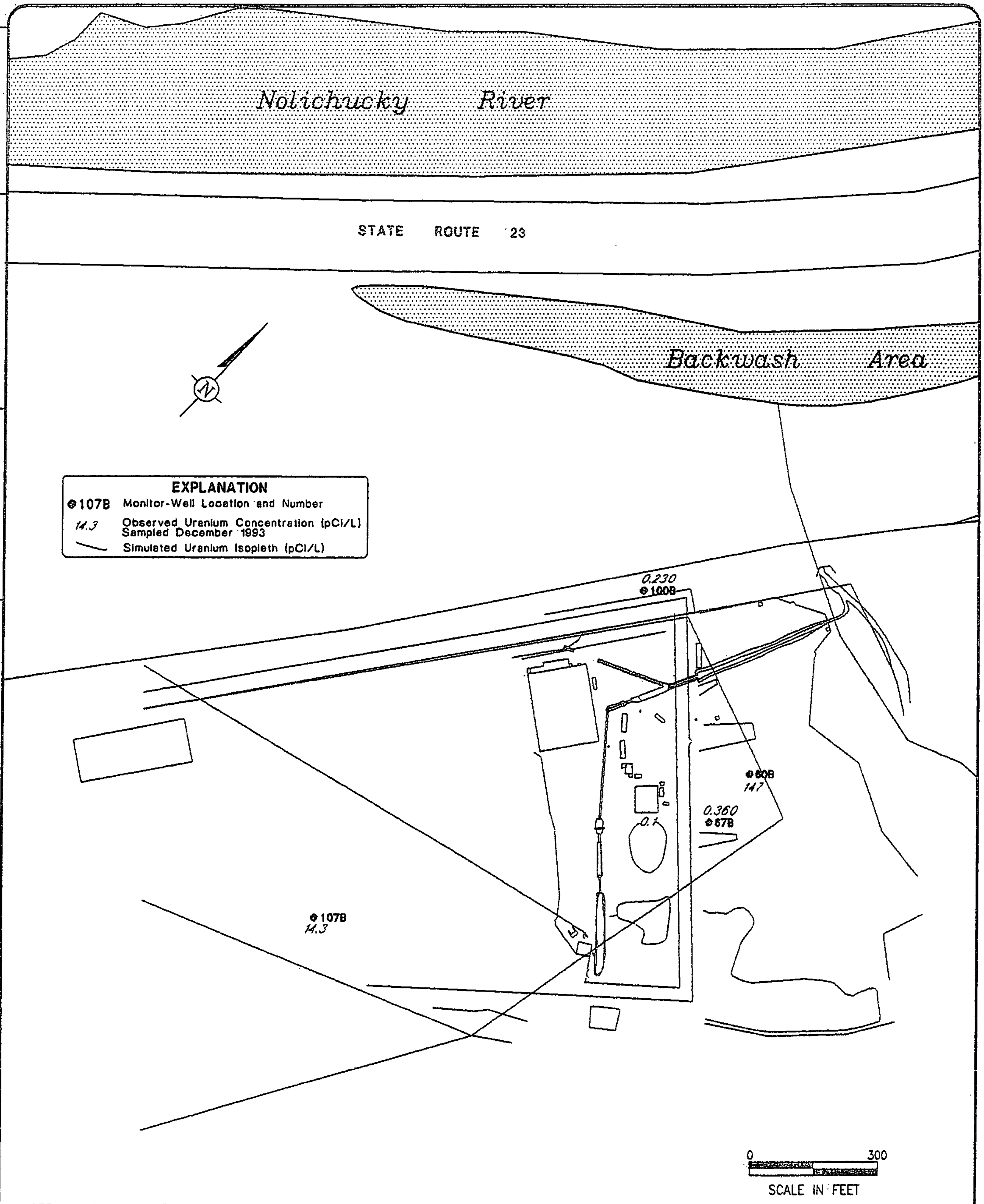
PROJ. MGR.: T. KHAN

DRAWING: D30092F.DWG

FILE: GW MODEL

PROJ. NO.: TN0333.001

DWG DATE: 23FEB96 Ba



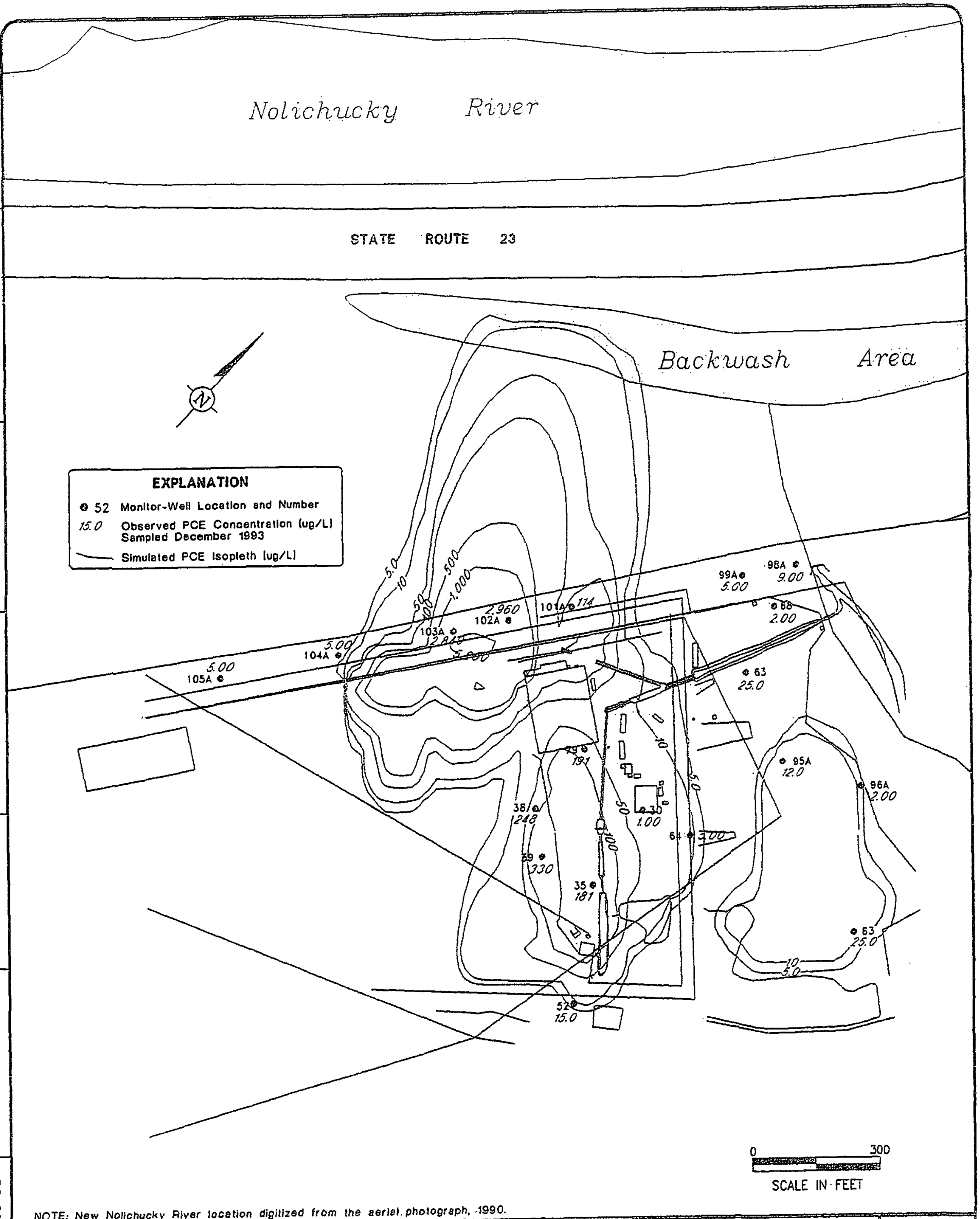
NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated 1993 Uranium Concentration Distribution in Model Layer 3

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 4-10



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated 1993 PCE Concentration Distribution in Model Layer 1

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 4-11

DRAFTER: S. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30092H.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 1APR96 Ba

DRAFTER: S. BAKER

PROJ. OFFICER: B. ILGNER

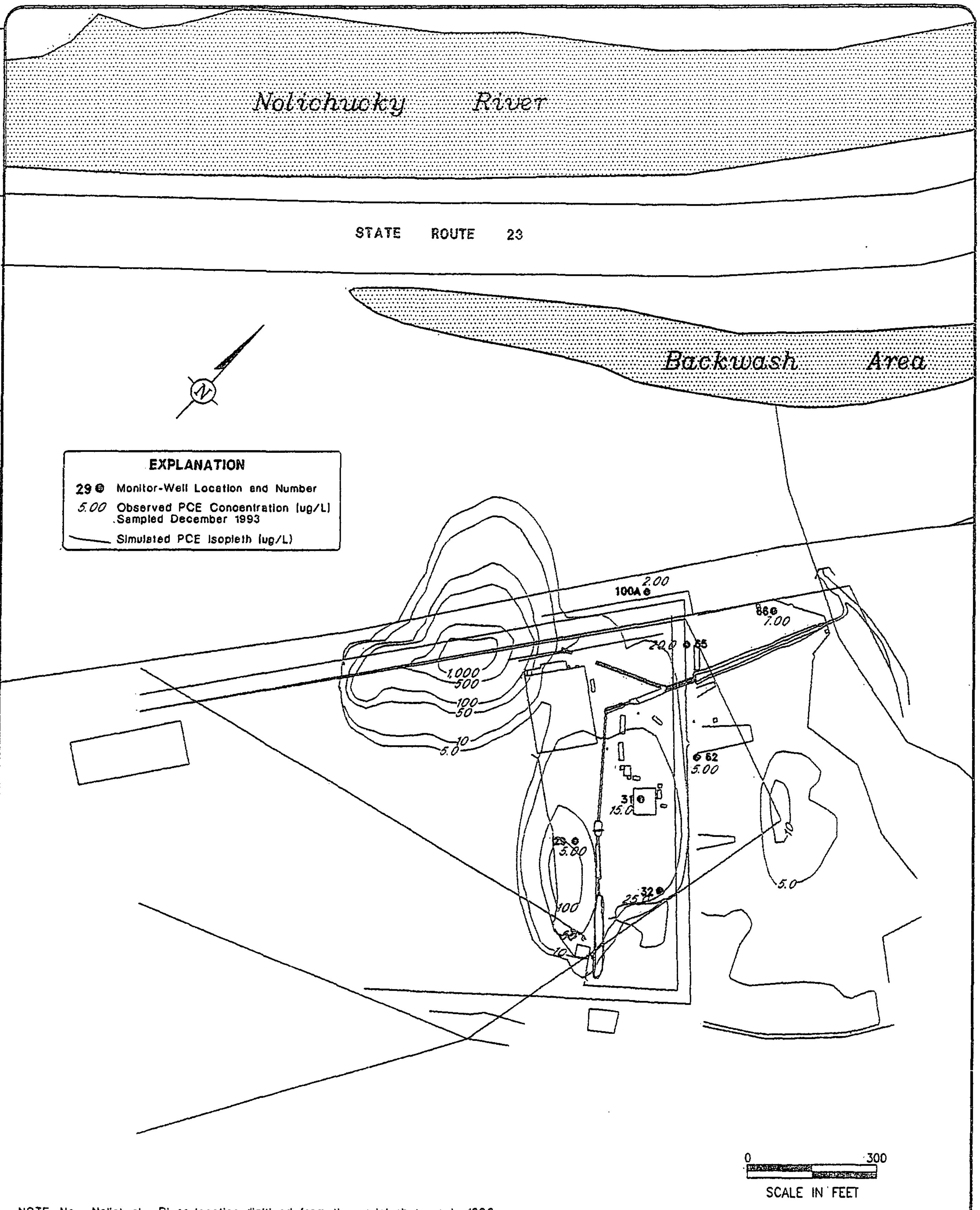
PROJ. MGR.: T. KHAN

DRAWING: D300921.DWG

FILE: GW MODEL

PROJ. NO.: TN0333.001

DWG DATE: 31MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

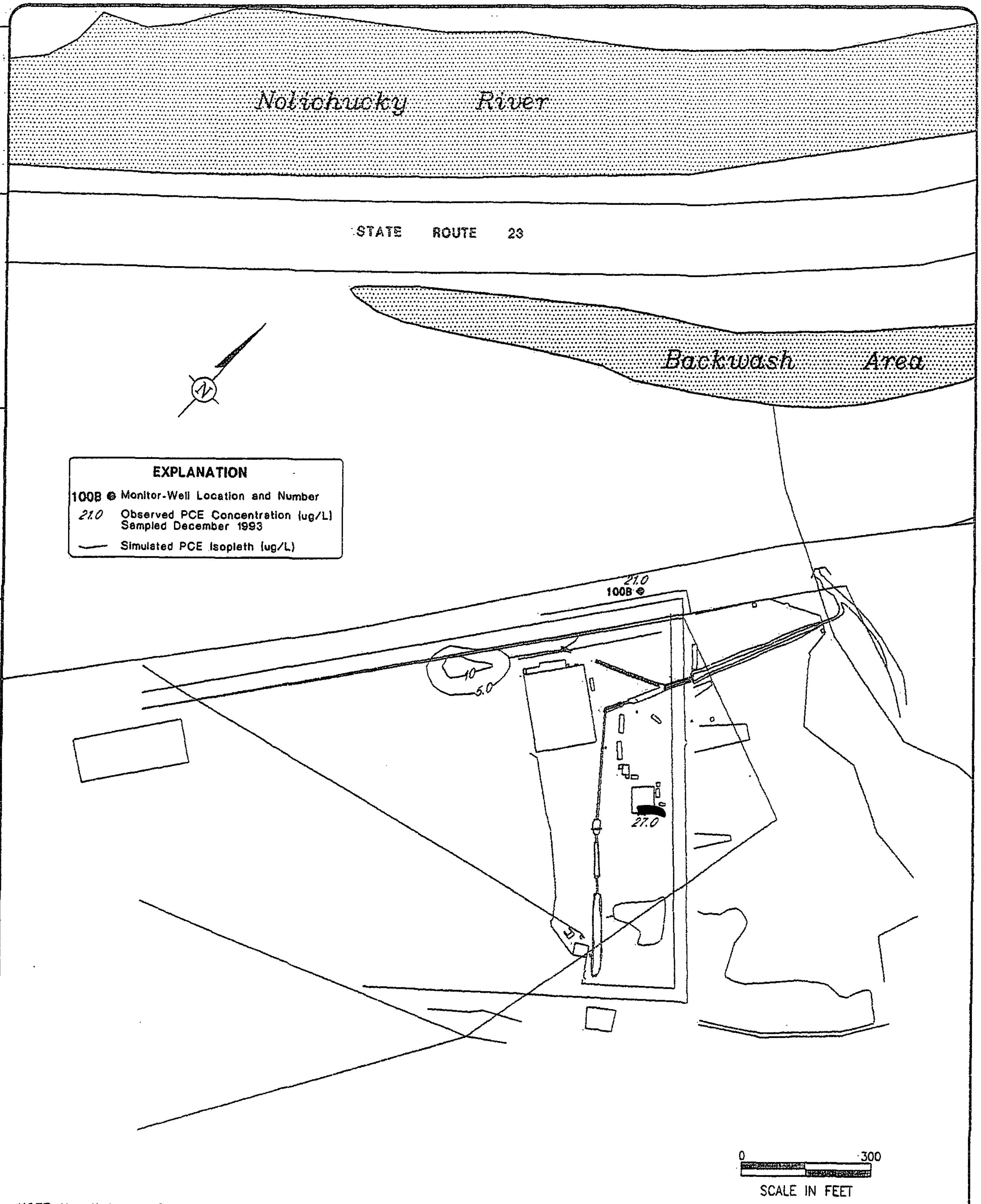
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated 1993 PCE Concentration Distribution in Model Layer 2

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 4-12

DRAFTER: S. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30092J.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 31MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

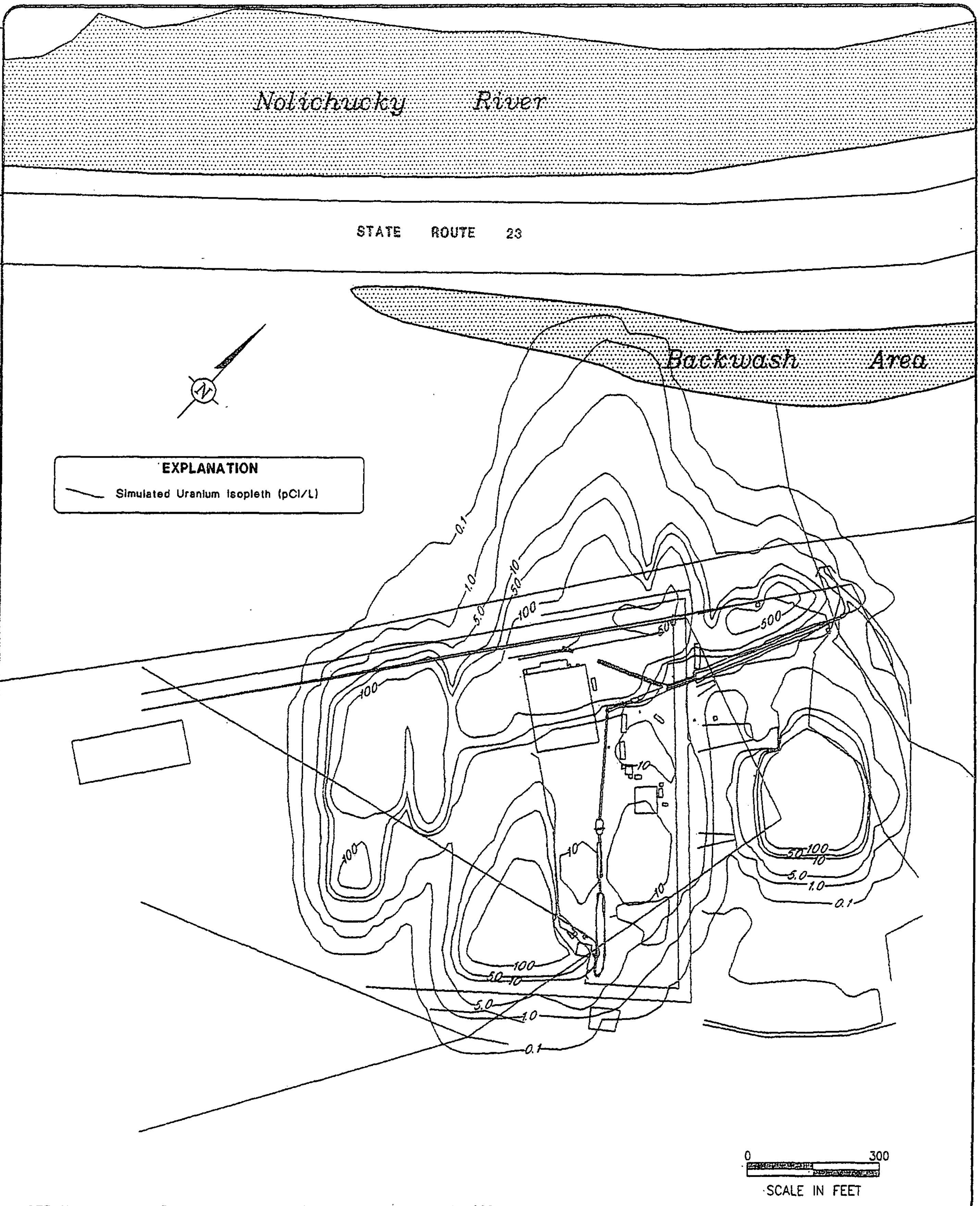
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated 1993 PCE Concentration Distribution in Model Layer 3

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
4-13

DRAFTER: J. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30092_.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: .MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

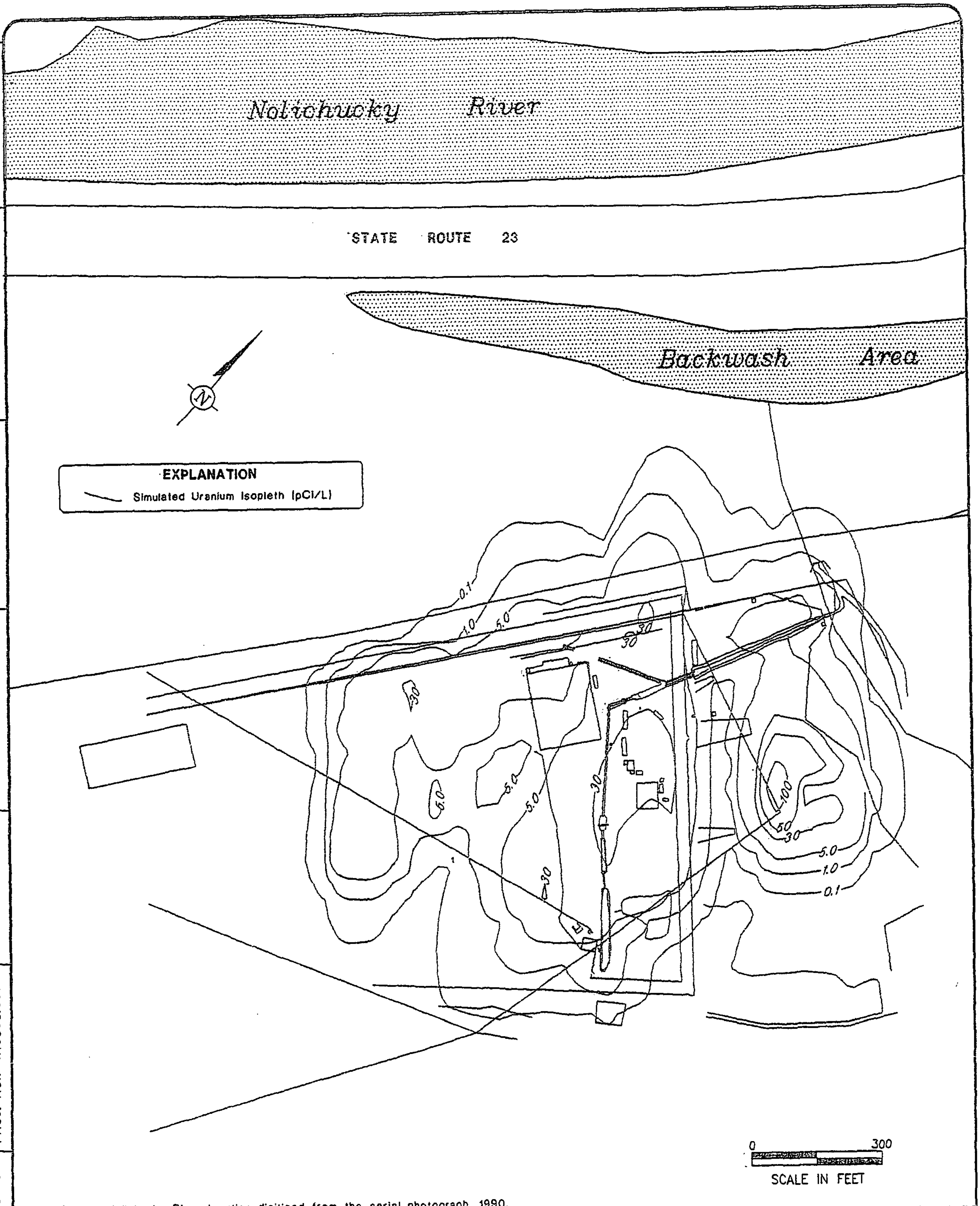
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution in Model Layer 1 after 500 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
5-1

DRAFTER: J. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D3009ZM.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 5MAR96 Ba



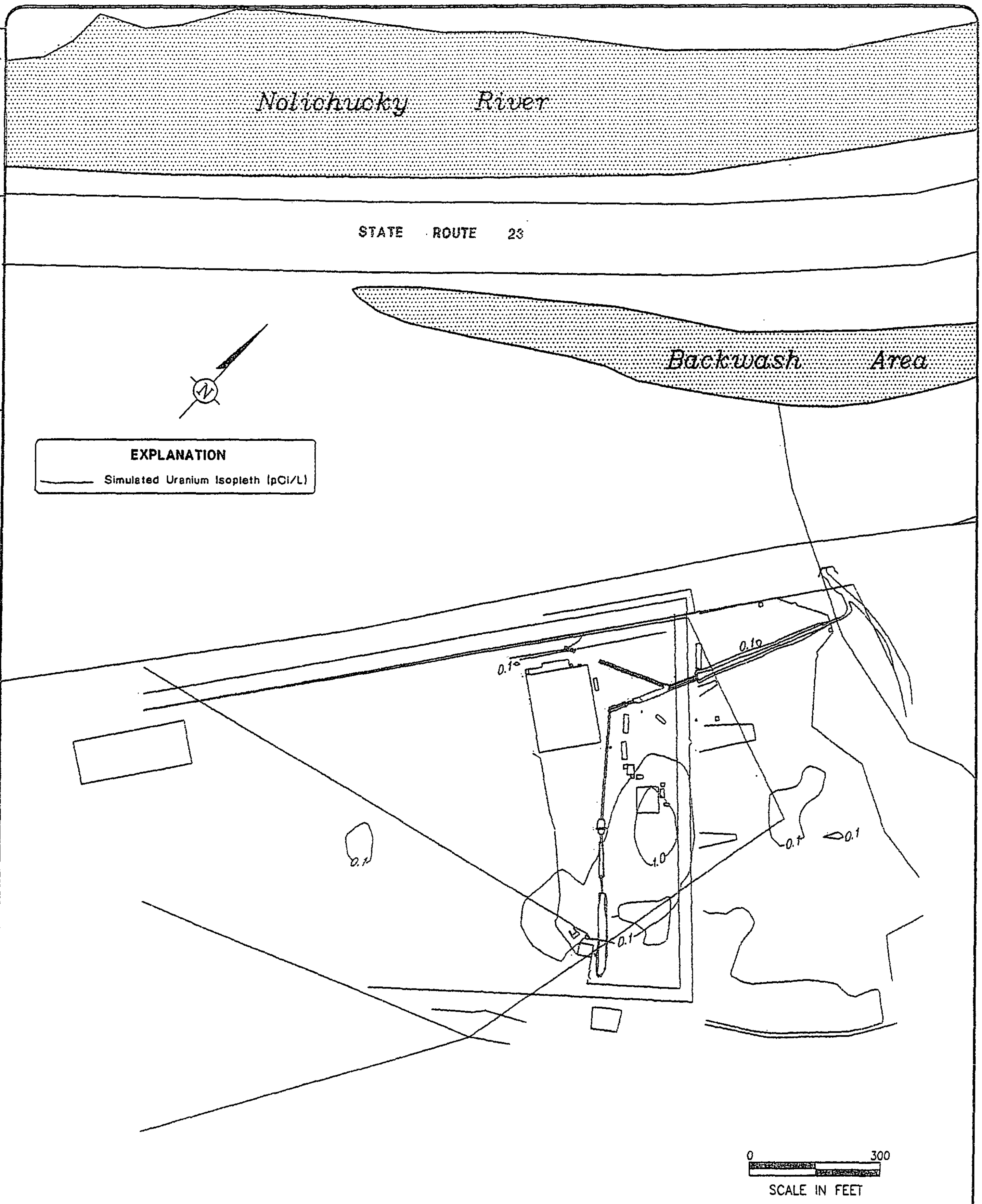
NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution Model Layer 2 after 500 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-2



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

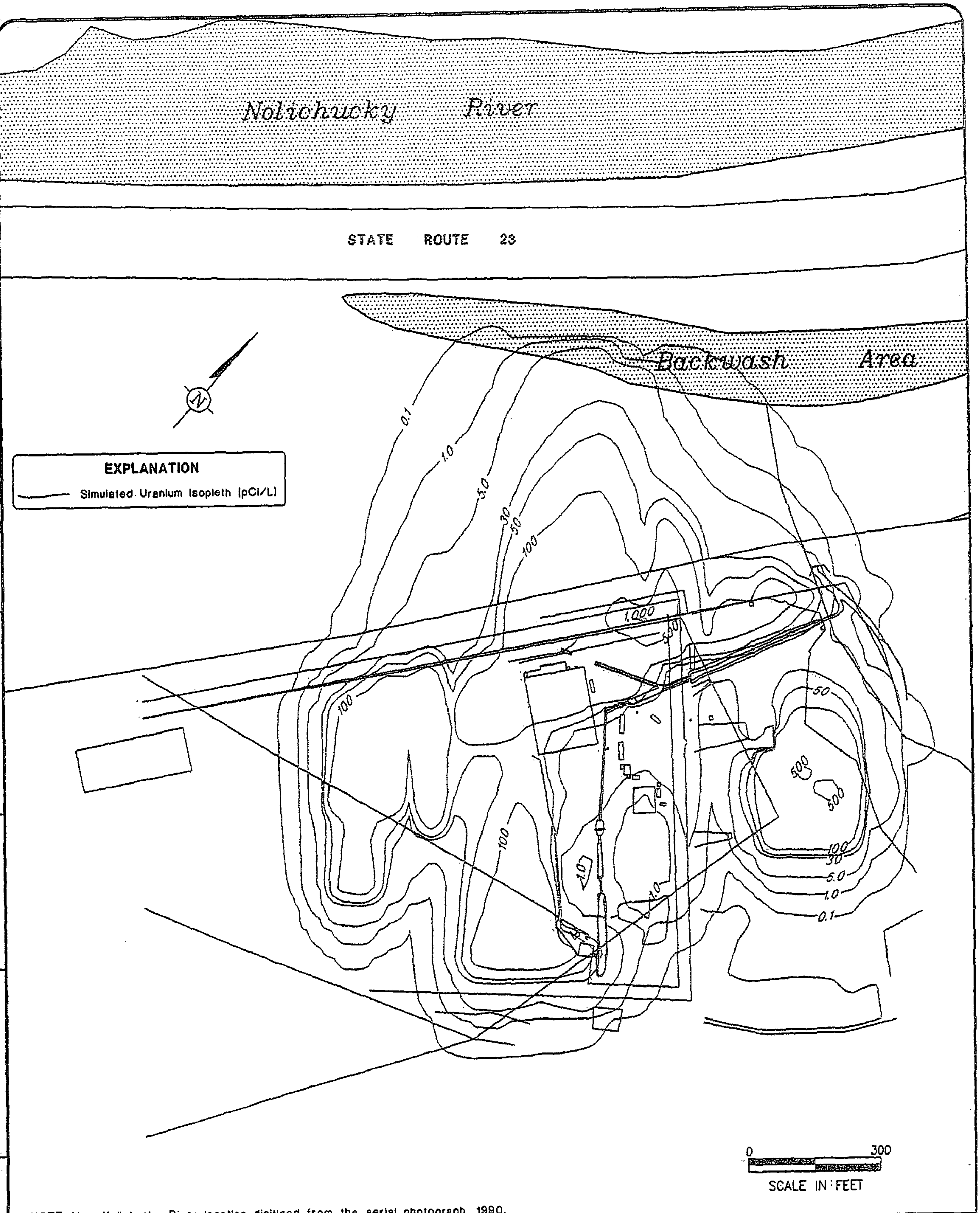
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution in Model Layer 3 after 500 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-3

DRAFTER: J. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D3009zr.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 3MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

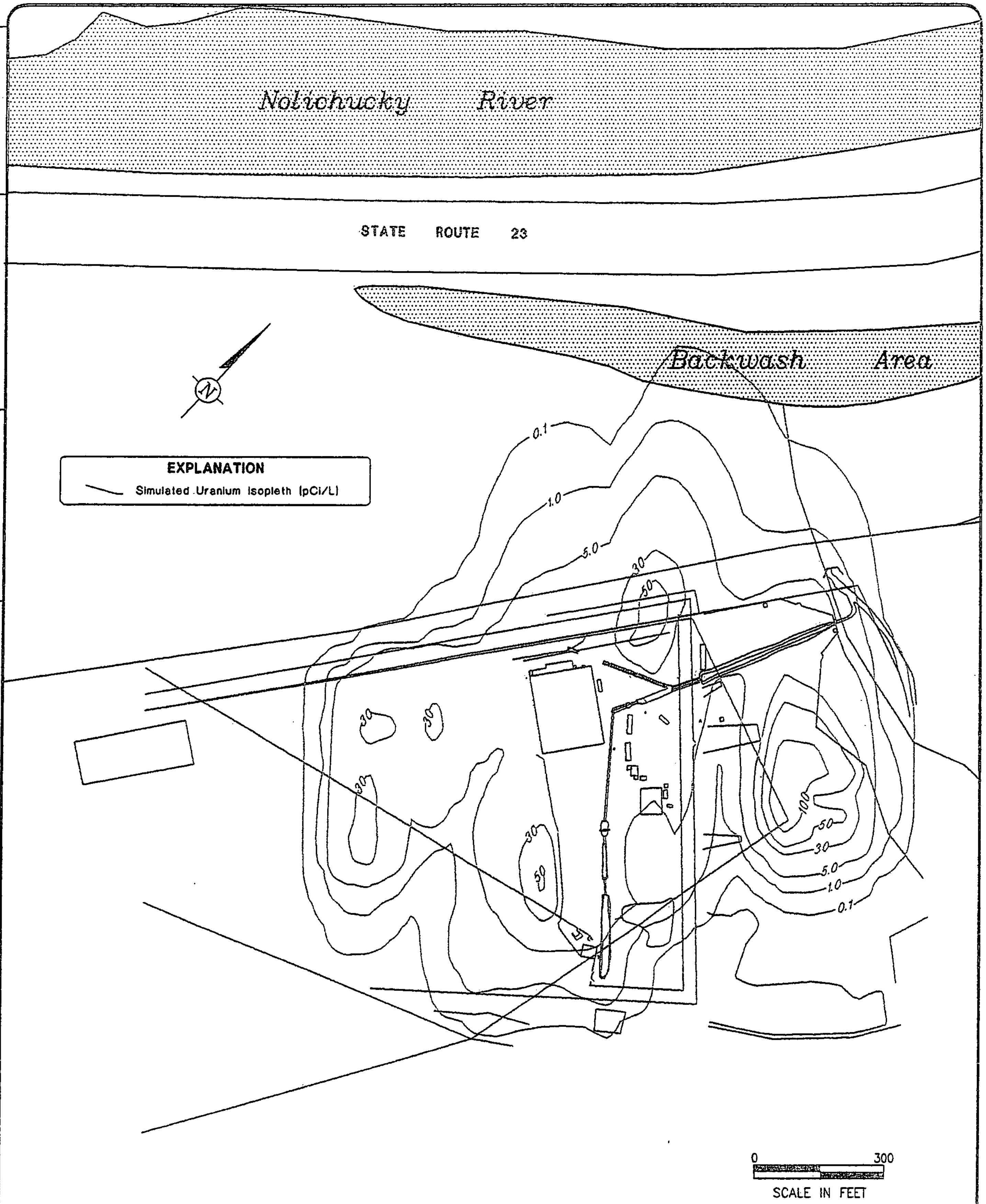
DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D300920.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 31MAR96 Bo

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution in Model Layer 1 after 1,000 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
5-4



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

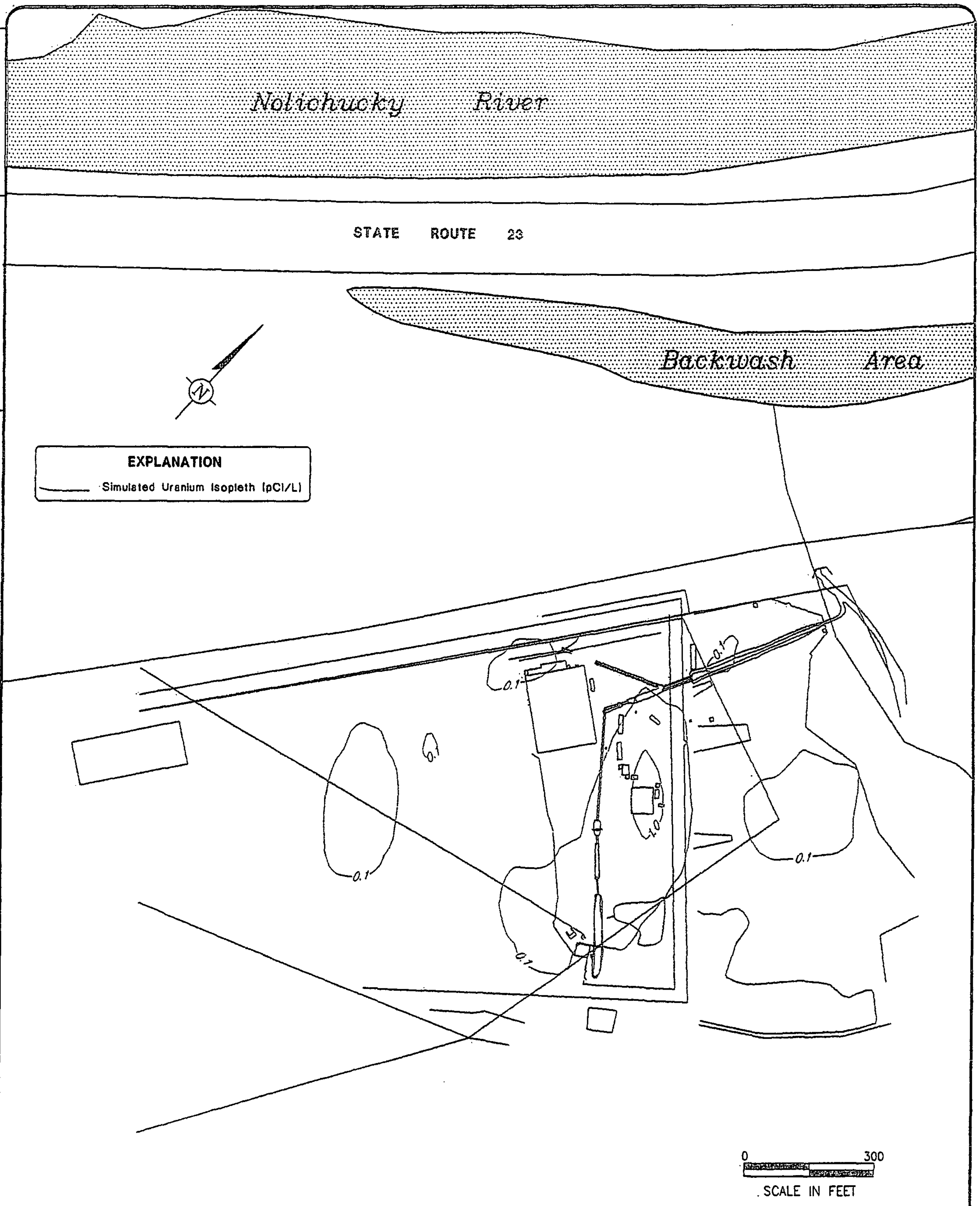
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution Model Layer 2 after 1,000 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-5

DRAFTER: S. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30092U.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

DRAFTER: _ BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30092...DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: ...AR96 Ba

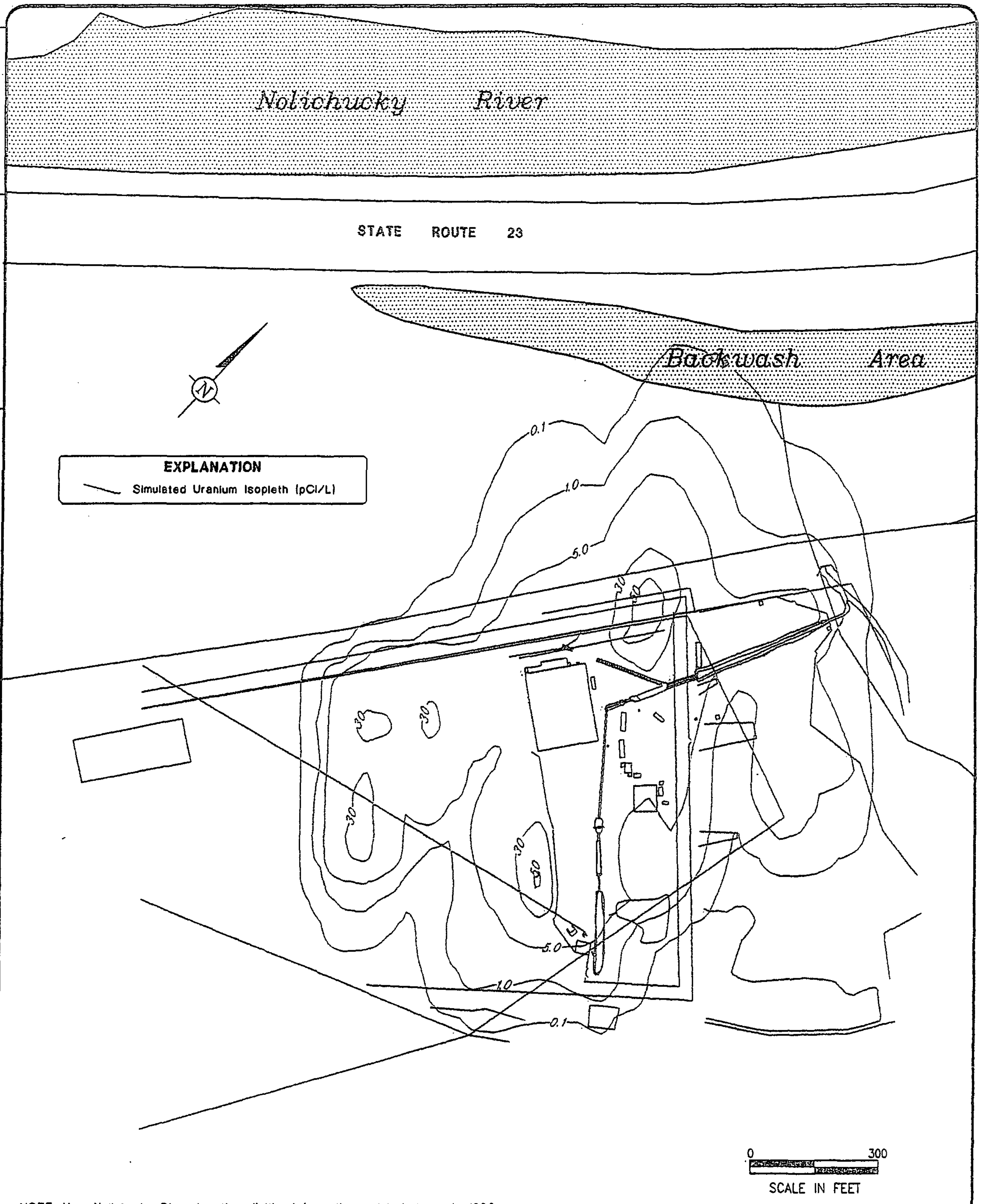
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution in Model Layer 3 after 1,000 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-6

DRAFTER: . BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D300 .DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: AR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

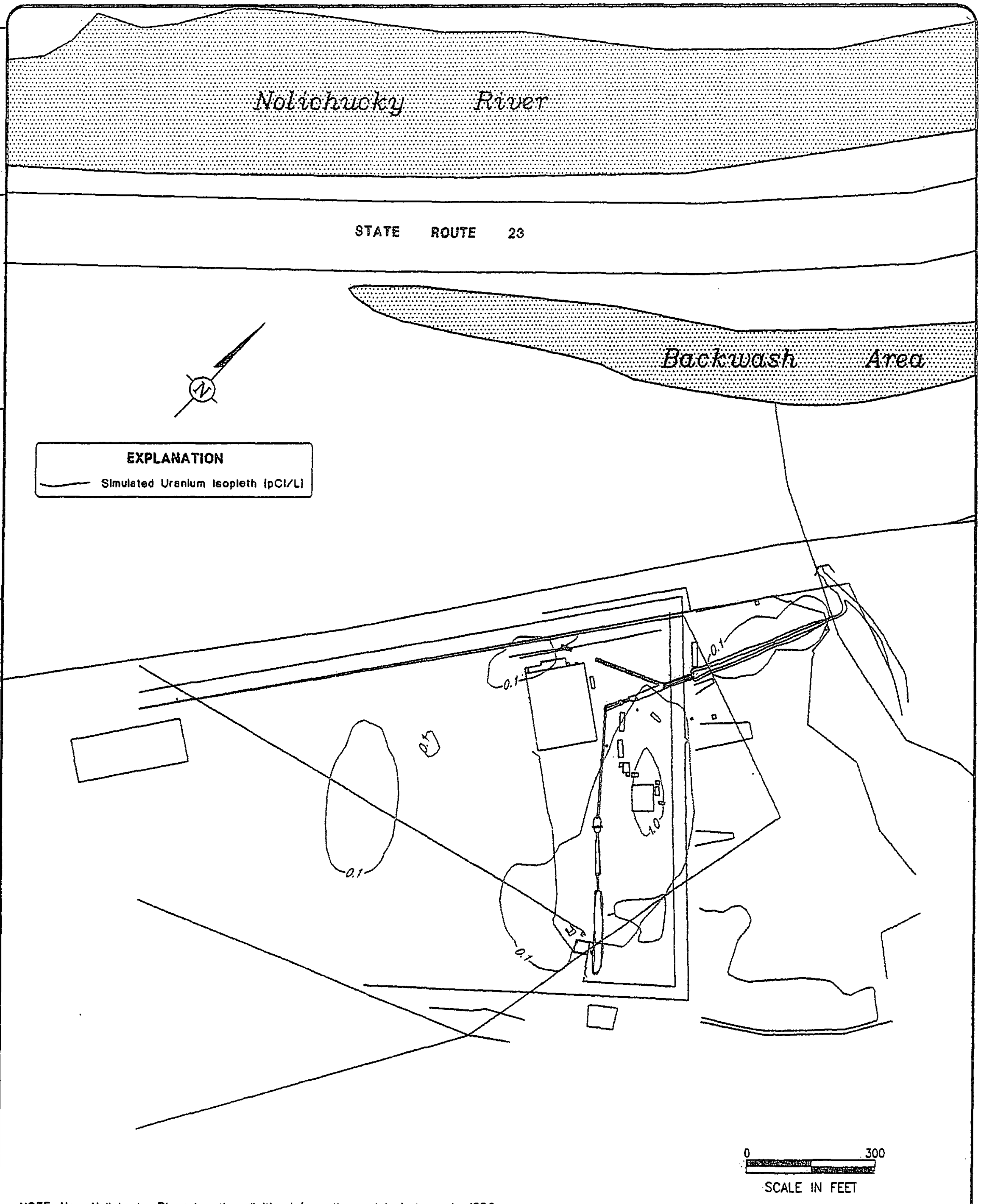
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution Model Layer 2 after 1,000 Years (No Burial Ground Source)

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-8

DRAFTER: BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30092...DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 31MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

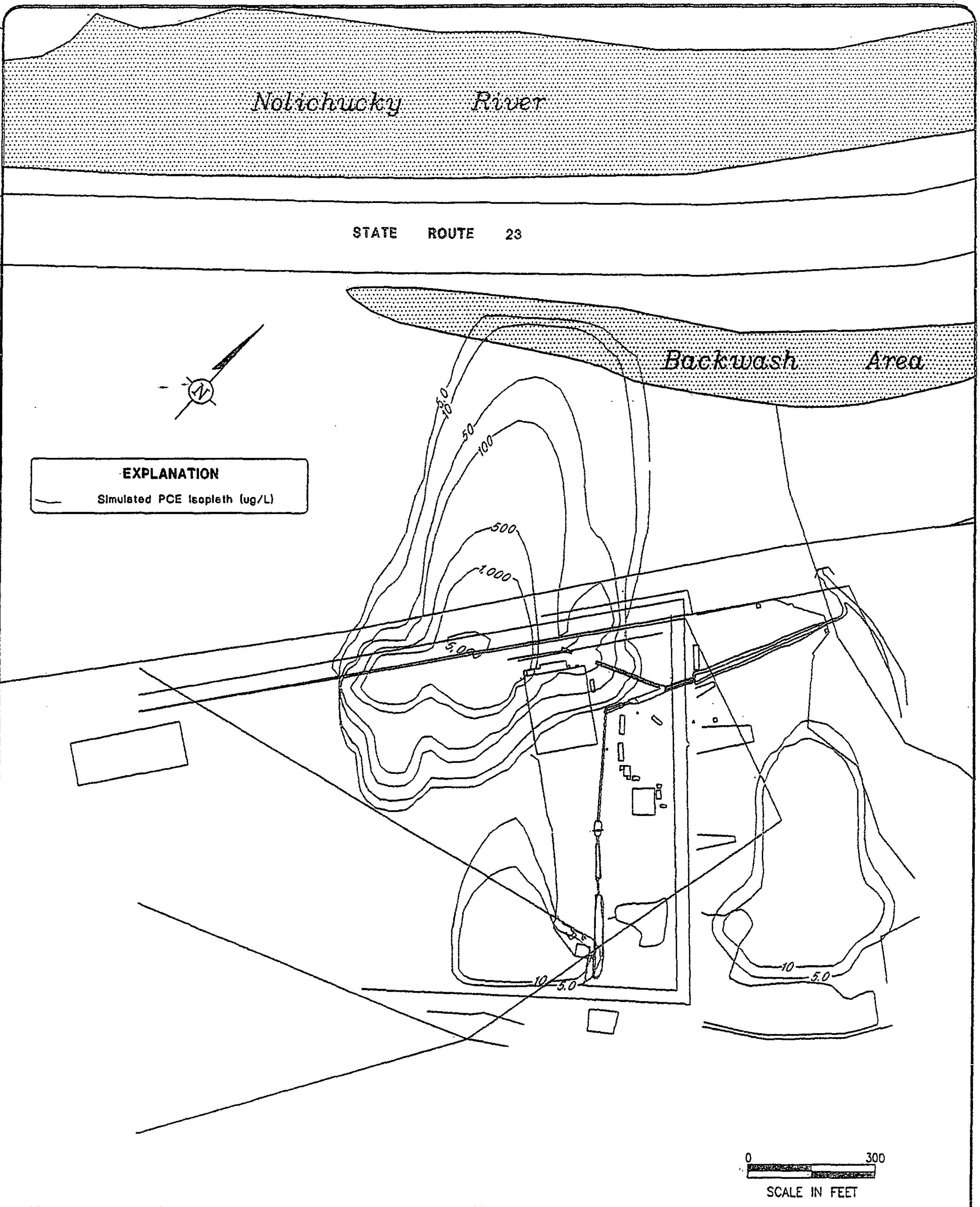
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated Uranium Concentration Distribution in Model Layer 3 after 1,000 Years (No Burial Grounds Source)

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-9

DWG DATE: 31MAR96 Ba | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30092.DWG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: BAKER



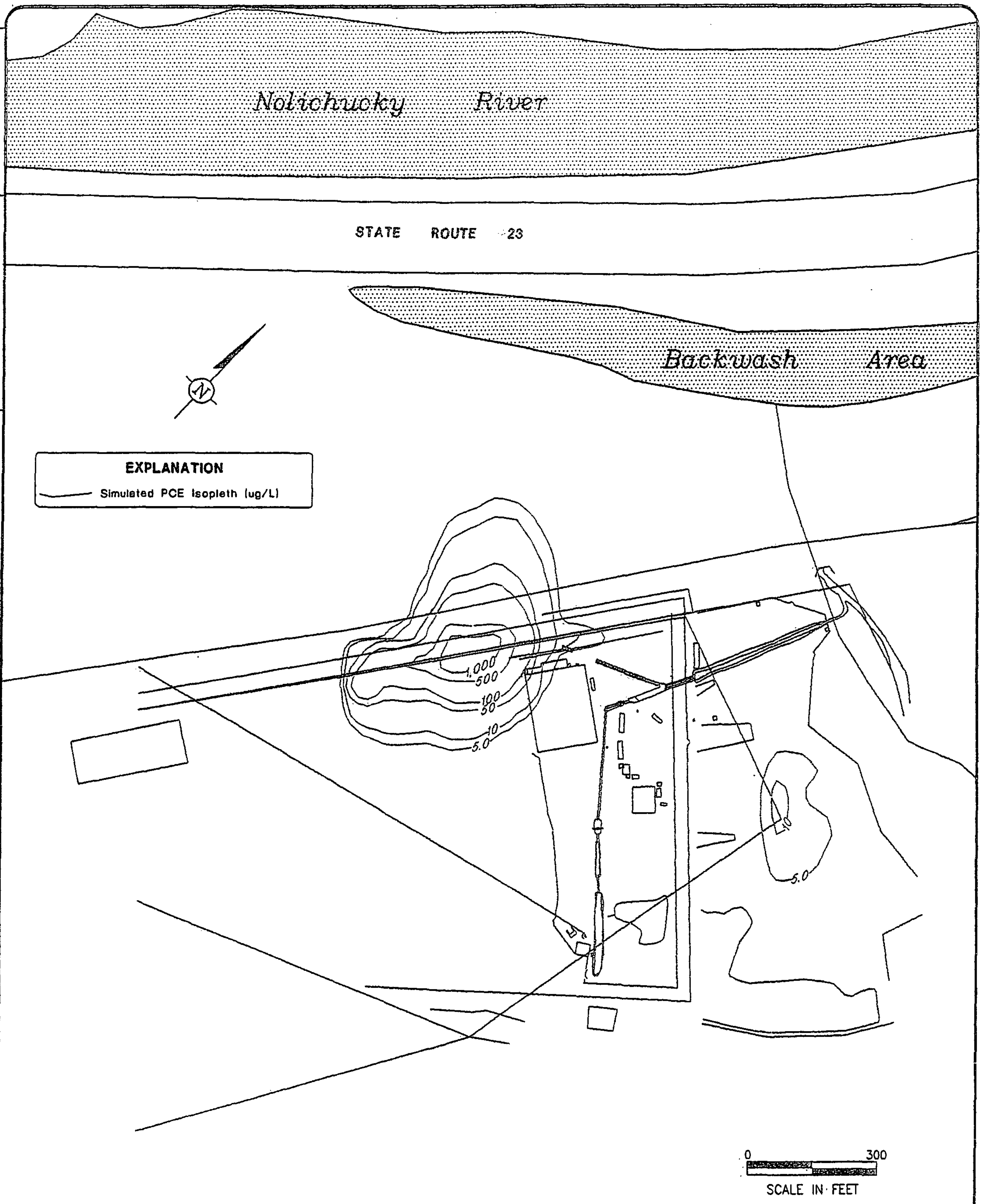
NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated PCE Concentration Distribution in Model Layer 1 after 10 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-10



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

DWG DATE: 31MAR96 Ba | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D30092..WG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER: BAKER

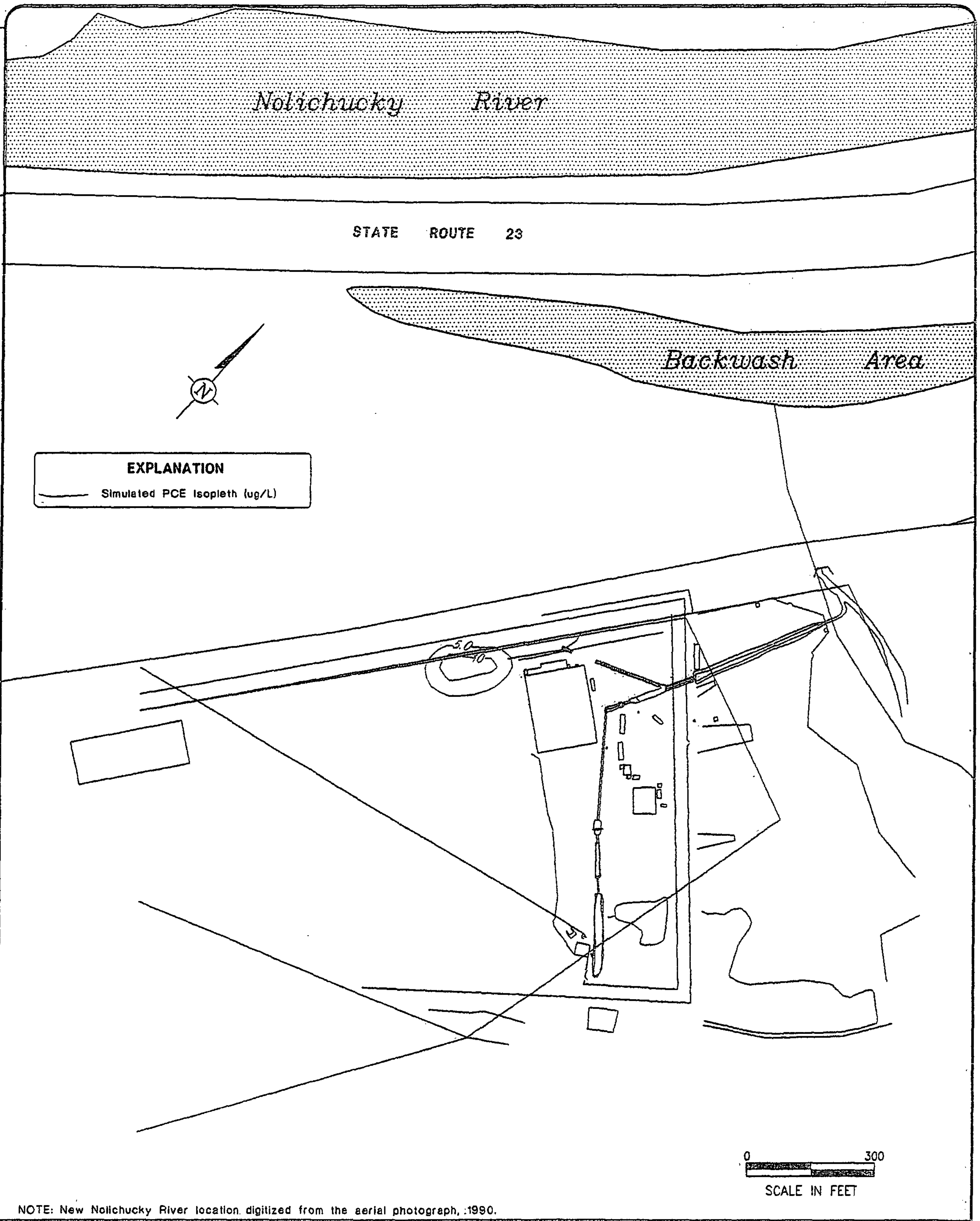
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated PCE Concentration Distribution in Model Layer 2 after 10 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
5-11

DRAFTER: JAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D30092[illegible]WG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 31MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

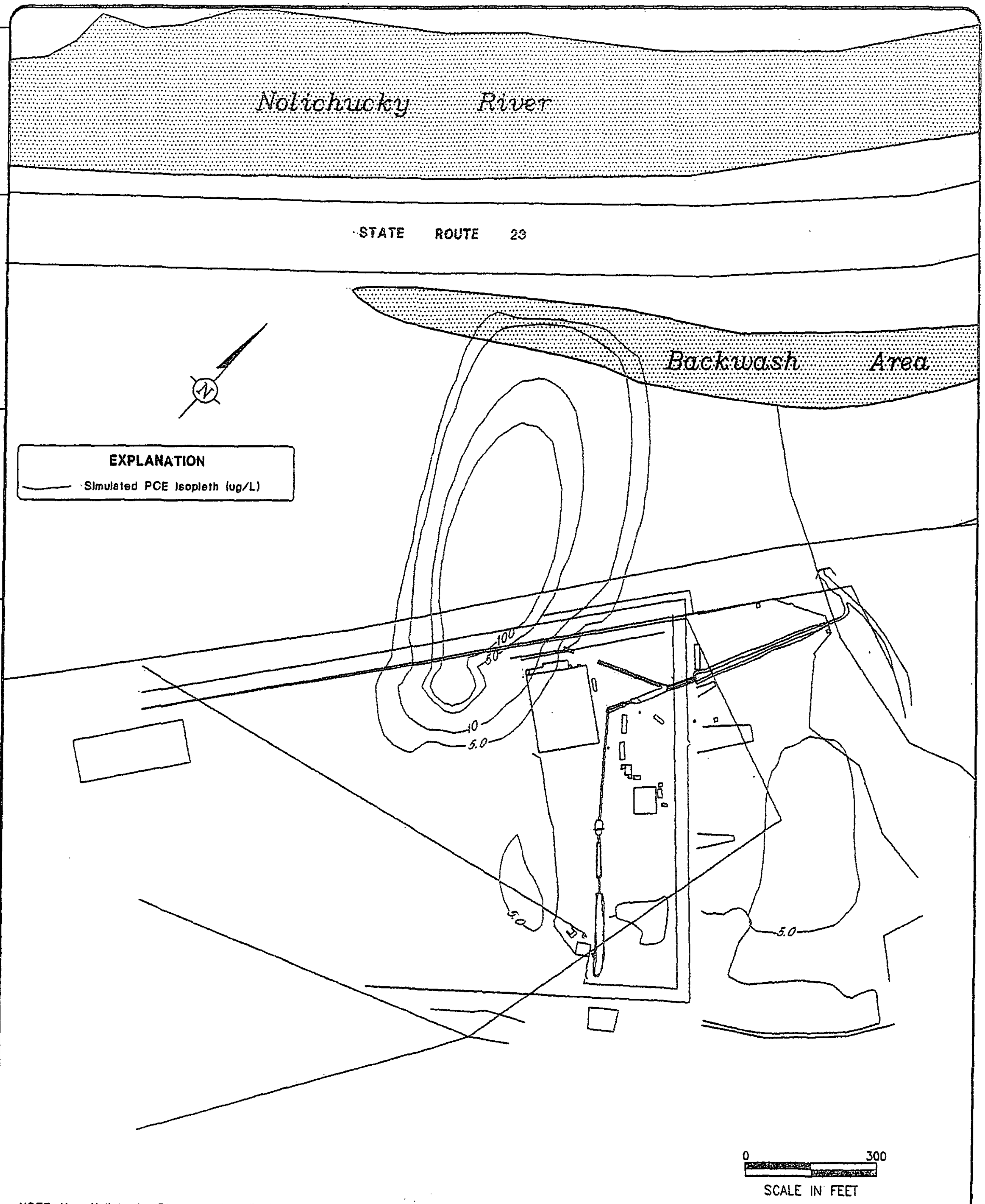
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated PCE Concentration Distribution in Model Layer 3 after 10 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
5-12

DRAFTER: BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D3009[illegible]DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 3[illegible]AR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated PCE Concentration Distribution in Model Layer 1 after 13 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE 5-13

DRAFTER: . BAKER

PROJ. OFFICER: B. ILGNER

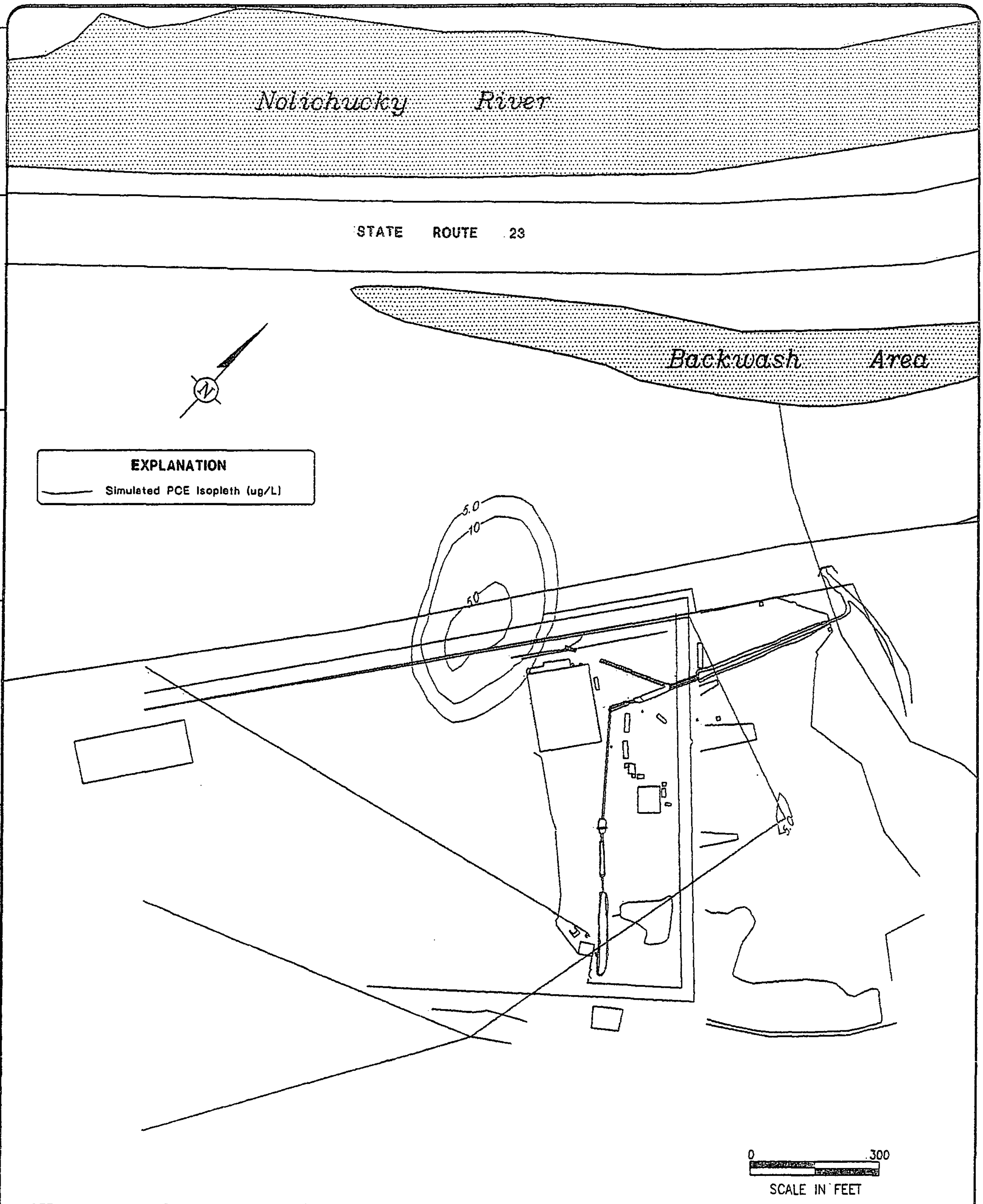
PROJ. MGR.: T. KHAN

DRAWING: D30092..DWG

FILE: GW MODEL

PROJ. NO.: TN0333.001

DWG DATE: 31MAR96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

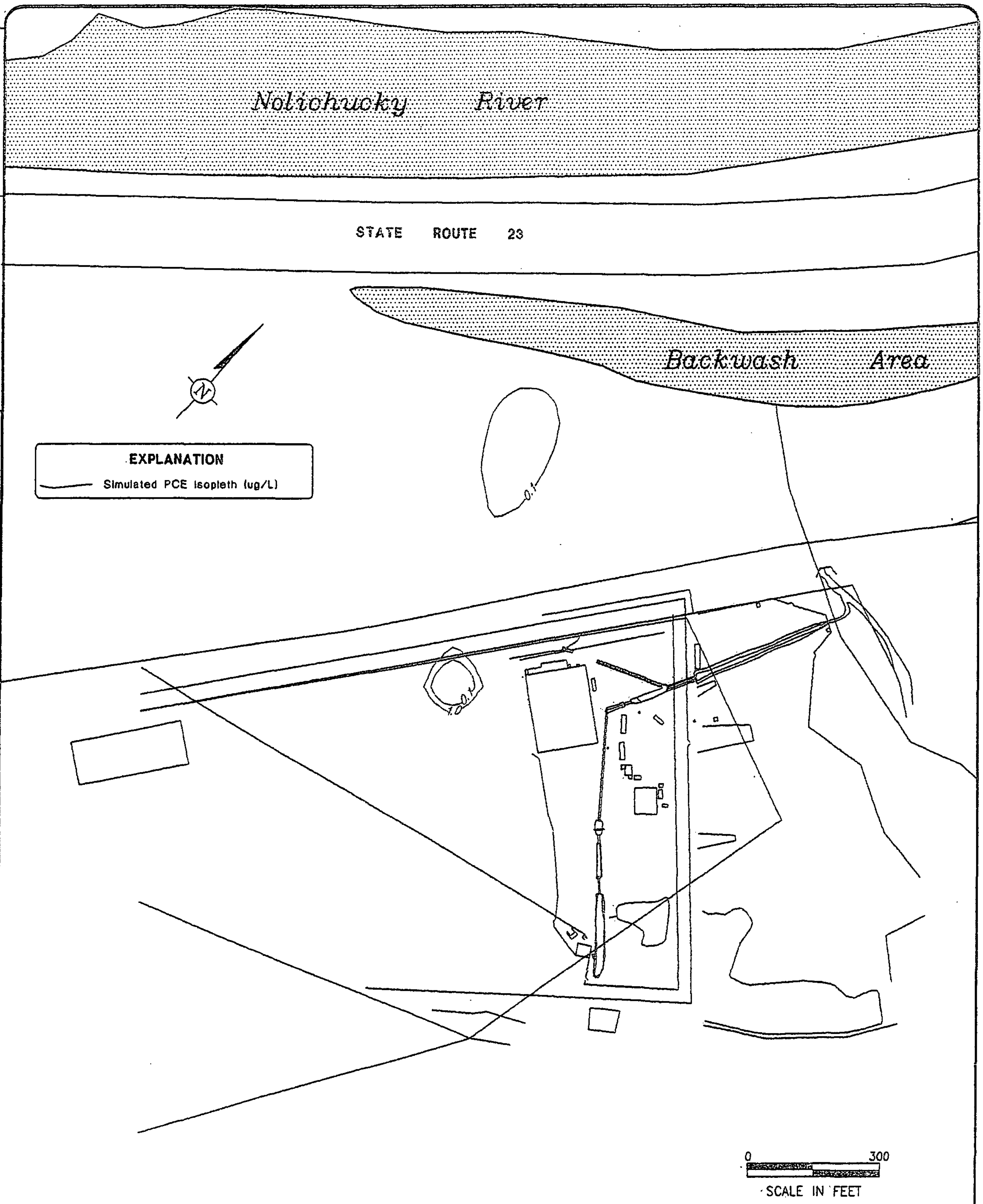
GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated PCE Concentration Distribution in Model Layer 2 after 13 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
5-14

DWG DATE: .. AR96 Ba | PROJ. NO.: TN0333.001 | FILE: GW MODEL | DRAWING: D3005. .WG | PROJ. MGR.: T. KHAN | PROJ. OFFICER: B. ILGNER | DRAFTER. . BAKER



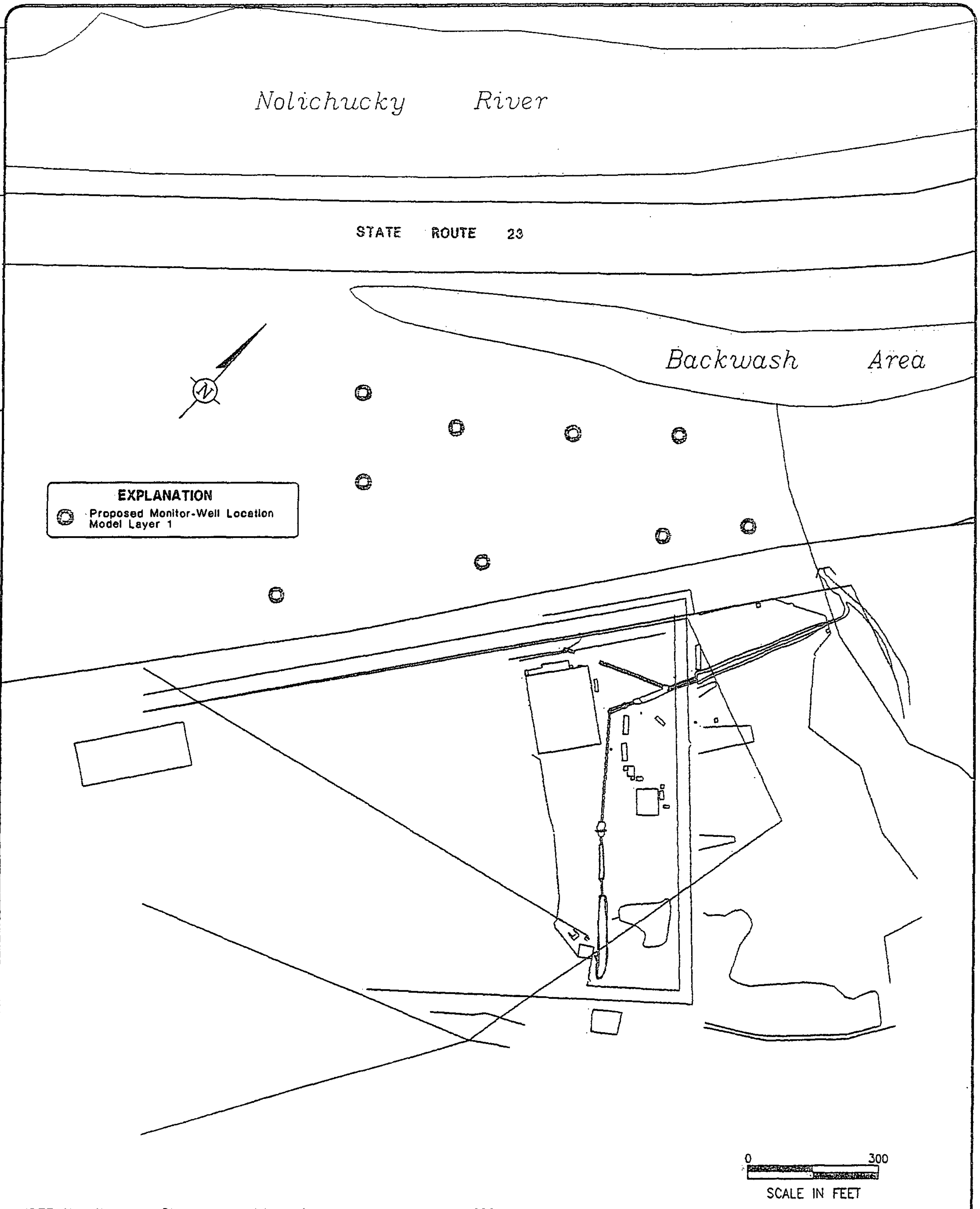
NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Simulated PCE Concentration Distribution in Model Layer 1 after 15 Years

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
5-15



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

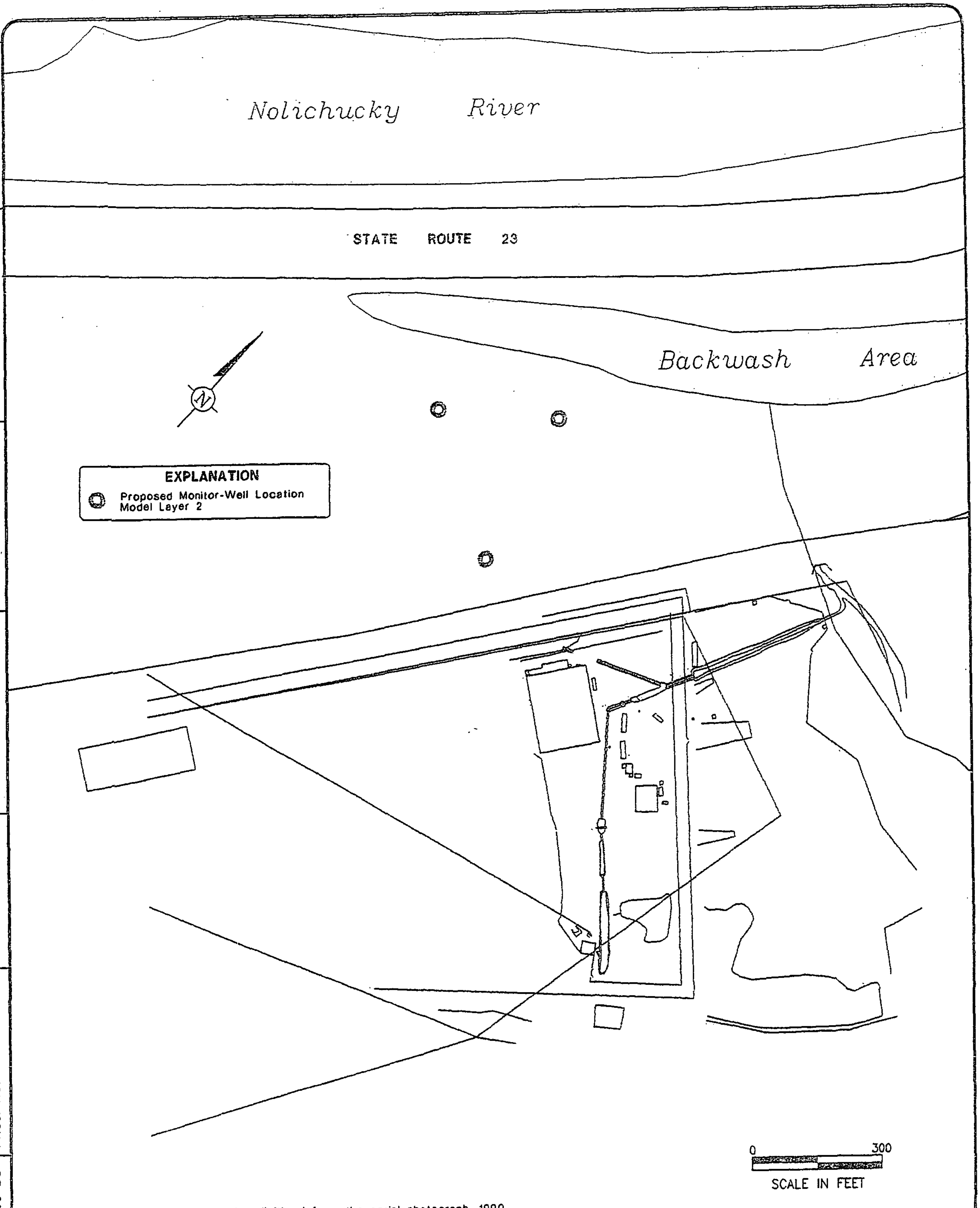
GERAGHTY
& MILLER, INC.
Environmental Services
A Heidemij company

Proposed Monitor-Well Locations in Model Layer 1

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
8-1

DRAFTER: J. BAKER
PROJ. OFFICER: B. ILGNER
PROJ. MGR.: T. KHAN
DRAWING: D30092A.DWG
FILE: GW MODEL
PROJ. NO.: TN0333.001
DWG DATE: 23FEB96 Ba



NOTE: New Nolichucky River location digitized from the aerial photograph, 1990.

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij company

Proposed Monitor-Well Locations in Model Layer 2

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
8-2

DRAFTER: S. BAKER | PROJ. OFFICER: B. ILGNER | PROJ. MGR.: T. KHAN | DRAWING: D300928.DWG | FILE: GW MODEL | PROJ. NO.: TN0333.001 | DWG DATE: 23FEB96 Ba

APPENDIX A

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 5	Well 10	Well 24	Well 25	Well 26	Well 27	Well 28	Well 29	Well 30	Well 31	Well 32	Well 33
	Depth to Water = feet below measuring point (TOC)											
20-JUN-89		6.93	4.95	4.88	6.43	5.64	7.16	5.33	6.78	8.05	4.00	6.10
21-JUN-89	6.58											
18-JUL-89	6.83		5.72	6.20	7.23	7.34	8.10	6.35	8.01	9.14	4.47	6.90
23-AUG-89	6.72	7.32	5.85	6.23	7.54	7.55	8.48	6.84	8.35	9.45	4.68	6.93
21-SEP-89	6.63	8.48	6.05	6.62	7.70	7.95	8.65	10.40	8.48	9.56	4.72	7.00
10-OCT-89	6.43	7.78	5.55	5.81	6.98	7.45	7.90	9.79	7.75	8.89	4.30	6.75
09-NOV-89		8.40	6.15	6.48	7.75	7.63	8.68	10.10	8.42	9.50	4.68	6.95
10-NOV-89	6.62											
01-DEC-89	6.52	7.68	5.55	5.75	6.85	7.13	7.78	4.98	7.62	8.88	4.35	6.60
24-JAN-90	6.48	7.25	5.10	5.00	6.55	6.50	7.33	4.30	7.10	8.38	4.08	6.40
02-FEB-90	6.60	7.45	5.25	5.35	6.58	6.83	7.45	4.70	7.25	8.55	4.14	6.60
08-MAR-90	6.58	7.13	5.20	5.10	6.20	6.73	7.95	4.28	3.28	3.98	3.83	6.50
06-APR-90	6.77	7.51	5.72	5.74	6.65	7.45	7.36	4.45			3.89	6.68
11-MAY-90	6.60	7.13	5.57	5.18	6.54	6.22	7.25	4.63	5.48	5.46	3.92	6.35
14-JUN-90	6.88	8.26	6.15	5.93	7.20	7.45	8.15	5.18	5.68	5.52	4.43	7.05
23-JUL-90	6.88	8.70	6.60	6.63	7.70	7.95	8.70	5.78	5.60	5.90	4.80	7.23
22-AUG-90	6.79	8.88	6.76	6.87	7.93	8.07	8.94	5.98	5.81	6.03	4.87	7.17
18-SEP-90	6.68	8.72	6.85	6.65	7.88	8.00	8.93	6.08	5.83	6.10	4.93	7.12
23-OCT-90	6.30	8.38	6.65		7.43	5.95	8.38	4.98	4.85		4.52	6.55
15-NOV-90	6.75	8.88	6.60	6.75	8.00	7.85	8.85	6.28	6.38	6.50	4.98	7.08
12-DEC-90	6.90	9.38	6.83	6.58	8.55	8.78	9.45	6.68	6.88	6.95	5.23	7.13
23-JAN-91	6.82	8.58	6.15	6.05	7.35	7.20	8.35	5.48	5.60	6.02	4.68	6.78
02-FEB-91	6.28	7.60	5.26	6.74	6.28	5.85	7.15	4.68			3.88	6.40
03-MAR-91	6.26	7.62	7.75	5.10	6.00	7.95	6.23	4.56			3.82	6.45
17-APR-91	6.85	8.28	5.60	5.73	6.75	7.18	7.68	5.05	5.13	3.16	6.05	6.75
27-MAY-91	6.89	8.55	5.83	5.88	7.13	7.26	8.05	5.14	5.48	5.68	4.38	6.78
10-JUN-91	6.91	8.72	6.04	6.08	7.39	7.55	8.41	5.60	5.55	5.91	4.61	6.88
22-JUL-91		8.95	6.33	6.90	7.89	8.04	8.82	6.03	6.30	6.55	4.88	7.12
06-AUG-91	6.79	8.55	5.68	6.00	7.20	7.48	8.23	4.46	5.72	5.69	4.60	6.78
03-SEP-91		8.77	5.89	6.48	7.45	7.87	8.51	6.75	5.90	5.95	4.62	6.98
02-OCT-91	6.80	8.85	5.95	6.35	7.55	7.80	8.70	5.50	5.70	5.75	4.70	6.95
06-NOV-91	7.05	9.72	6.63	7.91	8.54	8.93	9.62	6.93	6.95	7.02	5.69	7.66
09-DEC-91	6.73	8.65	5.74	6.05	7.15	7.57	8.24	5.15	5.70	5.33	4.54	6.71
07-JAN-92	6.67	8.34	5.21	5.70	6.82	6.80	7.89	4.99	4.85	4.05	4.44	6.55
04-FEB-92	7.05	8.62	5.60	6.44	7.40	7.71	8.54	5.30	6.05	6.20	4.70	6.98
09-MAR-92	6.90	8.62	5.45	5.85	7.10	6.85	8.10	5.35	5.65	5.85	4.45	6.85
06-APR-92	6.70	8.50	5.20	5.75	6.90	7.05	7.95	7.25	5.35	5.40	4.25	6.75
11-MAY-92	6.80	8.30	5.60	5.25	6.70	6.10	7.70	5.05	5.35	5.55	4.25	6.65
08-JUN-92	6.75	8.25	5.25	5.30	6.55	6.35	7.60	4.75	5.10	5.15	4.05	6.60

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 34	Well 35	Well 36	Well 37	Well 38	Well 39	Well 40	Well 41	Well 52	Well 55	Well 55A	Well 56
	Depth to Water = feet below measuring point (TOC)											
20-JUN-89	3.50	6.08	6.18		5.55	4.13	5.05	3.94				
21-JUN-89				7.53					6.28	5.24		14.55
18-JUL-89	4.20	6.35	8.21	8.01	6.27	4.60	5.12	4.14	6.38	5.49		15.29
23-AUG-89	4.45	6.53	8.54	8.23	6.73	5.00	5.21	4.30	6.47	5.67		15.65
21-SEP-89	4.48	6.55	8.76	8.25	7.00	5.23	5.23	4.33	6.52	5.71		15.75
10-OCT-89	4.00	6.32	7.87	7.68	6.29	4.57	5.13	4.10	6.43	5.48		15.13
09-NOV-89	4.40	6.45	8.68		7.10	5.13	5.23	4.30				
10-NOV-89				8.25					6.45	5.70		15.65
01-DEC-89	3.95	6.10	7.75	7.60	6.30	4.55	5.20	4.13	6.38	5.46		14.82
24-JAN-90	3.82	5.93	7.22	7.35	5.78	4.23	5.13	4.00	6.35	5.32		14.35
02-FEB-90	3.93	5.95	7.55	7.38	5.95	4.25	5.13	4.05	6.33	5.32		14.42
08-MAR-90	3.13	5.90	7.18	7.00	5.70	3.95	5.00	3.82	6.25	5.08		13.95
06-APR-90	3.34	6.00	7.63	7.15	6.12	4.08	5.05	3.85	6.21	5.08		14.25
11-MAY-90	3.65	6.00	6.83	7.25	5.80	4.13	5.05	3.90	6.28	5.18		14.32
14-JUN-90	4.21	6.33	8.28	7.88	6.40	4.75	5.20	4.19	6.38	5.50		15.15
23-JUL-90	4.55	6.57	8.65	8.28	6.95	5.15	5.28	4.38	6.48	5.72		15.65
22-AUG-90	4.77	6.57	9.04	8.46	7.33	5.39	5.26	4.43	6.46	5.81		15.87
18-SEP-90	4.83	6.63	8.74	8.50	7.28	5.65	5.28	4.48	6.52	5.88		15.95
23-OCT-90	4.49	6.13	7.82	8.15	6.63	5.18	5.25	4.35	6.68	5.73		15.48
15-NOV-90	4.38	6.63	8.65	6.98	7.53	5.80	5.35	4.58	6.63	6.00		15.75
12-DEC-90	4.80	6.78	9.65	7.35	8.10	6.18	5.43	4.73	6.73	6.15		16.13
23-JAN-91	4.32	6.33	7.98		6.93	5.23	5.32	4.43	5.93	6.08		16.10
02-FEB-91	3.81	5.85	6.30		6.03	4.58	5.13	4.08	6.43	5.35		13.43
03-MAR-91	3.80	5.88	6.20		5.65	3.90	5.12	3.90	6.38	5.20		13.40
17-APR-91	3.78	6.00	7.66		6.12	6.25	5.13	4.03	6.30	5.28		14.18
27-MAY-91	4.17	6.17	8.04		6.40	4.65	5.21	4.22	6.35	5.51		14.91
10-JUN-91	4.38	6.35	8.32		6.71	4.94	5.26	4.38	6.47	5.55		15.22
22-JUL-91	4.76	6.48	9.03		7.28	5.35	5.33	5.82	6.58	5.91		15.77
06-AUG-91	4.35	6.23	8.00		6.48	6.68	5.20	2.31	6.48	5.70		15.08
03-SEP-91	4.50	6.36	8.40		6.78	5.12	5.24	2.15	6.45	5.72		14.90
02-OCT-91	4.70	8.25	8.65		6.95	5.20	5.30	2.30	5.80	4.85		14.70
06-NOV-91		6.82	9.97	5.06	8.17	6.48	5.45	2.62	6.65	6.15		16.15
09-DEC-91	4.32	6.20	8.30		6.58	4.99	5.25	2.20	6.45	5.72		14.64
07-JAN-92	3.83	6.10	7.68		6.50	4.85	5.20	2.10	6.39	5.55		14.10
04-FEB-92	4.41	6.35	8.64		7.00	5.24	5.29	2.30	6.45	5.72		14.85
09-MAR-92	4.05	6.20	8.10		6.50	4.95	5.25	2.10	6.45	5.65		14.60
06-APR-92	3.95	6.10	7.50		6.45	4.80	5.20	2.65	6.35	5.45		14.20
11-MAY-92	4.15	6.05	7.45		6.05	4.65	5.25	2.10	6.45	5.50		14.65
08-JUN-92	3.80	5.85	7.25		5.95	4.30	5.10	1.90	6.30	5.30		14.25

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 57	Well 58	Well 59	Well 60	Well 60B	Well 62	Well 63	Well 63A	Well 63B	Well 64	Well 65	Well 66
	Depth to Water = feet below measuring point (TOC)											
20-JUN-89												
21-JUN-89	9.23	8.04	6.28	11.78		7.55	6.05			6.96	5.73	7.37
18-JUL-89	9.79	8.50	7.20	12.50		8.67	6.45			7.75	6.58	7.97
23-AUG-89	9.93	8.56	7.44	12.78		9.13	6.75			8.00	6.80	8.08
21-SEP-89	9.88	8.54	7.63	12.88		9.35	6.88			8.13	6.98	8.11
10-OCT-89	9.58	8.33	6.93	12.28		8.38	6.55			7.53	6.33	7.73
09-NOV-89												
10-NOV-89	9.83	8.47	7.52	12.88		9.32	6.82			8.13	6.92	8.02
01-DEC-89	9.38	8.18	6.78	12.20		8.20	6.40			7.60	6.25	7.63
24-JAN-90	9.15	8.00	6.43	11.78		7.70	6.05			7.10	5.90	7.40
02-FEB-90	9.30	8.10	6.62	11.88		7.98	6.05			7.18	6.05	7.55
08-MAR-90	9.20	8.08	6.35	11.45		7.53	5.55			6.80	5.75	7.45
06-APR-90	9.55	8.38	6.70			8.00				7.03	6.08	7.75
11-MAY-90	9.35	8.20	6.35	11.83		7.87	5.68			6.98	5.80	7.48
14-JUN-90	9.95	8.73	7.39	12.58		8.98	6.25			7.48	6.75	8.13
23-JUL-90	10.28	9.20	7.88	13.03		9.60	6.65			8.29	7.23	8.79
22-AUG-90	10.24	8.88	7.98	13.20		9.84	6.86			8.35	7.34	8.50
18-SEP-90	10.18	8.80	7.80	13.20		9.90	6.98			8.98	7.18	8.39
23-OCT-90	9.75	8.62	5.93	12.63		8.78	6.80			6.38	5.93	8.38
15-NOV-90	10.22	9.18	6.20	13.18		9.75	7.13			6.95	6.35	9.22
12-DEC-90	10.50	9.35	6.70	13.52		10.34	7.33			7.38	7.85	9.55
23-JAN-91	10.35	9.50	7.50	13.35		10.00	7.00			7.84	7.50	9.40
02-FEB-91	8.87	8.05	5.37	11.29		7.19	5.90			5.36	6.32	7.87
03-MAR-91	8.88	8.06	5.35	11.34		7.46	5.89			5.35	6.30	7.86
17-APR-91	9.72	8.70	5.90	11.83		8.10	5.85			5.75		8.58
27-MAY-91	9.97	8.85	6.91	12.37		8.69	6.22					8.53
10-JUN-91	10.09	8.92	7.50	12.71		12.07	11.31			5.95	9.55	10.58
22-JUL-91	10.33	9.07	6.25	13.12		9.72	6.95			6.95	7.55	5.78
06-AUG-91	9.98	8.88	5.98	12.50		8.54	6.68			6.30	7.34	8.55
03-SEP-91	10.10	8.95	6.15	12.63		9.05	6.71			6.44	7.20	8.68
02-OCT-91	9.45	8.95	6.25	12.50		9.15	5.80			6.3	6.70	9.90
06-NOV-91	10.65	9.48	7.16	13.65		10.30	7.30			7.35	8.18	10.10
09-DEC-91	9.75	8.06	6.10	12.36		8.38	6.70			6.27	8.20	8.73
07-JAN-92	9.48	8.61	6.00	11.91		8.00	6.31			5.90	5.95	8.42
04-FEB-92	9.97	8.89	6.10	12.56		8.95	7.30			6.48	6.30	8.70
09-MAR-92	9.85	8.85	6.06	12.20		8.45	6.50			6.15	7.35	8.65
06-APR-92	9.65	8.75	5.95	11.90		8.10	6.10			5.95		8.50
11-MAY-92	9.75	8.70	5.90	12.10		8.30	6.25			5.90		8.35
08-JUN-92	9.60	8.70	5.75	11.80		8.00	6.00			5.65		8.35

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Sampling Period	Well 67	Well 67B	Well 68	Well 70	Well 70A	Well 71	Well 72	Well 73	Well 74	Well 75	Well 76	Well 77	Well 78
Depth to Water = feet below measuring point (TOC)													
20-JUN-89				8.90		6.52	6.10	1.93	16.75	7.05	9.63	7.74	8.21
21-JUN-89	6.88		7.27										
18-JUL-89	7.40		7.90	9.92		7.56	7.27	2.87	17.14	8.10	10.32	8.75	9.11
23-AUG-89	7.74		8.00	10.37		7.86		2.97	17.79	8.38	10.66	9.06	9.34
21-SEP-89	7.78		8.05	10.59		7.99		3.33	18.01	8.62	10.73	9.13	9.52
10-OCT-89	7.25		7.65	9.71		7.28		2.88	17.13	7.93	10.09	8.48	9.14
09-NOV-89				10.55		8.10		2.75	18.05	8.60	10.68	9.10	9.48
10-NOV-89	7.75		7.98										
01-DEC-89	7.21		7.54	9.65		7.25		2.58	17.48	7.83	10.15	8.45	8.85
24-JAN-90	6.85		7.28	9.22		6.80		2.15	17.00	7.37	9.70	7.98	8.32
02-FEB-90	6.95		7.46	9.33		6.92		2.40	16.70	7.50	9.78	8.13	8.64
08-MAR-90	6.58		7.37	8.75		6.46		2.10	15.70	7.13	9.52	7.68	8.60
06-APR-90	6.75		7.73	9.12		6.82		2.32	15.72	7.42		7.95	9.03
11-MAY-90	6.82		7.36	9.03		6.64		1.93	16.45	7.23	9.56	7.88	8.72
14-JUN-90				10.13		7.63		2.88	17.08	8.13	10.45	8.69	8.28
23-JUL-90	7.88		8.75	10.80		8.19		3.40	18.09	8.70	10.85	9.22	9.68
22-AUG-90	8.08		8.47	11.09		8.49		3.63	18.55	8.99	11.06		9.97
18-SEP-90	8.08		8.35	11.03		8.42		3.32	18.68	8.94	11.10	9.32	9.88
23-OCT-90	7.55		8.40	10.55		8.00		2.80	18.42	8.30	10.46	8.63	8.62
15-NOV-90	8.00		9.17	11.08		8.43		3.63	18.58	8.95	11.03	9.33	9.75
12-DEC-90	8.40		9.58	11.80		9.16		6.60	19.23	9.68	11.48	9.76	10.34
23-JAN-91	8.35		8.98	10.43		7.73		2.92	18.10	8.33	10.57	8.83	9.13
02-FEB-91	6.60		7.83	9.10		6.65		1.68	17.68	7.08	9.45	7.40	8.08
03-MAR-91	6.58		7.82	8.70		6.45		2.10	15.68	7.12	9.40	7.75	8.10
17-APR-91	6.88		8.42	9.35		6.97		2.85	16.27	7.55	9.66	8.00	8.95
27-MAY-91	7.33		8.43	9.89		7.31		2.92	16.88	7.92	10.18	8.51	9.14
10-JUN-91	8.68		9.35	10.29		7.72		2.75	17.38	8.21	10.56	8.84	9.33
22-JUL-91	8.02		8.71	10.90		8.24		4.55	18.10	8.66	10.98	9.38	9.66
06-AUG-91	7.50		8.56	10.00		7.47		3.28	17.36	7.93	10.35	8.62	9.15
03-SEP-91	7.10		8.60	10.35		8.04		4.15	18.25	8.23	10.50	8.90	9.50
02-OCT-91	7.40		9.35	10.40		8.05	7.71	3.50	16.60	7.55	10.6	8.60	8.55
06-NOV-91	8.52		10.28	11.91		9.40	9.33	6.57	19.00	9.66	11.52	9.84	10.53
09-DEC-91	7.45		8.70	10.29		9.26	8.61	2.51	18.05	8.32	10.51	8.64	9.14
07-JAN-92	7.13		8.34	9.84		7.44	6.20	2.03	17.55	7.98	9.67		7.99
04-FEB-92	7.65		8.60	10.62		8.20	7.24	3.24	17.70	8.58	10.69	8.96	9.16
09-MAR-92	7.40		5.55	10.10		7.60	6.15	2.75	17.60	7.50	10.26	8.55	8.10
06-APR-92	7.20		8.35	9.70		7.35	6.30	2.25	16.85	7.80	9.95	8.30	8.38
11-MAY-92	7.20		8.35	9.60		7.15	5.85	2.35	17.05	7.10	10.05	8.25	7.70
08-JUN-92	6.95		8.20	9.30		7.00	5.90	2.60	16.50	7.40	9.70	8.00	8.05

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 79	Well 80	Well 81	Well 82	Well 91	Well 92	Well 93	Well 94	Well 95A	Well 96A	Well 97A	Well 98A	Well 99A	Well 100A
	Depth to Water = feet below measuring point (TOC)													
20-JUN-89	7.68	7.75	6.87											
21-JUN-89				23.49										
18-JUL-89	8.42	8.87	8.89	24.18										
23-AUG-89	8.79	9.23	8.19	24.65										
21-SEP-89	8.89	9.45	8.36	24.78										
10-OCT-89	8.27	8.58	7.58	23.90										
09-NOV-89	8.78	9.55	8.32											
10-NOV-89				24.85										
01-DEC-89	8.35	8.60	7.55	24.13										
24-JAN-90	7.88	8.03	7.10	23.53										
02-FEB-90	7.92	8.23	7.28	23.48										
08-MAR-90	7.50	7.75	6.88	22.75										
06-APR-90	7.62	8.21	7.25	23.03										
11-MAY-90	7.72	7.90	6.98	23.29										
14-JUN-90	8.52	9.05	8.05	24.35										
23-JUL-90	9.00	9.60	8.55	25.03										
22-AUG-90	9.21	9.86	8.75	25.40										
18-SEP-90	9.25	9.78	8.67	25.48										
23-OCT-90	8.65	9.23	8.22	24.58										
15-NOV-90	9.30	9.75	8.68	25.25										
12-DEC-90	9.64	10.31	9.20	25.78										
23-JAN-91	8.74	9.20	8.27	25.56										
02-FEB-91	7.72	8.05	7.26	23.36										
03-MAR-91	7.70	8.00	7.20	23.34										
17-APR-91	7.85	8.62	7.74	23.28										
27-MAY-91	8.37	8.92	8.11	24.25										
10-JUN-91	8.75	9.28	8.38	33.45										
22-JUL-91	9.13	9.10	8.81	25.20										
06-AUG-91	8.54	9.05	8.18	24.38										
03-SEP-91	8.68	9.38	8.40	25.00										
02-OCT-91	8.70	9.65	8.40	25.25	7.81	3.85	4.18	6.28						
06-NOV-91	9.86	10.40	9.44	26.30	10.50	6.50	5.76	7.60						
09-DEC-91	8.74	9.03	8.25	24.69	7.77	4.10	4.25	6.94						
07-JAN-92	8.36	8.71	7.91	24.34	7.48	3.68	3.98	4.70						
04-FEB-92	8.85	9.41	8.49	24.66	7.95	3.75	4.41	5.71						
09-MAR-92	8.45	9.15	8.15	25.00	7.65	3.95	3.68	5.55						
06-APR-92	8.20	8.80	7.95	23.80	7.50	3.75	4.05	6.15						
11-MAY-92	8.10	8.65	7.85	23.75	6.80	2.35	2.70	5.40						
08-JUN-92	7.90	8.55	7.70	23.45	7.15	3.30	3.15	5.50						

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 100B	Well 101A	Well 102A	Well 103A	Well 104A	Well 105A	Well 106A	Well 107A	Well 107B	Well LD-1A	Well LD-2A	Well 234-2	Well 234-3	Well SC-1	Well SC-3
	Depth to Water = feet below measuring point (TOC)														
20-JUN-89															
21-JUN-89															
18-JUL-89															
23-AUG-89															
21-SEP-89															
10-OCT-89															
09-NOV-89															
10-NOV-89															
01-DEC-89															
24-JAN-90															
02-FEB-90															
08-MAR-90															
06-APR-90															
11-MAY-90															
14-JUN-90															
23-JUL-90															
22-AUG-90															
18-SEP-90															
23-OCT-90															
15-NOV-90															
12-DEC-90															
23-JAN-91															
02-FEB-91															
03-MAR-91															
17-APR-91															
27-MAY-91															
10-JUN-91															
22-JUL-91															
06-AUG-91															
03-SEP-91															
02-OCT-91															
06-NOV-91															
09-DEC-91															
07-JAN-92															
04-FEB-92															
09-MAR-92															
06-APR-92															
11-MAY-92															
08-JUN-92															

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well SC-4	Well SC-6	Well SC-7	Well SC-8	Piez P1	Piez P2	Piez P3	Piez P4	Well A
	Depth to Water = feet below measuring point (TOC)								
20-JUN-89									
21-JUN-89									
18-JUL-89									
23-AUG-89									16.54
21-SEP-89									16.58
10-OCT-89									16.10
09-NOV-89									
10-NOV-89									15.50
01-DEC-89									16.00
24-JAN-90									15.63
02-FEB-90									15.75
08-MAR-90									15.45
06-APR-90									15.65
11-MAY-90									15.68
14-JUN-90									16.30
23-JUL-90									16.65
22-AUG-90									16.87
18-SEP-90									16.85
23-OCT-90									16.35
15-NOV-90									16.75
12-DEC-90									17.05
23-JAN-91									16.92
02-FEB-91									15.25
03-MAR-91									15.24
17-APR-91									15.73
27-MAY-91									
10-JUN-91									
22-JUL-91									
06-AUG-91									16.28
03-SEP-91									
02-OCT-91									15.08
06-NOV-91									17.15
09-DEC-91									16.09
07-JAN-92									15.75
04-FEB-92									16.25
09-MAR-92									16.05
06-APR-92									15.75
11-MAY-92									15.90
08-JUN-92									15.65

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Sampling Period	Well 5	Well 10	Well 24	Well 25	Well 26	Well 27	Well 28	Well 29	Well 30	Well 31	Well 32	Well 33
	Depth to Water = feet below measuring point (TOC)											
13-JUL-92	6.80	8.41	5.43	3.51	6.71	6.89	7.74	4.52	5.10	5.18	4.05	6.59
17-AUG-92	5.91	7.55	4.40		6.20	5.08	7.50	4.40	0.71	4.58	3.82	6.65
21-SEP-92	6.88	8.63	5.55	3.82	7.19	7.23	8.32	5.07	5.53	5.59	4.28	6.95
12-OCT-92	6.68	8.58	5.73	3.85	7.10	7.23	8.23	5.10	5.10	5.30	3.34	6.95
16-NOV-92	7.00	8.80	6.05	4.40	7.45	7.65	8.65	5.95	6.05	6.10	4.70	7.30
08-DEC-92	6.90	8.80	6.10	4.10	7.45	7.05	8.60	5.60	6.10	6.13	4.75	7.10
04-JAN-93	6.75	8.40	5.50	3.70	6.70	6.85	7.85	5.00	5.30	5.30	4.20	6.85
01-FEB-93	6.44	8.50	5.50	3.85	6.94	7.02	8.02	4.87	4.95	5.10	4.31	6.92
01-MAR-93	6.40	8.50	5.60	3.85	6.95	7.85	8.05	5.25	5.60	5.63	4.40	7.03
05-APR-93	6.15	8.00	5.10		6.17	6.30	7.20	4.60	4.38	4.70	3.70	6.65
03-MAY-93	6.30	8.38	5.70	3.95	6.79	7.02	7.77	4.82	4.90	4.98	4.18	6.88
04-JUN-93	6.16	8.58	5.93	4.17	7.10	7.32	8.28	5.46	5.80	5.85	5.70	4.45
09-JUL-93		8.95	6.25	5.00	7.60	7.95	8.80	5.95	6.31	6.30	6.05	4.60
01-AUG-93	6.61	8.90	6.44	4.69	7.55	7.61	8.74	5.57	6.31	6.30	5.91	4.27
07-SEP-93	6.81	9.45	6.84		8.11	8.55		6.77	6.33	6.40	6.41	5.28
27-OCT-93	6.88	9.55	7.10	5.55	8.16	8.35	9.55	6.13	6.42	6.44	6.25	4.95
02-NOV-93	6.78	9.67	7.16	5.15	8.18	7.95	9.38	6.50	6.42	6.19	6.21	4.95
03-DEC-93	6.70	9.18	Abandoned	Abandoned	8.31	Abandoned	9.30	6.10	6.45	6.86	6.32	
06-JAN-94	6.32	8.40			7.15		7.28	4.65	4.65	5.25	5.81	3.84
01-FEB-94	6.37	8.14			6.76		7.51	4.88	4.78	4.76	5.17	Dry
08-MAR-94	6.33	7.98			6.37		8.84	4.49	4.23	4.22	4.82	3.57
01-APR-94	6.00	7.07			5.24		No Reading	3.65	2.96	2.99	3.99	3.02
02-MAY-94	6.14	7.49			8.85		No Reading	4.01	3.67	3.61	4.34	3.05
02-JUN-94	6.40	8.32			6.85		7.55	4.75	5.70	4.80	5.10	3.55
21-JUL-94	6.54	8.53			7.07		7.86	4.96	5.76	4.93	5.23	3.70
03-AUG-94	6.50	8.42			7.04		7.87	5.08	4.98	5.02	5.28	3.70
01-SEP-94	6.51	8.73						5.62	5.95	5.70	5.65	3.85
03-OCT-94	6.56	8.98			11.94		11.14	5.80	5.72	5.76	5.68	4.52
02-NOV-94	6.58	9.02			9.00		10.77	6.04	6.89	6.00	5.89	5.12
01-DEC-94	6.67	9.03			9.05		10.90	6.27	6.92	6.06	5.99	5.40
02-JAN-95	6.68	9.27			9.12		10.80	6.27	6.22	6.50	6.12	5.49
01-FEB-95	6.44	8.45			8.08		10.00	5.05	5.00	5.00	5.30	4.26
01-MAR-95	6.08	7.80			7.36		7.84	4.65		3.62	4.50	3.72
04-APR-95	6.56	8.48			7.80		9.80	5.00	4.90	4.94	5.14	3.82
03-MAY-95	6.58	8.64			8.28		9.70	5.42	5.14	5.44	5.60	4.34

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Sampling Period	Well 34	Well 35	Well 36	Well 37	Well 38	Well 39	Well 40	Well 41	Well 52	Well 55	Well 55A	Well 56
	Depth to Water = feet below measuring point (TOC)											
13-JUL-92	3.90	6.00	7.50		5.99	4.21	5.08	1.90	6.25	5.22		14.21
17-AUG-92	3.51	5.85	6.05		5.85	4.35	5.02	1.75	6.24	5.11		13.88
21-SEP-92	3.93	6.04	7.95		6.27	4.55	5.12	2.0	6.30	5.36		14.61
12-OCT-92	4.24	6.08	7.92		6.59	4.48	5.12	2.04	6.37	5.44		14.69
16-NOV-92	4.60	6.50	8.10		6.95	5.30	5.20	4.20	6.50	5.60		15.00
08-DEC-92	4.60	6.40	8.50		6.85	5.25	5.25	4.25	6.55	5.75		15.05
04-JAN-93	4.05	6.10	7.70		6.25	4.50	5.15	4.05	6.35	5.40		14.15
01-FEB-93	4.15	6.18	8.02		6.31	4.37	5.16	2.02	7.95	5.41		14.53
01-MAR-93	4.20	6.20	8.05		6.55	4.75	5.20	4.08	7.95	5.25		13.40
05-APR-93	3.50	5.85	7.07		5.75	3.88	4.98	3.65	7.75	4.75		12.40
03-MAY-93	3.98	6.11	7.83		6.32	4.40	5.11	3.93	7.89	5.06		13.32
04-JUN-93	5.55	7.30	8.93		6.52	6.00	5.90	5.00	7.98	5.31	6.21	13.85
09-JUL-93	6.05	7.85	9.58		6.97	6.62	6.00	5.18	8.12	5.60	6.70	14.25
01-AUG-93	6.03	7.72	9.30		6.86	6.12		5.11	8.15	5.68	6.65	14.56
07-SEP-93	6.42	8.36	10.38		7.83	7.18	6.14	5.31	8.25	6.02	6.87	15.05
27-OCT-93	6.64	8.15	10.55		7.83	6.82	6.21	5.51	8.30	5.83	6.95	14.98
02-NOV-93	6.45	8.18	9.80		8.12	7.24	6.17	5.38	8.29	5.78	6.92	14.94
03-DEC-93	6.31	8.12	10.30		7.45	6.90	6.18	5.41	8.28	5.77	6.83	14.86
06-JAN-94	5.54	7.47	8.36		6.53		5.97		8.15	5.56	5.32	13.62
01-FEB-94	5.25	7.02	8.57		6.30	5.60	5.88	4.85	8.06	5.18	5.40	12.90
08-MAR-94	4.95	6.74	8.09		5.80	5.01	5.77	4.61	7.91	4.82	4.91	12.22
01-APR-94	3.99	5.89	6.48		5.01	4.11	5.56	4.15	7.73	4.33	4.29	11.30
02-MAY-94	4.41	6.27	7.00		5.15	4.45	5.62	4.29	7.71	4.39	4.66	12.07
02-JUN-94	5.30	7.12	8.53		5.95	5.25	5.82	4.75	7.91	5.06	5.64	13.26
21-JUL-94	5.50	7.14	8.65		6.08	5.56	5.92	4.94	8.10	5.07	6.13	13.82
03-AUG-94	5.58	7.13	8.69		6.12	5.68	5.94	5.00	8.04	5.12	6.20	13.58
01-SEP-94	5.68	6.80	9.00		7.35	5.86	5.84	4.80	8.02	5.12	6.30	13.55
03-OCT-94	6.16	7.07	9.80		7.30	6.35	5.98	5.08	8.13	5.40	6.72	14.18
02-NOV-94	6.34	7.20	10.01		7.76	6.62	6.02	5.22	8.18	5.50	6.72	14.34
01-DEC-94	6.30	7.17	10.01		7.94	7.05	6.08	5.25	8.22	5.60	6.56	14.40
02-JAN-95	6.43	7.42	10.50		8.66	7.60	6.16	5.33	8.26	5.72	6.60	14.56
01-FEB-95	5.58	6.40	8.74		6.40	5.92	5.90	4.92	8.09	5.26	5.37	13.29
01-MAR-95	4.82	6.05	7.22		6.57	5.30	5.76	4.60	7.92	4.86	4.42	12.58
04-APR-95	5.42	6.10	8.82		7.09	5.64	5.82	4.78	8.02	8.02	5.04	14.42
03-MAY-95	5.63	6.78	8.78		6.90	6.38	5.94	7.94	8.10	5.24	17.12	14.00

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 57	Well 58	Well 59	Well 60	Well 60B	Well 62	Well 63	Well 63A	Well 63B	Well 64	Well 65	Well 66
	Depth to Water = feet below measuring point (TOC)											
13-JUL-92	9.76	8.50	6.02	11.78		7.87	5.71			5.66	5.92	8.49
17-AUG-92	9.11	8.10	5.35	11.65		7.27	5.37			5.29	6.13	7.43
21-SEP-92	9.96	8.96	5.69	12.27		8.43	5.98			6.00	6.07	8.61
12-OCT-92	9.94	8.90	5.70	12.38		8.54	6.11			6.10	6.10	8.60
16-NOV-92	10.10	9.10	6.15	12.70		9.15	6.45			6.45		8.70
08-DEC-92	10.10	8.95	6.10	12.80		9.20	6.55			11.00		8.75
04-JAN-93	9.70	8.75	5.90	11.95		8.05	6.05			5.80		8.45
01-FEB-93	9.87	8.87	5.97	12.23		8.41	5.98			5.98	5.99	8.48
01-MAR-93	9.85	8.65	6.60	12.25		8.45	6.05			6.05	6.65	8.50
05-APR-93	9.35	8.25	5.45	11.15		7.30	5.20			5.65	6.05	7.95
03-MAY-93	9.83	8.65	5.82	11.98		8.19	5.55			5.90	6.55	8.40
04-JUN-93	10.05	8.70	5.93	12.40	12.60	8.70	5.95	4.65	4.82	6.28	6.69	8.45
09-JUL-93	10.30	8.97	6.22	12.85	13.23	9.35	6.40	5.15	5.20	6.72	7.05	8.84
01-AUG-93	10.25	8.69	6.20	12.98	13.23	9.26	6.58	4.98	5.25	6.30	7.03	8.82
07-SEP-93	10.61	9.25	6.80		13.60	10.05	6.93	5.24	5.45	7.22	7.53	9.18
27-OCT-93	10.60	8.92	6.45	13.61	13.80	9.98	7.23	5.21	5.61	6.91	6.92	8.85
02-NOV-93	10.50	8.81	6.26	13.52	13.72	9.60	7.21	5.07	5.60	6.84	6.70	8.78
03-DEC-93	10.95	8.95	7.51	13.45	13.64	9.95	7.24	5.15	5.60	7.35	6.25	8.95
06-JAN-94	9.74	8.44	5.83	11.90	12.59	8.12	6.58	4.90	5.30	6.28	6.65	8.28
01-FEB-94	9.64	8.27	5.46	11.90	12.09	7.93	6.21	4.59	5.01	5.49	5.84	8.06
08-MAR-94	9.43	8.14	5.31	11.34	11.52	7.10	5.58	4.30	4.58	5.00	5.62	7.97
01-APR-94	8.63	7.41	4.70	9.87	10.08	5.54	4.63	3.86	4.10	3.86	4.83	7.70
02-MAY-94	9.25	7.90	5.00	10.86	11.03	6.42	4.74	3.88	4.05	4.42	5.20	7.55
02-JUN-94	10.06	8.50	5.58	12.08	12.26	7.94	5.64	4.58	4.60	5.50	5.96	8.24
21-JUL-94	10.15	8.82	5.62	12.34	12.50	8.44	5.92	4.70	4.76	5.90	6.10	8.58
03-AUG-94	9.30	8.56	5.62	11.85	12.62	8.24	4.88	4.70	4.82	5.80	6.12	8.34
01-SEP-94	10.18	8.60	5.67	12.38	12.60	8.30	6.12	4.82	4.88	5.82	6.18	8.37
03-OCT-94	10.50	9.20	6.03	12.40	13.20	9.18	6.52	5.05	5.14	7.36	6.56	8.60
02-NOV-94	10.52	8.74	6.05	13.17	13.35	9.38	6.76	5.04	5.28	6.62	6.58	8.60
01-DEC-94	10.52	8.74	6.08	13.26	13.44	9.40	6.92	5.02	5.38	6.64	6.60	8.64
02-JAN-95	10.64	8.84	6.32	14.44	13.64	9.80	7.06	5.10	5.46	6.84	6.84	8.94
01-FEB-95	10.03	8.51	5.63	12.29	12.46	8.02	6.40	4.69	5.08	5.79	6.15	8.32
01-MAR-95	9.48	7.96	5.04	11.58	11.72	7.02	5.62	3.98	4.64	4.94	5.44	7.52
04-APR-95	10.13	8.18	6.65	12.16	12.34	8.43	5.95	4.57	4.75	6.50	6.16	8.38
03-MAY-95	10.24	8.60	5.68	12.80	12.62	8.60	6.30	4.58	4.96	6.05	6.20	8.56

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 67	Well 67B	Well 68	Well 70	Well 70A	Well 71	Well 72	Well 73	Well 74	Well 75	Well 76	Well 77	Well 78
	Depth to Water = feet below measuring point (TOC)												
13-JUL-92	6.85		8.41	9.31		7.06	6.20	2.71	15.95	7.54	9.72	8.05	8.36
17-AUG-92	6.65		7.15	8.90		6.67	4.91	1.24	16.14	6.92	9.60	7.62	6.88
21-SEP-92	7.20		8.55	9.78		7.55	6.71	2.92	16.19	7.90	10.22	8.40	8.73
12-OCT-92	7.25		8.52	9.84		7.57	6.61	2.81	16.61	7.98	10.27	8.48	8.74
16-NOV-92	7.55		8.65	10.50		8.05	6.85	3.55	17.35	8.40	10.70	8.95	9.30
08-DEC-92	7.70		5.60	10.60		8.10	6.85	3.15	17.70	8.40	10.70	8.95	8.95
04-JAN-93	7.05		8.30	9.60		7.35	6.45	2.55	16.70	7.75	9.95	8.15	8.60
01-FEB-93	7.25		8.41	9.83		7.45	6.58	2.59	16.57	7.86	10.12	8.42	8.70
01-MAR-93	7.15		8.40	9.85		7.50	6.50	2.65	16.75	7.75	10.15	8.50	8.65
05-APR-93	6.30		7.80	8.70		6.45	5.45	1.25	15.55	6.95	9.25	7.51	8.10
03-MAY-93	7.00		8.25	9.50		7.35	6.55	2.87	15.91	7.62	9.80	8.25	8.78
04-JUN-93	7.40	7.68	8.30	9.99	10.53	7.83	7.01	3.12	16.70	8.00	10.30	8.66	9.05
09-JUL-93	7.85	8.28	8.71	10.75	11.51	8.51	8.25	4.37	17.50	8.60	10.80	9.13	9.71
01-AUG-93	7.99	8.25	8.68	10.70	11.35	8.40	7.29	2.92	18.01	8.38	10.97	9.18	6.26
07-SEP-93	8.45	8.59	9.05	11.48	12.28	9.22	9.02	5.61	18.57	9.22	11.41	9.67	10.55
27-OCT-93	8.51	8.77	9.05	11.85		9.01	8.78	5.25	19.14	9.38	11.22	9.82	10.38
02-NOV-93	8.45	8.73	8.90	11.68	11.30	5.71	7.22	2.77	19.20	9.08	11.10	9.80	9.79
03-DEC-93	8.42	8.74	8.84	11.56	12.18	8.73	8.18	3.08	18.92	9.15	11.05	9.12	Abandoned
06-JAN-94	7.51	7.85	8.12	10.00	10.50	7.90	6.05	1.79	17.72	7.84	10.45	8.61	
01-FEB-94	7.16	7.39	8.11	9.57	10.09	7.40	6.20	2.21	16.98	7.77	9.90	8.20	
08-MAR-94	6.69	6.90	8.01	8.90	9.32	6.83	6.17	1.98	15.98	7.27	9.37	7.76	
01-APR-94	5.65	5.81	7.01	7.68	7.94	5.27	5.32	1.45	15.37	6.31	7.82	6.49	
02-MAY-94	6.16	6.38	7.56	8.13	8.46	5.71	5.51	1.52	14.91	6.55	8.38	7.12	
02-JUN-94	7.14	7.40	8.32	9.55	10.09	6.92	6.45	2.30	15.85	7.60	9.51	8.29	
21-JUL-94	7.42	7.64	8.46	9.87	10.41	7.09	6.32	2.20	10.64	7.64	9.76	8.41	
03-AUG-94	6.97	7.73	7.48	9.92	10.47	7.20	6.40	2.11	16.72	7.71	9.90	9.45	
01-SEP-94	7.46	7.72	8.48	10.50	10.60	8.02	6.98	2.70	16.73	8.25	10.35	8.58	
03-OCT-94	8.03	8.26	7.76	10.94	11.57	8.72	8.29	3.31	17.54	8.84	10.49	9.16	
02-NOV-94	8.10	8.40	8.71	10.78	11.78	8.76	7.82	2.96	18.02	9.10	10.70	9.37	
01-DEC-94	8.20	8.50	8.74	11.44	12.07	8.58	8.01	2.92	18.54	9.19	10.92	9.46	
02-JAN-95	7.92	8.70	8.92	11.76	12.38	9.33	9.02	4.17	18.87	9.60	11.32	9.64	
01-FEB-95	6.97	7.71	8.39	10.04	10.58	7.95	6.74	1.94	17.28	8.16	10.23	8.43	
01-MAR-95	6.30	7.00	7.47	6.04	9.38	6.98	5.43	1.20	16.46	7.50	9.60	7.60	
04-APR-95	7.30	7.56	8.50	9.90	10.50	7.70	7.06	2.60	16.40	8.10	10.04	8.34	
03-MAY-95	7.64	7.95	8.47	9.92	11.04	7.92	6.64	1.78	17.34	8.32	10.45	8.76	

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 79	Well 80	Well 81	Well 82	Well 91	Well 92	Well 93	Well 94	Well 95A	Well 96A	Well 97A	Well 98A	Well 99A	Well 100A
	Depth to Water = feet below measuring point (TOC)													
13-JUL-92	7.96	8.70	7.89	23.45	6.92	3.37	3.47	4.66						
17-AUG-92	7.72	8.25	7.28	23.61	6.27	2.88	2.47	3.51						
21-SEP-92	8.35	9.17	8.21	24.00	7.31	4.10	3.90	5.14						
12-OCT-92	8.41	9.11	8.20	24.20	7.48	3.88	4.05	5.05						
16-NOV-92	8.85	9.45	8.50	26.10	8.10	4.10	4.35	6.35						
08-DEC-92	8.90	9.60	8.50	26.05	8.10	4.65	4.25	6.25						
04-JAN-93	8.10	8.75	7.90	23.80	7.15	3.95	3.90	6.30						
01-FEB-93	8.33	8.96	8.09	23.91	7.26	3.31	3.71	4.97						
01-MAR-93	7.38	9.03	8.10	26.20	7.45	4.00	3.85	6.10						
05-APR-93	7.44	8.20	7.40	25.10	6.65	3.05	3.05	5.20						
03-MAY-93	8.02	8.74	7.92	25.33	7.33	3.85	3.75	6.26						
04-JUN-93	8.50	9.23	8.25	26.10	7.65	4.22	4.15	6.62	11.60	13.40	3.31	13.60	12.73	12.68
09-JUL-93	9.00	9.70	8.70	26.75	8.25	4.85	4.70	7.85	12.26	13.65	4.32	13.62	13.00	12.95
01-AUG-93	9.07		8.61	27.11	7.82	4.56	4.09	5.37	12.22	13.88	3.90	13.52	12.77	12.72
07-SEP-93	9.51	10.30	9.26	27.56	8.61	5.55	5.11	8.82	12.60	14.19	4.80	13.65	13.12	13.21
27-OCT-93	9.77		9.43	29.01	9.07	5.92	5.35	8.62	11.96	14.27		13.63	13.25	13.32
02-NOV-93	9.82	10.30	9.24	27.70	8.52	5.52	4.67	6.59	12.74	14.22	5.24	13.80	13.20	13.22
03-DEC-93	9.22	Abandoned		27.58	8.60	5.48	4.92	8.06	12.87	14.15	4.88	13.95	13.19	13.50
06-JAN-94	8.62		5.88	26.66	7.22	2.94	3.53	5.73	11.47	13.32	3.15	13.67	12.69	12.86
01-FEB-94	8.12		Dry	25.71	7.20	3.02	3.76	6.22	10.75	12.86	2.97	13.60	12.70	12.82
08-MAR-94	7.64		5.26	24.77	6.71	2.61	3.38	5.99	10.08	12.49	2.68	13.14	12.19	12.34
01-APR-94	6.41		4.09	23.25	5.75	2.23	2.95	5.67	8.75	10.90	2.15	12.75	11.20	11.95
02-MAY-94	6.97		4.64	23.84	5.97	2.43	3.04	5.52	9.80	12.39	2.33	13.12	11.85	12.38
02-JUN-94	8.05		5.65	25.38	7.05	3.55	3.85	6.35	11.28	13.48	2.96	13.54	12.70	12.78
21-JUL-94	8.33		5.84	25.87	7.06	3.63	3.81	6.21	11.50	13.64	3.02	13.70	12.56	12.51
03-AUG-94	8.41		5.92	26.05	7.14	3.66	3.84	6.21	11.65	13.68	3.28	13.47	12.53	12.52
01-SEP-94			7.95	25.92	7.63	4.00	4.45	6.85	11.52	13.66	3.62	13.50	12.63	12.55
03-OCT-94	9.34		8.04	26.84	8.28	4.90	4.96	7.55	12.22	14.10	4.36	13.60	12.90	12.88
02-NOV-94	9.56		7.10	26.92	8.50	4.94	5.10	7.40	12.40	14.18	4.58	13.60	12.92	12.88
01-DEC-94	15.06		7.60	27.04	8.60	5.30	5.33	7.36	12.52	14.22	4.78	13.58	12.88	12.84
02-JAN-95	9.62		7.80	27.28	6.04	5.69	5.82	8.88	12.70	14.38	5.14	13.66	13.12	13.24
01-FEB-95	12.06		6.60	25.73	7.55	3.86	4.43	6.32	11.27	13.40	3.18	13.48	12.48	12.50
01-MAR-95	11.45		6.13	24.88	6.38	2.70	3.76	5.25	10.46	12.72	2.66	13.06	11.98	12.08
04-APR-95	7.82		6.82	25.43	7.46	4.00	4.40	6.88	11.26	13.42	3.52	13.52	13.82	12.52
03-MAY-95	8.88		6.99	26.10	7.90	4.10	4.46	6.04	11.87	13.75	3.62	13.50	12.50	12.75

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 100B	Well 101A	Well 102A	Well 103A	Well 104A	Well 105A	Well 106A	Well 107A	Well 107B	Well LD-1A	Well LD-2A	Well 234-2	Well 234-3	Well SC-1	Well SC-3
	Depth to Water = feet below measuring point (TOC)														
13-JUL-92															
17-AUG-92															
21-SEP-92															
12-OCT-92															
16-NOV-92															
08-DEC-92															
04-JAN-93															
01-FEB-93															
01-MAR-93															
05-APR-93															
03-MAY-93															
04-JUN-93	13.11	12.56	12.68	13.23	12.95	13.60	16.46	16.71	18.32	4.62	5.55	3.65	3.47	6.06	7.91
09-JUL-93	13.51	13.02	13.32	13.99	14.12	16.20	18.05	18.02	19.52	5.21	6.22	3.75	3.47	6.75	8.10
01-AUG-93	13.35	12.60	13.07	13.62	13.55	14.87	17.80	18.36	19.71	4.79	5.67	4.13	4.28	6.60	8.10
07-SEP-93	13.80	13.32	13.65	14.35	14.70	16.06	18.05	19.00	20.34	6.82	6.91	4.82	4.46	6.98	8.21
27-OCT-93	14.00	13.49	13.82	14.52	14.90	16.50	19.45	19.60	20.85	5.82	7.07	5.40	4.65	7.35	8.30
02-NOV-93	13.93	13.42	13.83	14.58	14.51	16.68	19.71	19.70	20.89	5.68	6.68	4.95	4.67	7.38	8.30
03-DEC-93	14.15	13.45	14.15	14.80	14.66	16.50	19.55	19.52	20.70	5.95	6.66	5.30	4.38	7.46	8.30
06-JAN-94	13.38	12.65	12.61	13.15	12.88	14.93	17.81	18.40	19.35	4.44	4.80	3.87	4.19	6.96	8.13
01-FEB-94	13.12	12.58	12.45	12.86	12.41	14.10	16.98	17.24	18.54	4.85	5.20	3.85	3.52	6.52	8.04
08-MAR-94	12.31	11.89	11.77	12.10	11.59	12.63	15.49	16.21	17.56	3.56	4.05	3.02	3.07	5.70	7.85
01-APR-94	11.33	11.84	10.45	10.34	10.40	11.30	14.30	15.74	16.70	2.62	3.16	1.71	1.81	4.84	7.62
02-MAY-94	12.10	11.45	11.24	11.20	10.90	11.72	14.10	15.10	16.56	2.83	3.54	2.26	2.26	4.56	7.90
02-JUN-94	12.68	12.28	12.20	12.68	12.48	12.74	15.46	15.95	17.65	3.43	4.60	3.45	2.75	5.48	8.24
21-JUL-94	12.85	12.30	12.24	12.76	12.45	13.18	16.08	16.75	18.30	3.46	4.66	3.76	3.25	5.75	8.00
03-AUG-94	12.93	12.38	12.37	12.90	12.72	13.37	16.32	16.89	18.46	3.76	4.86	4.40	3.74	5.87	8.02
01-SEP-94	12.90	12.48	12.60	13.16	12.84	13.55	16.31	17.20	18.62	3.55	5.00	3.98	3.06	6.05	8.03
03-OCT-94	13.36	12.98	13.24	13.88	14.00	15.08	17.79	17.86	19.40	5.27	5.99	4.26	3.76	6.34	8.16
02-NOV-94	13.35	12.98	13.26	13.90	14.14	15.55	18.34	18.50	19.84	5.60	6.32	4.34	3.90	6.81	8.25
01-DEC-94	13.32	12.98	13.28	14.00	14.30	16.14	18.84	19.10	20.30	6.32	6.51	3.98	3.99	7.04	8.28
02-JAN-95	13.62	13.30	13.62	14.64	14.76	16.42	19.20	19.34	25.05	6.60	6.93	4.05	4.05	7.26	8.38
01-FEB-95	12.74	12.30	12.22	12.78	12.38	14.08	17.04	17.65	18.90	3.72	4.82	3.24	3.22	6.66	8.14
01-MAR-95	12.22	11.70	11.52	12.10	11.68	13.14	16.02	16.77	17.92	3.04	3.10	2.70	2.90	6.00	8.00
04-APR-95	12.74	12.35	12.34	12.90	12.75	13.44	16.20	16.60	18.10	3.86	5.56	3.54	3.02	6.93	8.00
03-MAY-95	12.94	12.38	12.40	13.10	12.90	14.60	17.36	17.68	19.05	5.48	5.32	3.40	3.76	6.40	8.12

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well SC-4	Well SC-6	Well SC-7	Well SC-8	Piez P1	Piez P2	Piez P3	Piez P4	Well A
	Depth to Water = feet below measuring point (TOC)								
13-JUL-92									15.65
17-AUG-92									15.33
21-SEP-92									15.90
12-OCT-92									15.98
16-NOV-92									16.30
08-DEC-92									16.30
04-JAN-93									15.70
01-FEB-93									15.85
01-MAR-93									15.95
05-APR-93									15.10
03-MAY-93									15.80
04-JUN-93	10.23	22.51	21.70	20.33					16.15
09-JUL-93	11.22	23.59	22.97	22.63					16.50
01-AUG-93	11.15	23.77	23.33	22.06					16.60
07-SEP-93	11.96	24.25	24.01	22.75					17.00
27-OCT-93	12.55	24.68	24.53	23.49					17.13
02-NOV-93	12.88	25.22	24.56	23.58					17.08
03-DEC-93	12.30	24.80	24.25	24.44					16.99
06-JAN-94	10.71	23.32	22.92	21.89	8.18	7.01	6.80	4.17	
01-FEB-94	9.62	22.39	21.80	20.91	7.97	8.64	7.04	3.91	15.82
08-MAR-94	8.48	20.92	20.61	19.72	7.48	6.95	7.15	4.21	15.41
01-APR-94	6.64	20.03	19.54	19.18	6.38	5.60	6.79	3.13	14.42
02-MAY-94	7.82	19.55	19.32	18.43	2.58	7.02	3.82	6.82	
02-JUN-94	9.56	21.94	20.66	19.38	6.35	4.40	7.20	5.02	15.96
21-JUL-94	10.16	22.42	21.74	20.37	6.59	4.41	6.93	5.16	16.13
03-AUG-94	10.31	22.76	21.81	20.62	6.63	4.49	6.81	5.25	16.20
01-SEP-94	10.30	22.75	21.46	20.60					16.22
03-OCT-94	11.43	23.64	22.55	21.52	9.00	9.46	12.00	6.70	16.70
02-NOV-94	11.82	24.11	23.20	22.26	8.05	7.76	11.20	6.89	16.80
01-DEC-94	12.26	24.48	23.70	22.84	5.04	7.45	10.30	7.22	
02-JAN-95	12.36	24.70	23.94	23.10	8.37	8.86	9.70	6.90	17.06
01-FEB-95	9.50	23.44	22.01	21.35	7.08	6.22	8.46	6.68	16.14
01-MAR-95	9.06	21.90	20.90	23.60	6.14	4.67	7.24	5.52	15.54
04-APR-95	10.16	22.40	21.04	20.20	7.14	6.40	8.06	5.28	16.05
03-MAY-95	11.00	23.50	22.20	21.30	7.16	4.92	9.04	6.24	16.36

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 5	Well 10	Well 24	Well 25	Well 26	Well 27	Well 28	Well 29	Well 30	Well 31	Well 32	Well 33
	Water-Level Elevation = feet, mean sea level											
20-JUN-89		1639.09	1641.85	1639.62	1639.87	1641.62	1639.84	1641.04	1642.44	1643.34	1640.08	1641.19
21-JUN-89	1632.81											
18-JUL-89	1632.56		1636.13	1633.42	1632.64	1634.28	1631.74	1634.69	1634.43	1634.20	1635.61	1634.29
23-AUG-89	1632.67	1631.77	1636.00	1633.39	1632.33	1634.07	1631.36	1634.20	1634.09	1633.89	1635.40	1634.26
21-SEP-89	1632.76	1630.61	1635.80	1633.00	1632.17	1633.67	1631.19	1630.64	1633.96	1633.78	1635.36	1634.19
10-OCT-89	1632.96	1631.31	1636.30	1633.81	1632.89	1634.17	1631.94	1631.25	1634.69	1634.45	1635.78	1634.44
09-NOV-89		1630.69	1635.70	1633.14	1632.12	1633.99	1631.16	1630.94	1634.02	1633.84	1635.40	1634.24
10-NOV-89	1632.77											
01-DEC-89	1632.87	1631.41	1636.30	1633.87	1633.02	1634.49	1632.06	1633.83	1634.82	1634.46	1635.73	1634.59
24-JAN-90	1632.91	1631.84	1636.75	1634.62	1633.32	1635.12	1632.51	1634.51	1635.34	1634.96	1636.00	1634.79
02-FEB-90	1632.79	1631.64	1636.60	1634.27	1633.29	1634.79	1632.39		1635.19	1634.79	1635.94	1634.59
08-MAR-90	1632.81	1631.96	1636.65	1634.52	1633.67	1634.89	1631.89	1634.53	1636.30	1635.75	1636.25	1634.69
06-APR-90	1632.62	1631.58	1636.13	1633.88	1633.22	1634.17	1632.48	1634.36			1636.19	1634.51
11-MAY-90	1632.79	1631.96	1636.28	1634.44	1633.33	1635.40	1632.59	1634.18	1634.10	1634.27	1636.16	1634.84
14-JUN-90	1632.51	1630.83	1635.70	1633.69	1632.67	1634.17	1631.69	1633.63	1633.90	1634.21	1635.65	1634.14
23-JUL-90	1632.51	1630.39	1635.25	1632.99	1632.17	1633.67	1631.14	1633.03	1633.98	1633.83	1635.28	1633.96
22-AUG-90	1632.60	1630.21	1635.09	1632.75	1631.94	1633.55	1630.90	1632.83	1633.77	1633.70	1635.21	1634.02
18-SEP-90	1632.71	1630.37	1635.00	1632.97	1631.99	1633.62	1630.91	1632.73	1633.75	1633.63	1635.15	1634.07
23-OCT-90	1633.09	1630.71	1635.20		1632.44	1635.67	1631.46	1633.83	1634.73		1635.56	1634.64
15-NOV-90	1632.64	1630.21	1635.25	1632.87	1631.87	1633.77	1630.99	1632.53	1633.20	1633.23	1635.10	1634.11
12-DEC-90	1632.49	1629.71	1635.02	1633.04	1631.32	1632.84	1630.39	1632.13	1632.70	1632.78	1634.85	1634.06
23-JAN-91	1632.57	1630.51	1635.70	1633.57	1632.52	1634.42	1631.49	1633.33	1633.98	1633.71	1635.40	1634.41
02-FEB-91	1633.11	1631.49	1636.59	1632.88	1633.59	1635.77	1632.69	1634.13			1636.20	1634.79
03-MAR-91	1633.13	1631.47	1634.10	1634.52	1633.87	1633.67	1633.61	1634.25			1636.26	1634.74
17-APR-91	1632.54	1630.81	1636.25	1633.89	1633.12	1634.44	1632.16	1633.76	1634.45	1636.57	1634.03	1634.44
27-MAY-91	1632.50	1630.54	1636.02	1633.74	1632.74	1634.36	1631.79	1633.67	1634.10	1634.05	1635.70	1634.41
10-JUN-91	1632.48	1630.37	1635.81	1633.54	1632.48	1634.07	1631.43	1633.21	1634.03	1633.82	1635.47	1634.31
22-JUL-91		1630.14	1635.52	1632.72	1631.98	1633.58	1631.02	1632.78	1633.28	1633.18	1635.20	1634.07
06-AUG-91	1632.60	1630.54	1636.17	1633.62	1632.67	1634.14	1631.61	1634.35	1633.86	1634.04	1635.48	1634.41
03-SEP-91		1630.32	1635.96	1633.14	1632.42	1633.75	1631.33	1632.06	1633.68	1633.78	1635.46	1634.21
02-OCT-91	1632.59	1630.24	1635.90	1633.27	1632.32	1633.82	1631.14	1633.31	1633.88	1633.98	1635.38	1634.24
06-NOV-91	1632.34	1629.37	1635.22	1631.71	1631.33	1632.69	1630.22	1631.88	1632.63	1632.71	1634.39	1633.53
09-DEC-91	1632.66	1630.44	1636.11	1633.57	1632.72	1634.05	1631.60	1633.66	1633.88	1634.40	1635.54	1634.48
07-JAN-92	1632.72	1630.75	1636.64	1633.92	1633.05	1634.82	1631.95	1633.82	1634.73	1635.68	1635.64	1634.64
04-FEB-92	1632.34	1630.47	1636.25	1633.18	1632.47	1633.91	1631.30	1633.51	1633.53	1633.53	1635.38	1634.21
09-MAR-92	1632.49	1630.47	1636.40	1633.77	1632.77	1634.77	1631.74	1633.46	1633.93	1633.88	1635.63	1634.34
06-APR-92	1632.69	1630.59	1636.65	1633.87	1632.97	1634.57	1631.89	1631.56	1634.23	1634.33	1635.83	1634.44
11-MAY-92	1632.59	1630.79	1636.25	1634.37	1633.17	1635.52	1632.14	1633.76	1634.23	1634.18	1635.83	1634.54
08-JUN-92	1632.64	1630.84	1636.60	1634.32	1633.32	1635.27	1632.24	1634.06	1634.48	1634.58	1636.03	1634.59

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Sampling Period	Well 34	Well 35	Well 36	Well 37	Well 38	Well 39	Well 40	Well 41	Well 52	Well 55	Well 55A	Well 56
	Water-Level Elevation = feet, mean sea level											
20-JUN-89	1637.60	1640.89	1642.53		1640.98	1638.99	1641.56	1640.82				
21-JUN-89				1635.55					1637.26	1638.88		1638.44
18-JUL-89	1633.40	1634.54	1634.32	1635.07	1634.71	1634.39	1636.44	1636.68	1637.16	1638.63		1637.70
23-AUG-89	1633.15	1634.36	1633.99	1634.85	1634.25	1633.99	1636.35	1636.52	1637.07	1638.45		1637.34
21-SEP-89	1633.12	1634.34	1633.77	1634.83	1633.98	1633.76	1636.33	1636.49	1637.02	1638.41		1637.24
10-OCT-89	1633.60	1634.57	1634.66	1635.40	1634.69	1634.42	1636.43	1636.72	1637.11	1638.64		1637.86
09-NOV-89	1633.20	1634.44	1633.85		1633.88	1633.86	1636.33	1636.52				
10-NOV-89				1634.83					1637.09	1638.42		1637.34
01-DEC-89	1633.65	1634.79	1634.78	1635.48	1634.68	1634.44	1636.36	1636.69	1637.16	1638.66		1638.17
24-JAN-90	1633.78	1634.96	1635.31	1635.73	1635.20	1634.76	1636.43	1636.82	1637.19	1638.80		1638.64
02-FEB-90	1633.67	1634.94	1634.98	1635.70	1635.03	1634.74	1636.43	1636.77	1637.21	1638.80		1638.57
08-MAR-90	1634.47	1634.99	1635.35	1636.08	1635.28	1635.04	1636.56	1637.00	1637.29	1639.04		1639.04
06-APR-90	1634.26	1634.89	1634.90	1635.93	1634.86	1634.91	1636.51	1636.97	1637.33	1639.04		1638.74
11-MAY-90	1633.95	1634.89	1635.70	1635.83	1635.18	1634.86	1636.51	1636.92	1637.26	1638.94		1638.67
14-JUN-90	1633.39	1634.56	1634.25	1635.20	1634.58	1634.24	1636.36	1636.63	1637.16	1638.62		1637.84
23-JUL-90	1633.05	1634.32	1633.88	1634.80	1634.03	1633.84	1636.28	1636.44	1637.06	1638.40		1637.34
22-AUG-90	1632.83	1634.32	1633.49	1634.62	1633.65	1633.60	1636.30	1636.39	1637.08	1638.31		1637.12
18-SEP-90	1632.77	1634.26	1633.79	1634.58	1633.70	1633.34	1636.28	1636.34	1637.02	1638.24		1637.04
23-OCT-90	1633.11	1634.76	1634.71	1634.93	1634.35	1633.81	1636.31	1636.47	1636.86	1638.39		1637.51
15-NOV-90	1633.22	1634.26	1633.88	1636.10	1633.45	1633.19	1636.21	1636.24	1636.91	1638.12		1637.24
12-DEC-90	1632.80	1634.11	1632.88	1635.73	1632.88	1632.81	1636.13	1636.09	1636.81	1637.97		1636.86
23-JAN-91	1633.28	1634.56	1634.55		1634.05	1633.76	1636.24	1636.39	1637.61	1638.04		1636.89
02-FEB-91	1633.79	1635.04	1636.23		1634.95	1634.41	1636.43	1636.74	1637.11	1638.77		1639.56
03-MAR-91	1633.80	1635.01	1636.33		1635.33	1635.09	1636.44	1636.92	1637.16	1638.92		1639.59
17-APR-91	1633.82	1634.89	1634.87		1634.86	1632.74	1636.43	1636.79	1637.24	1638.84		1638.81
27-MAY-91	1633.43	1634.72	1634.49		1634.58	1634.34	1636.35	1636.60	1637.19	1638.61		1638.08
10-JUN-91	1633.22	1634.54	1634.21		1634.27	1634.05	1636.30	1636.44	1637.07	1638.57		1637.77
22-JUL-91	1632.84	1634.41	1633.50		1633.70	1633.64	1636.23	1635.00	1636.96	1638.21		1637.22
06-AUG-91	1633.25	1634.66	1634.53		1634.50	1632.31	1636.36	1636.13	1637.06	1638.42		1637.91
03-SEP-91	1633.10	1634.53	1634.13		1634.20	1633.87	1636.32	1636.29	1637.09	1638.40		1638.09
02-OCT-91	1632.90	1632.64	1633.88		1634.03	1633.79	1636.26	1636.14	1637.74	1639.27		1638.29
06-NOV-91		1634.07	1632.56	1638.02	1632.81	1632.51	1636.11	1635.82	1636.89	1637.97		1636.84
09-DEC-91	1633.28	1634.69	1634.23		1634.40	1634.00	1636.31	1636.24	1637.09	1638.40		1638.35
07-JAN-92	1633.77	1634.79	1634.85		1634.48	1634.14	1636.36	1636.34	1637.15	1638.57		1638.89
04-FEB-92	1633.19	1634.54	1633.89		1633.98	1633.75	1636.27	1636.14	1637.09	1638.40		1638.14
09-MAR-92	1633.55	1634.69	1634.43		1634.48	1634.04	1636.31	1636.34	1637.09	1638.47		1638.39
06-APR-92	1633.65	1634.79	1635.03		1634.53	1634.19	1636.36	1635.79	1637.19	1638.67		1638.79
11-MAY-92	1633.45	1634.84	1635.08		1634.93	1634.34	1636.31	1636.34	1637.09	1638.62		1638.34
08-JUN-92	1633.80	1635.04	1635.28		1635.03	1634.69	1636.46	1636.54	1637.24	1638.82		1638.74

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 57	Well 58	Well 59	Well 60	Well 60B	Well 62	Well 63	Well 63A	Well 63B	Well 64	Well 65	Well 66
	Water-Level Elevation = feet, mean sea level											
20-JUN-89												
21-JUN-89	1633.30	1631.70	1631.81	1635.50		1635.31	1643.94			1636.29	1631.98	1631.20
18-JUL-89	1632.74	1631.24	1630.89	1634.78		1634.19	1643.54			1635.50	1631.13	1630.60
23-AUG-89	1632.60	1631.18	1630.65	1634.50		1633.73	1643.24			1635.25	1630.91	1630.49
21-SEP-89	1632.65	1631.20	1630.46	1634.40		1633.51	1643.11			1635.12	1630.73	1630.46
10-OCT-89	1632.95	1631.41	1631.16	1635.00		1634.48	1643.44			1635.72	1631.38	1630.84
09-NOV-89												
10-NOV-89	1632.70	1631.27	1630.57	1634.40		1633.54	1643.17			1635.12	1630.79	1630.55
01-DEC-89	1633.15	1631.56	1631.31	1635.08		1634.66	1643.59			1635.65	1631.46	1630.94
24-JAN-90	1633.38	1631.74	1631.66	1635.50		1635.16	1643.94			1636.15	1631.81	1631.17
02-FEB-90	1633.23	1631.64	1631.47	1635.40		1634.88	1643.94			1636.07	1631.66	1631.02
08-MAR-90	1633.33	1631.66	1631.74	1635.83		1635.33	1644.44			1636.45	1631.96	1631.12
06-APR-90	1632.98	1631.36	1631.39			1634.86				1636.22	1631.63	1630.82
11-MAY-90	1633.18	1631.54	1631.74	1635.45		1634.99	1644.31			1636.27	1631.91	1631.09
14-JUN-90	1632.58	1631.01	1630.70	1634.70		1633.88	1643.74			1635.77	1630.96	1630.44
23-JUL-90	1632.25	1630.54	1630.21	1634.25		1633.26	1643.34			1634.96	1630.48	1629.78
22-AUG-90	1632.29	1630.86	1630.11	1634.08		1633.02	1643.13			1634.90	1630.37	1630.07
18-SEP-90	1632.35	1630.94	1630.29	1634.08		1632.96	1643.01			1634.27	1630.53	1630.18
23-OCT-90	1632.78	1631.12	1628.74	1634.65		1634.08	1643.19			1635.21	1629.69	1630.19
15-NOV-90	1632.31	1630.56	1628.47	1634.10		1633.11	1642.86			1634.64	1629.27	1629.35
12-DEC-90	1632.03	1630.39	1627.97	1633.76		1632.52	1642.66			1634.21	1627.77	1629.02
23-JAN-91	1632.18	1630.24	1627.17	1633.93		1632.86	1642.99			1633.75	1628.12	1629.17
02-FEB-91	1633.66	1631.69	1629.30	1635.99		1635.67	1644.09			1636.23	1629.30	1630.70
03-MAR-91	1633.65	1631.68	1629.32	1635.94		1635.40	1644.10			1636.24	1629.32	1630.71
17-APR-91	1632.81	1631.04	1628.77	1635.45		1634.76	1644.14			1635.84		1629.99
27-MAY-91	1632.56	1630.89	1627.76	1634.91		1634.17	1643.77					1630.04
10-JUN-91	1632.44	1630.82	1627.17	1634.57		1630.79	1638.68			1635.64	1626.07	1627.99
22-JUL-91	1632.20	1630.67	1628.42	1634.16		1633.14	1643.04			1634.64	1628.07	1632.79
06-AUG-91	1632.55	1630.86	1628.69	1634.78		1634.32	1643.31			1635.29	1628.28	1630.02
03-SEP-91	1632.43	1630.79	1628.52	1634.65		1633.81	1643.28			1635.15	1628.42	1629.89
02-OCT-91	1633.08	1630.79	1628.42	1634.78		1633.71	1644.19			1635.29	1628.92	1628.67
06-NOV-91	1631.88	1630.26	1627.51	1633.63		1632.56	1642.69			1634.24	1627.44	1628.47
09-DEC-91	1632.78	1631.68	1628.57	1634.92		1634.48	1643.29			1635.32	1627.42	1629.84
07-JAN-92	1633.05	1631.13	1628.67	1635.37		1634.86	1643.68			1635.69	1629.67	1630.15
04-FEB-92	1632.56	1630.85	1628.57	1634.72		1633.91	1642.69			1635.11	1629.32	1629.87
09-MAR-92	1632.68	1630.89	1628.61	1635.08		1634.41	1643.49			1635.44	1628.27	1629.92
06-APR-92	1632.88	1630.99	1628.72	1635.38		1634.76	1643.89			1635.64		1630.07
11-MAY-92	1632.78	1631.04	1628.77	1635.18		1634.56	1643.74			1635.69		1630.22
08-JUN-92	1632.93	1631.04	1628.92	1635.48		1634.86	1643.99			1635.94		1630.22

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 67	Well 67B	Well 68	Well 70	Well 70A	Well 71	Well 72	Well 73	Well 74	Well 75	Well 76	Well 77	Well 78
	Water-Level Elevation = feet, mean sea level												
20-JUN-89				1643.80		1640.43	1640.65	1637.86	1651.71	1641.82	1643.62	1643.17	1643.72
21-JUN-89	1636.77		1631.28										
18-JUL-89	1636.25		1630.65	1633.88		1632.87	1633.38	1634.99	1634.57	1633.72	1633.30	1634.42	1634.61
23-AUG-89	1635.91		1630.55	1633.43		1632.57		1634.89	1633.92	1633.44	1632.96	1634.11	1634.38
21-SEP-89	1635.87		1630.50	1633.21		1632.44		1634.53	1633.70	1633.20	1632.89	1634.04	1634.20
10-OCT-89	1636.40		1630.90	1634.09		1633.15		1634.98	1634.58	1633.89	1633.53	1634.69	1634.58
09-NOV-89				1633.25		1632.33		1635.11	1633.66	1633.22	1632.94	1634.07	1634.24
10-NOV-89	1635.90		1630.57										
01-DEC-89	1636.44		1631.01	1634.15		1633.18		1635.28	1634.23	1633.99	1633.47	1634.72	1634.87
24-JAN-90	1636.80		1631.27	1634.58		1633.63		1635.71	1634.71	1634.45	1633.92	1635.19	1635.40
02-FEB-90	1636.70		1631.09	1634.47		1633.51		1635.46	1635.01	1634.32	1633.84	1635.04	1635.08
08-MAR-90	1637.07		1631.18	1635.05		1633.97		1635.76	1636.01	1634.69	1634.10	1635.49	1635.12
06-APR-90	1636.90		1630.82	1634.68		1633.61		1635.54	1635.99	1634.40		1635.22	1634.69
11-MAY-90	1636.83		1631.19	1634.77		1633.79		1635.93	1635.26	1634.59	1634.06	1635.29	1635.00
14-JUN-90				1633.67		1632.80		1634.98	1634.63	1633.69	1633.17	1634.48	1635.44
23-JUL-90	1635.77		1629.80	1633.00		1632.24		1634.46	1633.62	1633.12	1632.77	1633.95	1634.04
22-AUG-90	1635.57		1630.08	1632.71		1631.94		1634.23	1633.16	1632.83	1632.56		1633.75
18-SEP-90	1635.57		1630.20	1632.77		1632.01		1634.54	1633.03	1632.88	1632.52	1633.85	1633.84
23-OCT-90	1636.10		1630.15	1633.25		1632.43		1635.06	1633.29	1633.52	1633.16	1634.54	1635.10
15-NOV-90	1635.65		1629.38	1632.72		1632.00		1634.23	1633.13	1632.87	1632.59	1633.84	1633.97
12-DEC-90	1635.25		1628.97	1632.00		1631.27		1631.26	1632.48	1632.14	1632.14	1633.41	1633.38
23-JAN-91	1635.30		1629.57	1633.37		1632.70		1634.94	1633.61	1633.49	1633.05	1634.34	1634.59
02-FEB-91	1637.05		1630.72	1634.70		1633.78		1636.18	1634.03	1634.74	1634.17	1635.77	1635.64
03-MAR-91	1637.07		1630.73	1635.10		1633.98		1635.76	1636.03	1634.70	1634.22	1635.42	1635.62
17-APR-91	1636.77		1630.13	1634.45		1633.46		1635.01	1635.44	1634.27	1633.96	1635.17	1634.77
27-MAY-91	1636.32		1630.12	1633.91		1633.12		1634.94	1634.83	1633.90	1633.44	1634.66	1634.58
10-JUN-91	1634.97		1629.20	1633.51		1632.71		1635.11	1634.33	1633.61	1633.06	1634.33	1634.39
22-JUL-91	1635.63		1629.84	1632.90		1632.19		1633.31	1633.61	1633.16	1632.64	1633.79	1634.06
06-AUG-91	1636.15		1629.99	1633.80		1632.96		1634.58	1634.35	1633.89	1633.27	1634.55	1634.57
03-SEP-91	1636.55		1629.95	1633.45		1632.39		1633.71	1633.46	1633.59	1633.12	1634.27	1634.22
02-OCT-91	1636.25		1629.20	1633.40		1632.38	1632.94	1634.36	1635.11	1634.27	1633.02	1634.57	1635.17
06-NOV-91	1635.13		1628.27	1631.89		1631.03	1631.32	1631.29	1632.71	1632.16	1632.10	1633.33	1633.19
09-DEC-91	1636.20		1629.85	1633.51		1631.17	1632.04	1635.35	1633.66	1633.50	1633.11	1634.53	1634.58
07-JAN-92	1636.52		1630.21	1633.96		1632.99	1634.45	1635.83	1634.16	1633.84	1633.95		1635.73
04-FEB-92	1636.00		1629.95	1633.18		1632.23	1633.41	1634.62	1634.01	1633.24	1632.93	1634.21	1634.56
09-MAR-92	1636.25		1633.00	1633.70		1632.83	1634.50	1635.11	1634.11	1634.32	1633.36	1634.62	1635.62
06-APR-92	1636.45		1630.20	1634.10		1633.08	1634.35	1635.61	1634.86	1634.02	1633.67	1634.87	1635.34
11-MAY-92	1636.45		1630.20	1634.20		1633.28	1634.80	1635.51	1634.66	1634.72	1633.57	1634.92	1636.02
08-JUN-92	1636.70		1630.35	1634.50		1633.43	1634.75	1635.26	1635.21	1634.42	1633.92	1635.17	1635.67

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 79	Well 80	Well 81	Well 82	Well 91	Well 92	Well 93	Well 94	Well 95A	Well 96A	Well 97A	Well 98A	Well 99A	Well 100A
	Water-Level Elevation = feet, mean sea level													
20-JUN-89	1641.62	1639.76	1639.08											
21-JUN-89				1631.78										
18-JUL-89	1633.20	1630.89	1630.19	1631.09										
23-AUG-89	1632.83	1630.53	1630.89	1630.62										
21-SEP-89	1632.73	1630.31	1630.72	1630.49										
10-OCT-89	1633.35	1631.18	1631.50	1631.37										
09-NOV-89	1632.84	1630.21	1630.76											
10-NOV-89				1630.42										
01-DEC-89	1633.27	1631.16	1631.53	1631.14										
24-JAN-90	1633.74	1631.73	1631.98	1631.74										
02-FEB-90	1633.70	1631.53	1631.80	1631.79										
08-MAR-90	1634.12	1632.01	1632.20	1632.52										
06-APR-90	1634.00	1631.55	1631.83	1632.24										
11-MAY-90	1633.90	1631.86	1632.10	1631.98										
14-JUN-90	1633.10	1630.71	1631.03	1630.92										
23-JUL-90	1632.62	1630.16	1630.53	1630.24										
22-AUG-90	1632.41	1629.90	1630.33	1629.87										
18-SEP-90	1632.37	1629.98	1630.41	1629.79										
23-OCT-90	1632.97	1630.53	1630.86	1630.69										
15-NOV-90	1632.32	1630.01	1630.40	1630.02										
12-DEC-90	1631.98	1629.45	1629.88	1629.49										
23-JAN-91	1632.88	1630.56	1630.81	1629.71										
02-FEB-91	1633.90	1631.71	1631.82	1631.91										
03-MAR-91	1633.92	1631.76	1631.88	1631.93										
17-APR-91	1633.77	1631.14	1631.34	1631.99										
27-MAY-91	1633.25	1630.84	1630.97	1631.02										
10-JUN-91	1632.87	1630.48	1630.70	1621.82										
22-JUL-91	1632.49	1630.66	1630.27	1630.07										
06-AUG-91	1633.08	1630.71	1630.90	1630.89										
03-SEP-91	1632.94	1630.38	1630.68	1630.27										
02-OCT-91	1632.92	1630.11	1630.68	1630.02	1633.63	1634.69	1633.93	1634.22						
06-NOV-91	1631.76	1629.36	1629.64	1628.97	1630.94	1632.04	1632.35	1632.90						
09-DEC-91	1632.88	1630.73	1630.83	1630.58	1633.67	1634.44	1633.86	1633.56						
07-JAN-92	1633.26	1631.05	1631.17	1630.93	1633.96	1634.86	1634.13	1635.80						
04-FEB-92	1632.77	1630.35	1630.59	1630.61	1633.49	1634.79	1633.70	1634.79						
09-MAR-92	1633.17	1630.61	1630.93	1630.27	1633.79	1634.59	1634.43	1634.95						
06-APR-92	1633.42	1630.96	1631.13	1631.47	1633.94	1634.79	1634.06	1634.35						
11-MAY-92	1633.52	1631.11	1631.23	1631.52	1634.64	1636.19	1635.41	1635.10						
08-JUN-92	1633.72	1631.21	1631.38	1631.82	1634.29	1635.24	1634.96	1635.00						

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 100B	Well 101A	Well 102A	Well 103A	Well 104A	Well 105A	Well 106A	Well 107A	Well 107B	Well LD-1A	Well LD-2A	Well 234-2	Well 234-3	Well SC-1	Well SC-3
	Water-Level Elevation = feet, mean sea level														
20-JUN-89															
21-JUN-89															
18-JUL-89															
23-AUG-89															
21-SEP-89															
10-OCT-89															
09-NOV-89															
10-NOV-89															
01-DEC-89															
24-JAN-90															
02-FEB-90															
08-MAR-90															
06-APR-90															
11-MAY-90															
14-JUN-90															
23-JUL-90															
22-AUG-90															
18-SEP-90															
23-OCT-90															
15-NOV-90															
12-DEC-90															
23-JAN-91															
02-FEB-91															
03-MAR-91															
17-APR-91															
27-MAY-91															
10-JUN-91															
22-JUL-91															
06-AUG-91															
03-SEP-91															
02-OCT-91															
06-NOV-91															
09-DEC-91															
07-JAN-92															
04-FEB-92															
09-MAR-92															
06-APR-92															
11-MAY-92															
08-JUN-92															

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well SC-4	Well SC-6	Well SC-7	Well SC-8	Piez P1	Piez P2	Piez P3	Piez P4	Well A
	Water-Level Elevation = feet, mean sea level								
20-JUN-89									
21-JUN-89									
18-JUL-89									
23-AUG-89									1636.54
21-SEP-89									1636.50
10-OCT-89									1636.98
09-NOV-89									
10-NOV-89									1637.58
01-DEC-89									1637.08
24-JAN-90									1637.45
02-FEB-90									1637.33
08-MAR-90									1637.63
06-APR-90									1637.43
11-MAY-90									1637.40
14-JUN-90									1636.78
23-JUL-90									1636.43
22-AUG-90									1636.21
18-SEP-90									1636.23
23-OCT-90									1636.73
15-NOV-90									1636.33
12-DEC-90									1636.03
23-JAN-91									1636.16
02-FEB-91									1637.83
03-MAR-91									1637.84
17-APR-91									1637.35
27-MAY-91									
10-JUN-91									
22-JUL-91									
06-AUG-91									1636.80
03-SEP-91									
02-OCT-91									1638.00
06-NOV-91									1635.93
09-DEC-91									1636.99
07-JAN-92									1637.33
04-FEB-92									1636.83
09-MAR-92									1637.03
06-APR-92									1637.33
11-MAY-92									1637.18
08-JUN-92									1637.43

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Water-Level Elevation = feet, mean sea level

Sampling Period	Well 5	Well 10	Well 24	Well 25	Well 26	Well 27	Well 28	Well 29	Well 30	Well 31	Well 32	Well 33
13-JUL-92	1632.59	1630.68	1636.42	1636.11	1633.16	1634.73	1632.10	1634.29	1634.48	1634.55	1636.03	1634.60
17-AUG-92	1633.48	1631.54	1637.45		1633.67	1636.54	1632.34	1634.41		1635.15	1636.26	1634.54
21-SEP-92	1632.51	1630.46	1636.30	1635.80	1632.68	1634.39	1631.52	1633.74	1634.05	1634.14	1635.80	1634.24
12-OCT-92	1632.71	1630.51	1636.12	1635.77	1632.77	1634.39	1631.61	1633.71	1634.48	1634.43	1636.74	1634.24
16-NOV-92	1632.39	1630.29	1635.80	1635.22	1632.42	1633.97	1631.19	1632.86	1633.53	1633.63	1635.38	1633.89
08-DEC-92	1632.49	1630.29	1635.75	1635.52	1632.42	1634.57	1631.24	1633.21	1633.48	1633.60	1635.33	1634.09
04-JAN-93	1632.31	1630.69	1636.35	1635.92	1633.17	1634.77	1631.99	1633.81	1634.28	1634.43	1635.88	1634.34
01-FEB-93	1632.62	1630.59	1636.35	1635.77	1632.93	1634.60	1631.82	1633.94	1634.63	1634.63	1635.77	1634.27
01-MAR-93	1632.66	1630.59	1636.25	1635.77	1632.92	1633.77	1631.79	1633.56	1633.98	1634.10	1635.68	1634.16
05-APR-93	1632.91	1631.09	1636.75		1633.70	1635.32	1632.64	1634.21	1635.20	1635.03	1636.38	1634.54
03-MAY-93	1632.76	1630.86	1636.15	1633.92	1633.20	1634.74	1632.19	1634.70	1635.35	1635.32	1636.00	1634.31
04-JUN-93	1632.90	1630.66	1635.92	1633.70	1632.89	1634.44	1631.68	1634.06	1634.45	1634.45	1634.48	1634.35
09-JUL-93		1630.29	1635.60	1632.87	1632.39	1633.81	1631.16	1633.57	1633.94	1634.00	1634.13	1634.20
01-AUG-93	1632.45	1630.34	1635.41	1633.18	1632.44	1634.15	1631.22	1633.95	1633.94	1634.00	1634.27	1634.53
07-SEP-93	1632.25	1629.79	1635.01		1631.88	1633.21		1632.75	1633.92	1633.90	1633.77	1633.52
27-OCT-93	1632.18	1629.69	1634.75	1632.32	1631.83	1633.41	1630.41	1633.39	1633.83	1633.86	1633.93	1633.85
02-NOV-93	1632.28	1629.57	1634.69	1632.72	1631.81	1633.81	1630.58	1633.02	1633.83	1634.11	1633.97	1633.85
03-DEC-93	1632.36	1630.06	Abandoned	Abandoned	1631.68	Abandoned	1630.66	1633.42	1633.80	1633.44	1633.86	
06-JAN-94	1632.74	1630.84			1632.84		1632.68	1634.87	1635.60	1635.05	1634.37	1634.96
01-FEB-94	1632.69	1631.10			1633.23		1632.45	1634.64	1635.47	1635.54	1635.01	
08-MAR-94	1632.73	1631.26			1633.62		1631.12	1635.03	1636.02	1636.08	1635.36	1635.23
01-APR-94	1633.06	1632.17			1634.75			1635.87	1637.29	1637.31	1636.19	1635.78
02-MAY-94	1632.92	1631.75			1631.14			1635.51	1636.58	1636.69	1635.84	1635.75
02-JUN-94	1632.66	1630.92			1633.14		1632.41	1634.77	1634.55	1635.50	1635.08	1635.25
21-JUL-94	1632.52	1630.71			1632.92		1632.10	1634.56	1634.49	1635.37	1634.95	1635.10
03-AUG-94	1632.56	1630.82			1632.95		1632.09	1634.44	1635.27	1635.28	1634.90	1635.10
01-SEP-94	1632.55	1630.51						1633.90	1634.30	1634.60	1634.53	1634.95
03-OCT-94	1632.50	1630.26			1628.05		1628.82	1633.72	1634.53	1634.54	1634.50	1634.28
02-NOV-94	1632.48	1630.22			1630.99		1629.19	1633.48	1633.36	1634.30	1634.29	1633.68
01-DEC-94	1632.39	1630.21			1630.94		1629.06	1633.25	1633.33	1634.24	1634.19	1633.40
02-JAN-95	1632.38	1629.97			1630.87		1629.16	1633.25	1634.03	1633.80	1634.06	1633.31
01-FEB-95	1632.62	1630.79			1631.91		1629.96	1634.47	1635.25	1635.30	1634.88	1634.54
01-MAR-95	1632.98	1631.44			1632.63		1632.12	1634.87		1636.68	1635.68	1635.08
04-APR-95	1632.50	1630.76			1632.19		1630.16	1634.52	1635.35	1635.36	1635.04	1634.98
03-MAY-95	1632.48	1630.60			1631.71		1630.26	1634.10	1635.11	1634.86	1634.58	1634.46

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 34	Well 35	Well 36	Well 37	Well 38	Well 39	Well 40	Well 41	Well 52	Well 55	Well 55A	Well 56
	Water-Level Elevation = feet, mean sea level											
13-JUL-92	1633.70	1634.89	1635.03		1634.99	1634.78	1636.48	1636.54	1637.29	1638.90		1638.78
17-AUG-92	1634.09	1635.04	1636.48		1635.13	1634.64	1636.54	1636.69	1637.30	1639.01		1639.11
21-SEP-92	1633.67	1634.85	1634.58		1634.71	1634.44	1636.44	1636.44	1637.24	1638.76		1638.38
12-OCT-92	1633.36	1634.81	1634.61		1634.39	1634.51	1636.44	1636.40	1637.17	1638.68		1638.30
16-NOV-92	1633.00	1634.39	1634.43		1634.03	1633.69	1636.36	1634.24	1637.04	1638.52		1637.99
08-DEC-92	1633.00	1634.49	1634.03		1634.13	1633.74	1636.31	1634.19	1636.99	1638.37		1637.94
04-JAN-93	1633.55	1634.79	1634.83		1634.73	1634.49	1636.41	1634.39	1637.19	1638.72		1638.84
01-FEB-93	1633.45	1634.71	1634.51		1634.67	1634.62	1636.40	1636.42	1636.86	1638.50		1637.42
01-MAR-93	1633.40	1634.69	1634.48		1634.43	1634.24	1636.36	1634.36	1636.86	1638.66		1638.55
05-APR-93	1634.10	1635.04	1635.46		1635.23	1635.11	1636.58	1634.79	1637.06	1639.16		1639.55
03-MAY-93	1633.62	1634.78	1634.70		1634.68	1634.59	1636.45	1634.51	1637.09	1638.86		1638.63
04-JUN-93	1633.70	1634.20	1634.70		1634.48	1634.16	1636.26	1636.49	1637.00	1638.61	1638.41	1638.10
09-JUL-93	1633.20	1633.65	1634.05		1634.03	1633.54	1636.16	1636.31	1636.86	1638.32	1637.92	1637.70
01-AUG-93	1633.22	1633.78	1634.33		1634.14	1634.04		1636.38	1636.83	1638.24	1637.97	1637.39
07-SEP-93	1632.83	1633.14	1633.25		1633.17	1632.98	1636.02	1636.18	1636.73	1637.90	1637.75	1636.90
27-OCT-93	1632.61	1633.35	1633.08		1633.17	1633.34	1635.95	1635.98	1636.68	1638.09	1637.67	1636.97
02-NOV-93	1632.80	1633.32	1633.83		1632.88	1632.92	1635.99	1636.11	1636.69	1638.14	1637.70	1637.01
03-DEC-93	1632.94	1633.38	1633.33		1633.55	1633.26	1635.98	1636.08	1636.70	1638.15	1637.79	1637.09
06-JAN-94	1633.71	1634.03	1635.27		1634.47		1636.19		1636.83	1638.36	1639.30	1638.33
01-FEB-94	1634.00	1634.48	1635.06		1634.70	1634.56	1636.28	1636.64	1636.92	1638.74	1639.22	1639.05
08-MAR-94	1634.30	1634.76	1635.54		1635.20	1635.15	1636.39	1636.88	1637.07	1639.10	1639.71	1639.73
01-APR-94	1635.26	1635.61	1637.15		1635.74	1636.05	1636.60	1637.34	1637.25	1639.59	1640.33	1640.65
02-MAY-94	1634.84	1635.23	1636.63		1635.60	1635.71	1636.54	1637.20	1637.27	1639.53	1639.96	1639.88
02-JUN-94	1633.95	1634.38	1635.10		1634.80	1634.91	1636.34	1636.74	1637.07	1638.86	1638.98	1638.69
21-JUL-94	1633.75	1634.36	1634.98		1634.67	1634.60	1636.24	1636.55	1636.88	1638.85	1638.49	1638.13
03-AUG-94	1633.67	1634.37	1634.94		1634.63	1634.48	1636.22	1636.49	1636.94	1638.80	1638.42	1638.37
01-SEP-94	1633.57	1634.70	1634.63		1633.40	1634.30	1636.32	1636.69	1636.96	1638.80	1638.32	1638.40
03-OCT-94	1633.09	1634.43	1633.83		1633.45	1633.81	1636.18	1636.41	1636.85	1638.52	1637.90	1637.77
02-NOV-94	1632.91	1634.30	1633.62		1632.99	1633.54	1636.14	1636.27	1636.80	1638.42	1637.90	1637.61
01-DEC-94	1632.95	1634.33	1633.62		1632.81	1633.11	1636.08	1636.24	1636.76	1638.32	1638.06	1637.55
02-JAN-95	1632.82	1634.08	1633.13		1632.09	1632.56	1636.00	1636.16	1636.72	1638.20	1638.02	1637.39
01-FEB-95	1633.67	1635.10	1634.89		1634.35	1634.24	1636.26	1636.57	1636.89	1638.66	1639.25	1638.66
01-MAR-95	1634.43	1635.45	1636.41		1634.18	1634.86	1636.40	1636.89	1637.06	1639.06	1640.20	1639.37
04-APR-95	1633.83	1635.40	1634.81		1633.66	1634.52	1636.34	1636.71	1636.96	1635.90	1639.58	1637.53
03-MAY-95	1633.62	1634.72	1634.85		1633.85	1633.78	1636.22	1633.55	1636.88	1638.68	1627.50	1637.95

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 57	Well 58	Well 59	Well 60	Well 60B	Well 62	Well 63	Well 63A	Well 63B	Well 64	Well 65	Well 66
	Water-Level Elevation = feet, mean sea level											
13-JUL-92	1632.77	1631.24	1628.65	1635.50		1634.99	1644.28			1635.93	1629.70	1630.08
17-AUG-92	1633.42	1631.64	1629.32	1635.63		1635.59	1644.62			1636.30	1629.49	1631.14
21-SEP-92	1632.57	1630.78	1628.98	1635.01		1634.43	1644.01			1635.59	1629.55	1629.96
12-OCT-92	1632.59	1630.84	1628.97	1634.90		1634.32	1643.88			1635.49	1629.52	1629.97
16-NOV-92	1632.43	1630.64	1628.52	1634.58		1633.71	1643.54			1635.14		1629.87
08-DEC-92	1632.43	1630.79	1628.57	1634.48		1633.66	1643.44			1630.59		1629.82
04-JAN-93	1632.83	1630.99	1628.77	1635.33		1634.81	1643.94			1635.79		1630.12
01-FEB-93	1632.66	1630.63	1628.70	1635.05		1634.45	1644.01			1635.61	1629.63	1630.09
01-MAR-93	1632.68	1630.85	1628.07	1635.03		1634.41	1643.94			1635.54	1628.97	1630.07
05-APR-93	1633.18	1631.25	1629.22	1636.13		1635.56	1644.79			1635.94	1629.57	1630.62
03-MAY-93	1632.72	1630.85	1629.55	1635.31		1634.77	1644.44			1635.52	1630.17	1630.21
04-JUN-93	1632.50	1630.80	1629.44	1634.89	1634.91	1634.26	1644.04	1641.23	1641.18	1635.14	1630.03	1630.16
09-JUL-93	1632.25	1630.53	1629.15	1634.44	1634.28	1633.61	1643.59	1640.73	1640.80	1634.70	1629.67	1629.77
01-AUG-93	1632.30	1630.81	1629.17	1634.31	1634.28	1633.70	1643.41	1640.90	1640.75	1635.12	1629.69	1629.79
07-SEP-93	1631.94	1630.25	1628.57		1633.91	1632.91	1643.06	1640.64	1640.55	1634.20	1629.19	1629.43
27-OCT-93	1631.95	1630.58	1628.92	1633.68	1633.71	1632.98	1642.76	1640.67	1640.39	1634.51	1629.80	1629.76
02-NOV-93	1632.05	1630.69	1629.11	1633.77	1633.79	1633.36	1642.78	1640.81	1640.40	1634.58	1630.02	1629.83
03-DEC-93	1631.60	1630.55	1627.86	1633.84	1633.87	1633.01	1642.75	1640.73	1640.40	1634.07	1630.47	1629.66
06-JAN-94	1632.81	1631.06	1629.54	1635.39	1634.92	1634.84	1643.41	1640.98	1640.70	1635.14	1630.07	1630.33
01-FEB-94	1632.91	1631.23	1629.91	1635.39	1635.42	1635.03	1643.78	1641.29	1640.99	1635.93	1630.88	1630.55
08-MAR-94	1633.12	1631.36	1630.06	1635.95	1635.99	1635.86	1644.41	1641.58	1641.42	1636.42	1631.10	1630.64
01-APR-94	1633.92	1632.09	1630.67	1637.42	1637.43	1637.42	1645.36	1642.02	1641.90	1637.56	1631.89	1630.91
02-MAY-94	1633.30	1631.60	1630.37	1636.43	1636.48	1636.54	1645.25	1642.00	1641.95	1637.00	1631.52	1631.06
02-JUN-94	1632.49	1631.00	1629.79	1635.21	1635.25	1635.02	1644.35	1641.30	1641.40	1635.92	1630.76	1630.37
21-JUL-94	1632.40	1630.68	1629.75	1634.95	1635.01	1634.52	1644.07	1641.18	1641.24	1635.52	1630.62	1630.03
03-AUG-94	1633.25	1630.94	1629.75	1635.44	1634.89	1634.72	1645.11	1641.18	1641.18	1635.62	1630.60	1630.27
01-SEP-94	1632.37	1630.90	1629.70	1634.91	1634.91	1634.66	1643.87	1641.06	1641.12	1635.60	1630.54	1630.24
03-OCT-94	1632.05	1630.30	1629.34	1634.89	1634.31	1633.78	1643.47	1640.83	1640.86	1634.06	1630.16	1630.01
02-NOV-94	1632.03	1630.76	1629.32	1634.12	1634.16	1633.58	1643.23	1640.84	1640.72	1634.80	1630.14	1630.01
01-DEC-94	1632.03	1630.76	1629.29	1634.03	1634.07	1633.56	1643.07	1640.86	1640.62	1634.78	1630.12	1629.97
02-JAN-95	1631.91	1630.66	1629.05	1632.85	1633.87	1633.16	1642.93	1640.78	1640.54	1634.58	1629.88	1629.67
01-FEB-95	1632.52	1630.99	1629.74	1635.00	1635.05	1634.94	1643.59	1641.19	1640.92	1635.63	1630.57	1630.29
01-MAR-95	1633.07	1631.54	1630.33	1635.71	1635.79	1635.94	1644.37	1641.90	1641.36	1636.48	1631.28	1631.09
04-APR-95	1632.42	1631.32	1628.72	1635.13	1635.17	1634.53	1644.04	1641.31	1641.25	1634.92	1630.56	1630.23
03-MAY-95	1632.31	1630.90	1629.69	1634.49	1634.89	1634.36	1643.69	1641.30	1641.04	1635.37	1630.52	1630.05

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 67	Well 67B	Well 68	Well 70	Well 70A	Well 71	Well 72	Well 73	Well 74	Well 75	Well 76	Well 77	Well 78
	Water-Level Elevation = feet, mean sea level												
13-JUL-92	1636.80		1630.14	1634.49		1633.37	1634.45	1635.15	1635.76	1634.28	1633.90	1635.12	1635.36
17-AUG-92	1637.00		1631.40	1634.90		1633.76	1635.74	1636.62	1635.57	1634.90	1634.02	1635.55	1636.84
21-SEP-92	1636.45		1630.00	1634.02		1632.88	1633.94	1634.94	1635.52	1633.92	1633.40	1634.77	1634.99
12-OCT-92	1636.40		1630.03	1633.96		1632.86	1634.04	1635.05	1635.10	1633.84	1633.35	1634.69	1634.98
16-NOV-92	1636.10		1629.90	1633.30		1632.38	1633.80	1634.31	1634.36	1633.42	1632.92	1634.22	1634.42
08-DEC-92	1635.95		1632.95	1633.20		1632.33	1633.80	1634.71	1634.01	1633.42	1632.92	1634.22	1634.77
04-JAN-93	1636.60		1630.25	1634.20		1633.08	1634.20	1635.31	1635.01	1634.07	1633.67	1635.02	1635.12
01-FEB-93	1636.40		1630.14	1633.97		1632.98	1634.07	1635.27	1635.14	1633.96	1633.50	1634.75	1635.02
01-MAR-93	1636.50		1630.15	1633.95		1632.93	1634.15	1635.21	1634.96	1634.07	1633.47	1634.67	1635.07
05-APR-93	1637.35		1630.75	1635.10		1633.98	1635.20	1636.61	1636.16	1634.87	1634.37	1635.66	1635.62
03-MAY-93	1636.68		1630.31	1634.38		1633.30	1634.34	1635.20	1636.00	1634.20	1634.11	1635.25	1635.18
04-JUN-93	1636.28	1636.03	1630.26	1633.89	1634.09	1632.82	1633.88	1634.95	1635.21	1633.82	1633.61	1634.84	1634.91
09-JUL-93	1635.83	1635.43	1629.85	1633.13	1633.11	1632.14	1632.64	1633.70	1634.41	1633.22	1633.11	1634.37	1634.25
01-AUG-93	1635.69	1635.46	1629.88	1633.18	1633.27	1632.25	1633.60	1635.15	1633.90	1633.44	1632.94	1634.32	1637.70
07-SEP-93	1635.23	1635.12	1629.51	1632.40	1632.34	1631.43	1631.87	1632.46	1633.34	1632.60	1632.50	1633.83	1633.41
27-OCT-93	1635.17	1634.94	1629.51	1632.03		1631.64	1632.11	1632.82	1632.77	1632.59	1632.69	1633.68	1633.58
02-NOV-93	1635.23	1634.98	1629.66	1632.20	1633.32	1634.94	1633.67	1635.30	1632.71	1632.89	1632.81	1633.70	1634.17
03-DEC-93	1635.26	1634.97	1629.72	1632.32	1632.44	1631.92	1632.71	1634.99	1632.99	1632.82	1632.86	1634.38	Abandoned
06-JAN-94	1636.17	1635.86	1630.44	1633.88	1634.12	1632.75	1634.84	1636.28	1634.19	1634.13	1633.46	1634.89	
01-FEB-94	1636.52	1636.32	1630.45	1634.31	1634.53	1633.25	1634.69	1635.86	1634.93	1634.20	1634.01	1635.30	
08-MAR-94	1636.99	1636.81	1630.55	1634.98	1635.30	1633.82	1634.72	1636.09	1635.93	1634.70	1634.54	1635.74	
01-APR-94	1638.03	1637.90	1631.55	1636.20	1636.68	1635.38	1635.57	1636.62	1636.54	1635.66	1636.09	1637.01	
02-MAY-94	1637.52	1637.33	1631.00	1635.75	1636.16	1634.94	1635.38	1636.55	1637.00	1635.42	1635.53	1636.38	
02-JUN-94	1636.54	1636.31	1630.24	1634.33	1634.53	1633.73	1634.44	1635.77	1636.06	1634.37	1634.40	1635.21	
21-JUL-94	1636.26	1636.07	1630.10	1634.01	1634.21	1633.56	1634.57	1635.87	1641.27	1634.33	1634.15	1635.09	
03-AUG-94	1636.71	1635.98	1631.08	1633.96	1634.15	1633.45	1634.49	1635.96	1635.19	1634.26	1634.01	1634.05	
01-SEP-94	1636.22	1635.99	1630.08	1633.38	1634.02	1632.63	1633.91	1635.37	1635.18	1633.72	1633.56	1634.92	
03-OCT-94	1635.65	1635.45	1630.80	1632.94	1633.05	1631.93	1632.60	1634.76	1634.37	1633.13	1633.42	1634.34	
02-NOV-94	1635.58	1635.31	1629.85	1633.10	1632.84	1631.89	1633.07	1635.11	1633.89	1632.87	1633.21	1634.13	
01-DEC-94	1635.48	1635.21	1629.82	1632.44	1632.55	1632.07	1632.88	1635.15	1633.37	1632.78	1632.99	1634.04	
02-JAN-95	1635.76	1635.01	1629.64	1632.12	1632.24	1631.32	1631.87	1633.90	1633.04	1632.37	1632.59	1633.86	
01-FEB-95	1636.71	1636.00	1630.17	1633.84	1634.04	1632.70	1634.15	1636.13	1634.63	1633.81	1633.68	1635.07	
01-MAR-95	1637.38	1636.71	1631.09	1637.84	1635.24	1633.67	1635.46	1636.87	1635.45	1634.47	1634.31	1635.90	
04-APR-95	1636.38	1636.15	1630.06	1633.98	1634.12	1632.95	1633.83	1635.47	1635.51	1633.87	1633.87	1635.16	
03-MAY-95	1636.04	1635.76	1630.09	1633.96	1633.58	1632.73	1634.25	1636.29	1634.57	1633.65	1633.46	1634.74	

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well 79	Well 80	Well 81	Well 82	Well 91	Well 92	Well 93	Well 94	Well 95A	Well 96A	Well 97A	Well 98A	Well 99A	Well 100A
	Water-Level Elevation = feet, mean sea level													
13-JUL-92	1633.66	1631.06	1631.19	1631.82	1634.52	1635.17	1634.64	1635.84						
17-AUG-92	1633.90	1631.51	1631.80	1631.66	1635.17	1635.66	1635.64	1636.99						
21-SEP-92	1633.27	1630.59	1630.87	1631.27	1634.13	1634.44	1634.21	1635.36						
12-OCT-92	1633.21	1630.65	1630.88	1631.07	1633.96	1634.66	1634.06	1635.45						
16-NOV-92	1632.77	1630.31	1630.58	1629.17	1633.34	1634.44	1633.76	1634.15						
08-DEC-92	1632.72	1630.16	1630.58	1629.22	1633.34	1633.89	1633.86	1634.25						
04-JAN-93	1633.52	1631.01	1631.18	1631.47	1634.29	1634.59	1634.21	1634.20						
01-FEB-93	1633.29	1630.80	1630.99	1633.13	1634.18	1635.23	1634.40	1635.53						
01-MAR-93	1634.24	1630.73	1630.98	1630.84	1633.99	1634.54	1634.26	1634.40						
05-APR-93	1634.18	1631.56	1631.68	1631.94	1634.79	1635.49	1635.06	1635.30						
03-MAY-93	1633.86	1631.29	1631.42	1631.80	1634.11	1634.11	1634.28	1634.34						
04-JUN-93	1633.38	1630.80	1631.09	1631.03	1633.79	1633.74	1633.88	1633.98	1635.20	1636.77	1634.86	1628.22	1628.96	1629.74
09-JUL-93	1632.88	1630.33	1630.64	1630.38	1633.19	1633.11	1633.33	1632.75	1634.54	1636.52	1633.85	1628.20	1628.69	1629.47
01-AUG-93	1632.81		1630.73	1630.02	1633.62	1633.40	1633.94	1635.23	1634.58	1636.29	1634.27	1628.30	1628.92	1629.70
07-SEP-93	1632.37	1629.73	1630.08	1629.57	1632.83	1632.41	1632.92	1631.78	1634.20	1635.98	1633.37	1628.17	1628.57	1629.21
27-OCT-93	1632.11		1629.91	1628.12	1632.37	1632.04	1632.68	1631.98	1634.84	1635.90		1628.19	1628.44	1629.10
02-NOV-93	1632.06	1629.73	1630.10	1629.43	1632.92	1632.44	1633.36	1634.01	1634.06	1635.95	1632.93	1628.02	1628.49	1629.20
03-DEC-93	1632.66	Abandoned		1629.55	1632.84	1632.48	1633.11	1632.54	1633.93	1636.02	1633.29	1627.87	1628.50	1628.92
06-JAN-94	1633.26		1632.05	1630.47	1634.22	1635.02	1634.50	1634.87	1635.33	1636.85	1635.02	1628.15	1629.00	1629.56
01-FEB-94	1633.76			1631.42	1634.24	1634.94	1634.27	1634.38	1636.05	1637.31	1635.20	1628.22	1628.99	1629.60
08-MAR-94	1634.24		1632.67	1632.36	1634.73	1635.35	1634.65	1634.61	1636.72	1637.68	1635.49	1628.68	1629.50	1630.08
01-APR-94	1635.47		1633.84	1633.88	1635.69	1636.15	1635.29	1634.93	1638.05	1639.27	1636.02	1629.07	1630.49	1630.47
02-MAY-94	1634.91		1633.29	1633.29	1635.47	1635.95	1635.20	1635.08	1637.00	1637.78	1635.84	1628.70	1629.84	1630.04
02-JUN-94	1633.83		1632.28	1631.75	1634.39	1634.83	1634.39	1634.25	1635.52	1636.69	1635.21	1628.28	1628.99	1629.64
21-JUL-94	1633.55		1632.09	1631.26	1634.38	1634.75	1634.43	1634.39	1635.30	1636.53	1635.15	1628.12	1629.13	1629.91
03-AUG-94	1633.47		1632.01	1631.08	1634.30	1634.72	1634.40	1634.39	1635.15	1636.49	1634.89	1628.35	1629.16	1629.90
01-SEP-94	1641.88		1629.98	1631.21	1633.81	1634.38	1633.79	1633.75	1635.28	1636.51	1634.55	1628.32	1629.06	1629.87
03-OCT-94	1632.54		1629.89	1630.29	1633.16	1633.48	1633.28	1633.05	1634.58	1636.07	1633.81	1628.22	1628.79	1629.54
02-NOV-94	1632.32		1630.83	1630.21	1632.94	1633.44	1633.14	1633.20	1634.40	1635.99	1633.59	1628.22	1628.77	1629.54
01-DEC-94	1626.82		1630.33	1630.09	1632.84	1633.08	1632.91	1633.24	1634.28	1635.95	1633.39	1628.24	1628.81	1629.58
02-JAN-95	1632.26		1630.13	1629.85	1635.40	1632.69	1632.42	1631.72	1634.10	1635.79	1633.03	1628.16	1628.57	1629.18
01-FEB-95	1629.82		1631.33	1631.40	1633.89	1634.52	1633.81	1634.28	1635.53	1636.77	1634.99	1628.34	1629.21	1629.92
01-MAR-95	1630.43		1631.80	1632.25	1635.06	1635.68	1634.48	1635.35	1636.34	1637.45	1635.51	1628.76	1629.71	1630.34
04-APR-95	1634.06		1631.11	1631.70	1633.98	1634.38	1633.84	1633.72	1635.54	1636.75	1634.65	1628.30	1627.87	1629.90
03-MAY-95	1633.00		1630.94	1631.03	1633.54	1634.28	1633.78	1634.56	1634.93	1636.42	1634.55	1628.32	1629.19	1629.67

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Sampling Period	Well 100B	Well 101A	Well 102A	Well 103A	Well 104A	Well 105A	Well 106A	Well 107A	Well 107B	Well LD-1A	Well LD-2A	Well 234-2	Well 234-3	Well SC-1	Well SC-3
	Water-Level Elevation = feet, mean sea level														
13-JUL-92															
17-AUG-92															
21-SEP-92															
12-OCT-92															
16-NOV-92															
08-DEC-92															
04-JAN-93															
01-FEB-93															
01-MAR-93															
05-APR-93															
03-MAY-93															
04-JUN-93	1629.36	1629.96	1630.25	1630.38	1632.06	1633.25	1633.97	1635.05	1634.35	1633.85	1634.04	1634.87	1634.86	1645.91	1637.73
09-JUL-93	1628.96	1629.50	1629.61	1629.62	1630.89	1630.65	1632.38	1633.74	1633.15	1633.26	1633.37	1634.77	1634.86	1645.22	1637.54
01-AUG-93	1629.12	1629.92	1629.86	1629.99	1631.46	1631.98	1632.63	1633.40	1632.96	1633.68	1633.92	1634.39	1634.05	1645.37	1637.54
07-SEP-93	1628.67	1629.20	1629.28	1629.26	1630.31	1630.79	1632.38	1632.76	1632.33	1631.65	1632.68	1633.70	1633.87	1644.99	1637.43
27-OCT-93	1628.47	1629.03	1629.11	1629.09	1630.11	1630.35	1630.98	1632.16	1631.82	1632.65	1632.52	1633.12	1633.68	1644.62	1637.34
02-NOV-93	1628.54	1629.10	1629.10	1629.03	1630.50	1630.17	1630.72	1632.06	1631.78	1632.79	1632.91	1633.57	1633.66	1644.59	1637.34
03-DEC-93	1628.32	1629.07	1628.78	1628.81	1630.35	1630.35	1630.88	1632.24	1631.97	1632.52	1632.93	1633.22	1633.95	1644.51	1637.34
06-JAN-94	1629.09	1629.87	1630.32	1630.46	1632.13	1631.92	1632.62	1633.36	1633.32	1634.03	1634.79	1634.65	1634.14	1645.01	1637.51
01-FEB-94	1629.35	1629.94	1630.48	1630.75	1632.60	1632.75	1633.45	1634.52	1634.13	1633.62	1634.39	1634.67	1634.81	1645.45	1637.60
08-MAR-94	1630.16	1630.63	1631.16	1631.51	1633.42	1634.22	1634.94	1635.55	1635.11	1634.91	1635.54	1635.50	1635.26	1646.27	1637.79
01-APR-94	1631.14	1630.68	1632.48	1633.27	1634.61	1635.55	1636.13	1636.02	1635.97	1635.85	1636.43	1636.81	1636.52	1647.13	1638.02
02-MAY-94	1630.37	1631.07	1631.69	1632.41	1634.11	1635.13	1636.33	1636.66	1636.11	1635.64	1636.05	1636.26	1636.07	1647.41	1637.74
02-JUN-94	1629.79	1630.24	1630.73	1630.93	1632.53	1634.11	1634.97	1635.81	1635.02	1635.04	1634.99	1635.07	1635.58	1646.49	1637.40
21-JUL-94	1629.62	1630.22	1630.69	1630.85	1632.56	1633.67	1634.35	1635.01	1634.37	1635.01	1634.93	1634.76	1635.08	1646.22	1637.64
03-AUG-94	1629.54	1630.14	1630.56	1630.71	1632.29	1633.48	1634.11	1634.87	1634.21	1634.71	1634.73	1634.12	1634.59	1646.10	1637.62
01-SEP-94	1629.57	1630.04	1630.33	1630.45	1632.17	1633.30	1634.12	1634.56	1634.05	1634.92	1634.59	1634.54	1635.27	1645.92	1637.61
03-OCT-94	1629.11	1629.54	1629.69	1629.73	1631.01	1631.77	1632.64	1633.90	1633.27	1633.20	1633.60	1634.26	1634.57	1645.63	1637.48
02-NOV-94	1629.12	1629.54	1629.67	1629.71	1630.87	1631.30	1632.09	1633.26	1632.83	1632.87	1633.27	1634.18	1634.43	1645.16	1637.39
01-DEC-94	1629.15	1629.54	1629.65	1629.61	1630.71	1630.71	1631.59	1632.66	1632.37	1632.15	1633.08	1634.54	1634.34	1644.93	1637.36
02-JAN-95	1628.85	1629.22	1629.31	1628.97	1630.25	1630.43	1631.23	1632.42	1627.62	1631.87	1632.66	1634.47	1634.28	1644.71	1637.26
01-FEB-95	1629.73	1630.22	1630.71	1630.83	1632.63	1632.77	1633.39	1634.11	1633.77	1634.75	1634.77	1635.28	1635.11	1645.31	1637.50
01-MAR-95	1630.25	1630.82	1631.41	1631.51	1633.33	1633.71	1634.41	1634.99	1634.75	1635.43	1636.49	1635.82	1635.43	1645.97	1637.64
04-APR-95	1629.73	1630.17	1630.59	1630.71	1632.26	1633.41	1634.23	1635.16	1634.57	1634.61	1634.03	1634.98	1635.31	1645.04	1637.64
03-MAY-95	1629.53	1630.14	1630.53	1630.51	1632.11	1632.25	1633.07	1634.08	1633.62	1632.99	1634.27	1635.12	1634.57	1645.57	1637.52

Summary of Groundwater Elevations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Sampling Period	Well SC-4	Well SC-6	Well SC-7	Well SC-8	Piez P1	Piez P2	Piez P3	Piez P4	Well A
	Water-Level Elevation = feet, mean sea level								
13-JUL-92									1637.43
17-AUG-92									1637.75
21-SEP-92									1637.18
12-OCT-92									1637.10
16-NOV-92									1636.78
08-DEC-92									1636.78
04-JAN-93									1637.38
01-FEB-93									1637.23
01-MAR-93									1637.13
05-APR-93									1637.98
03-MAY-93									1637.28
04-JUN-93	1635.64	1639.24	1634.47	1634.30					1636.93
09-JUL-93	1634.65	1638.16	1633.20	1632.00					1636.58
01-AUG-93	1634.72	1637.98	1632.84	1632.57					1636.48
07-SEP-93	1633.91	1637.50	1632.16	1631.88					1636.08
27-OCT-93	1633.32	1637.07	1631.64	1631.14					
02-NOV-93	1632.99	1636.53	1631.61	1631.05					1636.00
03-DEC-93	1633.57	1636.95	1631.92	1630.19					1636.09
06-JAN-94	1635.16	1638.43	1633.25	1632.74	1631.71	1634.50	1635.51	1634.50	1653.08
01-FEB-94	1636.25	1639.36	1634.37	1633.72	1631.92	1632.87	1635.27	1634.76	1637.26
08-MAR-94	1637.39	1640.83	1635.56	1634.91	1632.41	1634.56	1635.16	1634.46	1637.67
01-APR-94	1639.23	1641.72	1636.63	1635.45	1633.51	1635.91	1635.52	1635.54	1638.66
02-MAY-94	1638.05	1642.20	1636.85	1636.20	1635.53	1631.32	1638.52	1632.43	
02-JUN-94	1636.31	1639.81	1635.51	1635.25	1631.76	1633.94	1635.14	1634.23	1637.12
21-JUL-94	1635.71	1639.33	1634.43	1634.26	1631.52	1633.93	1635.41	1634.09	1636.95
03-AUG-94	1635.56	1638.99	1634.36	1634.01	1631.48	1633.85	1635.53	1634.00	1636.88
01-SEP-94	1635.57	1639.00	1634.71	1634.03	1638.11	1638.34	1642.34	1639.25	1636.86
03-OCT-94	1634.44	1638.11	1633.62	1633.11	1629.11	1628.88	1630.34	1632.55	1636.38
02-NOV-94	1634.05	1637.64	1632.97	1632.37	1630.06	1630.58	1631.14	1632.36	1636.28
01-DEC-94	1633.61	1637.27	1632.47	1631.79	1633.07	1630.89	1632.04	1632.03	
02-JAN-95	1633.51	1637.05	1632.23	1631.53	1629.74	1629.48	1632.64	1632.35	1636.02
01-FEB-95	1636.37	1638.31	1634.16	1633.28	1631.03	1632.12	1633.88	1632.57	1636.94
01-MAR-95	1636.81	1639.85	1635.27	1631.03	1631.97	1633.67	1635.10	1633.73	1637.54
04-APR-95	1635.71	1639.35	1635.13	1634.43	1630.97	1631.94	1634.28	1633.97	1637.03
03-MAY-95	1634.87	1638.25	1633.97	1633.33	1630.95	1633.42	1633.30	1633.01	1636.72

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Attachment 4

Revised Groundwater Flow and Solute-Transport Modeling Report,
February 1999

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CSM-99-021

Revised Groundwater Flow and Solute-Transport Modeling Report

Nuclear Fuel Services, Inc./Erwin, Tennessee

ARCADIS
GERAGHTY & MILLER

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REPORT

February 1999

Revised Groundwater Flow and Solute-Transport Modeling Report
Nuclear Fuel Services
Erwin, Tennessee

February 8, 1999

Prepared by ARCADIS Geraghty & Miller, Inc.

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APPENDICES

1.0 Introduction

ARCADIS Geraghty & Miller, Inc. was retained by Nuclear Fuel Services (NFS) to revise the existing numerical groundwater flow and constituent transport model previously developed in 1996. This model was used to predict the migration of uranium and tetrachloroethene (PCE) in groundwater and to help select optimal locations for additional groundwater monitoring wells. The model predicted that PCE had migrated offsite along the northwestern NFS property boundary at concentrations exceeding the maximum contaminant level (MCL) [i.e., 5 micrograms per liter (μg/L)]. Nine on-site groundwater monitoring wells were installed in December 1995 during the development of the original groundwater model. Eleven off-site groundwater monitoring wells were installed in December 1996 to confirm the groundwater modeling results. Groundwater sampling and analysis results for these wells verified the groundwater modeling results. In general, the original solute transport model accurately predicted the distribution of PCE in the alluvial aquifer system. However, the original model under-predicted the extent of PCE in the shallow bedrock.

Revision of the groundwater flow and solute transport models was designed to incorporate lithologic, hydraulic conductivity, water-level, and analytical data collected from the new borings/monitoring wells. The revised groundwater flow and solute-transport models will be used to predict the future migration of PCE and uranium. This report documents the revisions that were made to the groundwater flow and solute-transport models and the results of predictive simulations that were performed using the revised models. Although recently collected field data have refined the understanding of site conditions in several key locations, the hydrogeologic conceptual model that was developed during the original modeling effort (Geraghty & Miller, Inc. 1995a and Geraghty & Miller, Inc. 1996) is still applicable and, therefore, these elements were utilized in the model revision. Key aspects of this conceptual model are summarized in this document, however, a more complete description of the site conceptual model is presented in previous reports (Geraghty & Miller, Inc. 1995a and Geraghty & Miller, Inc. 1996).

1.1 Site Location and History

NFS is a nuclear fuel fabrication and uranium recovery facility that has been operational since the late 1950s. The NFS facility, approximately 64 acres in size, is located in the mountainous region of east Tennessee, east of the Nolichucky River and adjacent to the CSX Railroad (Figure 1-1). The NFS Erwin site, located in Unicoi County, is within the city limits of Erwin and is immediately west of the community of Banner Hill. Situated in a narrow valley surrounded by rugged mountains, the site occupies a relatively level area approximately 20 to 30 feet (ft) above the elevation of the Nolichucky River. To the west, east, and south, the mountains rise to elevations of 3,500 to 5,000 ft within a few miles of the site. The CSX railroad adjoins the site on the northwest boundary. A light industrial park is located opposite the site on the northwest side of the railroad (EcoTek 1994a). Residential, commercial, and industrial lands constitute 19 percent of the surrounding area, with about 7 percent covered by farms and suburban homes (Figure 1-2) (U.S. Nuclear Regulatory Commission 1991). The remaining area is mountainous land which is forested.

1.2 Project Objectives and Methodology

The primary objectives for this modeling effort are twofold: 1) revise and recalibrate the existing groundwater flow and solute-transport models based on some of the wells installed in 1995 and 1996; and 2) use the revised models to predict the future migration of PCE and uranium. The project was completed in five distinct phases which included:

1) Review field data that were not available during the original modeling effort and refine the site conceptual model based on these new data.
2) Revise and recalibrate the groundwater flow model based on the refined site conceptual model.
3) Recalibrate the solute-transport model to better represent the current spatial distribution of PCE and uranium.
4) Complete simulations using the revised models to predict the migration, extent, and concentration of uranium and PCE originating from the NFS facility.
5) Prepare and submit a final report to NFS documenting the modeling effort completed at the site.

2.0 Geologic and Hydrogeologic Setting

2.1 Geologic Framework

Several regional geologic studies have been published for the area of Tennessee in which the NFS Erwin plant is located. Detailed discussions of these studies and the geologic setting of the Erwin area are presented in the original modeling report (Geraghty & Miller, Inc. 1996).

2.1.1 Bedrock

Unicoi County lies within the Blue Ridge physiographic province. Mountains surrounding Erwin are underlain primarily by quartzite and other clastic rocks of Cambrian and pre-Cambrian age (Figure 2-1). They project 1,000 to 2,500 ft above the adjacent lowlands. The Erwin valley is underlain chiefly by the Honaker Dolomite, Rome Formation, and Shady Dolomite, all of Cambrian age (DeBuchananne and Richardson 1956).

The NFS Erwin Plant is underlain by Cambrian and Ordovician sedimentary rocks which have been folded and thrust faulted (Figure 2-2). No faults have been mapped through or adjacent to the plant site (EcoTek 1994a), however, significant folding of formations has occurred.

The Rome, which underlies the NFS site, is described as red, maroon, or brown silty shale. Coring at the site has shown that the Rome is dipping at steep angles, many times is vertical, and contains highly weathered zones. Locally at the NFS site, the Rome is generally dolomitic in the northern portions of the site while shales are more common in the southern portions.

2.1.2 Unconsolidated Sediments

Bedrock underlying the mountains surrounding Erwin has been weathered to produce a blanket of residuum. Residuum is also present in the Erwin valley away from the depositional influences of the Nolichucky River, however, accumulations tend to be thinner over the Rome or away from the Nolichucky River.

The bedrock surface (Figure 2-3) mimics topography in only the most general sense as there is a perceptible westward increase in depth to bedrock toward the Nolichucky River. The depth to bedrock from the surface varies from 6.5 to 32 ft at the facility as evidenced by historical drilling activities (EcoTek 1994a).

An alluvial overburden of varying thickness is present across the site. This overburden consists of 2 to 4 ft of brown to dark brown, fine- to medium-grain clay/silt rich sand. Below the cohesive alluvial material is a zone of medium- to coarse-grain, light to medium gray, micaceous sand, or orange to brown quartzitic sand. The sand extends to a depth of 10 to 15 ft. A sharp contact does not exist between the clayey unit and underlying sand, but rather the change is gradational to a coarser texture with depth. Underlying the sand is a bed of rounded pebbles coarsening with depth into cobbles and boulders (EcoTek 1994a). Thickness of the alluvium ranges from 0 ft, at an outcrop of shale (possible alluvial terrace) along the eastern plant perimeter road, to 29 ft at the northeast corner of the burial ground (EcoTek 1994a). Clayey material extends from the ground surface to as deep as 15 ft with increased sand to the north (Plate 1). Underlying the northern portion of the plant is a consistent sand unit that is gray in color, mostly quartzitic, but with a high mica content (20 to 30 percent) and rich in heavy minerals (5 to 10 percent).

The coarsest material (cobbles/boulders) lies directly on the bedrock surface. The cobble/boulder zone occupies a similar horizon across the site, but the thickness and elevation varies across the site (Figure 2-4 and Plate 2). The origin of this material is probably channel fill brought into the valley by the Nolichucky River and its tributaries, therefore, its continuity and thickness is variable across the floodplain occupied by the NFS site (EcoTek 1994a).

The surface of the cobble/boulder zone is variable with a high elevation of 1,642 ft mean sea level (msl) to a low of 1,620 ft msl. The cobble/boulder zone is highest in the southern corner of the site with a high feature extending to the approximate center of the site. A high also is evident northeast of the burial ground. Low elevations occur along the CSX Railroad property and in the vicinity of boring 234-1. Cobbles are apparently non-existent near Building 234 and the shale outcrop below the contractors parking lot, around the Building 105 complex, along the northeastern reach of Banner Spring Branch, and in the vicinity of wells 59 and 65 (northern corner of the fenced portion of the site) (EcoTek 1994a).

2.2 Hydrologic Framework

The aquifer underlying the NFS site is composed of two principal hydrostratigraphic units: an unconsolidated unit and a bedrock unit. The water-table aquifer occurs in the unconsolidated surficial sediments at the site which are predominantly alluvial in origin. This alluvial aquifer is limited in areal extent and is found mainly in the lowland areas. The alluvial aquifer pinches out just north and south of the site due to the presence of shallow bedrock.

Alluvial deposits are generally very heterogeneous in sediment size, composition, and depositional pattern, causing varying degrees of anisotropy throughout these deposits. The presence of large amounts of clay in suspended and mixed-load stream deposits commonly causes the vertical hydraulic conductivity to be orders-of-magnitude less than in a horizontal direction.

The bedrock aquifer beneath the site occurs in the Rome Formation. Even though the alluvial aquifer is of greater permeability than the bedrock aquifer, regional groundwater flow patterns exist in the bedrock aquifer beneath the site to a depth of at least 350 ft. Groundwater originating in the upland areas flows through the Shady and Honaker Dolomite before exiting the groundwater flow system through surface water in the valley.

Previous investigations have determined that water in the Rome Formation in the site area occurs under weak artesian conditions for the range of depths investigated. Locally, the Rome bedrock surface is shallow and intersects the water table in several areas.

2.2.1 Groundwater Usage

Wells and springs are the principal source of water supply for several communities in the Erwin region. Erwin Utilities uses a combination of wells and springs for its water supply. A total of six public groundwater wells are located within a 5-mile radius of the site. Average pumping rates for these wells are known, but specific pumping rates over time are not available. Little is known about the usage of most of the private water wells within the 5-mile radius of the NFS site. The nearest public water intake downstream from the NFS facility along the Nolichucky River is at Jonesborough, approximately 8 miles in distance (EcoTek 1989).

In relation to the NFS site, the nearest water withdrawal well used by Erwin Utilities is approximately 1/2 mile north of the northern NFS facility boundary ("Railroad Well"). In addition to Erwin Utilities, other users of groundwater in Unicoi County consume approximately 3 million gallons per day (EcoTek 1994a). Most public and industrial supply wells tap the fractures and solution cavities in the limestone and occasionally in shale aquifers. Domestic water supplies generally obtain water from the shallow bedrock (EcoTek 1994a). Surface water in the Erwin area is not used for water supplies. Table 2-1 summarizes the water-supply wells in the vicinity of the NFS facility and identifies the geologic formation in which they are completed.

2.2.2 Water Levels

The Erwin valley is characterized as a discharge zone for groundwater as evidenced by the number of springs in the valley and along its hillsides. Groundwater occurs beneath the site in both the unconsolidated alluvium and bedrock lithologies. The water table is present in the alluvium from where it intersects the land surface to as much as 14 ft below ground surface (bgs) in the southwestern area of the plant. Water-level data is available throughout the site. Recent drilling and monitoring well installation has provided significant water-level information northwest of the site toward the Nolichucky River.

Monitoring wells at the NFS site are completed in four hydrostratigraphic zones: 1) across the water table in the shallow alluvium; 2) the deep alluvium (cobble zone); 3) shallow bedrock; and 4) in the intermediate depth bedrock, from 50 to 120 ft bgs (EcoTek 1994a). Generally, groundwater flows in a northwest direction towards the Nolichucky River (Figure 2-5). The general groundwater flow direction in the cobble/boulder zone (Figure 2-6) and shallow bedrock (Figure 2-7) is roughly uniform to that in the alluvium zone, exhibiting flow toward the northwest.

Water-level data from well clusters (wells located nearby and screened at various depths) indicate that consistent upward gradients exist in at least the northeast area of the site. This upward gradient is most likely due to regional discharge of groundwater (typically from the mountains) to large sinks like the Nolichucky River.

2.2.3 Hydraulic Properties

Several aquifer tests have been performed to define the hydraulic properties at the site. The subsurface lithologies have been partitioned into three distinct zones on the basis of their hydraulic properties as described below.

- Alluvium: This unit is fine- to coarse-grained unconsolidated sediments with hydraulic conductivity increasing with depth. Hydraulic conductivity values range from 0.51 feet/day (ft/d) to 114.0 ft/d. Cobble/boulder zone hydraulic conductivity estimates range from 0.54 and 168 ft/d.

  Coring across the site revealed no laterally continuous aquitard separating the bedrock from the alluvium. The groundwater in the bedrock is therefore considered to be unconfined (EcoTek 1989).

- Shallow Bedrock: Analysis of hydraulic tests indicate that shallow bedrock displays variable hydraulic conductivity as low as 0.05 ft/d in competent dolomite and as high as 27.64 ft/d in weathered shale (EcoTek 1989).

- Deeper Bedrock: Five wells and piezometers are screened in intermediate or deeper bedrock down to a maximum depth of 120 ft. Hydraulic conductivity is estimated to be 33.0 ft/d.

Fractures between the beds of the nearly vertically dipping dolomite probably provide the easiest pathways for water to flow. Flow through fractures across the beds may be more restrictive relative to flow through fractures along the bedding planes. This may help explain the consistent north-northwest groundwater flow directions and elliptical drawdowns (observed during well 80 pumping test) along strike during pumping. Consequently, the primary effect of pumping is expressed asymmetrically in a northeast-southwest direction, following strike of the beds (EcoTek 1993).

2.2.4 Surface Water

There are three surface-water bodies in the vicinity of the NFS Erwin site: Banner Spring Branch, Martin Creek, and the Nolichucky River. Banner Spring Branch is a small (1.5 to 3.0 ft wide) spring-fed stream lying entirely within the NFS Erwin plant boundaries. Banner Spring Branch originates on NFS property at Banner Spring which flows at a rate of about 300 gallons per minute (gpm) and flows toward the west and north into Martin Creek at the northwest corner of the site, about 1,200 ft from its source. Banner Spring Branch currently is confined to a straight, incised channel which flows between Ponds 1, 2, and 3. Prior to creation, the Ponds area was marshy with the Banner Spring channel exiting the area along its western boundary. Banner Spring Branch is generally a gaining stream in its upper man-made reaches and is a losing stream west of the ponds area until its confluence with Martin Creek. Historically, the ponds have altered groundwater flow directions onsite. The ponds generally acted as additional recharge sources to the groundwater as indicated by historical observed mounding of the water table in the vicinity of the ponds.

Martin Creek, fed by mountain springs, groundwater, and runoff, runs nearly parallel to the northern property line of the site, crossing the property for just a few yards at the northwest corner. The width of Martin Creek varies from 8 to 15 ft, with depth varying from a few inches to pools of 3 to 4 ft deep. The flow rate varies seasonally from 1,000 to 5,000 gpm.

Monthly stage data for the Nolichucky River were obtained from the United States Geological Survey (USGS) at the gauging station near Embreeville, roughly 2.5 miles northwest of the site. The average river stage is approximately 1,515 ft msl at Embreeville.

There are several large springs in the vicinity of the NFS site. The majority of springs exhibit quick response (within about 1 day) to local precipitation. In particular, many of the springs show a measurable increase in flow and the water often becomes turbid. Banner Spring water rarely has storm-related turbidity, signifying relatively deep groundwater circulation. Groundwater pumping can influence spring flow rates indicating good hydraulic communication exists in the fractured bedrock units.

2.2.5 Precipitation and Groundwater Recharge

The average annual mean precipitation for Erwin is about 45.2 inches (Erwin Utilities Weather Station). It is estimated that 19 to 25 percent of the precipitation in eastern Tennessee is expected to infiltrate as groundwater recharge (Zarawski 1978).

The unconsolidated aquifer is primarily recharged by infiltration of rainfall as well as upward seepage of water into the unconsolidated deposits from the bedrock beneath. A secondary local source of groundwater recharge is seepage/infiltration from the ponds, marshes, and streambeds. Groundwater recharge may also occur on an intermittent basis from leaking storm drains and pipelines (EcoTek 1989).

The Rome aquifer beneath the facility is primarily recharged by subsurface movement of water from beneath the adjacent upland areas. Rainfall directly infiltrates into aquifers on the upland areas and moves downgradient in the subsurface through fractures. The higher elevations of the recharge areas help to create the hydraulic head that creates the artesian pressures in the valley. A secondary localized source of recharge to the Rome aquifer beneath the facility is downward infiltration of water from the unconsolidated aquifer into the Rome (Geraghty & Miller, Inc. 1995a).

2.3 Constituent Distributions

Operations at the NFS plant have resulted in the presence of radionuclides and organic constituents in the groundwater below the facility. The prime source areas: 1) three unlined surface impoundments (Ponds 1, 2, and 3); 2) the "Pond 4" disposal area; 3) the burial grounds; and 4) the areas associated with Buildings 111, 130, and 120/131, all of which are located in the northern portion of the NFS site. A solute transport model was previously developed for two types of constituents, one radioactive (uranium) and one representative chlorinated solvent [tetrachloroethene (PCE)]. Total uranium concentrations are present primarily onsite, situated within the unconsolidated sediments (Figure 2-8) and extending into shallow bedrock (Figure 2-9). Elevated uranium concentrations are present throughout the central and northern area of the site near known source areas (Figure 2-8). PCE concentrations in the alluvium (Figure 2-10) and shallow bedrock (Figure 2-11) encompass the northern portions of the NFS site and extend offsite toward the Nolichucky River.

The U.S. Environmental Protection Agency (EPA) drinking water MCLs were exceeded for uranium [proposed standard of 30 picoCuries per liter (pCi/L)] and PCE (5 μg/L) in various wells (EcoTek 1994b). Most of these exceedances exist in the vicinity of the ponds, burial grounds (SWMU 9), Building 234, Solid Waste Management Unit (SWMU) 13/14 area, and SWMUs 2, 4, and 6, and in groundwater downgradient of these sources. Additionally, Buildings 130, 126, and 131 may be source areas for PCE. Vinyl chloride has also been detected in the same areas as PCE and is probably the result of PCE biotransformation. The observed total uranium concentrations, when compared to PCE distribution, indicate that uranium moves very slowly in the alluvial aquifer material.

3.0 Groundwater Flow Model Development

In 1996, Geraghty & Miller, Inc. developed a three-dimensional numerical model that simulates regional groundwater flow in the vicinity of the NFS site. The groundwater flow model was constructed and calibrated for a 38-square mile area surrounding the NFS facility for the purpose of simulating groundwater flow on a regional scale in a multi-unit system, consisting of alluvium (unconsolidated material) and underlying bedrock.

As part of the current modeling investigation, the groundwater flow model developed in 1996 by Geraghty & Miller was revised to incorporate field data collected after the original model was developed. During this phase of work, field data were reviewed to update the hydrogeologic conceptual model for the NFS site. These recently collected field data include the following: 1) water-level data; 2) groundwater sampling and analysis results for uranium and PCE; 3) lithologic data; and 4) hydraulic conductivity data. These data were used to revise the representation of stratigraphic units assigned in the model (i.e., thickness and geometry of stratigraphic units, to revise the delineation of hydraulic conductivity zones in the model, and to better delineate the current extent of uranium and PCE constituent concentrations. In addition, the new water-level data were used to recalibrate groundwater flow characteristics.

The model revisions were focused on areas where data collected after 1995 have augmented the data that were used to develop the original model. These data were used to make significant changes to the groundwater flow model within the NFS property boundary and directly northwest of the NFS facility. New regional data were not available for the area outside the immediate vicinity of the NFS facility, therefore, regional changes were not warranted. Further, recently collected data did not enhance the original understanding of groundwater sources and sinks. Therefore, with the exception of pumping rates assigned to several of the on-site and off-site wells, the boundary conditions assigned in the model were not altered. In summary, the following features were <u>not</u> revised during the recent modeling investigation:

- Model discretization;
- Thickness, elevation, geometry, and hydraulic properties associated with the aquifer units outside the immediate vicinity of the NFS facility;
- Groundwater flow boundary conditions;
- Thickness and geometry of the deep bedrock; and
- Representation of historical pumping conditions.

The following sections provide a description of the groundwater flow model developed for the NFS facility with recent changes highlighted.

3.1 Regional Model Description

3.1.1 Code Selection

The MODFLOW code, a publicly available groundwater flow simulation program, was used in both the original and recent modeling investigations to simulate groundwater flow at the NFS site. MODFLOW was developed by the USGS (McDonald and Harbaugh 1988). It is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted by the regulatory and scientific community. Given the intended use for the NFS site groundwater flow model as a decision-making tool, regulatory acceptance is vital for any code selected for this study.

In addition to its attributes of widespread use and acceptance, MODFLOW was also selected because of its versatile simulation features. MODFLOW can simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions and offers a variety of boundary conditions including specified head, areal recharge, injection or extraction wells, evapotranspiration, drains, rivers or streams, and horizontal flow barriers. Aquifers simulated by MODFLOW can be confined or unconfined, or convertible between confined and unconfined conditions. For the NFS site, which consists of a multi-unit system with variable hydrogeologic unit thickness and boundary conditions, MODFLOW's three-dimensional capability and boundary condition versatility are essential for the proper simulation of groundwater flow conditions.

3.1.2 Model Discretization

The finite-difference technique employed in MODFLOW to simulate hydraulic head distributions in multi-aquifer systems requires areal and vertical discretization or subdivision of the continuous aquifer system into a set of discrete blocks that forms a three-dimensional model grid. In the block-centered, finite-difference formulation used in MODFLOW, the center of each grid block corresponds to a computational point or node. When MODFLOW solves the set of linear algebraic finite-difference equations for the complete set of blocks, the solution yields values of hydraulic head at each node in the three-dimensional grid.

Water levels computed for each block represent an average water level over the volume of the block. Thus, adequate discretization (i.e., a sufficiently fine grid) is required to resolve features of interest, and yet not be computationally burdensome. MODFLOW allows the use of variable grid spacing such that a model may have a finer grid in areas of interest where greater accuracy is required and a coarser grid in areas requiring less detail.

The areal discretization of the revised model was not altered during the recent modeling effort. The three-dimensional model grid developed for the NFS groundwater flow model (Figure 3-1, Plate 3) extends over an area covering approximately 38 square miles. The grid boundaries were specified to coincide with natural boundaries, when possible, and to minimize the influence of model boundaries on simulation results at the site. The model domain extends approximately 6.6 miles from the east to west boundaries and 5.7 miles from the north to south boundaries. The finite-difference grid consists of 128 columns and 100 rows with five layers for a total of 64,000 grid cells or nodes. The model grid uses a uniform 50-ft areal grid spacing in the vicinity of the NFS facility to provide increased computational detail in the area of interest and grades to larger grid spacing at greater distances from the site.

The boundaries of the finite-difference grid and the 50-ft areal grid spacing at the NFS site were selected for the purpose of accurately simulating both regional and local groundwater flow around the site, and to accurately define the extent of hydraulic parameters and model structure. The extent selected for the grid ensured adequate incorporation of regional groundwater flow features that affect site conditions. The groundwater flow model was also oriented such that a principal axis of the model grid conforms to regional groundwater flow directions (northwest to southeast). The strike of the bedrock units (northeast to southwest) is also roughly perpendicular to the average groundwater flow direction.

The regional groundwater flow model uses five layers to simulate groundwater flow in the hydrogeologic units encountered within the study area. Within each model layer, the hydraulic parameters assigned in the model represent the various lithologies found beneath the site. In the vicinity of the Nolichucky River and the NFS facility, model layers are represented as follows:

- Model Layer 1 - shallow alluvium;
- Model Layer 2 - cobble/boulder zone;
- Model Layer 3 - shallow bedrock; and
- Model Layers 4 and 5 - deeper bedrock.

Information from the previous investigations on the site, public water-supply well logs, and published reports by USGS and other agencies were used to help define the total model depth which corresponds to the assumed depth of the active groundwater flow system. In areas where the alluvium pinches out (i.e., outside the vicinity of the NFS facility), Model Layers 1 and 2 also represent bedrock. Even though the NFS facility is underlain by the Rome Formation, the model domain extends to areas where the Honaker Dolomite, Shady Dolomite, Erwin, Hampton, Unicoi, and Snowbird Formations outcrop. Differences in the material properties associated with the bedrock formations are represented in the model by the assignment of differing hydraulic properties. The use of multiple model layers corresponding to the bedrock allows for the simulation of vertical gradients within the bedrock and for more accurate representation of the steeply dipping beds.

Lithologic descriptions from on-site wells were used to define the structural top and bottom elevations of the shallow alluvial sediments and top of bedrock in the vicinity of the site. In more distant areas of the model domain, land surface elevation data were used to define the bottom elevations for Model Layers 1 and 2 such that the layer bottoms were a subdued reflection of topography. Model Layer 2 eventually graded to a horizontal plane in Model Layers 3 through 5. The bottom elevations specified for Model Layers 3, 4, and 5 are 1,525, 1,450, and 1,325 ft msl, respectively.

In the vicinity of the NFS facility, the elevation and thickness of shallow alluvium, cobble/boulder zone, and the shallow bedrock were updated in the revised model based on lithologic logs developed for the new monitoring wells. As part of this effort, significant changes were made to the model in the area of the new off-site monitoring wells. These changes to the model were facilitated by developing contour maps illustrating the elevation of the top of bedrock (Figure 2-3) and the thickness of the cobble/boulder zone (Figure 2-4). The base of the shallow alluvium (i.e., the top of the cobble/boulder zone) was determined by adding the cobble/boulder zone thickness to the bedrock surface elevation. In the vicinity of the new monitoring wells, the thickness of the boulder/cobble zone was determined to be higher than the thickness assigned in the original model. The elevation of Model Layers 1, 2, and 3 were adjusted to better correspond to this new lithologic data.

3.1.3 Boundary Conditions

MODFLOW features a variety of boundary condition options, facilitating the incorporation of natural and anthropogenic boundaries in the model. The model uses various types of mathematical boundary conditions to represent natural boundaries. Natural boundaries simulated by the regional model include groundwater divides, precipitation recharge, rivers, and streams. As discussed in Section 3.0, the specification of boundary conditions in the revised model is identical to the boundary conditions specified in the original groundwater flow model developed for NFS (Geraghty & Miller, Inc. 1996). These boundary conditions are summarized below.

Within the model domain, external model boundaries coincide with well-defined, natural flow system boundaries where possible. Within the regional model, no-flow boundaries were assigned to represent barriers to groundwater flow, including groundwater divides and regional groundwater flowlines. Groundwater flow divides were delineated by locating topographic highs from topographic maps in the general model area. Model extents are defined to correspond to the divides, or in some cases actual grid nodes were set to "no flow" to better represent the actual groundwater divide.

The model simulates precipitation recharge using a prescribed flux boundary condition in the uppermost active layer of the model. A uniform precipitation recharge rate of 6 in/year is assigned throughout the model domain. This rate was estimated during the model calibration process. This is slightly lower than previous estimates by Zarawski (1978); however, when realistic hydraulic parameter values were assigned in the model, precipitation recharge rates greater than 6 in/year caused the model to calculate water-level elevations that were much higher than those observed in the field.

Head-dependent flux conditions represent rivers and tributary streams, such as the Nolichucky River, South and North Indian Creek, Broad Shoal Creek, Rock Creek, Martin Creek, drainage ditches, and the on-site ponds (Plate 3). The model simulates these head-dependent fluxes using "river and drain cells," a boundary condition option provided by MODFLOW to represent rivers and streams. River cells allow the model to compute the flow into or out of a surface-water feature as a function of the head difference between the stream elevation and the hydraulic head simulated in the aquifer. An advantage of this type of boundary condition is that the model can simulate influent or effluent conditions along different reaches of a stream depending on local head relationships between the stream and aquifer. River cells are used in Model Layer 1 to represent larger tributary streams, the Nolichucky River, and the ponds. Minor tributaries are simulated with drain cells to allow groundwater to flow only into the tributary. If the simulated water level falls below the drain elevation, the drain becomes inactive. Springs such as Banner Spring, Erwin Spring, and Love Spring were simulated using drain cells.

The elevations of the various head-dependent boundary conditions were derived from actual field measurements or were taken from topographic maps. The Nolichucky River stage was determined from monthly stage data at the gauging station near Embreeville, roughly 2.5 miles northwest of the site. The average stage for 1994 calibration conditions is 1521.65 ft msl at Embreeville. The grade of the river was determined from topographic maps to determine the actual river stage throughout the model domain. The elevations of the on-site ponds were assigned in the model based on measurements made in August 1995. The elevations for Ponds 1, 2, and 3 were defined in the model as 1633.39, 1636.24, and 1638.11 ft msl, respectively. The conductance term associated with the river and drain cells was generally calculated using the current estimated hydraulic parameters of the underlying aquifer material.

A total of three groundwater supply wells and ten groundwater dewatering wells (i.e., around Pond 4) are represented in the model using prescribed flux boundary conditions. Table 3-1 summarizes the pumping rates assigned to these wells during the calibration process. Average pumping rates for the public supply wells (Railroad Well, Birchfield Well, and the O'Brien Well) were determined from Erwin Utilities pumping records. The above mentioned off-site wells did not produce any significant effects on simulated groundwater flow directions in the vicinity of the site. The total average rate of the ten on-site dewatering wells was provided by NFS personnel. It was assumed that the pumping rate assigned to each of the wells was the same. Groundwater pumping wells specified in the model that penetrate more than one model layer are termed multi-aquifer wells and are specified in the model as individual wells in each model layer they penetrate. The pumping rate allocated to each model layer is a function of the transmissivity of each model layer relative to the total transmissivity of the aquifer unit penetrated by the well.

3.1.4 Hydraulic Conductivity Zonation

In the original groundwater flow model developed by Geraghty & Miller in 1996, the hydraulic conductivity of the shallow alluvium, cobble/boulder zone, and the bedrock formations were simulated by assigning zones of differing hydraulic conductivity in each model layer. In the upper model layers, the distribution of hydraulic conductivity was simulated to be heterogeneous to reflect the contrast between relatively high permeability alluvial material and the steeply dipping bedrock units. Distinct hydraulic conductivity zones were prescribed in the model to represent the Rome Formation, the Honaker Formation, and the Shady Dolomite. In each model layer, a single hydraulic conductivity zone was assigned to represent the Erwin, Hampton, Unicoi, and Snowbird Formations. In Model Layer 1, two hydraulic conductivity zones were assigned to represent the shallow alluvium, and one hydraulic conductivity zone was assigned in Model Layer 2 to represent the cobble/boulder zone. These zones were delineated based on slug test and packer test data collected at the site.

3.2 Groundwater Flow Model Recalibration

3.2.1 Model Calibration Methodology

During the model calibration process, model parameters and/or boundary conditions are adjusted to obtain a satisfactory match between observed and simulated water-level elevations, which are referred to as calibration targets. For best calibration results, a model should rely on discrete water-level measurements to produce answers free of contouring interpretations and artifacts. In the calibration of a groundwater flow model, use of point data eliminates the potential for interpretive bias that may result from attempting to match a contoured potentiometric surface (Konikow 1978; Anderson and Woessner 1992).

As a further goal for the calibration of a model, the principle of parameter parsimony should be used, which seeks to achieve an adequate model calibration through the use of the fewest number of model parameters. It should be noted that the use of greater numbers of model parameters during model calibration creates a situation in which many combinations of model parameter values produce equivalent calibration results. In this case, the model calibration parameters are called nonunique. Following the principle of parameter parsimony reduces the degree of nonuniqueness and results in more reliable calibrated parameter values. The information gathered for the conceptual model guides any decision to add model parameters (e.g., zones of hydraulic conductivity) to the model during the calibration process. Therefore, in the absence of hydrogeologic evidence, the simpler model is preferred.

The primary criterion for evaluating the calibration of a groundwater flow model is the difference between simulated and observed water levels at a set of calibration targets (i.e., typically monitoring wells). A residual or model error, e_i, is defined as the difference between the observed and simulated hydraulic head measured at a target location:

$$e_i = h_i - \hat{h}_i \qquad \text{(Eq. 3-1)}$$

where h_i is the measured value of hydraulic head and $\hat{h}_i$ is the simulated value at the ith target location. A residual with a negative sign indicates overprediction by the model (i.e., the simulated head is higher than the measured value). Conversely, a positive residual indicates underprediction.

There are several useful statistics that are commonly used to gauge the success of the model calibration process. During the calibration process, a primary objective is to lower the residual sum of squares (RSS) while still honoring the field data.

$$RSS = \sum_{i=1}^{n} (h_i - \hat{h}_i)^2 \qquad \text{(Eq. 3-2)}$$

where n is the total number of calibration targets. The RSS is the primary measure of model fit. The residual standard deviation (RSTD), which normalizes the RSS by the number of calibration targets and number of estimated parameters (p), is defined as follows:

$$RSTD = \sqrt{\frac{RSS}{n - p}} \qquad \text{(Eq. 3-3)}$$

The RSTD is useful for comparing model calibrations with different numbers of calibration targets and estimated parameters. Another calibration measure is the mean of all residuals ($\bar{e}$):

$$\bar{e} = \frac{1}{n}\sum_{i=1}^{n} e_i \qquad \text{(Eq. 3-4)}$$

A mean residual significantly different from zero indicates model bias.

3.2.2 Calibration Targets

In the original model developed by Geraghty & Miller (1996), average water-level elevations from August through December 1994 were used as calibration targets. This time period was selected to incorporate relatively recent data corresponding to a period of constant pumping from the ten on-site dewatering wells located around the Pond 4 area. In total, 68 on-site monitoring wells were used as calibration targets (Table 3-2). Thirty-two of these targets are located in the shallow alluvial aquifer (Model Layer 1); 25 targets are located within the cobble/boulder zone (Model Layer 2); and 11 targets are located within the shallow bedrock (Model Layer 3).

As part of recent data collection activities, water levels were measured in 53 monitoring wells during December 1997. Water-level measurements were collected in 42 wells that were previously used as calibration targets in the original model and in 11 wells that did not exist during the previous calibration. Using data collected in wells that were sampled in 1994 and December 1997, a statistical and visual comparison was conducted to determine whether the water-level data collected during both time periods could be combined into a composite data set and used during the model calibration. Figure 3-2 illustrates the relationship between water levels for the two time periods. Note that the data points are clustered closely along a 45-degree line and that the correlation coefficient (R^2) is close to 1. This indicates that the there is a strong correlation between water levels measured during the two time periods. Based on the results of this analysis, a composite water-level data set was compiled which includes: 1) all of the water-level calibration targets used during the original model calibration; and 2) water levels collected in the new off-site monitoring wells. Table 3-2 lists the wells that were used to revise the model.

3.2.3 Recalibration Results

3.2.3.1 Hydraulic Conductivity Estimates

During the original groundwater flow model calibration (Geraghty & Miller, Inc. 1996), precipitation recharge, horizontal hydraulic conductivity, and hydraulic conductivity anisotropy ratios were adjusted in the model to obtain a satisfactory match between observed and simulated water levels. During the recent modeling investigation, the precipitation recharge rate and hydraulic conductivity anisotropy ratios assigned in the original model were not altered. Horizontal hydraulic conductivity values were adjusted within the range of measured values to obtain a satisfactory match between simulated and observed water levels. Because the horizontal to vertical anisotropy ratios were not altered during the calibration process, the vertical hydraulic conductivity values changed as the horizontal hydraulic conductivity was adjusted during the calibration process.

The hydraulic conductivity values assigned to the model in Layers 1 and 2 were the primary variables that were adjusted during the model calibration process. Because new lithologic, hydraulic conductivity, and water-level data are only available in the vicinity of the site, the model calibration was focused on this area. Outside the immediate vicinity of the site, the hydraulic conductivity zones assigned in the model were not modified. Figures 3-3, 3-4, and 3-5 illustrate the hydraulic conductivity zones assigned in the model for Model Layers 1, 2, 3, 4, and 5, respectively. Note that the hydraulic conductivity zones that represent the bedrock formations exhibit a northeast-southwest trend that corresponds to the direction of geologic strike. The bedrock hydraulic conductivity zonation was entered into the model directly from published geologic maps. During the original model calibration (Geraghty & Miller, Inc. 1996), it was found that three of the rock formations contained different hydraulic properties (Rome Formation, Shady Dolomite, and Honaker Dolomite), but that the Hampton, Erwin, Unicoi, and Snowbird Formations are hydraulically similar. Thus the latter four formations were simulated as a combined hydraulic zone in the model. Descriptions of groundwater flow from USGS literature (DeBuchananne and Richardson 1956) support the model finding that these units have similar flow characteristics.

In the vicinity of the NFS facility, recently collected field data were used to adjust the hydraulic conductivity zonation in Model Layers 1 and 2. As part of this effort, hydraulic conductivity measurements determined from slug tests were evaluated to delineate spatial trends which are not consistent with the hydraulic conductivity zonation assigned in the original groundwater flow model. As part of this evaluation, hydraulic conductivity values determined through slug tests were overlain onto site maps and compared to hydraulic conductivity zones assigned in the original model. These hydraulic conductivity maps were used during the model calibration process to revise the hydraulic conductivity zones representing the shallow alluvium and the cobble/boulder zone. Because there are relatively high measurement uncertainties associated with hydraulic conductivity values measured using slug tests, the hydraulic conductivity zones and values were not prescribed in the model based solely on the measured hydraulic conductivity values. Instead, these values were used to guide the delineation of hydraulic conductivity zones during the model calibration process. In general, lithologic descriptions were not used to define hydraulic conductivity zones. However, the thickness of the cobble/boulder zone appeared to be somewhat correlated with hydraulic conductivity. Consequently, the cobble/boulder zone thickness was used qualitatively during the delineation of hydraulic conductivity zones in Model Layer 2.

Figures 3-6, 3-7, and 3-8 illustrate the revised delineation of hydraulic conductivity zones and calibrated hydraulic conductivity values in the vicinity of the NFS facility (i.e., Model Layers 1, 2, and 3). Hydraulic conductivity values determined from historical and recent slug tests are posted on the maps. In Model Layer 1, the spatial orientation of a high hydraulic conductivity zone (i.e., Zone 6) was extended to the southwest and to the north (Figure 3-6) to better match a hydraulic conductivity measurement obtained in well 107A and to improve the model calibration. In Model Layer 2, an additional hydraulic conductivity zone was assigned in the model to represent the cobble/boulder zone (i.e., Zone 6). This zone was added to the model based on the high hydraulic conductivity value measured in well 116A and to improve the model calibration. The hydraulic conductivity zonation in Model Layer 3 was not modified during the recent modeling investigation (Figure 3-8); however the hydraulic conductivity values assigned in the in the vicinity of the NFS facility were adjusted within the range of observed values during the model calibration to better match observed field conditions.

3.2.3.2 Simulated Hydraulic Heads

The simulated hydraulic head surfaces for Model Layers 1 and 2 show regional water levels declining from all areas surrounding the NFS site toward the Nolichucky River and Indian Creek (Figures 3-9 and 3-10). The water table significantly flattens in the higher permeability units, specifically the alluvial and cobble zones and in the Rome Formation along the Nolichucky River and Indian Creek.

Basically, the simulated heads in the bedrock (Model Layers 3 through 5) reflect those in the shallow zone (Figures 3-11 through 3-13). In the upland areas, decreasing hydraulic heads are simulated with depth. This indicates downward flow of recharge in the upland areas. Groundwater originating in the highland areas ultimately flows towards the valleys, exiting the groundwater system via the rivers. In the lowland areas, beneath the rivers, upward hydraulic gradients are simulated by the model. Simulated head contours in the bedrock beneath the site indicate a northwest groundwater flow direction towards the Nolichucky River.

3.2.3.3 Analysis of Model Residuals

A primary model recalibration objective for the NFS groundwater flow model was to minimize the residual sum of squares (Eq. 3) computed for the 78 water-level calibration targets. Table 3-3 lists the simulated water elevations and model residuals for each calibration target. The maps of simulated hydraulic head (Figures 3-14, 3-15, and 3-16) show the spatial distribution of the residuals in each of the calibrated model layers.

Throughout the model domain, the absolute residuals ranged from 0.002 to 4.409 ft (Figures 3-14, 3-15, and 3-16; Table 3-3). The majority of the water-level residuals are less than 1 ft (i.e., 49 out of 78), and there are few residuals higher than 2 ft (i.e., nine out of 78). Residual statistics for the calibrated groundwater flow model indicate that there is good agreement between simulated and measured groundwater elevations. The residual mean is close to zero (-0.076 ft) indicating that there is not a significant bias that causes the model to systematically over-predict or under-predict water-level elevations across the model domain (Table 3-3). In addition, the residual standard deviation (1.328 ft) is less than 0.1 percent of the range of simulated water-level elevations for the entire model domain and is less than 5 percent of the range found onsite.

Both the residual standard deviation and the residual sum of squares are lower than the residual statistics calculated for the original model (Geraghty & Miller, Inc. 1996). This indicates that the revised groundwater flow model more accurately simulates observed water levels in the vicinity of the NFS facility. The success of the model calibration is illustrated on Figure 3-17 which shows the relationship between observed and calculated water levels within the study domain. The data points fall closely along the 45-degree line which indicates that the there is a strong correlation between observed and simulated water levels.

4.0 Solute Transport Model Calibration

In 1996, Geraghty & Miller developed a solute transport model for the NFS facility (Geraghty & Miller, Inc. 1996) using the MT3D code. This model was used to predict the current and future extent of uranium and PCE constituents in groundwater. The results of predictive solute-transport simulations were used to assist NFS in the refinement of their groundwater monitoring network.

As part of the Geraghty & Miller (1996) modeling investigation, a qualitative solute-transport calibration was completed by specifying historic source terms in the model and simulating conditions from 1957 to 1993. A groundwater flow model, developed by Geraghty & Miller (1996) using the MODFLOW code, was used to simulate groundwater flow conditions for this same time period, and the groundwater velocities and volumetric flow terms computed by the flow model were input into the MT3D solute transport model. The effects of historical changes in groundwater pumping rates at on-site and off-site pumping wells were incorporated into the flow model by specifying several stress periods in the MODFLOW model that correspond to periods where the average groundwater pumping conditions remained relatively constant. During the solute-transport calibration process of the original model, source concentrations and transport parameters were adjusted until the PCE and uranium concentrations computed by the MT3D model for the last stress period (i.e., corresponding to December 1993) reasonably matched those observed in the field.

During the recent groundwater modeling investigation, the solute-transport model developed by Geraghty & Miller (1996) was revised based on groundwater sampling data collected after the development of the original model. Flow conditions simulated using the recalibrated groundwater flow model were used in the revised transport model. The model revisions were completed to more accurately predict the current and future extent of uranium and PCE in groundwater. In the future, the revised solute-transport model will aid NFS in the development and evaluation of environmental remedies at the site.

The general structure of the revised solute transport model is similar to the original model. The source terms (location and concentration), model discretization, and boundary conditions specified in the revised model are identical to the original model. The three primary differences between the revised solute-transport model and the original model are the: 1) transport model was calibrated to 1997 conditions; 2) transport parameters (i.e., distribution coefficients, degradation rates, and dispersivities) were adjusted during the recalibration process; and 3) revised solute-transport model utilizes groundwater flow velocities and volumetric flow rates computed using the recently recalibrated groundwater flow model.

4.1 Description of PCE and Uranium Source Areas

Operations at the NFS plant have resulted in the presence of radionuclides and organic constituents in the groundwater beneath the facility. The primary sources of these constituents are the: 1) three unlined surface impoundments (Ponds 1, 2, and 3); 2) "Pond 4" disposal area; 3) radiological waste burial grounds; and 4) various areas in the vicinity of plant buildings (Figure 4-1). Many of the PCE and uranium releases within the main plant area occurred near the buildings that are identified on Figure 4-1. The following subsections describe the primary sources of PCE and uranium in groundwater at the NFS site that were represented in the solute-transport model.

4.1.1 Ponds 1, 2, and 3 (SWMU 1)

SWMU 1 and area of concern (AOC) 5 are located north of plant production facilities and include Ponds 1, 2, and 3, which were unlined impoundments built from 1957 to 1963; both received process waste waters associated with the production of nuclear materials. These ponds received fluids until 1978, when a wastewater treatment plant was built to treat wastewater. The three ponds contained approximately 91,000 cubic feet (ft^3) of waste material. The predominant radiological waste contaminants were isotopes of uranium and thorium. PCE was also detected among other contaminants in the waste samples. Waste from Pond 2 was also identified as characteristically hazardous for PCE and cadmium (Advanced Recovery Systems, Inc. 1994b).

Waste removal began in August 1991 at Pond 3 with dredging to remove most of the contaminated sediments. Removal of waste from Ponds 1, 2, and 3 was completed in September 1993, August 1994, and May 1994, respectively (Advanced Recovery Systems, Inc. 1994b). Waste from Pond 2 was treated to reduce PCE and cadmium concentrations below Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels in an on-site treatment unit prior to disposal.

The historical discharge rates of contaminated water to the ponds was calculated using the NFS Lagoon Historical Data Report (Nuclear Fuel Services, Inc. 1985). Information on various buildings at the facility, the chemical processes for which these buildings were used, operating periods, and quantities of wastewater discharged (flow rates) to the ponds has been detailed in previous reports. These flow rates were calculated for appropriate time stress periods, defined in Section 4.3, and incorporated into the solute-transport model.

4.1.2 Pond 4 (SWMU 2)

SWMU 2 (Pond 4) was originally a marshy or low lying area located in the western portion of the facility (west of the ponds) and received waste material (Figure 4-1). The types and forms of materials placed in the Pond 4 area have been identified as the following: press cake, incinerator ash, sludges, drums (empty), buckets, (empty), conduit, pipes, old equipment, and general trash. No records of these materials and disposal activities are available. SWMU 2 has been identified as a potential source for uranium and PCE (EcoTek, Inc. 1994b).

4.1.3 Banner Spring's Abandoned Stream Bed Channel (SWMU 6)

SWMU 6 designates the abandoned channel of Banner Spring Branch which received supernatant from the three NFS impoundments (Figure 4-1). This channel is located north of the main plant facilities in the Pond 4 area. Stream sediments were contaminated with isotopes of uranium and thorium. In 1967, the lower portion of the channel of Banner Spring Branch was relocated approximately 200 ft east/southeast leaving the existing channel abandoned. Sediments from this portion of the abandoned channel were left in place and then backfilled. SWMU 6 is located within the boundary of SWMU 2 and has been identified as a potential source for uranium only (EcoTek, Inc. 1994b).

4.1.4 Building 130 Scale Pit (SWMU 20) and Adjoining Buildings 131 & 120

Building 130 was constructed in the late 1950s. Operations in Building 130 include thorium processing, HEU processing, and cleaning uranium hexaflouride cylinders. Potential contaminants may include uranium, PCE, and trichloroethene (TCE). Building 120 was constructed in the late 1950s. Building 131 was constructed in the early 1960s adjacent to Building 120. The Building 120/131 area has been used for maintenance, product storage, and as a pilot plant. Currently, the Building 120/131 complex houses the maintenance department and a research and development laboratory. Chlorinated solvents were thought to have been used and stored in the vicinity of Buildings 120 and 131 (Nuclear Fuel Services, Inc. 1995d).

4.1.5 Radiological Waste Burial Ground (SWMU 9)

NFS disposed of low-level radioactive waste onsite in a shallow burial ground referred to as the radiological waste burial ground (SWMU 9) (Figure 4-1). The waste included contaminated equipment, construction debris, laboratory waste, and process waste. The waste was buried in units 120 to 160 ft long, 25 to 26 ft wide, and no greater that 10 ft deep with 3 to 6 ft of overburden. This SWMU was active from 1966 to 1977, and is a potential source for both uranium and PCE constituents (Nuclear Fuel Services, Inc. 1995a).

4.1.6 Bulk Chemical Storage Area at Building 111 (SWMU 13)

Building 111 was used as a storage area for processed chemical products, operating from 1957 to 1979 (Figure 4-1). This building is thought to be a potential source for both uranium and PCE (Nuclear Fuel Services, Inc. 1995b).

4.1.7 Miscellaneous Potential Source Areas

In addition to the above described sources, Buildings 234 was identified as a potential source area for PCE, and Buildings 110, 234, 302, 303, 304, 306, and 309 were identified as potential source areas for uranium.

4.2 Solute Transport Model Description

4.2.1 Code Description

The NFS solute-transport model developed by Geraghty & Miller (1996) was constructed using the MT3D code, a three-dimensional solute transport program developed for EPA (Zheng 1990). This code functions with MODFLOW, thereby providing a seamless transition between the recently recalibrated flow model to the solute-transport model. The code uses the flow terms (i.e., volumetric flow rates and velocities) computed by MODFLOW (McDonald and Harbaugh 1988) for use in the transport calculations. Developed in the public domain, MT3D is thoroughly documented, extensively tested, and benchmarked against analytical solutions. MT3D can simulate the migration of dissolved constituents using the Methods of Characteristics or an explicit finite-difference scheme to solve the transport equation. The code is fully three-dimensional, simulates transport in confined or unconfined aquifers, and includes hydrodynamic dispersion, adsorption assuming a linear isotherm, and decay in the solute transport calculations.

4.2.2 Transport Parameters

4.2.2.1 Adsorption

Adsorption is the process by which a solute adheres to a solid surface. Adsorption results in the solute, which was originally in solution, to become distributed between the solution and the solid phase, a process called partitioning. As a result of adsorption, a solute will move slower through the aquifer than the groundwater. This effect is called retardation. Adsorption is mathematically represented using a partitioning coefficient (K_d) which is the ratio of the concentration of the constituent in the sorbed (i.e., solid) phase to the concentration of the constituent in the dissolved phase (eq. 4-1).

$$K_d = \frac{C_s}{C_d} \qquad \text{(Eq. 4-1)}$$

where: C_s = the concentration of the constituent in the sorbed phase [milligrams per kilogram (mg/kg)]; and

C_d = the concentration of the constituent in the dissolved phase [milligrams per liter (mg/L)].

Both PCE and uranium, the two constituents for which the model was run, are adsorbed by the geologic materials during transport; therefore, a partitioning coefficient (K_d) was assigned in the model for each constituent during the transport simulations. The distribution coefficient for organic compounds is calculated using the following equation:

$$K_d = f_{oc} * Koc \qquad \text{(Eq. 4-2)}$$

where: f_{oc} = the fraction of organic carbon; and

Koc = the octinal carbon ratio.

Based on site-specific fraction of organic carbon measurements (mean = 0.00086), which were not available during the original model development, and the octinal carbon ratio of 272 reported in the EPA Soil Screening Guidance Document (1997), a K_d of 0.24 liters per kilogram (L/kg) was calculated for PCE and used in the model. This value is higher than the value used in the original model calibration (i.e., 0.12 L/kg). A partitioning coefficient of 107 L/kg was selected for uranium based on literature values. This is the value that was used in the original modeling investigation.

4.2.2.2 Decay and Degradation

Radioactive decay and biodegradation are simulated by specifying a degradation or decay rate in the MT3D model. Radioactive decay was simulated for uranium by specifying a decay rate of 1.2×10^{-8} days^{-1} (i.e., corresponds to a half life of 6.3×10^{8} years) in the solute transport model. PCE is degraded by microbial activity at the site as indicated from the presence of daughter products such as vinyl chloride. The half life for PCE can range from 6 months to 2 years (Howard, et al. 1991). During the model calibration, the corresponding degradation rate was varied within this range, and a value of 2 years was found to produce the best match between observed and calculated PCE concentrations.

4.2.2.3 Effective Porosity

Literature values of effective porosity for materials hydrogeologically similar to those at the NFS site range from 25 to 40 percent for gravels, 35 to 50 percent for silts, and 0 to 10 percent for shales (includes fractured rock) (Freeze & Cherry 1979). Since most constituents at the NFS site occur in the alluvial materials, the effective porosity used in the model was assumed to be in the higher range, more representative of the sandy materials. The estimated effective porosity in the calibrated transport models is 25 percent, which fits within the range suggested in the literature. The total porosity measured at the site is 41 percent (Nuclear Fuel Services, Inc. 1995c). The effective porosity is the net pore space through which groundwater flows and is less than the total porosity because it excludes pores which are not interconnected. The effective porosity is typically estimated to be equal to a factor of about 1.5 below the measured total porosity (de Marsily 1986).

4.2.2.4 Dispersivity

Dispersion describes the mixing of a contaminant in the subsurface due to tortuous, non-linear flow paths in the aquifer medium. Dispersion is simulated using a coefficient known as dispersivity. The dispersivity values are multiplied by the velocity terms to develop dispersive flux terms which are added to the advective flux terms. A longitudinal dispersivity of 10 ft was specified in the original transport model developed by Geraghty & Miller (1996). Longitudinal dispersivity applies to the local direction of groundwater flow within a grid cell, and the transverse value of dispersivity applies to dispersion perpendicular (right angles) to the flow direction. The transverse dispersivity was estimated to be 1 ft in the original model.

Generally, the transverse dispersivity is within a factor of 5 to 20 of the longitudinal dispersivity and is usually estimated empirically through the use of groundwater models (Freeze and Cherry 1979). Gelhar et al. (1992) also cites evidence from tracer tests that dispersivities should be on the order of 3 to 30 ft for the scale of transport. These dispersivities can be an order-of-magnitude greater if the geologic material is fractured (Gelhar et al. 1992). Gelhar et al. (1992) found that in many tracer tests the transverse dispersivities are commonly one to two orders-of-magnitude less than longitudinal dispersivities. Gelhar et al. (1992) also cite evidence that dispersivities generally increase, possibly indefinitely with scale. Reilly (1990) states that:

> "the more closely we represent the actual permeability distribution of an aquifer; the more closely our calculation of advective transport will match reality. The finer the +scale of simulation, the greater will be the opportunity to match natural permeability variations. In most situations, however, when both data collection and computational accuracy have been extended to their practical limits, calculations of advective transport will fail to match field observation. To the extent that scale variations represent random deviation from the velocity used in the advective transport calculation, and to the extent that they occur on a scale which is significantly smaller than the size of the region used for advective calculation, dispersion theory may adequately describe the differences between advective calculation and field observation. Determination of the dispersion coefficients are usually approached empirically (for example, through model calibration)."

Dispersivity was estimated during the recent transport modeling investigation to improve the calibration.

4.3 Transport Model Recalibration

The solute-transport model was recalibrated to estimate transport parameter values that control the migration of PCE and uranium. The model was calibrated by simulating uranium and PCE migration from January 1957 through December 1997. Due to uncertainties regarding the distribution and release history associated with contaminant sources at the NFS facility, a rigorous transport calibration was not performed. Instead, the calibration process was performed to ensure that the specified transport parameters produce the general shape and extent of the currently observed uranium and PCE plumes. Consequently, residual statistics were not used to describe the transport calibrations. Instead, observed constituent concentrations were posted on maps along with the computed uranium and PCE concentrations to allow for quick determination of the quality of the fit between observed and computed values. Model adjustments were performed to minimize, to the extent possible, the difference between computed and observed constituent concentrations.

To accomplish this task, plume maps were prepared using the most recent analytical data collected during fourth quarter 1997 (Figures 2-8 through 2-11). All monitoring wells were not sampled in 1997; consequently, historical data were used to augment the spatial distribution of recent groundwater sampling data. Because there is a high degree of hydraulic interconnection between the shallow alluvium and cobble/bedrock zones, data from these two zones were combined and presented on the same maps (Figures 2-8 and 2-10). The uranium and PCE plumes were illustrated on these figures by hand-contouring the data posted on the maps. Few data were available to define the spatial distribution of PCE and uranium in the shallow bedrock (Figures 2-9 and 2-11). Therefore, contour maps were not prepared for this zone.

Prior to performing the solute-transport simulations, the recently recalibrated groundwater flow model was used to simulate flow conditions for the time period corresponding to January 1957 through December 1997. The flow model was set up to simulate eight stress periods which correspond to periods associated with pumping conditions in the vicinity of the NFS facility. The velocities and volumetric flow rates calculated by the flow model were then input into the solute-transport model, and the solute-transport model was used to simulate dissolved PCE and uranium. The pumping schedules for the supply wells were used to define the stress periods presented below and in Table 4-1.

- Stress Period 1: This first stress period covers the time period extending from January 1957 through December 1970. During this period, only two supply wells within the model domain, the Birchfield Well and the O'Brien Well, were actively pumping. The Birchfield Well is screened in Model Layers 3, 4, and 5, while the O'Brien Well is screened only in Model Layer 3. The daily average pumping rates were calculated from recorded monthly pumping totals. Additionally, effluent was discharged to the three impoundments during this period from plant operations which was simulated by 20 (number of model cells encompassing ponds) injection wells continuously discharging into the ponds at a constant rate of 132.35 ft^3/day/well.

- Stress Period 2: The second stress period extends from January 1971 through December 1975. This period uses the same pumping wells and average rates used in Stress Period 1, except that the injection rate of processed waste water effluent sent to the impoundments was reduced to 49.47 ft^3/day/well.

- Stress Period 3: This stress period extends from January 1976 through December 1978 and was included in the model to simulate an increase in pumping rates for the Birchfield Well and O'Brien Well. This period maintained the injection rate of processed waste water effluent sent to the impoundments as used in Stress Period 2.

- Stress Period 4: The fourth stress period extends from January 1979 through December 1985, and was included to account for additional pumping rate increases at both the Birchfield Well and O'Brien Well. This period was also modified to remove wastewater effluent entering the impoundments as effluent to the ponds was stopped in 1978.

- Stress Period 5: The fifth stress period extends from January 1986 through December 1990. During this time, the Railroad Well started pumping in addition to the other wells. The Railroad Well withdraws all its water from Model Layers 3, 4, and 5.
- Stress Period 6: The sixth stress period extends from January 1991 through December 1993. This stress period incorporates changes in the pumping rates of the three supply wells in the model domain.
- Stress Period 7: The seventh stress period extends from January 1994 through July 1994. This stress period was specified in the model to incorporate changes in the pumping rates at the three water-supply wells.
- Stress Period 8: The last stress period extends from July 1994 through December 1997. At the beginning of this time period, ten dewatering wells were put into service around the Pond 4 area.

The first six stress periods are identical to the stress periods that were simulated during the previous solute-transport model calibration (Geraghty & Miller, Inc. 1996). The seventh and eighth stress periods were added during the recent modeling investigation in order to simulate the extent of PCE and uranium in December 1997. The flow rates (Table 4-1) are a conservative estimate of actual flow rates during any one operational time period.

The following PCE and uranium sources were assigned in the model: 1) Ponds 1, 2, and 3; 2) Pond 4 disposal area; 3) burial grounds; and 4) various areas in the vicinity of the plant buildings. The timing and constituent concentrations associated with these sources was estimated from disposal records and conversations with NFS personnel during the original solute-transport model calibration. Because additional historical data were not available for the current modeling effort, the sources were represented in the revised model in the same manner as the original model. Pond sources were simulated by assigning concentrations to the river cells in the model, and the sources around the buildings and the burial ground were simulated by assigning a concentration to precipitation recharge entering the source area. Figures 4-2 and 4-3 illustrate the distribution of sources that were simulated in the model. The concentrations assigned to these sources are summarized in Table 4-2.

4.4 Calibration Results

Initially, the solute-transport simulations were performed using the transport parameters that were assigned in the original model (Table 4-3). However, the spatial distribution of PCE and uranium predicted by the model did not adequately match the constituent distribution observed in December 1997. Overall, the simulated constituent concentrations did not extend far enough in the downgradient (i.e., northerly) direction, and PCE and uranium were not simulated in the shallow bedrock at significant concentrations. Consequently, the transport parameters were adjusted individually and in combination until an adequate match was achieved.

After performing numerous transport simulations, the dispersivity and the PCE degradation rate were found to have the most beneficial impact on the transport results. In the original transport model the longitudinal, transverse, and vertical dispersivities were assigned values of 10, 1, and 0 ft, respectively. After trying numerous values in the revised transport model, a longitudinal dispersivity of 26 ft was assigned based on the following empirical formula developed by Xu and Eckstein (1995):

$$\alpha_x = 3.28 \cdot 0.83 \cdot [\log(\frac{L_P}{3.28})]^{2.414} \qquad \text{(Eq. 4-3)}$$

where: α_x = longitudinal dispersivity (ft); and

L_P = the length of the contaminant plume (ft).

Typically, the transverse to longitudinal dispersivity ratio is approximately 1:10. Consequently, the transverse dispersivity was assigned a value of 2.6 ft in the model. A value of 2.6 ft was also assigned to the vertical dispersivity in the model.

After numerous transport simulations, the parameter values summarized in Table 4-3 were found to produce the best match between the observed and simulated plume geometry. Figures 4-4 through 4-9 illustrate simulated uranium and PCE concentrations with the observed concentrations posted on the maps. Observed and calculated uranium and PCE concentrations are also summarized in Tables 4-4 and 4-5, respectively. Contour maps were not prepared for Model Layers 4 and 5, because constituent concentrations were not observed in the lower model layers. Note that there is a blank area within the PCE contours represented on the PCE plume map prepared for the shallow alluvium (Figure 4-4). This area represents an area where the shallow alluvium is desaturated; consequently, constituent concentrations are not predicted in this area.

In several locations, there are localized areas where the predicted constituent concentrations do not closely match those observed in the field. This discrepancy between observed and simulated conditions is most likely due to uncertainties associated with the extent and release history for contaminant source areas within the NFS facility. Nonetheless, the shape and extent of the uranium and PCE plumes are similar to the observe plumes illustrated on Figures 2-8 and 2-10, respectively.

5.0 Predictive Simulations

As part of the current modeling investigation, the calibrated solute-transport model was used to predict the future migration of uranium and PCE. The simulations were conducted by assigning initial concentrations in the model based on plume maps that were developed using historical data and new data collected northwest of the NFS property boundary. Source terms were adjusted in the model to account for completed, ongoing, and/or planned remedial activities at the site. Due to uncertainties associated with the nature of several source areas represented in the model, two sets of solute-transport simulations were completed based on different source assumptions (discussed in Section 5.2). The transport parameters that were assigned in the transport model were determined during the transport model calibration process (Section 4.0).

5.1 Expected Groundwater Pumping Conditions

Prior to performing the predictive solute-transport simulations, the recently revised groundwater flow model was used to simulate flow conditions beginning on January 1998. It was assumed that the pumping conditions will remain constant in the future. With the exception of the on-site remediation wells currently operating near the Pond 4 area, it was assumed that the pumping conditions in the future will remain the same as observed during December 1997 (Table 5-1). Groundwater extraction from the on-site remediation wells is expected to be discontinued in the near future; consequently, groundwater extraction corresponding to these wells was not represented in the predictive flow simulations. The volumetric flow rates and velocities predicted using MODFLOW were used to complete the solute-transport modeling.

5.2 Source Distributions

Several source removal actions are currently being planned and/or implemented at the NFS facility over the next 5 years. These actions include: 1) excavation of the Burial Grounds; 2) removal of contaminated soil in the vicinity of the unlined surface impoundments (i.e., Ponds 1, 2, 3, and 4); 3) excavation of contaminated soil and sediment associated with the abandoned Banner Spring Branch; 4) removal of contaminated soil around the soil stockpile area; and 5) excavation of contaminated soil around Building 234. At the beginning of the predictive solute-transport simulations, the PCE and uranium source locations (Figures 4-2 and 4-3) and source strengths (Table 4-2) are represented in the model in the same manner as they were represented during model calibration. However, the source areas described above were removed from the model after 5 years to account for ongoing remediation efforts at the NFS facility.

There is some uncertainty regarding the nature of the uranium and PCE source areas located around the following buildings: 110, 111, 120, 130, 131, 303, 309, 302, 304, and 306. Based on the existing data, it is not known whether there is a continuing source of contamination at these areas in either the unsaturated or saturated zones that will continue to leach to the groundwater. Given this uncertainty, two sets of solute-transport simulations were completed. In the first set of simulations, the contaminant sources near the aforementioned buildings area were removed after 5 years. In the second set of simulations, these sources remain as continuous source terms in the model. Tables 5-2 and 5-3 summarize the source concentrations that were represented in the predictive solute-transport simulations.

5.3 Predictive Simulation Results

For each of the predictive simulations, contour maps were prepared illustrating the simulated constituent concentrations. On each of the maps, the regulatory limit of 5 μg/L for PCE or the proposed MCL of 30 pCi/L for uranium are plotted for multiple time periods. Displaying the data in this manner provides a simple method to visualize the predicted change in plume extent with time. For completeness, additional contour maps are included in Appendix A which show multiple concentration contours for each time period. On these figures, constituent concentrations for one time period are shown on each figure. In addition to the contour maps, x-y plots were prepared for each of the simulations which illustrate the relationship between constituent concentrations and time at selected locations within the study area. Figures 5-1 and 5-2 illustrate the locations for these observation points for PCE and uranium, respectively.

5.3.1 Discontinuous Sources Near Buildings

The predicted areal extent of dissolved PCE in the shallow alluvium, cobble/boulder, and shallow bedrock zones are illustrated on Figures 5-3 through 5-5 for time periods corresponding to 1, 5, and 10 years into the future (e.g., years 1999, 2003, and 2008). The model predicts that in December 1999, the extent of PCE contamination is almost identical to the current extent of contamination except for a slight increase in the downgradient extent of the plume in the shallow alluvium and cobble/boulder zones. In 2003, the extent of the PCE plume is not expected to extend as far to the northwest, but the plume is expected to extend farther in a northerly direction in the shallow alluvium and cobble/boulder zones. Within the shallow bedrock zone, the model predicts that the northern extent of PCE will increase by the year 2003; however, the extent of the plume in other areas of the site is expected to decline.

Throughout the study area, the total PCE mass is predicted to significantly decline by the year 2003. In 2008, the extent and total PCE mass is significantly reduced in all model layers. Predictive simulations indicate that PCE concentrations above the EPA MCL of 5 µg/L are limited to on-site locations by 2011 in all model layers. Groundwater concentrations are below the MCL throughout the model domain by the year 2018 (figures not shown).

The lack of significant changes in the extent and movement of the center of mass in all model layers from 1998 to 2003 with active source areas suggests that the PCE plume is currently stable. Furthermore, the rapid reduction in the PCE plume extent and mass from 2003 to 2008 indicates groundwater PCE concentrations should respond quickly to source area remediation.

Figure 5-6 shows a time series plot illustrating the predicted PCE concentrations at the observation locations shown on Figure 5-1. For the selected observation points, a maximum concentration of 2,925 mg/L is predicted in January 1998, and PCE concentrations are expected to decrease slowly until 2003, when source areas are removed. After 2003, PCE concentrations at all observation nodes decrease quickly in response to the source removal. The PCE concentrations at all observation locations are predicted to be below the EPA MCL of 5 µg/L by the year 2011.

The predicted areal extent of dissolved uranium in the shallow alluvium zone (Model Layer 1), cobble/gravel zone (Model Layer 2), and shallow bedrock zone (Model Layer 3) is illustrated in Figures 5-7 through 5-9 for 5, 500, and 1,000 years into the future (i.e., years 2003, 2498, and 2998). As a result of the high sorption and low mobility associated with uranium, the predicted plume in 2003 appears nearly identical to the distribution currently observed at the site. The model predicts that by 2498, the uranium plume will migrate a significant distance to the northwest beyond the northwest property boundary in the shallow alluvium and cobble/boulder zones (Model Layers 1 and 2). By 2498, a small uranium plume is predicted to be present in the shallow bedrock zone (Model Layer 3) as a result of vertical groundwater flow and dispersion. The extent of uranium predicted in the shallow bedrock zone (Model Layer 3) is greater than the currently observed extent, and greater than the extent of uranium concentrations predicted by the model for the year 2003. The model predicts that by the year 2998, the uranium concentrations in the shallow alluvium and cobble/boulder zones will be significantly reduced. However, the extent of uranium impact in the shallow bedrock is predicted to increase by the year 2998.

Figure 5-10 illustrates an x-y plot illustrating the relationship between uranium activity and time at selected observation locations. The time series plot indicates that a maximum activity of 90 pCi/L is observed in the year 2430. Concentrations in all observation nodes are below the EPA proposed standard of 30 pCi/L by 3850.

5.3.2 Continuous Sources Near Buildings

Figures 5-11 through 5-13 illustrate the predicted extent of PCE concentrations 1, 5, and 10 years into the future (i.e., years 1999, 2003, and 2008) for the continuous source simulations. The PCE plume predicted in 1999 in Model Layers 1 and 2 is nearly identical to the PCE plume observed in December 1997 which was used to establish initial concentrations in the model (Figure 2-10), except that the simulated plume extends farther to the north. Transport of the PCE plume to the north, is in response to northward groundwater flow towards discharge points in Model Layers 1 and 2 (e.g., the Backwash Area). In Model Layer 3, the plume has the same approximate magnitude and extent as the initialized plume in January 1998.

After 5 years (i.e., year 2003), the model predicts that the center of mass of the PCE plume will extend slightly more to the north, near State Route 23. In Model Layer 3, the northern extent of the plume is expected to increase; however the overall width of the plume is expected to decrease.

In 2008, the extent and total PCE mass is significantly reduced in areas where source areas have been removed in all model layers. Predictive simulations indicate that PCE concentrations above the EPA MCL of 5 μg/L are limited to locations downgradient of active source areas after 2011 in all model layers. Furthermore, after year 2008, active source areas result in a stable plume in which mass is biodegraded at the same rate as it is added in all model layers.

The lack of significant changes in extent in the direction of groundwater flow and center of mass in all model layers from 1999 to 2003, suggests that the PCE plume is stable even with the presence of sources. The predicted changes in PCE plume width suggests that even the limited source material removal that has occurred to date is capable of reducing the areal extent and total mass of the PCE plume. Furthermore, the rapid reduction in the PCE plume extent and mass from 2003 to 2008 in areas where source areas have been removed indicates that PCE concentrations should respond quickly to additional source area removal.

A time series plot of PCE concentrations at select observation nodes is shown in Figure 5-14. The time series plot indicates that a maximum concentration of 2,925 μg/L is predicted in 1998 (i.e., current conditions). Furthermore, dissolved PCE concentrations in groundwater are expected to reach steady-state conditions by approximately 2008 at all observation nodes. Beyond 2008, the PCE concentrations do not decrease, because of the constant source terms that are simulated in the model.

Figures 5-15 through 5-17 illustrate the predicted extent of uranium in groundwater 5, 500, 1,000, and 10,000 years into the future (i.e., corresponding to years 2003, 2498, 2998, and 11998). As a result of a high retardation factor associated with uranium, the predicted plume in 2003 appears nearly identical to the initial uranium concentrations that were assigned in the model.

Within 500 years (year 2498), the uranium plume is predicted to migrate a significant distance to the northwest, beyond the northwest property boundary in Model Layers 1 and 2. In 2498, a small uranium plume is predicted in Model Layer 3 below the center of the plume in Model Layer 2 as a result of vertical groundwater flow and dispersion; the small uranium plume in Model Layer 3 was not present in 2003. The continuous source terms that remained in the model at year 2498 do not have a significant effect on uranium concentrations in Model Layer 3. Furthermore, the predictive simulations indicate the removal of some sources in 2003 do not cause a rapid decrease in dissolved uranium concentrations in Model Layers 1, 2, and 3.

After 1000 year (i.e., by year 2998), uranium concentrations are predicted to decrease slightly in areas where sources have been removed. Significant reductions in mass are predicted in 2998 in areas of Model Layers 1 and 2 where source areas have been removed. In areas with continuing sources, the uranium plume is expected to cover nearly the same areal extent in Model Layers 1 and 2 in 2998 as in 2498. In Model Layer 3 in 2998, the extent of the uranium plume extent is expected to be slightly larger and is predicted to migrate past the northwest property boundary. The increase in areal extent of the uranium plume in Model Layer 3 is a result of vertical groundwater flow and/or dispersion and not a result of continuing sources. By 3998, the uranium plume is expected to be below the EPA proposed standard of 30 pCi/L in Model Layer 3.

From 2998 to 11998, a continual reduction in the extent of the uranium plume above 30 pCi/L in Model Layers 1 and 2 is observed. The reduction in areal extent of the uranium plumes in Model Layers 1 and 2 may be a result of dispersion induced dilution or effective radioactive decay occurring at a greater rate than input of additional uranium to Model Layers 1 and 2.

A time series plot of uranium concentrations at select observation points is shown in Figure 5-18. As can be seen on the time series plot a maximum concentration of 90 pCi/L is predicted in year 2430. Concentrations in all observation nodes are below the EPA proposed MCL of 30 pCi/L by year 3850. The time series plot indicates that essentially steady state (asymptotic) conditions with continuous source areas are observed by approximately year 7998.

6.0 Model Assumptions and Limitations

The NFS groundwater flow and solute-transport models assume that the fractured media present at the site and within the surrounding bedrock aquifer system can be represented as an equivalent porous media. Representation of the fractured bedrock aquifer system as a porous media is valid as long as the fractures are closely spaced relative to the scale of the problem that is being evaluated with the model. The equivalent porous media approach adequately represents the behavior of a regional flow system, but may poorly reproduce local conditions on a scale of several meters.

In areas of the model where specific data are lacking, the model may not accurately simulate local flow conditions. The model may also be less accurate away from the site due to the relatively large grid spacing used in these areas which requires averaging hydrologic parameters over a larger area. The accuracy of the model away from the site has not been evaluated due to a lack of detailed hydraulic information outside the NFS plant area. However the accuracy in model parameters in the vicinity of the site was addressed through the model calibration process and the completion of a detailed sensitivity analysis.

It should be noted that even though the estimated biodegradation rate of 2 years for PCE was the best value determined during model calibration, it may over-estimate or underestimate the actual rate of biotransformation at the site. To more accurately determine the effective biodegradation rate in the subsurface, additional bioactivity and biogeochemical parameters should be collected at the site to reduce model uncertainties.

Although the current solute-transport model accurately simulates the large-scale migration of dissolved PCE and uranium plumes, finer discretization in the vicinity of the site may increase the resolution and accuracy of the model predictions. The current model utilizes a 50-ft grid spacing in the site area which is often several times greater than the scale of changes in observed concentrations. Averaging of observed groundwater concentrations and concentrations associated with source areas over individual grid cells may lead to inaccuracies. The model-error introduced by the relatively large grid spacing in the vicinity of the site has not been assessed.

The accuracy of the NFS flow model was determined statistically by comparing the simulated results with observed values. This does not necessarily indicate the model will perform with the same level of accuracy for long-term predictions use. The predictive simulations discussed in the report contain the same aquifer recharge rates and similar flow system stresses as for the calibration period. Thus, assuming that significant changes to the aquifer system water balance do not occur, the predictions should have a level of reliability similar to the calibrated flow model. It should be noted, however, that as predictive simulation time increase, confidence in the applicability of the present water balance and aquifer conditions (e.g., porosity, stream downcutting or meandering, climate changes, etc.) to future conditions continues to decrease with increasing simulation time. Therefore, predictive simulations in excess of hundreds of years into the future may be inaccurate due to the inability to predict long-term climatic trends, changes in groundwater divide locations, changes in porosity, meandering/ downcutting of streams and rivers, etc. which can occur over these time scales.

7.0 Summary and Conclusions

Geraghty & Miller previously developed and calibrated a regional groundwater flow model (MODFLOW) for the NFS site that simulates groundwater flow in an unconsolidated and bedrock aquifer system. In conjunction with the flow model, a solute-transport model was developed (MT3D) for uranium and PCE. Primary source areas were developed as part of solute-transport model development. These source areas are represented by three unlined surface impoundment ponds, the "Pond 4" disposal area, the burial grounds, and various areas in the vicinity of plant particularly Buildings 130, 120, and 131. Additionally, model simulation incorporated the production history of nearby Erwin Utility supply wells and infiltration at the ponds to define individual aquifer stress periods.

The current modeling effort focused on integrating new off-site data into the existing model. Incorporation of these data into the groundwater flow model resulted in close agreement with the existing model, with local refinements in quantifying flow conditions. Revision of the solute transport model resulted in an excellent match to the observed uranium and PCE ~~concentrations~~ plume morphology or shape + extent, and the calibrated solute transport parameters exhibited good agreement with field measured values. Through the calibration process, model parameters were refined and then used for predictive simulations.

The predictive simulations were performed for uranium and PCE constituents observed at the site under two scenarios: 1) all sources removed after 5 years, and 2) some sources remaining after 5 years. A maximum time period of 10,000 years for uranium and 25 years for PCE was used for these simulations into the future. The future pumping stresses were simulated which were defined based on the current and future pumping schedules and the waste disposal history.

Based on the results of the solute-transport analysis, PCE concentrations will decrease dramatically after the continuing sources are remediated. If all of the continuing sources are remediated within 5 years, the PCE concentrations should decrease to acceptable levels outside the NFS property boundary within 15 years. If a significant source of contamination is left in place around the buildings, then concentrations exceeding the MCL (5 µg/L) will persist until these sources are remediated or depleted. The solute transport simulations suggest that PCE is at steady-state conditions, and the PCE concentrations are not expected to dramatically increase downgradient of the NFS property boundary.

Due to the high partitioning coefficient associated with uranium, it is expected to migrate slowly through the aquifer system. Even if all sources of uranium are remediated, dissolved uranium is predicted to migrate across the NFS property boundary at concentrations exceeding the EPA proposed standard (30 pCi/L) within the next 500 years. However, the model does not predict this to occur for the next 50 years. If the sources of uranium are not depleted or remediated, then uranium may migrate across the NFS property boundary for an extended period of time.

The ability of the model to perform predictive simulations has helped to predict the current and future extent of uranium and PCE at the Site. The model can be a powerful tool to evaluate the effectiveness of proposed remedial systems, for risk assessment, and to develop a cost-effective monitoring well program. These models can be utilized as a tool to enhance the understanding of site conditions as new site information is gathered.

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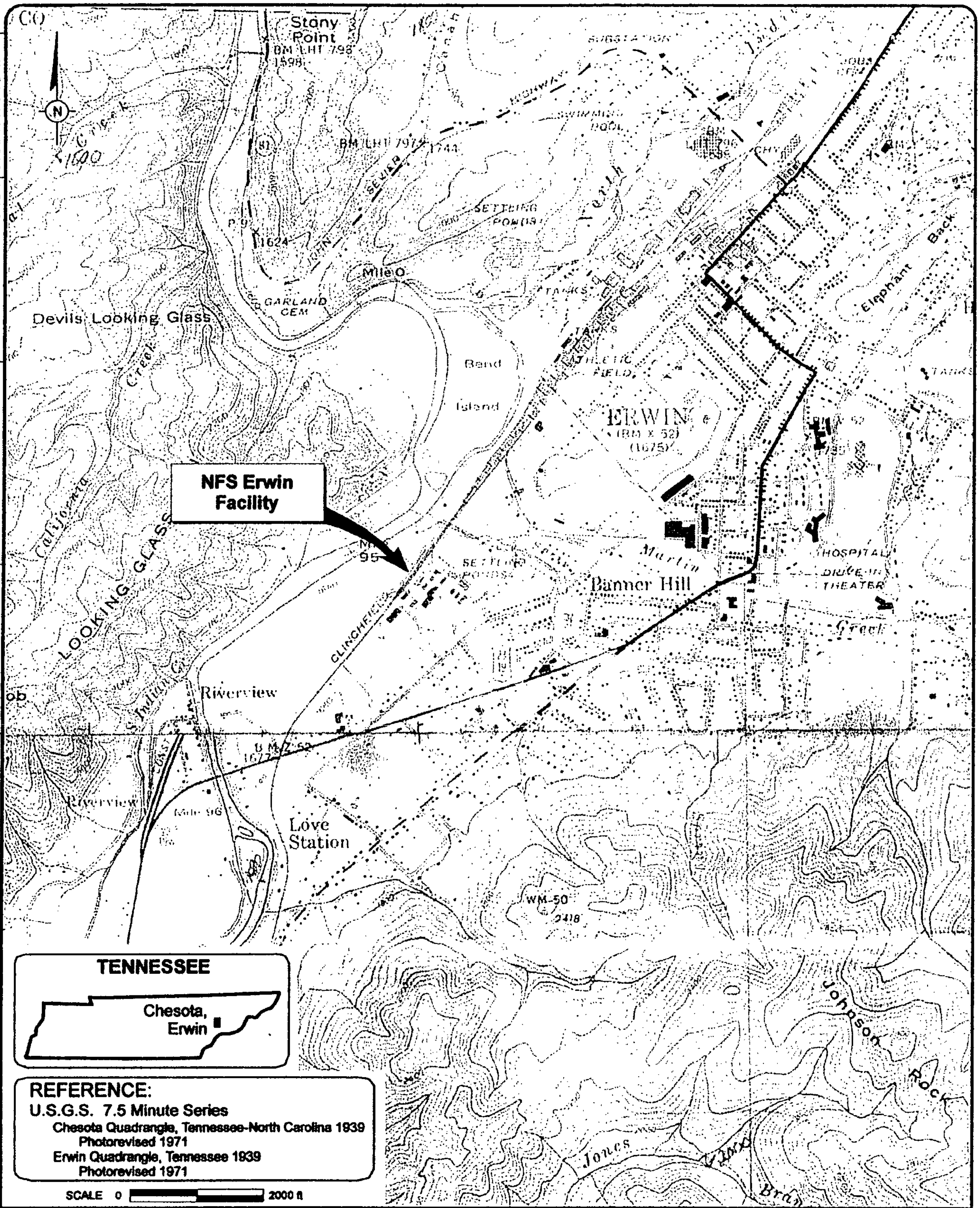

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Regional Location Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

1-1

Table 2-1. Public and Private Groundwater Supplies in the Unicoi County Area

Nuclear Fuel Services, Inc. Erwin, Tennessee

Public Groundwater Supplies in Unicoi County

Source	Geologic Horizon[1]	Depth (ft)	Potential Yield (gpm)	Location in Relation to NFS
Erwin Utility District				
Anderson-McInturff Spring	Cu/Chk	---	450	Approx. 3.8 mi. NE of NFS
Birchfield Well and Spring	Cu/Chk/Cs	222	1,500	Approx 1.5 mi. N or NFS
O'Brien Well and Spring	Ce (spring)	606	630	Approx 1.3 mi. NE of NFS
Railroad Well	Cr/Chk	240	315	Approx 3,500 ft NE of NFS
Plassco Well	Chk	350	---	Approx 2.5 mi. ENE of NFS
Elk's Club Well	Chk	305	1,200	Approx 1.6 mi. NE of NFS
Ambrose Well	Chk	270	1,100	Approx 1.5 mi. N of NFS
Johnson City Water Department				
Unicoi Springs (3)	Cu	---	2,500	Approx. 6 mi. NE of NFS

SOURCE: First Tennessee Development District, March 1987 and Bradfield Environmental Services, Inc.

Private Groundwater Supplies Within a 5-mile Radius of NFS

Owner and/or Name	Geologic Horizon[1]	Depth (ft)	Potential Yield (gpm)[3]	Use
Crystal Ice, Coal & Laudry (well)	Chk	135	75	Industrial
Love Spring	Cs	---	500	---
Grady Ledford (well)	Ce	122	N/A	Domestic
Sam Tipton (well)	Ce	80	N/A	Domestic
E.L. Lewis (spring)	Ce	---	5	Domestic
Unaka Springs	Cu	---	N/A	Domestic
U.S. Dept. of the Interior (spring)	Chk	---	916	Industrial
Fess Radford (well)	Chk	30	N/A	Domestic
Kelley Rice (well)	Cs	24	N/A	Domestic
Charles Erwin (well)	Chk	323	N/A	Domestic
Yates Spring	Cu	---	10	Domestic
W.B. Walker	Ch	N/A	3	Domestic

NOTES:

1. Chk -- Honaker Dolomite Cs -- Shady Dolomite Ce -- Erwin Formation
   Cu -- Unicoi Formation Cr -- Rome Formation Ch -- Hampton Formation
2. Banner Spring was listed as a potential water supply source in the Survey of Public Groundwater Supplies published by the First Tennessee Development District in March 1987. Banner Spring is owned by Nuclear Fuel Services, Inc. and is not a water supply.
3. N/A -- Not Available

SOURCE: EcoTek Inc., Hydrogeologic Characterization Study of NFS Facility, Vol. I, March 1989

Table 3-1. Summary of Withdrawal Wells

Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Layer	Row	Column	Rate (gpm)
Railroad Well	3, 4, 5	40	116	270.4
Birchfield Well	3, 4, 5	12	122	552.7
O'Brien Well	3	7	123	241.5
PW-1	1	55	92	0.6
PW-2	1	54	92	0.6
PW-3	1	53	91	0.6
PW-4	1	52	90	0.6
PW-5	1	53	89	0.6
PW-6	1	53	88	0.6
PW-7	1	54	89	0.6
PW-8	1	55	89	0.6
PW-9	1	56	90	0.6
PW-10	1	56	91	0.6

gpm - gallon per minute

Table 3-2. Calibration Targets for the Groundwater Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Northing	Easting	Layer	Row	Column	Observed Water-Level (ft amsl)[A]
5	652981.205	3054220.098	1	52	99	1632.496
10	652856.305	3054017.969	1	51	94	1630.404
26	652671.008	3054001.125	1	53	91	1630.733
28	652630.903	3053885.862	1	53	89	1629.790
33	652479.872	3054165.106	1	59	91	1634.282
36	652661.138	3054190.162	1	56	94	1634.128
39	652322.453	3054167.434	1	61	89	1633.848
40	652208.614	3054416.253	1	65	91	1636.188
52	652122.965	3054450.65	1	67	91	1636.862
55	652478.794	3054661.522	1	65	98	1638.572
55A	652272.778	3054729.74	1	68	97	1638.120
56	652859.691	3054710.746	1	60	103	1637.940
57	652965.759	3054405.027	1	55	101	1632.346
58	653091.196	3054301.482	1	51	101	1630.732
63	652683.71	3054819.865	1[1]	64	103	1643.750
63A	652508.988	3054977.285	1	68	102	1640.954
64	652587.549	3054386.843	1	60	96	1634.972
68	653111.714	3054177.259	1	49	100	1630.326
72	652474.402	3053753.965	1[2]	53	85	1633.390
73	652279.746	3053628.427	1[2]	54	81	1635.270
74	651843.763	3053642.664	1[2]	61	75	1634.400
75	652403.197	3053924.082	1	56	87	1633.352
95A	652860.441	3054433.149	1	57	100	1634.738
96A	652941.854	3054607.646	1	58	103	1636.202
98A	653216.576	3054151.025	1	48	101	1628.270
99A	653112.972	3054073.956	1	48	99	1628.918
101A	652794.572	3053830.678	1	49	91	1629.760
103A	652568.813	3053663.376	1	50	85	1630.042
104A	652349.805	3053502.568	1	51	80	1631.410
105A	652126.085	3053338.605	1	52	74	1632.112
106A	651887.784	3053163.064	1	54	68	1632.910
107A	651884.799	3053454.078	1	58	73	1633.850

Footnotes:

A - Average of August to December 1994 water level data used for onsite calibration targets December 1997 water level data used for offsite calibration targets in wells installed after completion of previous modeling report.

ft amsl - Feet above mean sea level.

1 - Not used for calibration since it was determined to be anamously high in previous model.

2 - Not used for calibration since the well crosses Layers 1, 2, and 3.

3 - In Layer 2 in previous model.

4 - Not used for calibration since the well crosses Layers 2 and 3.

5 - Installed after completion of previous model.

6 - New well not used in calculating statistics due to proximity to a boundary condition.

Table 3-2. Calibration Targets for the Groundwater Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Northing	Easting	Layer	Row	Column	Observed Water-Level (ft amsl)[A]
234-2	652114.124	3054225.994	1	65	87	1634.328
234-3	652157.008	3054243.132	1	64	88	1634.640
SC-6	651295.536	3053407.042	1	65	64	1638.202
29	652406.715	3054203.003	2	60	91	1633.758
30	652556.261	3054266.345	2	59	94	1634.158
31	652578.446	3054245.84	2	58	94	1634.592
32	652456.285	3054420.335	2	62	95	1634.482
34	652744.933	3054106.928	2[3]	54	94	1633.238
35	652353.942	3054298.123	2	62	91	1634.426
38	652394.072	3054082.228	2	59	89	1633.456
41	652317.841	3054460.583	2	65	93	1636.420
59	652947.436	3054036.982	2	50	96	1629.480
60	652793.235	3054398.301	2[4]	57	99	1634.678
62	652735.927	3054272.716	2[4]	56	96	1634.060
63B	652499.371	3054969.643	2	68	102	1640.900
65	652908.251	3054078.469	2	51	96	1630.312
66	653100.988	3054174.408	2	50	100	1630.100
70	652156.687	3054038.762	3[2]	62	85	1633.164
79	652570.817	3054073.05	2	56	91	1633.406
81	652716.156	3053976.252	2	52	92	1630.608
91	652391.217	3053852.075	2	56	85	1633.410
92	652334.343	3053852.075	2	56	85	1633.820
93	652482.138	3053800.231	2	54	86	1633.504
94	652528.91	3053760.161	2	52	86	1633.526
100A	652934.255	3053930.138	2	49	94	1629.686
102A	652673.432	3053741.839	2	50	88	1629.980
116A	652748.799	3053585.397	2[5]	47	86	1629.350
116B	652739.984	3053580.137	2[5]	47	86	1629.470
117A	652992.237	3053508.093	2[5]	42	89	1627.780
117B	652987.308	3053516.538	2[5]	42	89	1627.160
118A	653263.456	3053922.531	2[5]	44	98	1625.920
119A	652446.266	3053348.383	2[5]	48	79	1629.580
120A	652809.274	3053207.13	2[5]	41	82	1626.650

Footnotes:

A - Average of August to December 1994 water level data used for onsite calibration targets December 1997 water level data used for offsite calibration targets in wells installed after completion of previous modeling report.

ft amsl - Feet above mean sea level.

1 - Not used for calibration since it was determined to be anamously high in previous model.

2 - Not used for calibration since the well crosses Layers 1, 2, and 3.

3 - In Layer 2 in previous model.

4 - Not used for calibration since the well crosses Layers 2 and 3.

5 - Installed after completion of previous model.

6 - New well not used in calculating statistics due to proximity to a boundary condition.

Table 3-2. Calibration Targets for the Groundwater Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Northing	Easting	Layer	Row	Column	Observed Water-Level (ft amsl)[A]
121A	653179.434	3053207.13	2[6]	35	87	1626.370
70A	652139.9	3054045.536	2	62	85	1633.322
97A	652262.799	3053779.718	2	56	83	1634.046
LD-1A	652197.828	3053115.946	2	48	72	1633.570
LD-2A	652194.665	3053906.403	2	59	84	1633.854
SC-7	651507.657	3053407.042	2	62	67	1633.626
SC-8	651689.117	3053115.946	2	56	65	1633.062
67	652622.258	3054409.088	3	60	97	1635.928
71	652491.704	3053759.583	3	53	85	1632.394
76	652616.475	3054209.093	3	57	94	1633.438
77	652580.277	3054289.545	3	59	94	1634.296
82	651596.819	3053093.01	3	57	63	1630.576
100B	652924.455	3053922.754	3	49	94	1629.298
107B	651865.112	3053484.427	3	58	73	1633.346
118B	653247.768	3053925.182	3[5]	44	98	1626.550
120B	652803.725	3053214.953	3[5]	41	82	1626.810
121B	653166.959	3053474.205	3[5]	39	90	1626.900
60B	652783.245	3054388.823	3	57	99	1634.468
67B	652638.597	3054394.326	3	59	97	1635.588
SC-1	652674.441	3054969.88	3[1]	66	104	1645.548
SC-3	652060.198	3054389.876	3	67	89	1637.492
SC-4	652025.702	3054042.663	3	63	83	1634.646

Footnotes:

A - Average of August to December 1994 water level data used for onsite calibration targets December 1997 water level data used for offsite calibration targets in wells installed after completion of previous modeling report.

ft amsl - Feet above mean sea level.

1 - Not used for calibration since it was determined to be anamously high in previous model.

2 - Not used for calibration since the well crosses Layers 1, 2, and 3.

3 - In Layer 2 in previous model.

4 - Not used for calibration since the well crosses Layers 2 and 3.

5 - Installed after completion of previous model.

6 - New well not used in calculating statistics due to proximity to a boundary condition.

Table 3-3. Observed and Simulated Water Levels for the Calibrated Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

							Previous Model		Revised Model	
Well ID	Northing	Easting	Layer	Row	Column	Observed Water Level (ft amsl)[A]	Simulated Water-Level (ft amsl)	Residual[B]	Simulated Water-Level (ft amsl)	Residual[B]
5	652981.2	3054220.1	1	52	99	1632.496	1628.346	-4.154	1628.123	-4.373
10	652856.3	3054018.0	1	51	94	1630.404	1630.304	-0.096	1630.496	0.092
26	652671.0	3054001.1	1	53	91	1630.733	1631.138	0.408	1631.103	0.370
28	652630.9	3053885.9	1	53	89	1629.790	1631.066	1.276	1630.954	1.164
33	652479.9	3054165.1	1	59	91	1634.282	1633.706	-0.574	1633.713	-0.569
36	652661.1	3054190.2	1	56	94	1634.128	1632.740	-1.390	1633.047	-1.081
39	652322.5	3054167.4	1	61	89	1633.848	1635.259	1.409	1635.246	1.398
40	652208.6	3054416.3	1	65	91	1636.188	1634.766	-1.424	1634.687	-1.501
52	652123.0	3054450.7	1	67	91	1636.862	1635.280	-1.580	1635.169	-1.693
55	652478.8	3054661.5	1	65	98	1638.572	1637.820	-0.750	1637.948	-0.624
55A	652272.8	3054729.7	1	68	97	1638.120	1639.042	0.922	1638.982	0.862
56	652859.7	3054710.7	1	60	103	1637.940	1636.194	-1.746	1636.858	-1.082
57	652965.8	3054405.0	1	55	101	1632.346	1631.832	-0.518	1632.664	0.318
58	653091.2	3054301.5	1	51	101	1630.732	1628.098	-2.632	1628.237	-2.495
63	652683.7	3054819.9	1[1]	64	103	1643.750			1638.819	
63A	652509.0	3054977.3	1	68	102	1640.954	1640.765	-0.185	1640.928	-0.026
64	652587.5	3054386.8	1	60	96	1634.972	1635.397	0.427	1635.669	0.697
68	653111.7	3054177.3	1	49	100	1630.326	1628.152	-2.178	1628.997	-1.329
72	652474.4	3053754.0	1[2]	53	85	1633.390			1631.696	
73	652279.7	3053628.4	1[2]	54	81	1635.270			1632.332	
74	651843.8	3053642.7	1[2]	61	75	1634.400			1635.577	
75	652403.2	3053924.1	1	56	87	1633.352	1633.532	0.182	1633.650	0.298
95A	652860.4	3054433.1	1	57	100	1634.738	1633.407	-1.333	1633.984	-0.754
96A	652941.9	3054607.6	1	58	103	1636.202	1634.168	-2.032	1635.020	-1.182

Footnotes:

A - Average of August to December 1994 water level data used for onsite calibration targets December 1997 water level data used for offsite calibration targets in wells installed after completion of previous modeling report.

B - Residual = Simulated - Observed

ft amsl - Feet above mean sea level.

1 - Not used for calibration since it was determined to be anamously high in previous model.

2 - Not used for calibration since the well crosses Layers 1, 2, and 3.

3 - In Layer 2 in previous model.

4 - Not used for calibration since the well crosses Layers 2 and 3.

5 - Installed after completion of previous model.

6 - New well not used in calculating statistics due to proximity to a boundary condition.

Table 3-3. Observed and Simulated Water Levels for the Calibrated Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

							Previous Model		Revised Model	
Well ID	Northing	Easting	Layer	Row	Column	Observed Water Level (ft amsl)[A]	Simulated Water-Level (ft amsl)	Residual[B]	Simulated Water-Level (ft amsl)	Residual[B]
98A	653216.6	3054151.0	1	48	101	1628.270	1626.238	-2.032	1625.835	-2.435
99A	653113.0	3054074.0	1	48	99	1628.918	1628.443	-0.477	1628.803	-0.115
101A	652794.6	3053830.7	1	49	91	1629.760	1629.895	0.135	1629.753	-0.007
103A	652568.8	3053663.4	1	50	85	1630.042	1630.570	0.530	1630.242	0.200
104A	652349.8	3053502.6	1	51	80	1631.410	1631.401	-0.009	1631.031	-0.379
105A	652126.1	3053338.6	1	52	74	1632.112	1631.879	-0.231	1631.608	-0.504
106A	651887.8	3053163.1	1	54	68	1632.910	1632.797	-0.113	1632.384	-0.526
107A	651884.8	3053454.1	1	58	73	1633.850	1634.920	1.070	1634.661	0.811
234-2	652114.1	3054226.0	1	65	87	1634.328	1636.624	2.294	1636.393	2.065
234-3	652157.0	3054243.1	1	64	88	1634.640	1636.389	1.749	1636.188	1.547
SC-6	651295.5	3053407.0	1	65	64	1638.202	1638.089	-0.111	1637.666	-0.536
29	652406.7	3054203.0	2	60	91	1633.758	1634.855	1.095	1634.871	1.113
30	652556.3	3054266.3	2	59	94	1634.158	1634.462	0.302	1634.649	0.491
31	652578.4	3054245.8	2	58	94	1634.592	1634.136	-0.454	1634.305	-0.287
32	652456.3	3054420.3	2	62	95	1634.482	1636.061	1.581	1636.058	1.576
34	652744.9	3054106.9	2[3]	54	94	1633.238	1630.441	-2.799	1631.796	-1.442
35	652353.9	3054298.1	2	62	91	1634.426	1635.558	1.128	1635.536	1.110
38	652394.1	3054082.2	2	59	89	1633.456	1634.266	0.806	1634.305	0.849
41	652317.8	3054460.6	2	65	93	1636.420	1635.734	-0.686	1635.715	-0.705
59	652947.4	3054037.0	2	50	96	1629.480	1629.817	0.337	1630.269	0.789
60	652793.2	3054398.3	2[4]	57	99	1634.678			1634.110	
62	652735.9	3054272.7	2[4]	56	96	1634.060			1633.290	
63B	652499.4	3054969.6	2	68	102	1640.900	1640.734	-0.166	1640.801	-0.099
65	652908.3	3054078.5	2	51	96	1630.312	1630.224	-0.086	1630.672	0.359
66	653101.0	3054174.4	2	50	100	1630.100	1628.795	-1.305	1629.492	-0.608

Footnotes:

A - Average of August to December 1994 water level data used for onsite calibration targets December 1997 water level data used for offsite calibration targets in wells installed after completion of previous modeling report.

B - Residual = Simulated - Observed

ft amsl - Feet above mean sea level.

1 - Not used for calibration since it was determined to be anamously high in previous model.

2 - Not used for calibration since the well crosses Layers 1, 2, and 3.

3 - In Layer 2 in previous model.

4 - Not used for calibration since the well crosses Layers 2 and 3.

5 - Installed after completion of previous model.

6 - New well not used in calculating statistics due to proximity to a boundary condition.

Table 3-3. Observed and Simulated Water Levels for the Calibrated Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

							Previous Model		Revised Model	
Well ID	**Northing**	**Easting**	**Layer**	**Row**	**Column**	**Observed Water Level (ft amsl)[A]**	**Simulated Water-Level (ft amsl)**	**Residual[B]**	**Simulated Water-Level (ft amsl)**	**Residual[B]**
70	652156.7	3054038.8	3[2]	62	85	1633.164			1635.655	
79	652570.8	3054073.1	2	56	91	1633.406	1632.596	-0.814	1632.838	-0.568
81	652716.2	3053976.3	2	52	92	1630.608	1631.020	0.410	1631.235	0.627
91	652391.2	3053852.1	2	56	85	1633.410	1633.365	-0.045	1633.357	-0.053
92	652334.3	3053852.1	2	56	85	1633.820	1633.769	-0.051	1633.907	0.087
93	652482.1	3053800.2	2	54	86	1633.504	1632.198	-1.302	1631.966	-1.538
94	652528.9	3053760.2	2	52	86	1633.526	1631.037	-2.493	1630.978	-2.548
100A	652934.3	3053930.1	2	49	94	1629.686	1629.506	-0.184	1629.384	-0.302
102A	652673.4	3053741.8	2	50	88	1629.980	1630.207	0.227	1630.083	0.104
116A	652748.8	3053585.4	2[5]	47	86	1629.350			1628.699	-0.301
116B	652740.0	3053580.1	2[5]	47	86	1629.470			1628.783	-0.687
117A	652992.2	3053508.1	2[5]	42	89	1627.780			1625.769	-2.011
117B	652987.3	3053516.5	2[5]	42	89	1627.160			1625.882	-1.278
118A	653263.5	3053922.5	2[5]	44	98	1625.920			1624.453	-1.467
119A	652446.3	3053348.4	2[5]	48	79	1629.580			1629.944	0.364
120A	652809.3	3053207.1	2[5]	41	82	1626.650			1626.218	-0.432
121A	653179.4	3053207.1	2[6]	35	87	1626.370			1621.601	
70A	652139.9	3054045.5	2	62	85	1633.322	1635.942	2.622	1635.607	2.285
97A	652262.8	3053779.7	2	56	83	1634.046	1633.907	-0.143	1633.909	-0.137
LD-1A	652197.8	3053115.9	2	48	72	1633.570	1631.954	-1.616	1631.026	-2.543
LD-2A	652194.7	3053906.4	2	59	84	1633.854	1635.068	1.218	1634.995	1.141
SC-7	651507.7	3053407.0	2	62	67	1633.626	1637.036	3.406	1636.557	2.931
SC-8	651689.1	3053115.9	2	56	65	1633.062	1635.040	1.980	1634.483	1.421
67	652622.3	3054409.1	3	60	97	1635.928	1635.211	-0.719	1635.531	-0.397

Footnotes:

A - Average of August to December 1994 water level data used for onsite calibration targets December 1997 water level data used for offsite calibration targets in wells installed after completion of previous modeling report.

B - Residual = Simulated - Observed

ft amsl - Feet above mean sea level.

1 - Not used for calibration since it was determined to be anamously high in previous model.

2 - Not used for calibration since the well crosses Layers 1, 2, and 3.

3 - In Layer 2 in previous model.

4 - Not used for calibration since the well crosses Layers 2 and 3.

5 - Installed after completion of previous model.

6 - New well not used in calculating statistics due to proximity to a boundary condition.

Table 3-3. Observed and Simulated Water Levels for the Calibrated Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

							Previous Model		Revised Model	
Well ID	Northing	Easting	Layer	Row	Column	Observed Water Level (ft amsl) ^{A}	Simulated Water-Level (ft amsl)	Residual ^{B}	Simulated Water-Level (ft amsl)	Residual ^{B}
71	652491.7	3053759.6	3	53	85	1632.394	1632.084	-0.306	1631.970	-0.424
76	652616.5	3054209.1	3	57	94	1633.438	1633.847	0.407	1634.078	0.641
77	652580.3	3054289.5	3	59	94	1634.296	1634.588	0.288	1634.876	0.580
82	651596.8	3053093.0	3	57	63	1630.576	1635.588	5.008	1634.985	4.409
100B	652924.5	3053922.8	3	49	94	1629.298	1629.655	0.355	1629.728	0.430
107B	651865.1	3053484.4	3	58	73	1633.346	1636.962	3.612	1634.781	1.435
118B	653247.8	3053925.2	3^5	44	98	1626.550			1626.766	0.216
120B	652803.7	3053215.0	3^5	41	82	1626.810			1627.225	0.415
121B	653167.0	3053474.2	3^5	39	90	1626.900			1625.063	-1.837
60B	652783.2	3054388.8	3	57	99	1634.468	1634.050	-0.420	1634.470	0.002
67B	652638.6	3054394.3	3	59	97	1635.588	1635.008	-0.582	1635.335	-0.253
SC-1	652674.4	3054969.9	3^1	66	104	1645.548			1639.888	
SC-3	652060.2	3054389.9	3	67	89	1637.492	1638.057	0.567	1637.800	0.308
SC-4	652025.7	3054042.7	3	63	83	1634.646	1636.743	2.093	1636.356	1.710

RESIDUAL SUM OF SQUARES	160.333	ft^2	137.552	ft^2
RESIDUAL STANDARD DEVIATION	1.536	ft	1.328	ft
MEAN RESIDUAL	0.002	ft	-0.076	ft

Footnotes:

A - Average of August to December 1994 water level data used for onsite calibration targets December 1997 water level data used for offsite calibration targets in wells installed after completion of previous modeling report.

B - Residual = Simulated - Observed

ft amsl - Feet above mean sea level.

1 - Not used for calibration since it was determined to be anamously high in previous model.

2 - Not used for calibration since the well crosses Layers 1, 2, and 3.

3 - In Layer 2 in previous model.

4 - Not used for calibration since the well crosses Layers 2 and 3.

5 - Installed after completion of previous model.

6 - New well not used in calculating statistics due to proximity to a boundary condition.

Table 4-1. Water Supply Pumping History, 1957 through 1997

Nuclear Fuel Services, Inc. Erwin, Tennessee

		Railroad Well		Birchfield Well		O'Brien Well		Dewatering Wells (10 wells)	
		MGY	ft^3/day	MGY	ft^3/day	MGY	ft^3/day	MGY	ft^3/day
Stress Period 1 January 1957 to December 1970									
	1957-1970			224.09	82073.99	252.62	92520.43		
	Average:			**224.09**	**82073.99**	**252.62**	**92520.43**		
Stress Period 2 January 1971 to December 1975									
	1971-1975			224.09	82073.99	252.62	92520.43		
	Average:			**224.09**	**82073.99**	**252.62**	**92520.43**		
Stress Period 3 January 1976 to December 1978									
	1976			223.87	81991.98	252.62	92520.42		
	1977			254.73	93293.00	266.35	97548.28		
	1978			259.53	95053.48	265.78	97341.80		
	Average:			**246.05**	**90113.15**	**261.58**	**95803.50**		
Stress Period 4 January 1979 to December 1985									
	1979			288.24	105565.58	276.61	101307.56		
	1980			226.19	82841.28	258.85	94803.92		
	1981			228.08	83533.13	261.36	95723.78		
	1982			273.53	100179.00	292.10	106980.84		
	1983			256.90	94087.20	295.76	108322.56		
	1984			278.17	101877.60	264.45	96854.95		
	1985			244.01	89367.57	225.20	82478.46		
	Average:			**256.44**	**93921.62**	**267.76**	**98067.44**		

Footnotes:

MGY - million gallons per year

ft^3/day - cubic feet per day

Average was calculated for the stress periods

Source for January 1957 to December 1993: NFS correspondence dated August 8, 1995

Source for January 1994 to December 1997: Previous groundwater flow model

Table 4-1. Water Supply Pumping History, 1957 through 1997

Nuclear Fuel Services, Inc. Erwin, Tennessee

		Railroad Well		Birchfield Well		O'Brien Well		Dewatering Wells (10 wells)	
		MGY	ft^3/day	MGY	ft^3/day	MGY	ft^3/day	MGY	ft^3/day
Stress Period 5 January 1986 to December 1990									
	1986	12.95	4742.28	226.80	83064.84	231.65	84841.06		
	1987	71.91	26338.38	194.82	71350.64	230.79	84526.89		
	1988	161.49	59146.61	159.90	58561.72	158.36	57999.48		
	1989	40.27	14748.22	239.49	87711.30	213.68	78260.18		
	1990	58.12	21287.14	244.48	89539.88	243.42	89151.81		
	Average:	**68.95**	**25252.23**	**213.10**	**78045.68**	**215.58**	**78955.88**		
Stress Period 6 January 1991 to December 1993									
	1991	162.89	59659.09	207.89	76139.71	202.44	74142.16		
	1992	174.80	64021.46	225.09	82439.10	144.12	52785.20		
	1993	161.29	59070.86	232.35	85097.30	166.64	61032.38		
	Average:	**166.33**	**60917.10**	**221.78**	**81225.36**	**171.07**	**62653.00**		
Stress Period 7 January 1994 to July 1994									
	1993-1994	142.26	52101.95	290.79	106500.39	126.94	46492.60		
	Average:	**142.26**	**52101.95**	**290.79**	**106500.39**	**126.94**	**46492.60**		
Stress Period 8 July 1994 to December 1997									
	1993-1997	142.26	52101.95	290.79	106500.39	126.94	46492.60	3.15	1155.10
	Average:	**142.26**	**52101.95**	**290.79**	**106500.39**	**126.94**	**46492.60**	**3.15**	**1155.10**

Footnotes:

MGY - million gallons per year
ft^3/day - cubic feet per day
Average was calculated for the stress periods
Source for January 1957 to December 1993: NFS correspondence dated August 8, 1995
Source for January 1994 to December 1997: Previous groundwater flow model

Table 4-2. Source Concentrations Used in the Historical Solute-Transport Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Source Area	Initial Uranium Concentrations (pCi/L)	Final Uranium Concentrations (pCi/L)	Initial PCE Concentrations (µg/L)	Final PCE Concentrations (µg/L)
Pond 1	1,200	1.200	900	900
Pond 2	1,200	1.200	900	600
Pond 3	1,200	1.200	900	50
Pond 4	2.600	2,600	2,000	2.000
Burial Grounds	2.000	2.000	200	200
Bldg. 110 Area	1,600	1,600	0	0
Bldg. 111 Area	1,600	1,600	1,000	1,000
Bldg. 120 Area	0	0	50,000	50,000
Bldg. 130 Area	1,600	1.600	1,000	1,000
Bldg. 302, 304, and 306 Area	1.600	1,600	0	0
Bldg. 303 Area	1.600	1.600	0	0
Bldg. 309 Area	1.600	1.600	0	0
Bldg. 234 Area	0	0	1,000	1.000
Bldg. 234A	3,000	3.000	0	0
Bldg. 234C	2,000	2.000	0	0
Stockpile Soil	1,600	1,600	0	0

Footnotes:

pCi/L - picocuries per liter

µg/L - micrograms per liter

Table 4-3. Parameters Assigned in the Solute-Transport Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

Transport Parameter	Value Assigned in Original Model	Value Assigned in Revised Model
Longitudinal Dispersivity (ft)	10	26
Transverse Dispersivity (ft)	1	2.6
Vertical Dispersivity (ft)	0	2.6
Uranium Decay Rate (days^{-1})	1.2×10^{-8}	1.2×10^{-8}
PCE Degradation Rate (days^{-1})	2.53×10^{-3}	9.49×10^{-4}
PCE Distribution Coefficient (L/kg)	0.12	0.24
Uranium Distribution Coefficient (L/kg)	107	107

Footnotes:

ft - feet
L - liters
kg- kilograms

Table 4-4. Observed and Simulated Uranium Concentrations for the Calibrated Solute Transport Model

Nuclear Fuel Service, Inc. Erwin, Tennessee

Well ID	Layer	Row	Column	Observed Uranium Concentration (pCi/L)	Model Calculated Uranium Concentration (pCi/L)
26	1	53	91	4585.3	36.03
27	1	54	89	91.95	23.61
28	1	53	89	34.66	29.46
33	1	59	91	1582.2	157.03
39	1	61	89	34.73	64.52
52	1	67	91	0.62	0.09
55	1	65	98	4.11	0.00
56	1	60	103	0.16	0.05
57	1	55	101	0.92	0.16
58	1	51	101	0.08	-0.06
63	1	64	103	0.78	0.00
64	1	60	96	20.92	6.45
68	1	49	100	84.33	29.35
78	1	56	90	60.75	51.20
101A	1	49	91	2.46	8.16
103A	1	50	85	0.42	0.00
104A	1	51	80	0.35	0.00
105A	1	52	74	0.63	0.00
106A	1	54	68	0.54	0.00
107A	1	58	73	5.77	0.00
108A	1	54	84	1230.01	50.88
109A	1	54	82	538.51	0.34
110A	1	55	81	6.67	2.12
111A	1	52	85	56.32	0.02
112A	1	53	82	0.86	0.25
113A	1	53	81	0.43	0.28
114A	1	52	83	0.91	2.05
115A	1	52	82	0.95	0.10
234-2	1	65	87	973.94	28.38
234-3	1	64	88	47.72	24.84
55A	1	68	97	0.21	0.00
63A	1	68	102	0.23	0.00
95A	1	57	100	226.54	3.67
96A	1	58	103	183.85	0.08
98A	1	48	101	15.36	0.68
99A	1	48	99	0.32	-0.05
29	2	60	91	55.67	16.57
30	2	59	94	391.5	93.51
31	2	58	94	21.57	21.07
35	2	62	91	307.18	24.86
38	2	59	89	109.34	1.97
59	2	50	96	0.28	0.04
60	2	57	99	615.15	0.16
62	2	56	96	0.22	0.00
65	2	51	96	0.43	-0.10
66	2	50	100	35.69	0.33

Note: Sampling dates may vary for individual wells.

pCi/L - picoCuries per liter

Table 4-4. Observed and Simulated Uranium Concentrations for the Calibrated Solute Transport Model

Nuclear Fuel Service, Inc. Erwin, Tennessee

Well ID	Layer	Row	Column	Observed Uranium Concentration (pCi/L)	Model Calculated Uranium Concentration (pCi/L)
100A	2	49	94	9.2	0.89
102A	2	50	88	4.03	5.24
114B	2	52	83	0.34	2.15
116A	2	47	86	0.28	0.00
116B	2	47	86	0.63	0.00
117A	2	42	89	1.06	0.00
117B	2	42	89	0.46	0.00
118A	2	44	98	3.3	0.00
119A	2	48	79	0.62	0.00
120A	2	41	82	0.88	0.00
121A	2	35	87	0.89	0.00
63B	2	68	102	0.23	0.00
70A	2	62	85	1.58	0.00
97A	2	56	83	4.2	0.04
LD-1A	2	48	72	0.74	0.00
LD-2A	2	59	84	30.1	8.02
77	3	59	94	19.12	0.22
100B	3	49	94	0.57	0.00
107B	3	58	73	16.23	0.00
116C	3	47	87	1.45	0.00
118B	3	44	98	0.67	0.00
120B	3	41	82	1.06	0.00
121B	3	39	90	0.74	0.00
60B	3	57	99	199.47	0.00
67B	3	59	97	2.59	0.00

Note: Sampling dates may vary for individual wells.

pCi/L - picoCuries per liter

Table 4-5. Observed and Simulated PCE Concentrations for the Calibrated Solute Transport Model

Nuclear Fuel Service, Inc. Erwin, Tennessee

Well ID	Layer	Row	Column	Observed PCE Concentration (µg/L)	Model Calculated PCE Concentration (µg/L)
26	1	53	91	1.28	73.04
28	1	53	89	2172.5	98.76
39	1	61	89	290	141.63
52	1	67	91	16.6	0.74
55	1	65	98	20.8	3.24
56	1	60	103	2	1.65
57	1	55	101	10.3	3.27
58	1	51	101	4.2	0.60
63	1	64	103	26.4	10.85
64	1	60	96	12.1	6.24
68	1	49	100	2.82	0.22
101A	1	49	91	151	64.84
103A	1	50	85	4113.9	1572.32
104A	1	51	80	6	9.07
105A	1	52	74	10.7	0.00
107A	1	58	73	0.05	0.00
108A	1	54	84	14901	135.47
109A	1	54	82	78.3	144.54
110A	1	55	81	110.6	23.76
111A	1	52	85	2915	2964.29
112A	1	53	82	67	916.87
113A	1	53	81	200	460.68
114A	1	52	83	559	1026.90
115A	1	52	82	216.8	974.10
234-2	1	65	87	71	25.01
234-3	1	64	88	179	21.83
55A	1	68	97	5.04	0.00
63A	1	68	102	4.1	0.01
95A	1	57	100	6.5	8.52
96A	1	58	103	2.03	0.78
98A	1	48	101	13.4	0.15
99A	1	48	99	1.44	0.14
38	2	59	89	125.4	59.31
59	2	50	96	14.1	1.15
60	2	57	99	9.4	2.53
62	2	56	96	0.31	1.39
65	2	51	96	22.76	1.32
66	2	50	100	1.42	0.38
92	2	56	85	2.5	45.45
93	2	54	86	2.5	589.39

Note: Observed PCE concentrations from most recent sampling event.
Dates may vary for individual wells.
µg/L - micrograms per liter

Table 4-5. Observed and Simulated PCE Concentrations for the Calibrated Solute Transport Model

Nuclear Fuel Service, Inc. Erwin, Tennessee

Well ID	Layer	Row	Column	Observed PCE Concentration (µg/L)	Model Calculated PCE Concentration (µg/L)
94	2	52	86	2.5	3220.44
100A	2	49	94	64	3.60
102A	2	50	88	1561.2	1784.09
114B	2	52	83	2883.7	805.81
116A	2	47	86	599	508.72
116B	2	47	86	1823	508.72
117A	2	42	89	227	147.80
117B	2	42	89	384	147.80
118A	2	44	98	10	0.14
119A	2	48	79	144	0.57
120A	2	41	82	203	10.13
121A	2	35	87	79	0.62
63B	2	68	102	21.9	0.01
97A	2	56	83	3.5	46.77
LD-1A	2	48	72	0.05	0.00
LD-2A	2	59	84	0.05	0.53
67	3	60	97	970	0.36
100B	3	49	94	71	2.02
107B	3	58	73	0.47	0.00
116C	3	47	87	316	154.20
118B	3	44	98	22	0.10
120B	3	41	82	364	3.41
121B	3	39	90	71	25.79
60B	3	57	99	15	0.77
67B	3	59	97	32.1	0.36

Note: Observed PCE concentrations from most recent sampling event.
Dates may vary for individual wells.
µg/L - micrograms per liter

Table 5-1. Summary of Withdrawal Wells and Production Rates Assigned in Model During Predictive Simulations

Nuclear Fuel Services, Inc. Erwin, Tennessee

Well	Pumping Rate (gpm)	Location in Relation to NFS
Birchfield Well and Spring	520	Approx. 1.5 miles north of NFS
O'Brien Well and Spring	400	Approx. 1.3 miles northeast of NFS
Railroad Well	350	Approx. 3,500 feet northeast of NFS
Ambrose Well	0	Approx. 1.5 miles north of NFS
Pond Wells	0	Onsite

Footnotes:

gpm - gallons per minute

Table 5-2. Source Concentrations Used in the Predictive Solute-Transport Model (Discontinuous Sources Near Buildings)

Nuclear Fuel Services, Inc. Erwin, Tennessee

Source Area	1998 to 2003 Uranium Concentrations (pCi/L)	2003 to 11998 Uranium Concentrations (pCi/L)	1998 to 2003 PCE Concentrations (µg/L)	2003 to 2008 PCE Concentrations (µg/L)
Pond 1	1,200	0	900	0
Pond 2	1,200	0	600	0
Pond 3	1,200	0	50	0
Pond 4	2,600	0	2,000	0
Abandoned Banner Spring Branch	2,600	0	0	0
Burial Grounds	2,000	0	200	0
Bldg. 110 Area	1,600	0	0	0
Bldg. 111 Area	1,600	0	1,000	0
Bldg. 120 Area	0	0	50,000	0
Bldg. 130 Area	1,600	0	1,000	0
Bldg. 131 Area	0	0	105	0
Bldg. 302, 304, and 306 Area	1,600	0	0	0
Bldg. 303 Area	1,600	0	0	0
Bldg. 309 Area	1,600	0	0	0
Bldg. 234 Area	0	0	1,000	0
Bldg. 234A	3,000	0	0	0
Bldg. 234C	2,000	0	0	0
Stockpile Soil	1,600	0	0	0

Footnotes:

pCi/L - picoCuries per liter

µg/L - micrograms per liter

Table 5-3. Source Concentrations Used in the Predictive Solute-Transport Model (Continuous Sources Near Buildings)

Nuclear Fuel Services, Inc. Erwin, Tennessee

Source Area	**1998 to 2003 Uranium Concentrations (pCi/L)**	**2003 to 11998 Uranium Concentrations (pCi/L)**	**1998 to 2003 PCE Concentrations (μg/L)**	**2003 to 2008 PCE Concentrations (μg/L)**
Pond 1	1,200	0	900	0
Pond 2	1,200	0	600	0
Pond 3	1,200	0	50	0
Pond 4	2,600	0	2,000	0
Abandoned Banner Spring Branch	2,600	0	0	0
Burial Grounds	2,000	0	200	0
Bldg. 110 Area	1,600	1,600	0	0
Bldg. 111 Area	1,600	1.600	1.000	1,000
Bldg. 120 Area	0	0	50,000	50,000
Bldg. 130 Area	1,600	1,600	1,000	1,000
Bldg. 131 Area	1,600	1,600	105	105
Bldg. 302, 304, and 306 Area	1,600	1,600	0	0
Bldg. 303 Area	1,600	1,600	0	0
Bldg. 309 Area	1,600	1,600	0	0
Bldg. 234 Area	0	0	1,000	0
Bldg. 234A	3,000	0	0	0
Bldg. 234C	2,000	0	0	0
Stockpile Soil	1.600	0	0	0

Footnotes:
pCi/L - picoCuries per liter
μg/L - micrograms per liter

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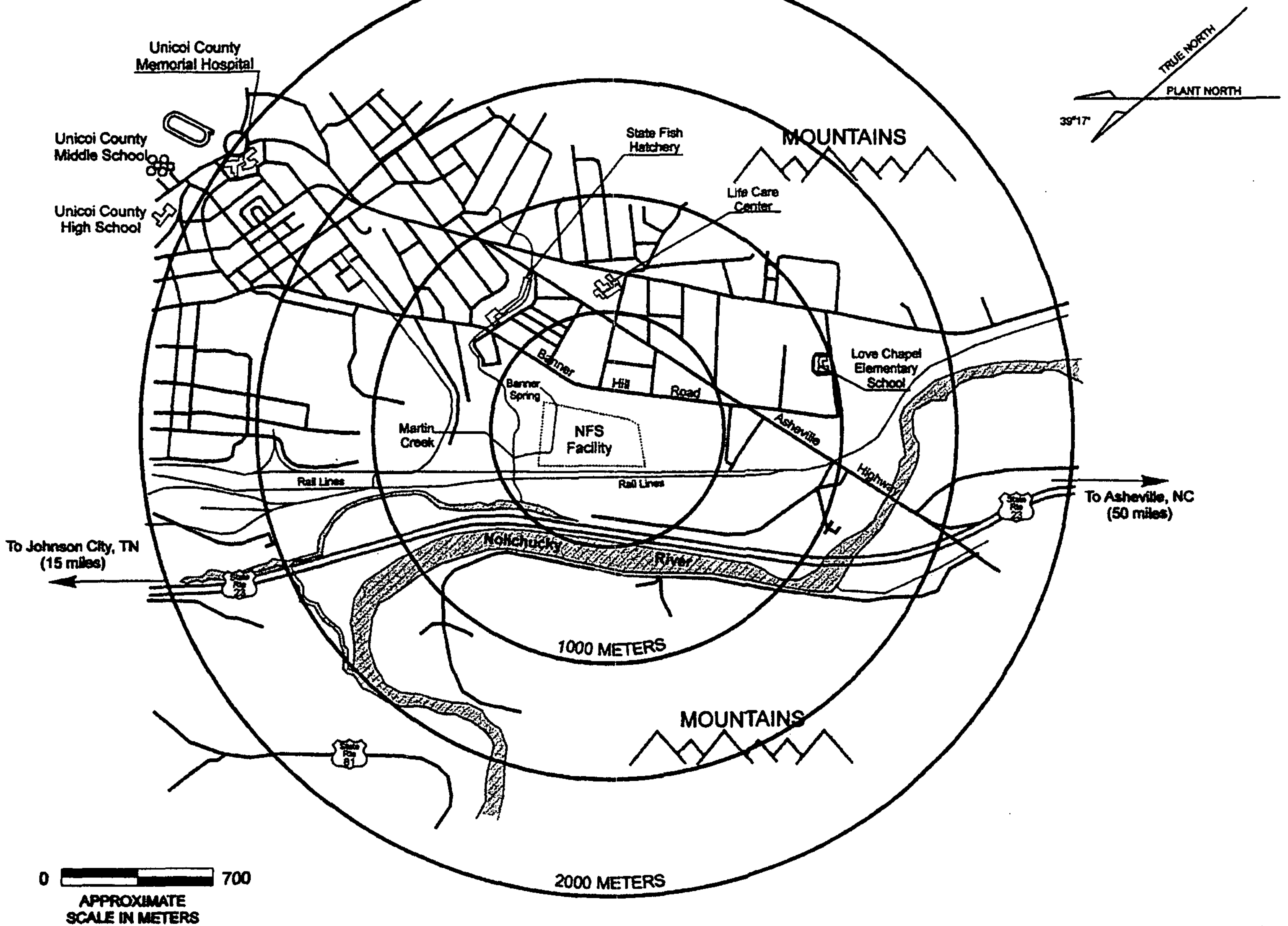

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GERAGHTY&MILLER

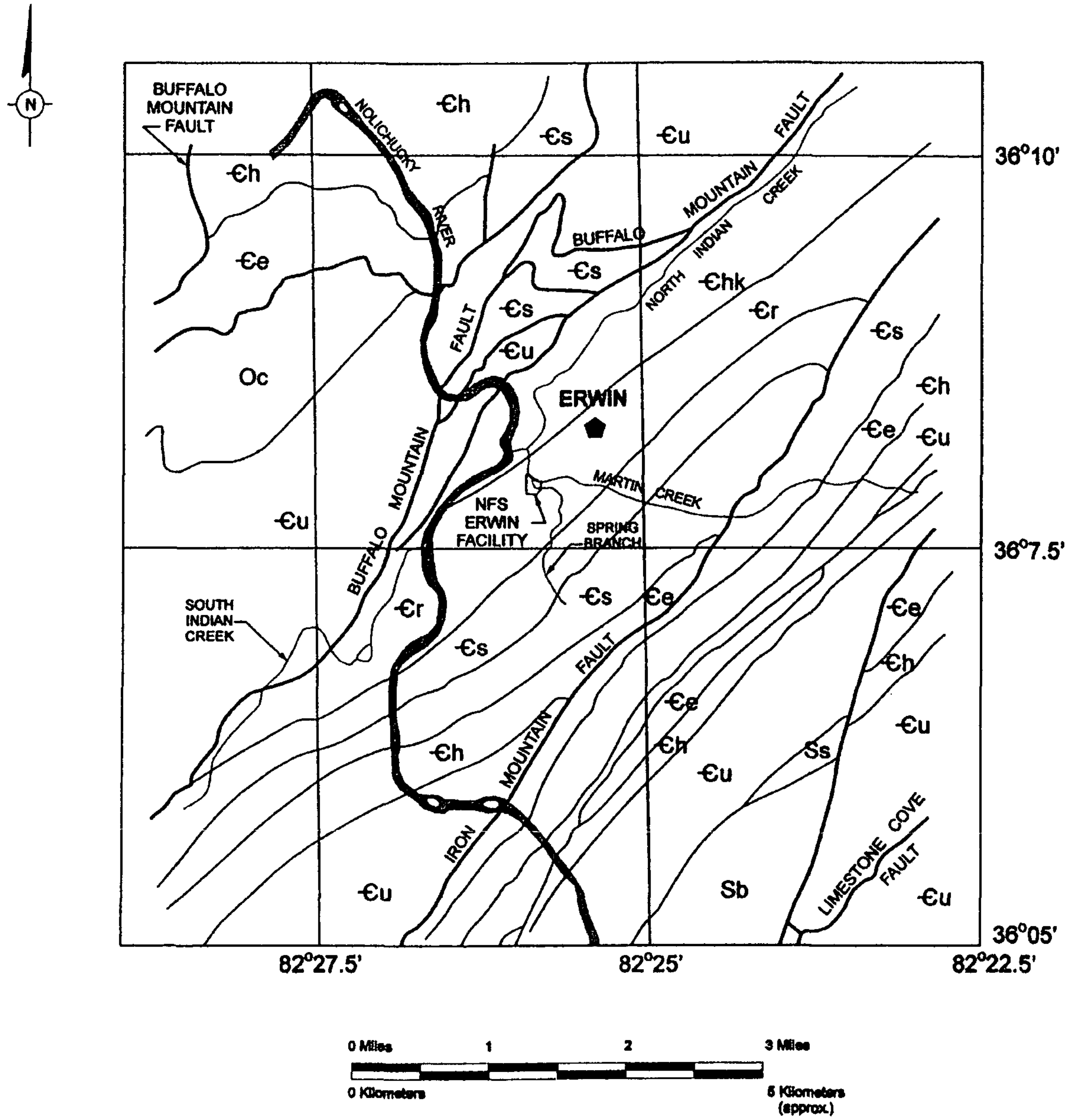
Area Location Map

Nuclear Fuel Services, Inc.   Erwin, Tennessee

FIGURE

1-2

DWG. DATE: 30NOV98 MD | PROJ. NO.: TN000487.0004.00001 | FILE NAME: MODEL RPT | DRAWING: D32740.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



EXPLANATION

PRECAMBRIAN (p€)

O c	Ocoee Group
S s	Sandsuck Shale
S b	Snowbird Formation

CAMBRIAN (€)

€ hk	Honaker Dolomite
€ r	Rome Formation
€ s	Shady Dolomite
€ e	Erwin Formation
€ h	Hampton Formation
€ u	Unicoi Formation

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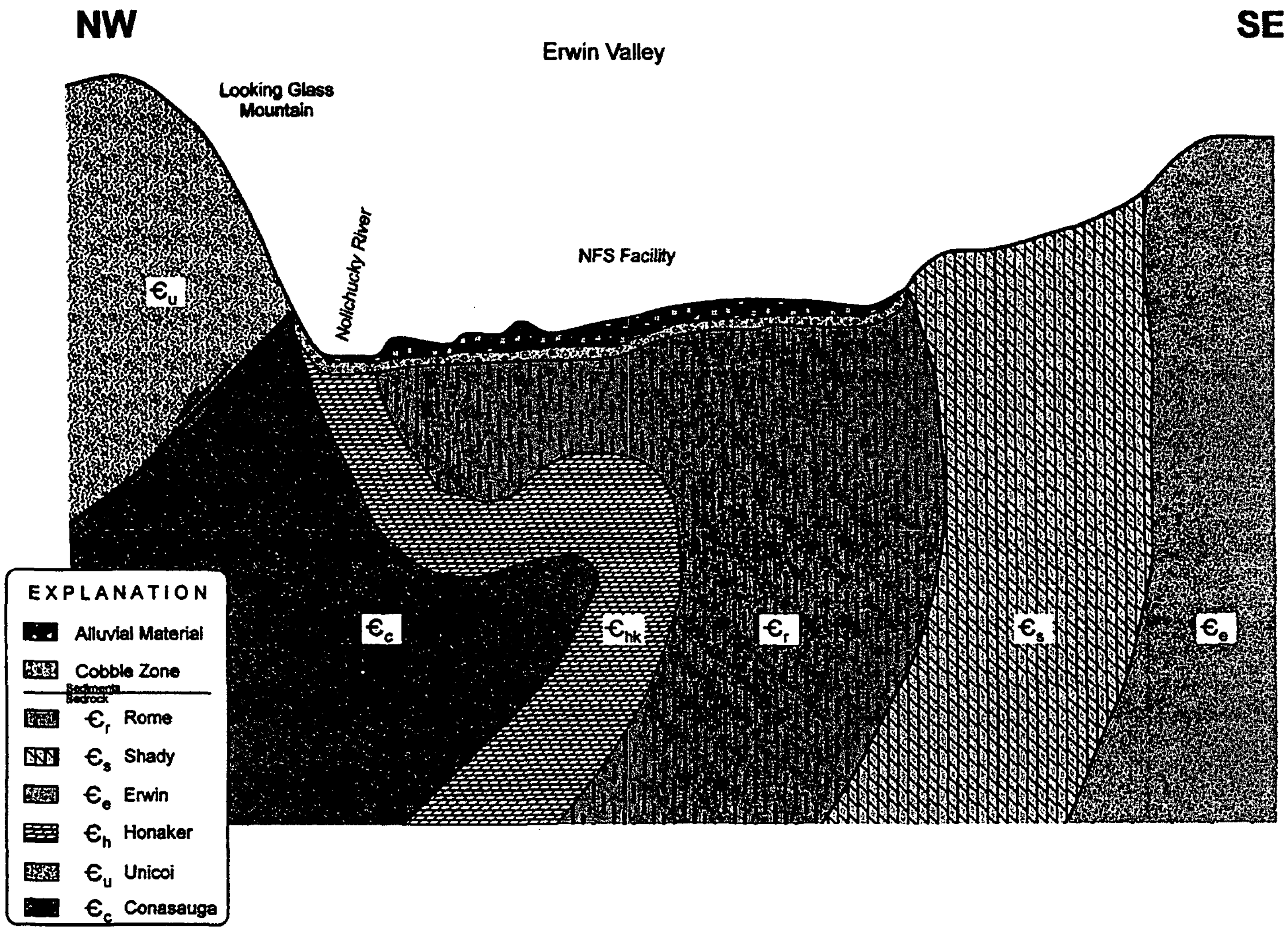
Geologic Map of the Erwin Region

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

2-1

DWG. DATE: 13DEC98 MD | PROJ. NO.: TN000487.0004.0001 | FILE NAME: MODEL RPT | DRAWING: D32739B.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



ARCADIS
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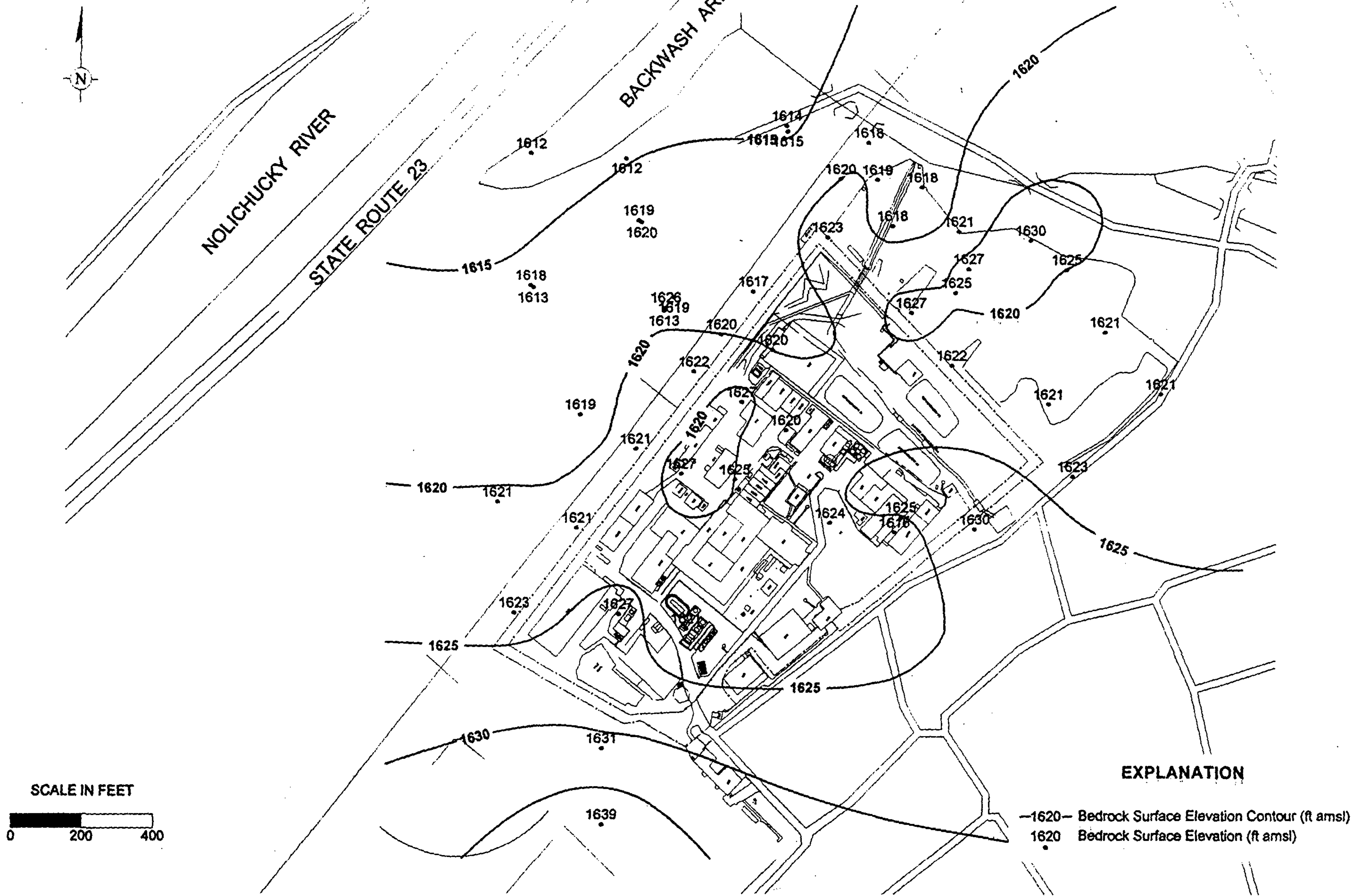
Generalized Geologic Cross Section, Literature Interpretation

Nuclear Fuel Services, Inc. Erwin, Facility

FIGURE
2-2

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG2-3A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS

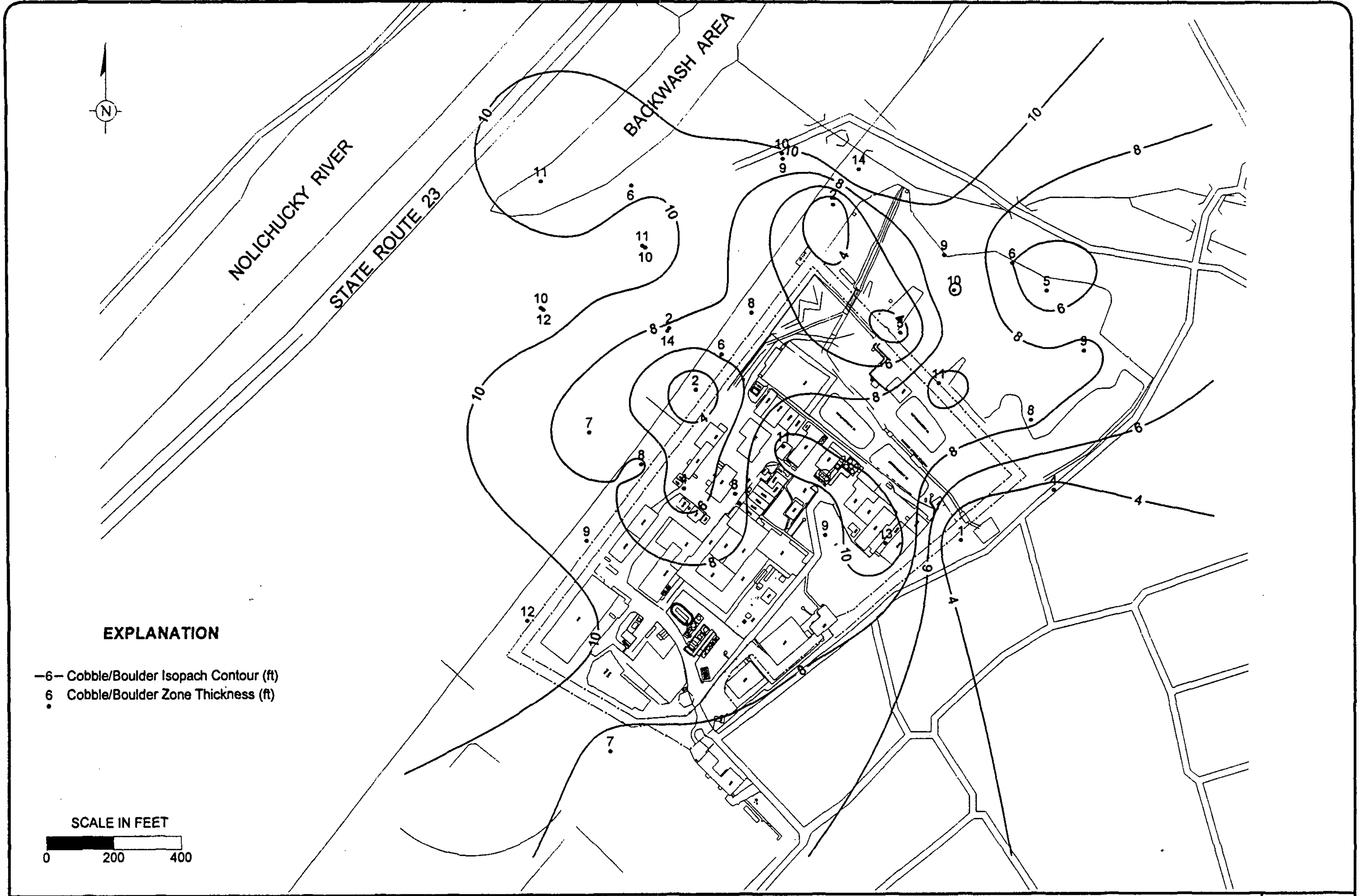
Revised Bedrock Surface Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

2-3

DWG DATE: 30NOV98 JH	PROJ. NO.:TN000487.0004.0001	RPT NAME: MODEL	DRAWING: FIG2-4A.SRF	PROJ. MANAGER: B. MOORE	PROJ. OFFICER: B. ILGNER	DRAFTER: J. HUGHES



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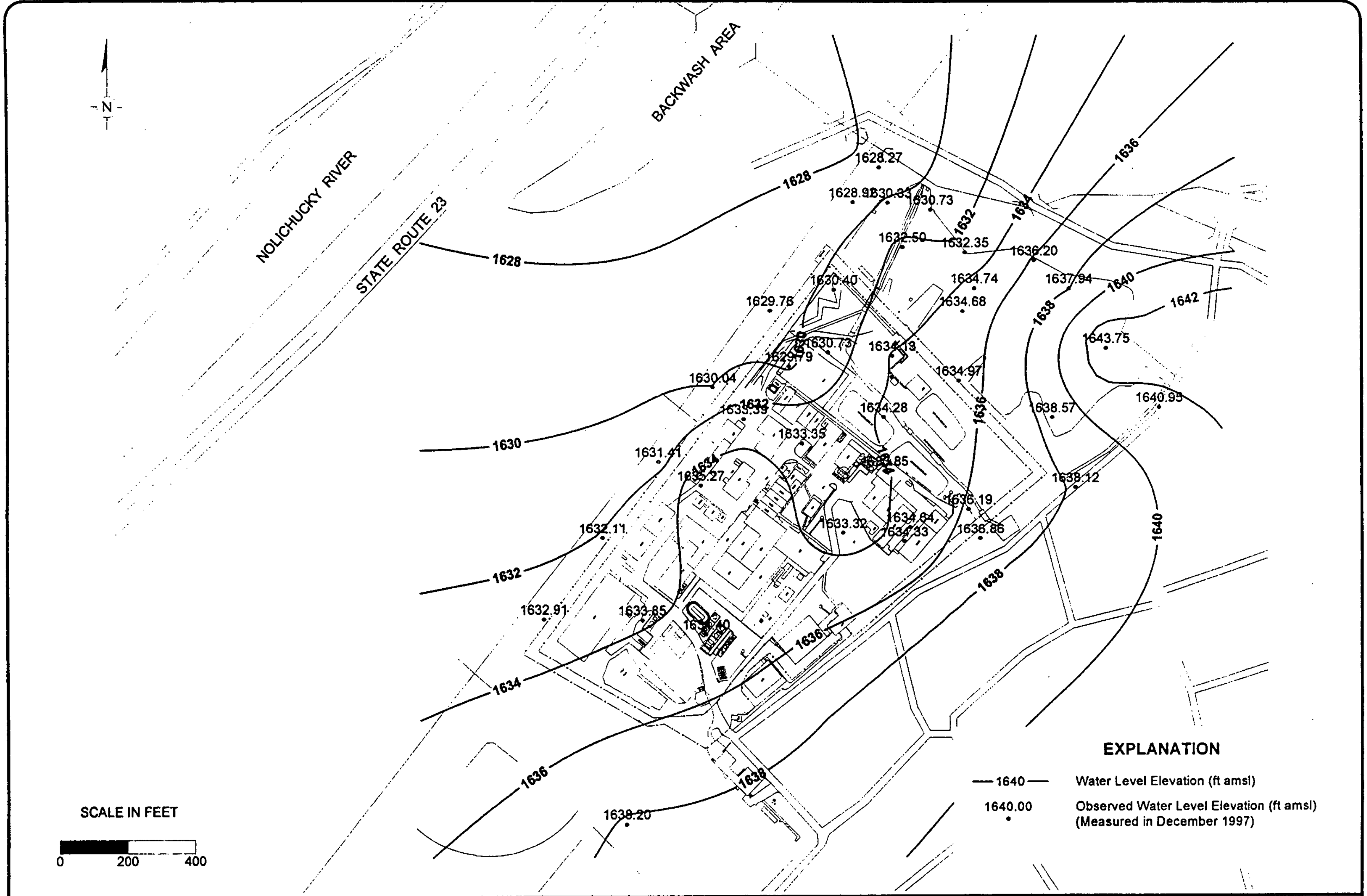
Revised Cobble/Boulder Zone Isopach Map

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-4

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG2-5A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



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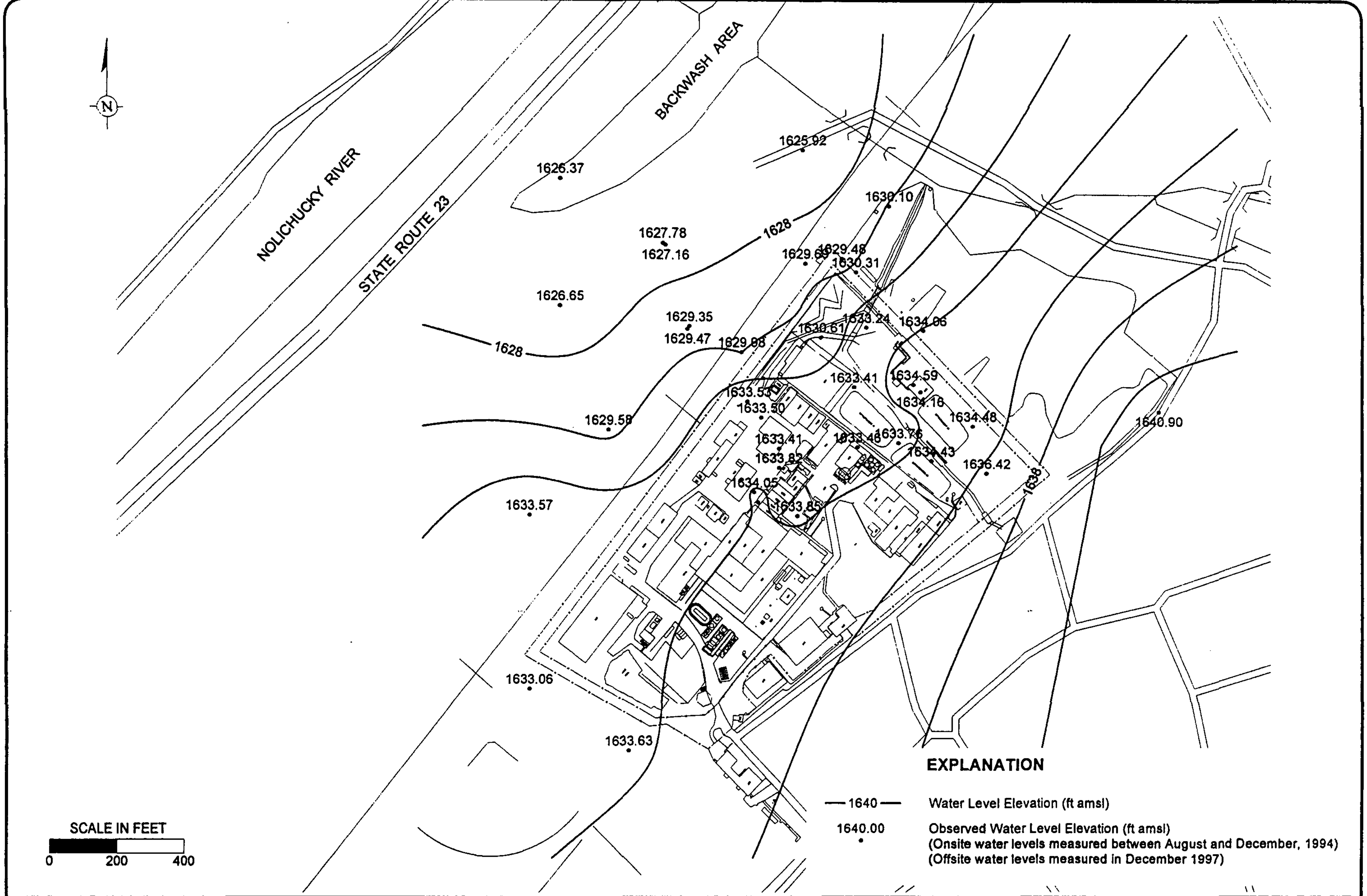
GERAGHTY&MILLER

Water-Level Elevation in the Shallow Alluvium Zone

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-5

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG2-6A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

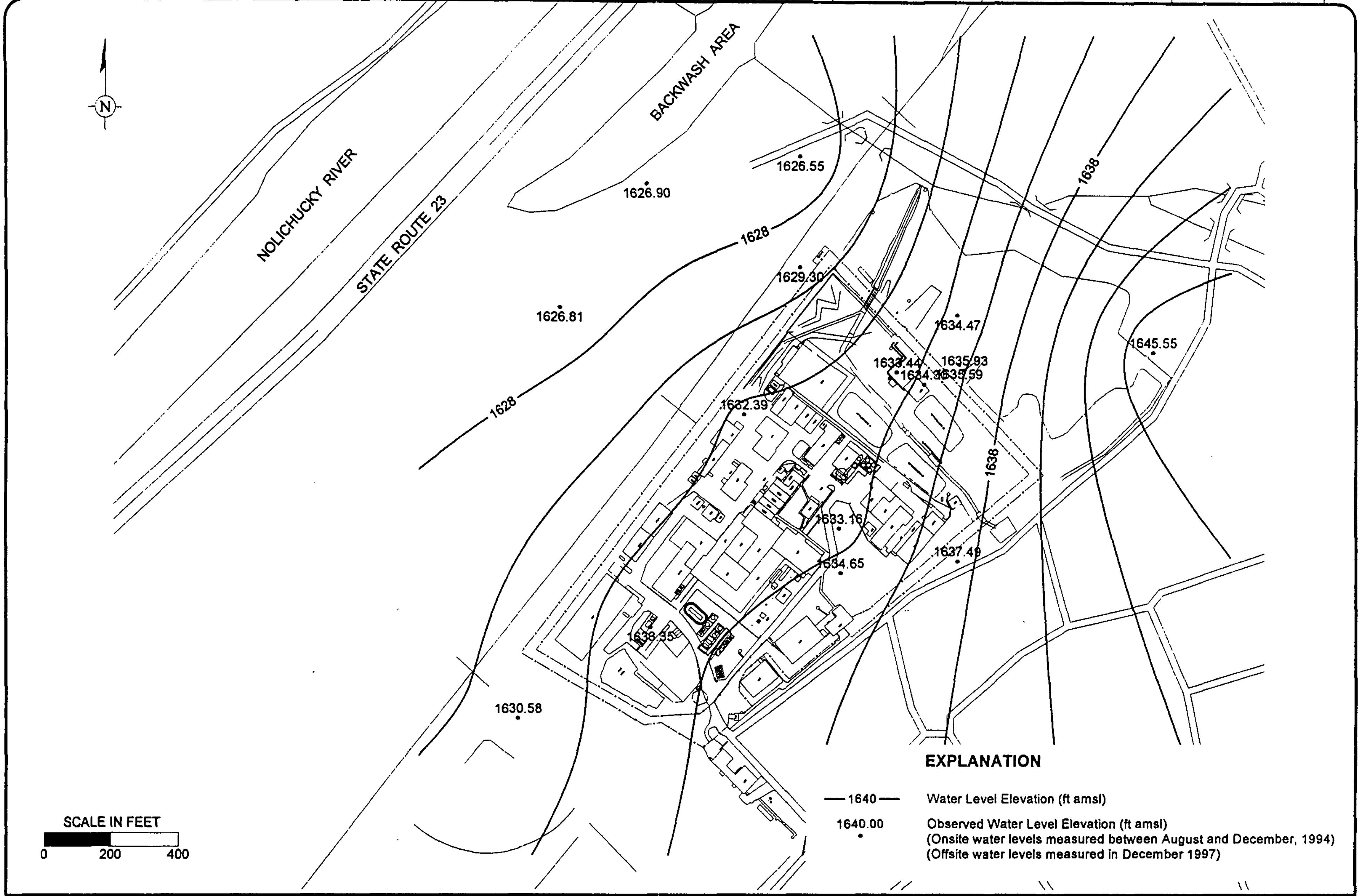
Water-Level Elevation in the Cobble/Boulder Zone

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

2-6

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG2-7A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



EXPLANATION

—1640—	Water Level Elevation (ft amsl)
1640.00 •	Observed Water Level Elevation (ft amsl) (Onsite water levels measured between August and December, 1994) (Offsite water levels measured in December 1997)

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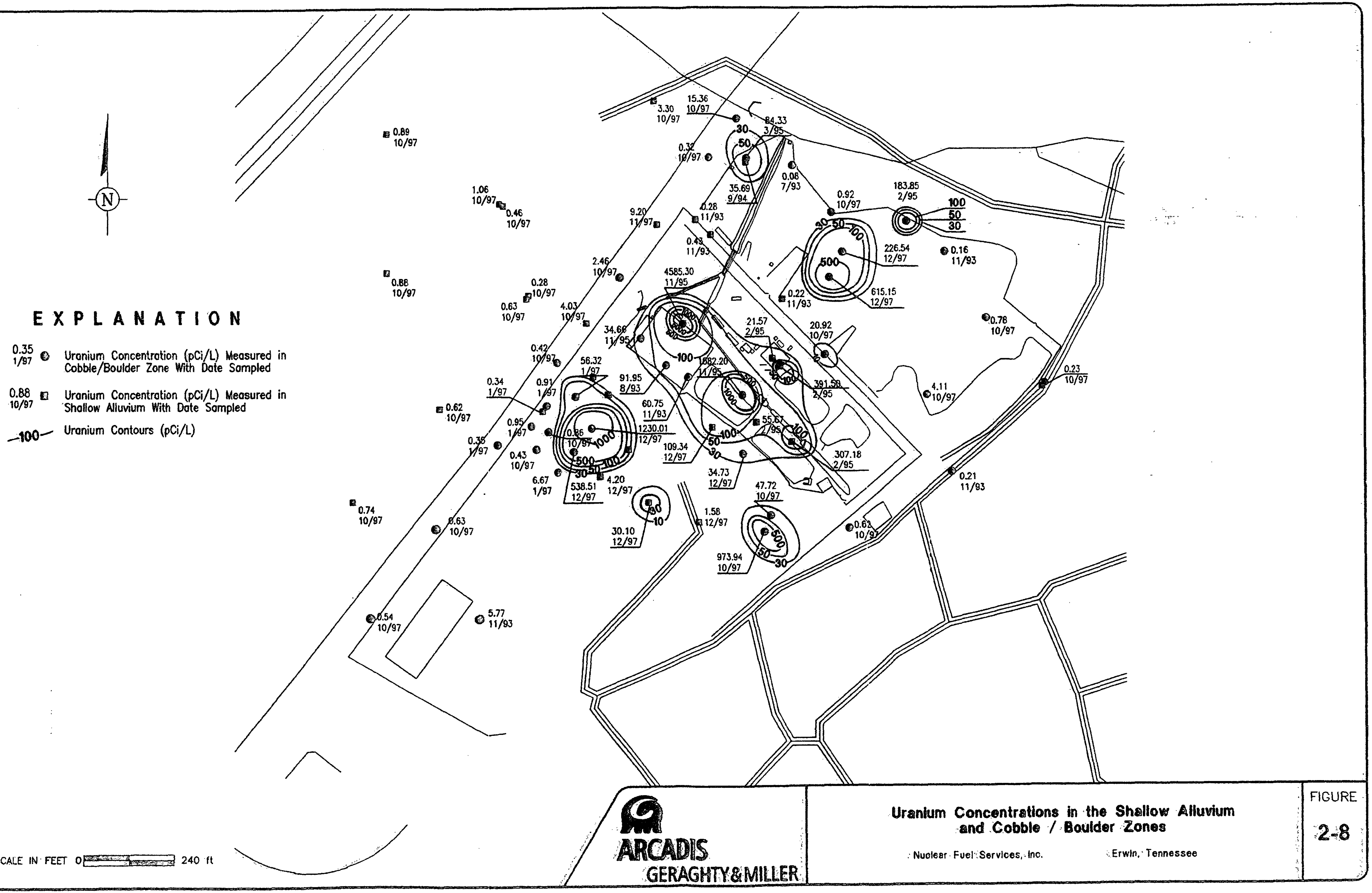
Water-Level Elevation in the Shallow Bedrock Zone

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-7



EXPLANATION

0.35 1/97	●	Uranium Concentration (pCi/L) Measured in Cobble/Boulder Zone With Date Sampled
0.88 10/97	▣	Uranium Concentration (pCi/L) Measured in Shallow Alluvium With Date Sampled
—100—		Uranium Contours (pCi/L)

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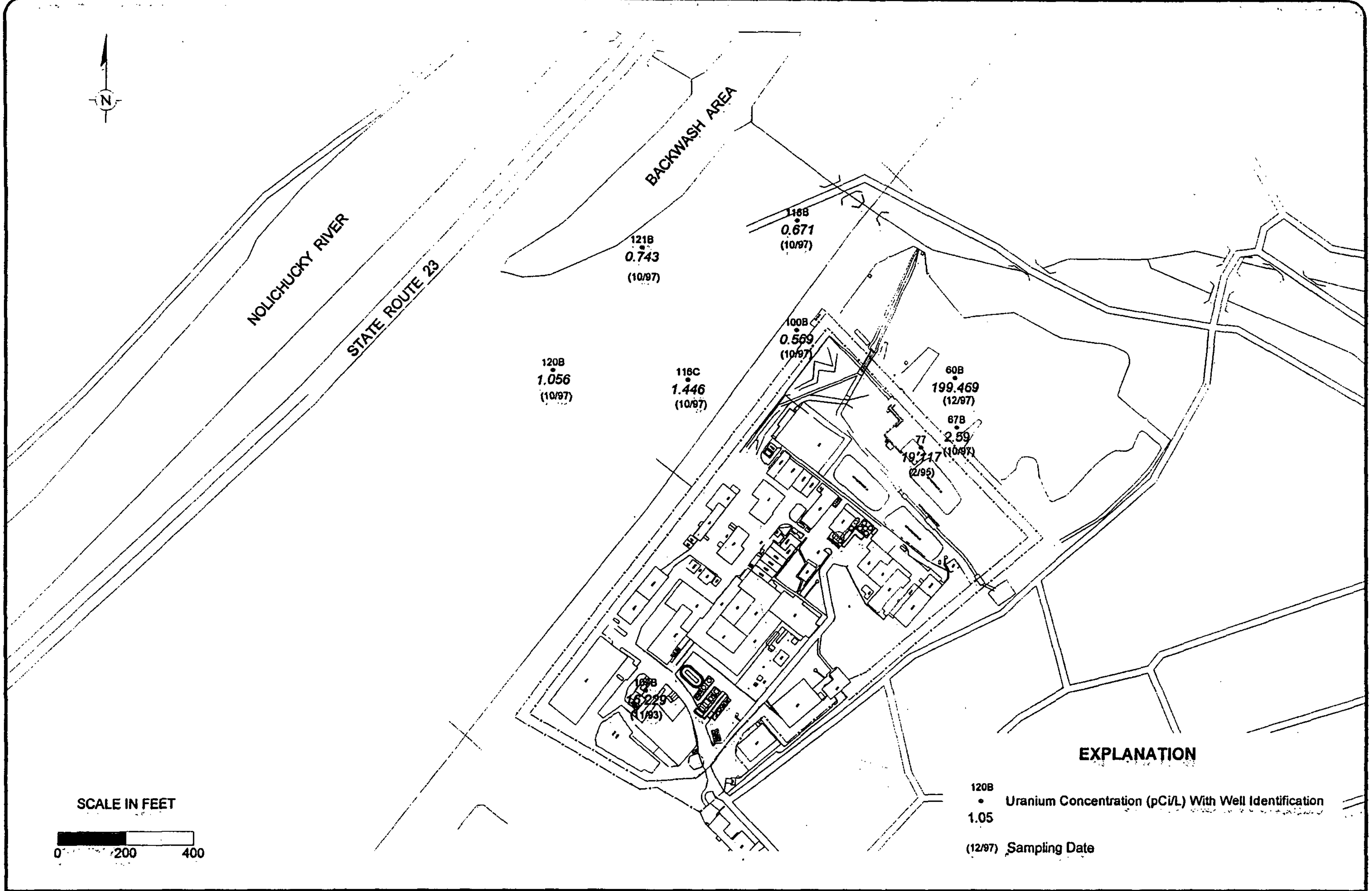
Uranium Concentrations in the Shallow Alluvium and Cobble / Boulder Zones

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-8

DWG DA 01DEC98 MD | PROJ. NO.: TN000487.0004 | FILE: MODEL RPT | DRAWING: D32657.DWG | PROJ. MGR.: B. MOORE | PROJ. OFFICER: J. ARCHER | DRAFTER: M. DAY

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG2-9.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



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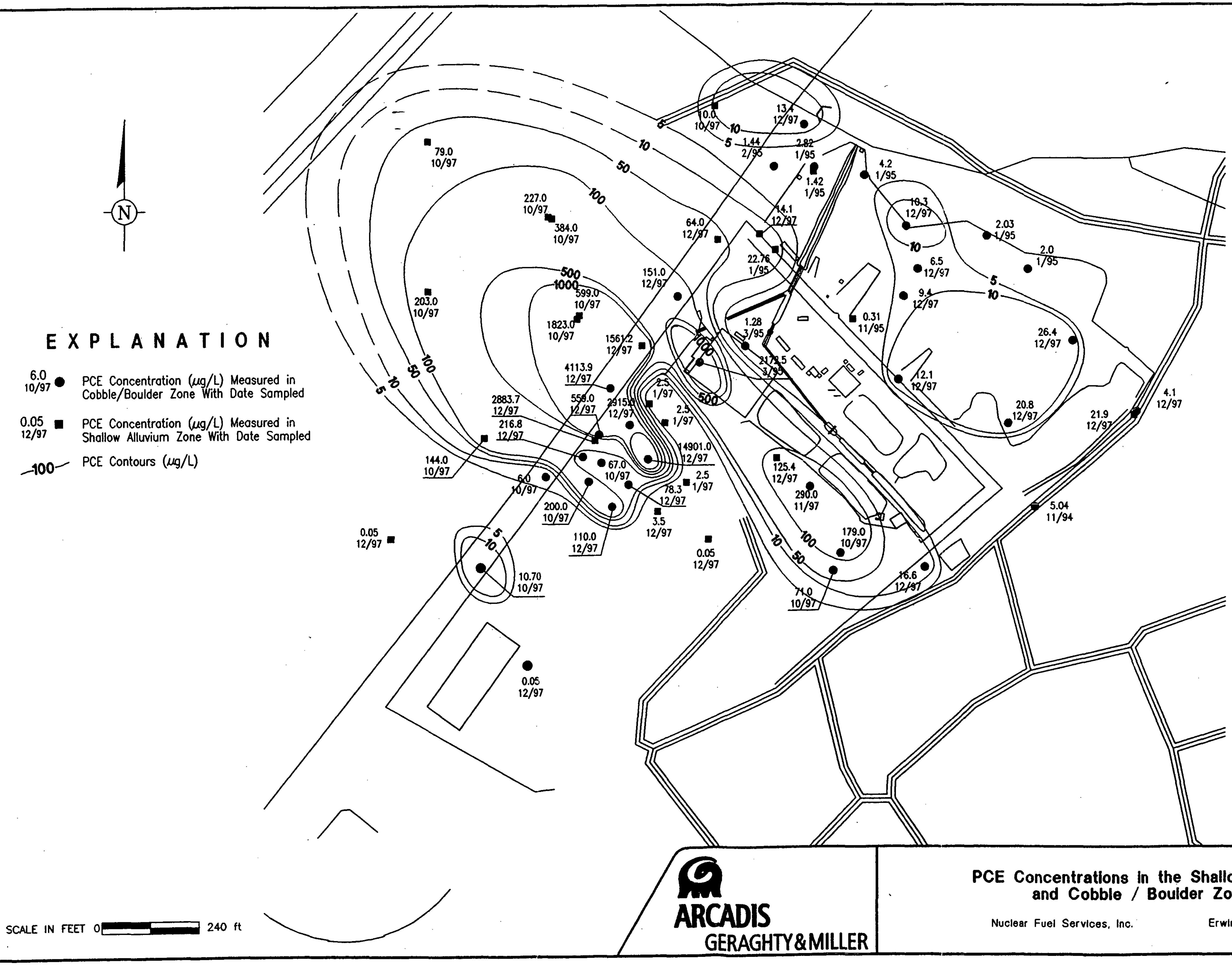
Uranium Concentrations in the Shallow Bedrock

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-9



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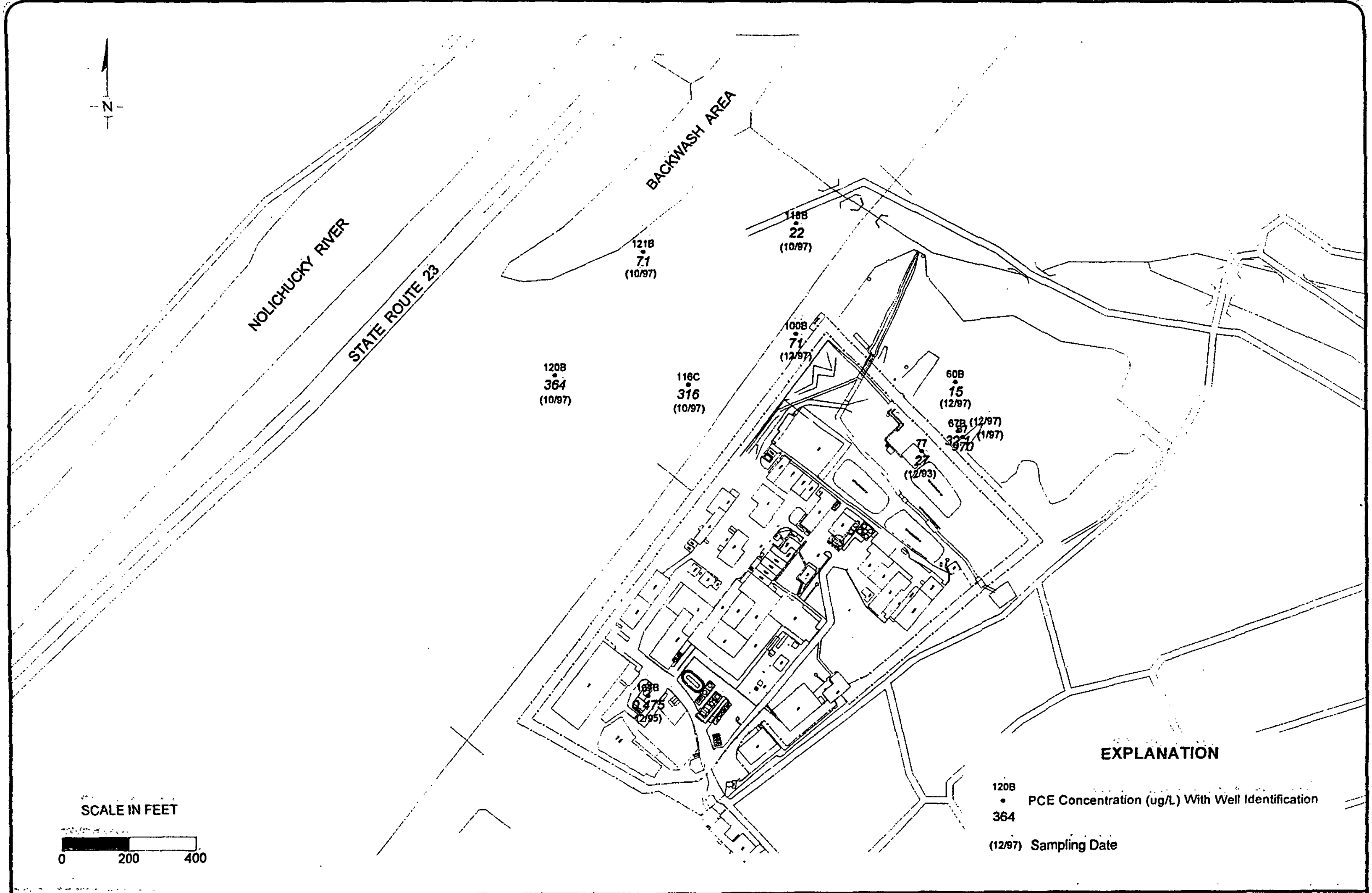
PCE Concentrations in the Shallow Alluvium and Cobble / Boulder Zones

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
2-10

DWG DATE: 01DEC98 MD | PROJ. NO.: TN000487.0004 | FILE: MODEL RPT | DRAWING: D32657.DWG | PROJ. MGR.: B. MOORE | PROJ. OFFICER: J. ARCHER | DRAFTER: M. DAY

DWG DATE: 30NOV98 JH | PROJ: NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG2-11A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



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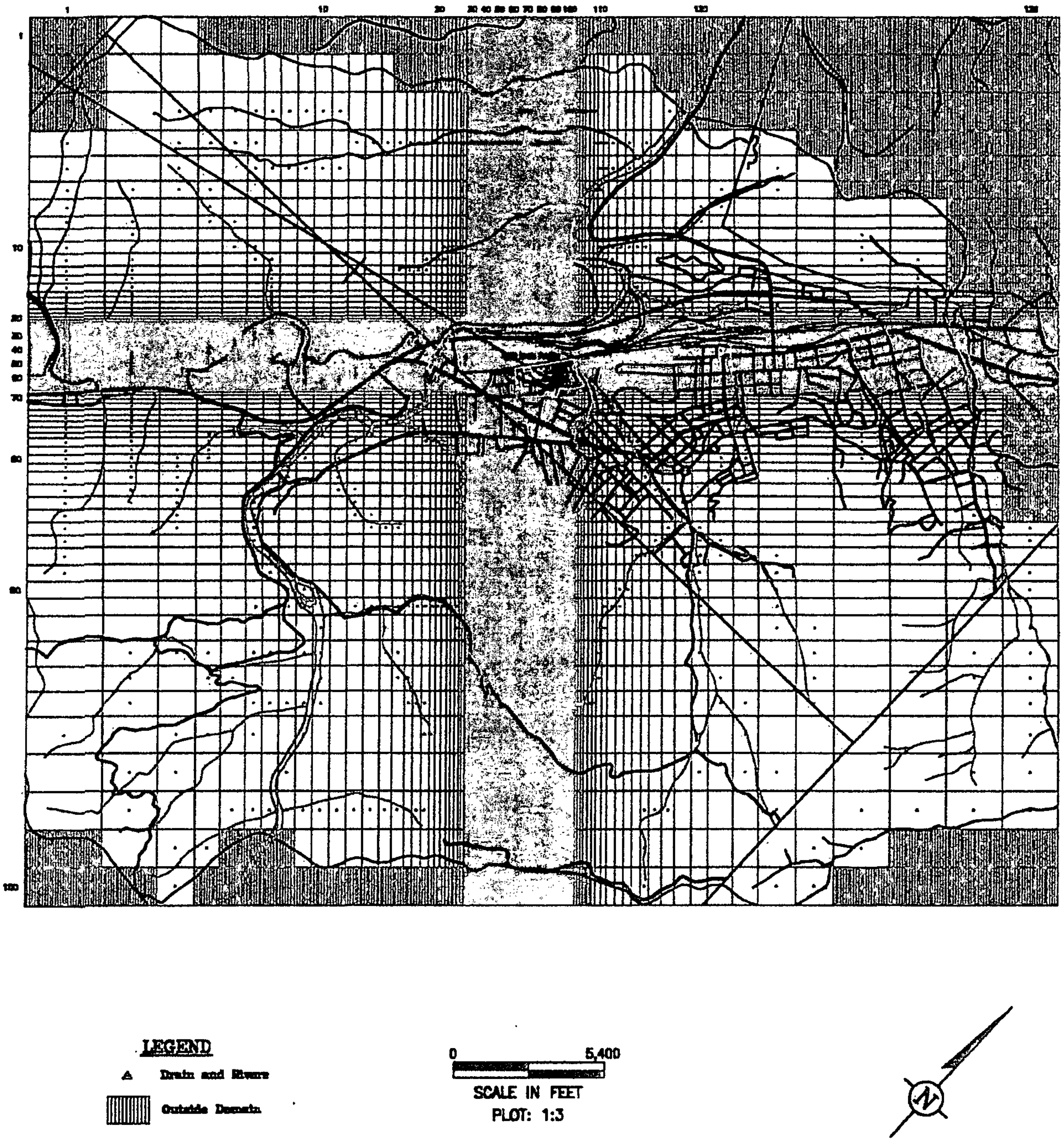
PCE Concentrations in the Shallow Bedrock

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

2-11

DWG DATE: 25NOV98 MD | PROJ. NO.: TN000487.0004.00001 | FILE: GW MODEL | DRAWING: D32736.DWG | PROJ. MGR.: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



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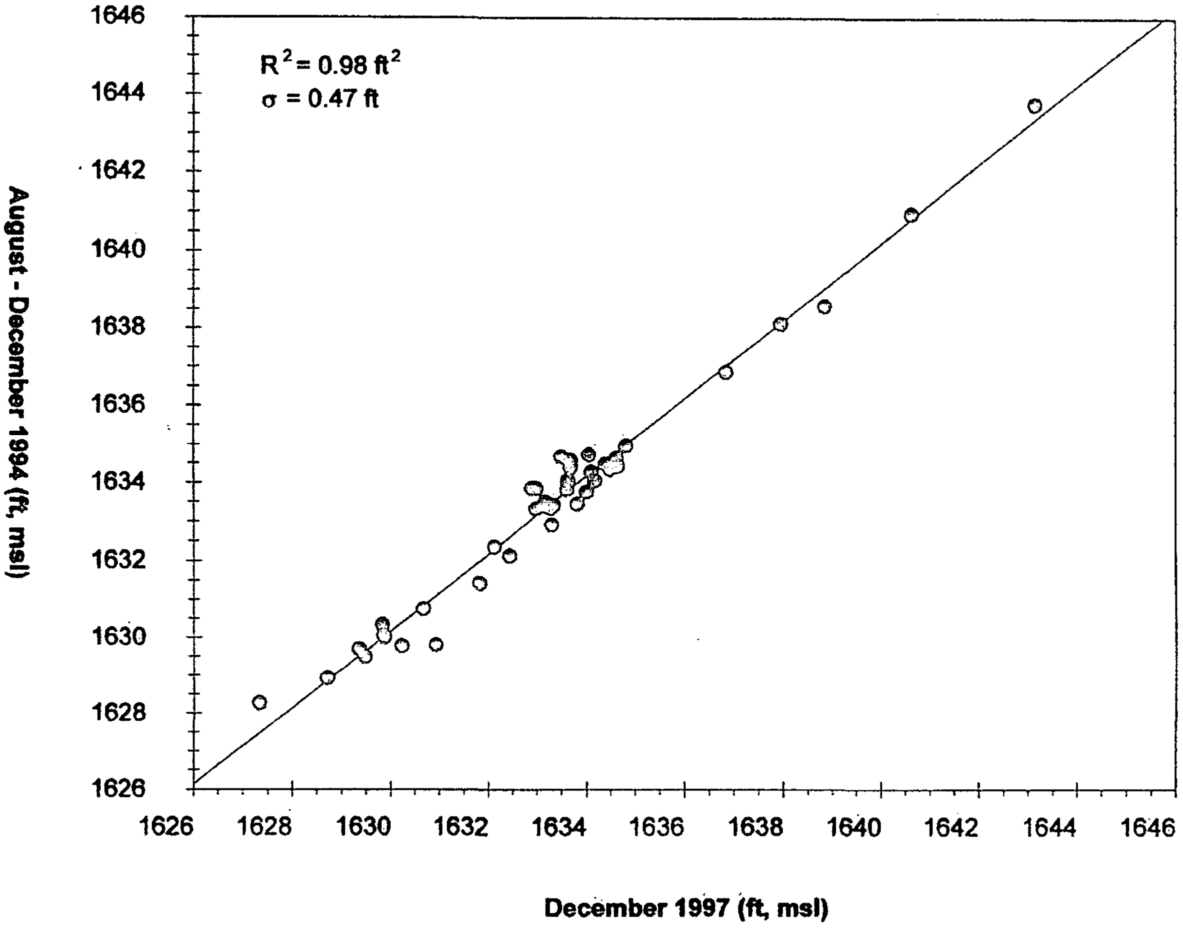
Finite Difference Mesh and Boundary Conditions

Nuclear Fuel Service, Inc. Erwin, Tennessee

FIGURE
3-1

DWG. DATE: 01DEC98 MD | PROJ. NO.: TN000487.0004.00001 | FILE NAME: MODEL RPT | DRAWING: D32744.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



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Relationship Between Water Levels Measured in Dec. 1997 and Average Water Levels Measured from Aug. Through Dec. 1994

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
3-2

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-3A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES

EXPLANATION

Zone	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Formation
1	15	10	1.25	Rome
2	8	4	0.8	Honaker
3	4	2	0.2	Shady
4	0.04	0.02	0.02	Erwin, Hampton, Unicoi, Snowbird
5	3	3	0.15	Zone 1 Alluvium
6	40	40	2	Zone 2 Alluvium
7	Outside model domain (No flow cells)			

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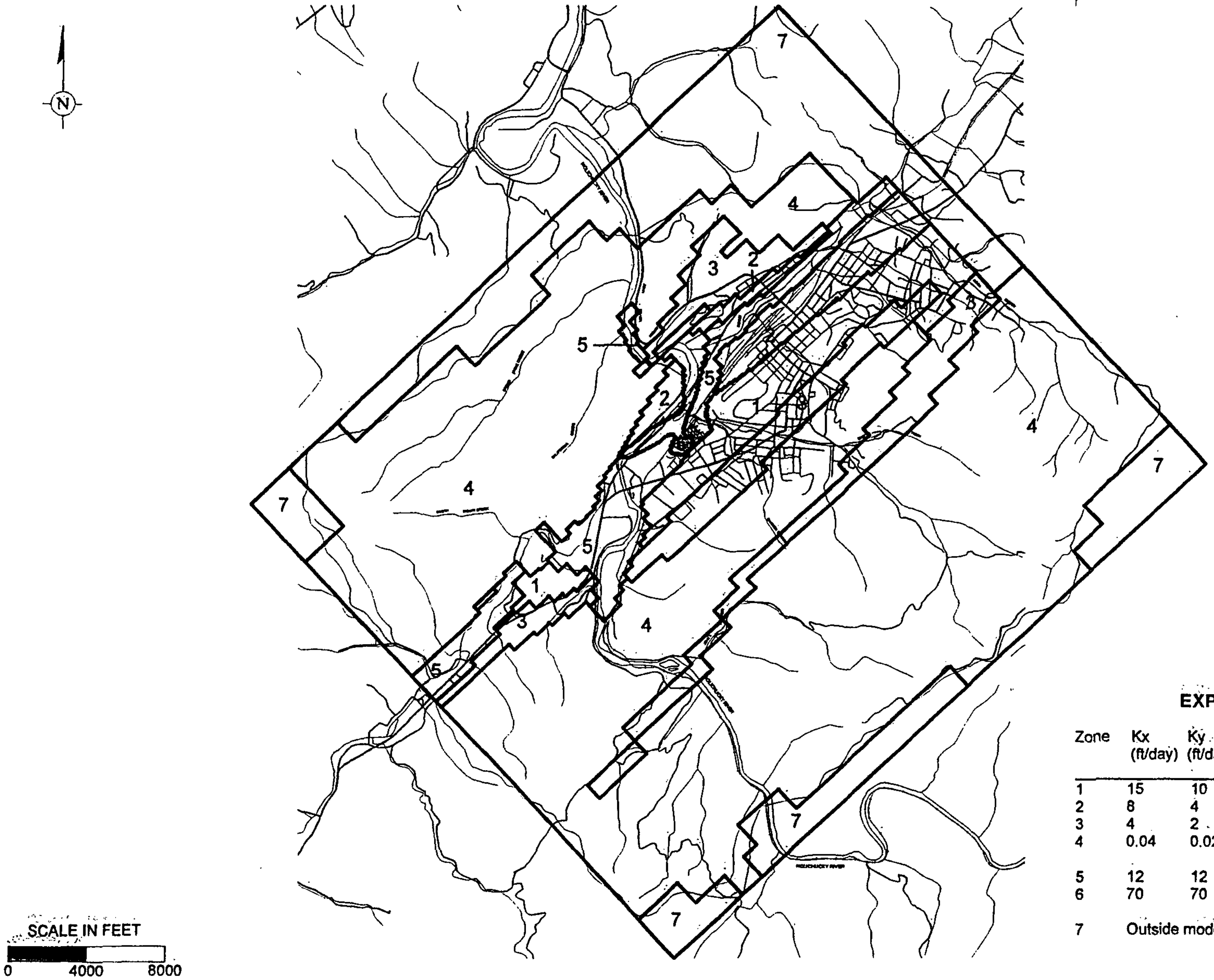
Hydraulic Conductivity Zonation for Model Layer 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 3-3

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-4A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



EXPLANATION

Zone	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Formation
1	15	10	1.25	Rome
2	8	4	0.8	Honaker
3	4	2	0.2	Shady
4	0.04	0.02	0.02	Erwin, Hampton, Unicoi, Snowbird
5	12	12	0.6	Zone 1 Cobble Zone
6	70	70	3.5	Zone 2 Cobble Zone
7	Outside model domain (No flow cells)			

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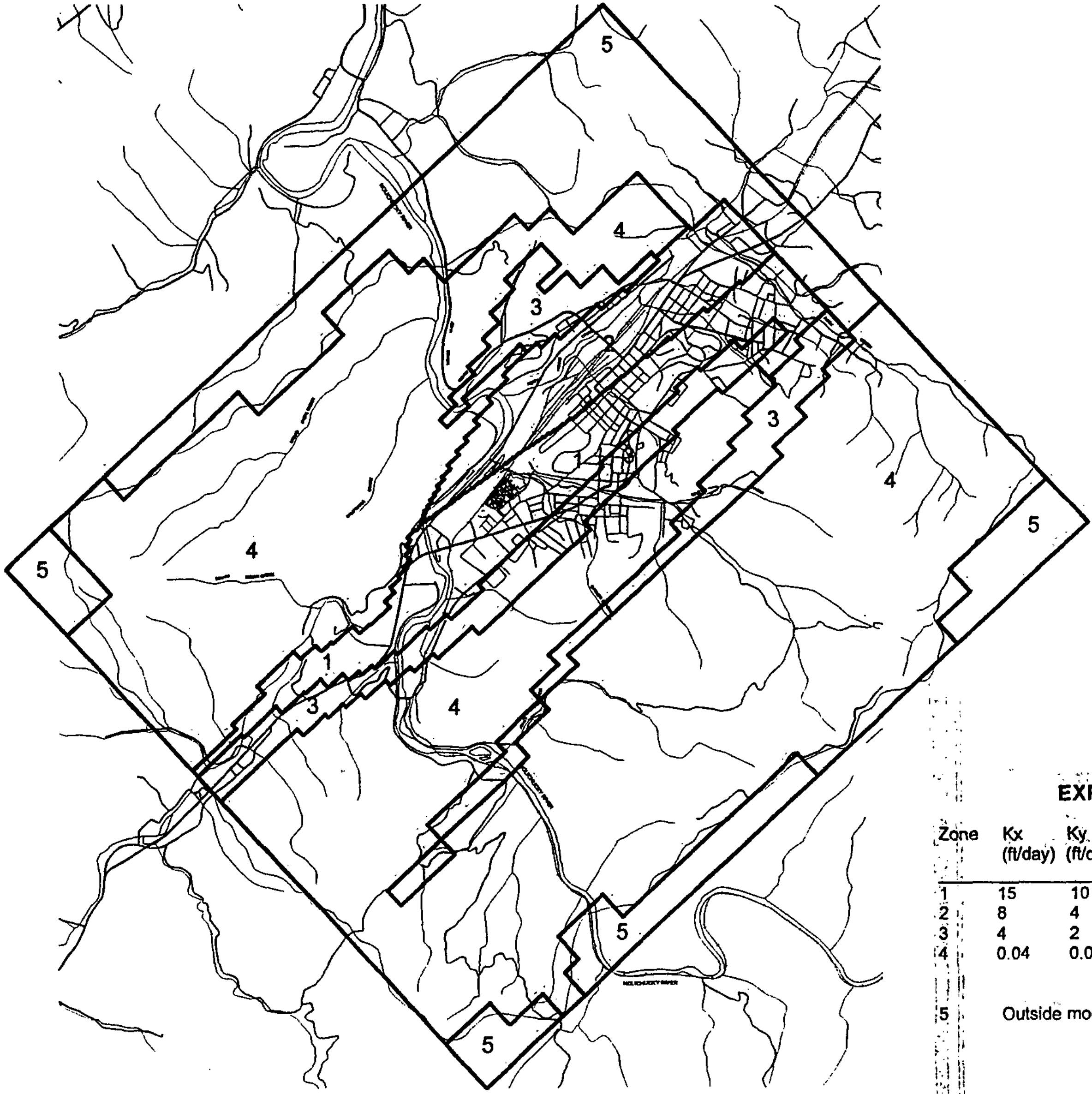
Hydraulic Conductivity Zonation for Model Layer 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

3-4

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-5A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



EXPLANATION

Zone	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Formation
1	15	10	1.25	Rome
2	8	4	0.8	Honaker
3	4	2	0.2	Shady
4	0.04	0.02	0.02	Erwin, Hampton, Unicoi, Snowbird
5	Outside model domain (No flow cells)			

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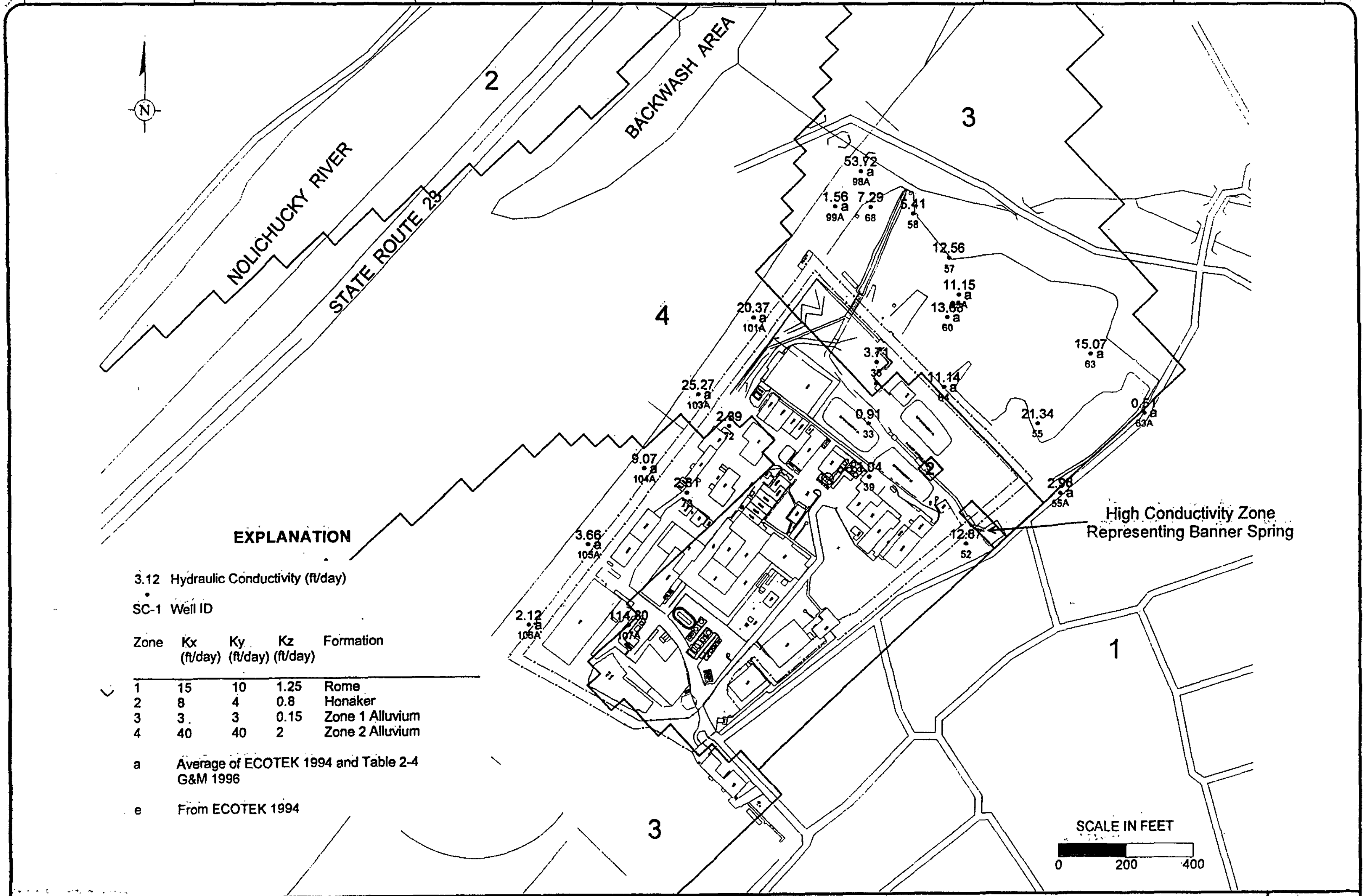
Hydraulic Conductivity Zonation for Model Layers 3, 4, and 5

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
3-5

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-6A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



EXPLANATION

3.12 Hydraulic Conductivity (ft/day)

SC-1 Well ID

Zone	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Formation
1	15	10	1.25	Rome
2	8	4	0.8	Honaker
3	3	3	0.15	Zone 1 Alluvium
4	40	40	2	Zone 2 Alluvium

a Average of ECOTEK 1994 and Table 2-4 G&M 1996

e From ECOTEK 1994

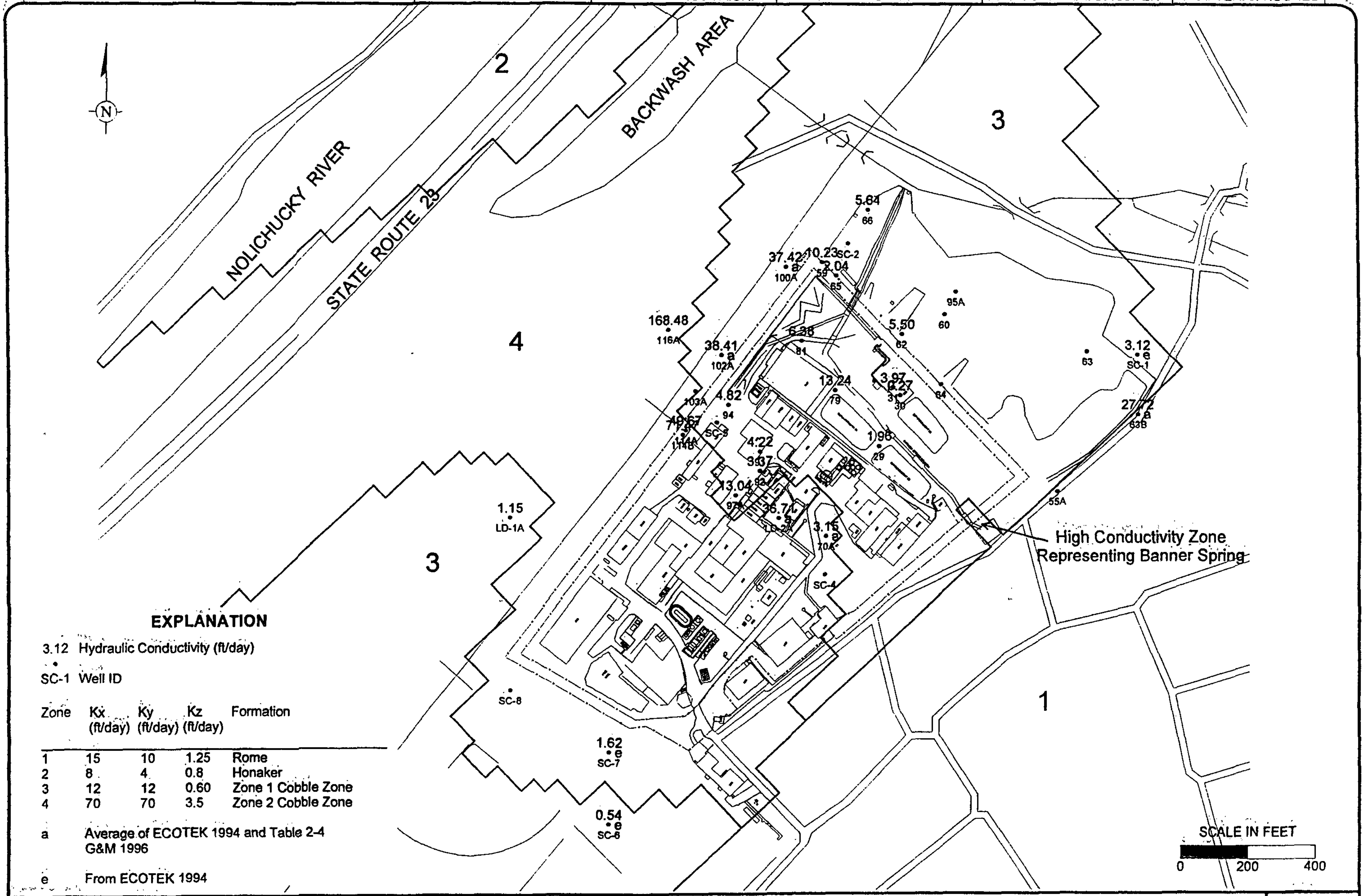
ARCADIS
GERAGHTY & MILLER

Observed Hydraulic Conductivity and Hydraulic Conductivity Zonation in Model Layer 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
3-6

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-7A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



EXPLANATION

3.12 Hydraulic Conductivity (ft/day)

SC-1 Well ID

Zone	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Formation
1	15	10	1.25	Rome
2	8	4	0.8	Honaker
3	12	12	0.60	Zone 1 Cobble Zone
4	70	70	3.5	Zone 2 Cobble Zone

a Average of ECOTEK 1994 and Table 2-4 G&M 1996

e From ECOTEK 1994

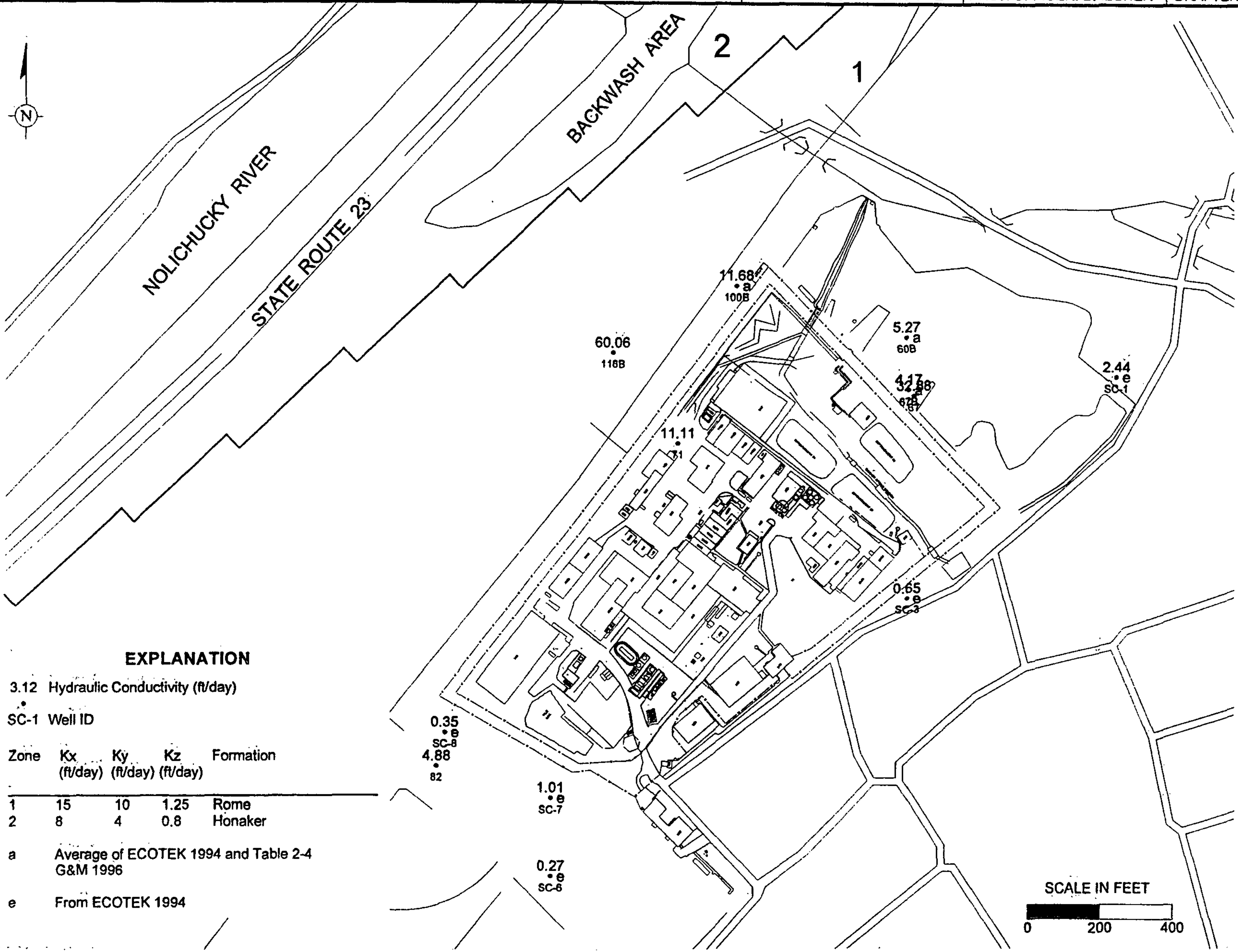
ARCADIS
GERAGHTY & MILLER

Observed Hydraulic Conductivity and Hydraulic Conductivity Zonation in Model Layer 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
3-7

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-8A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



EXPLANATION

3.12 Hydraulic Conductivity (ft/day)

SC-1 Well ID

Zone	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Formation
1	15	10	1.25	Rome
2	8	4	0.8	Honaker

a Average of ECOTEK 1994 and Table 2-4 G&M 1996

e From ECOTEK 1994

ARCADIS
GERAGHTY & MILLER

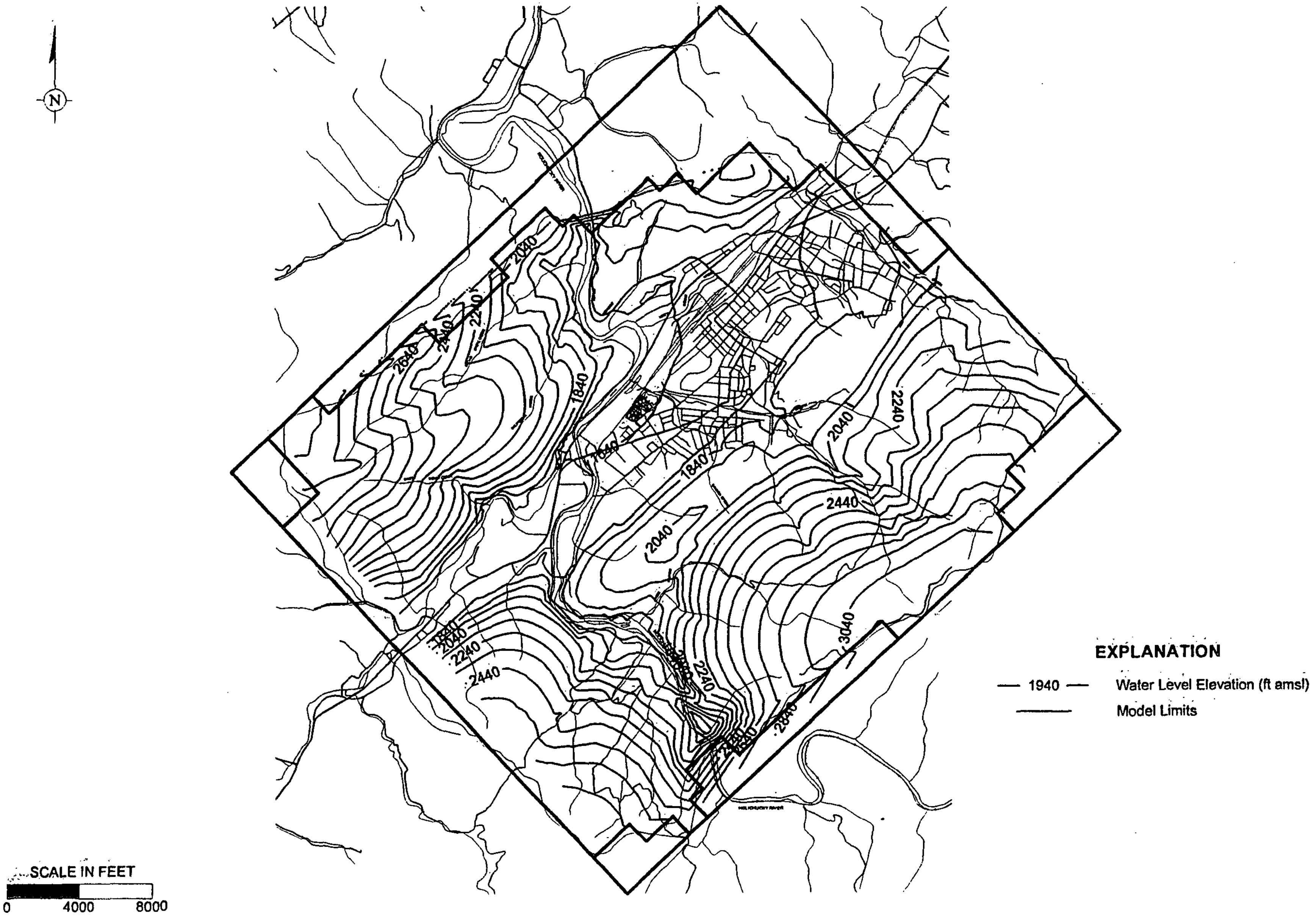
Observed Hydraulic Conductivity and Hydraulic Conductivity Zonation in Model Layer 3

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

3-8

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-9A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS GERAGHTY & MILLER

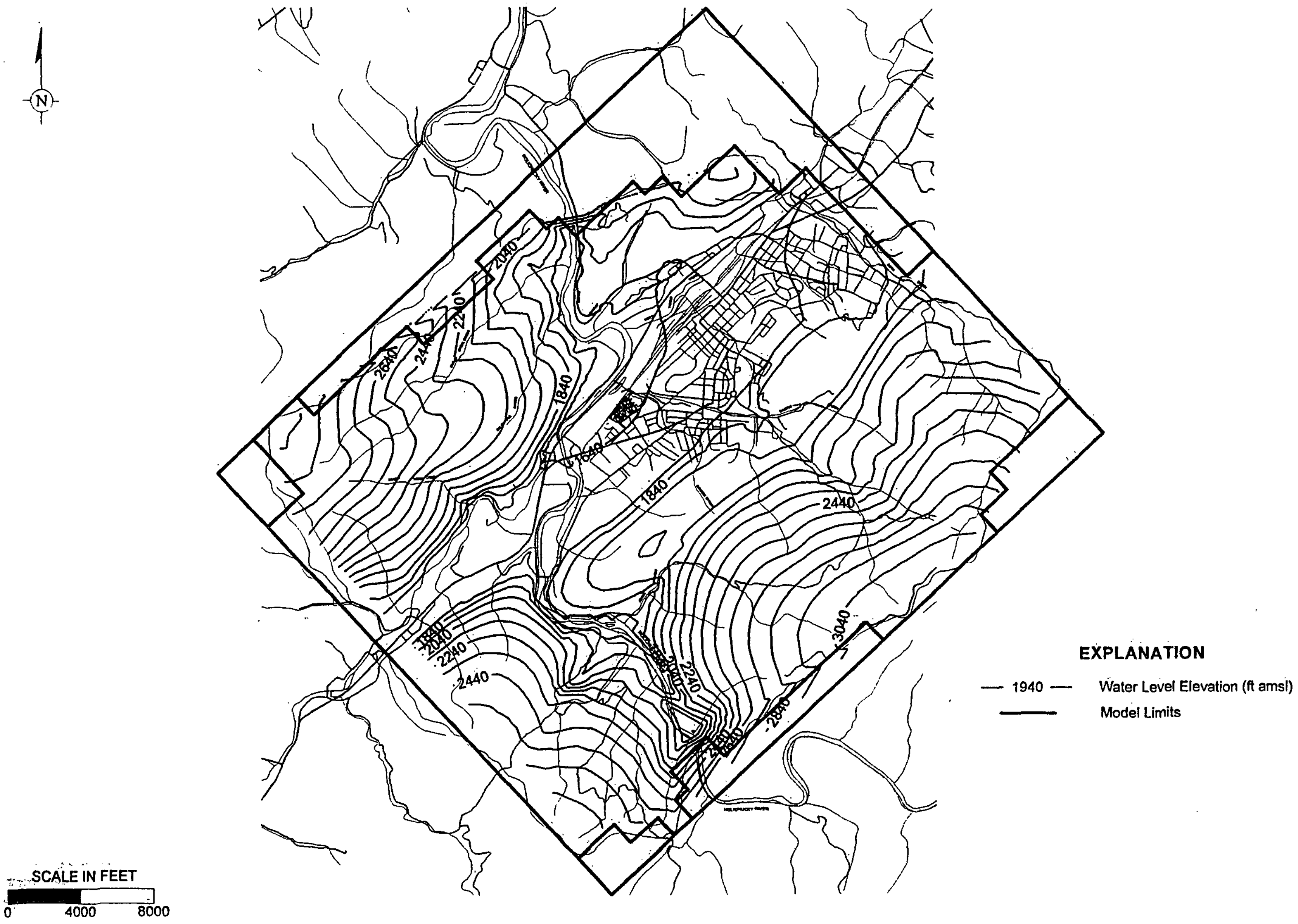
Simulated Regional Hydraulic Head Distribution in Model Layer 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

3-9

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-10A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS GERAGHTY & MILLER

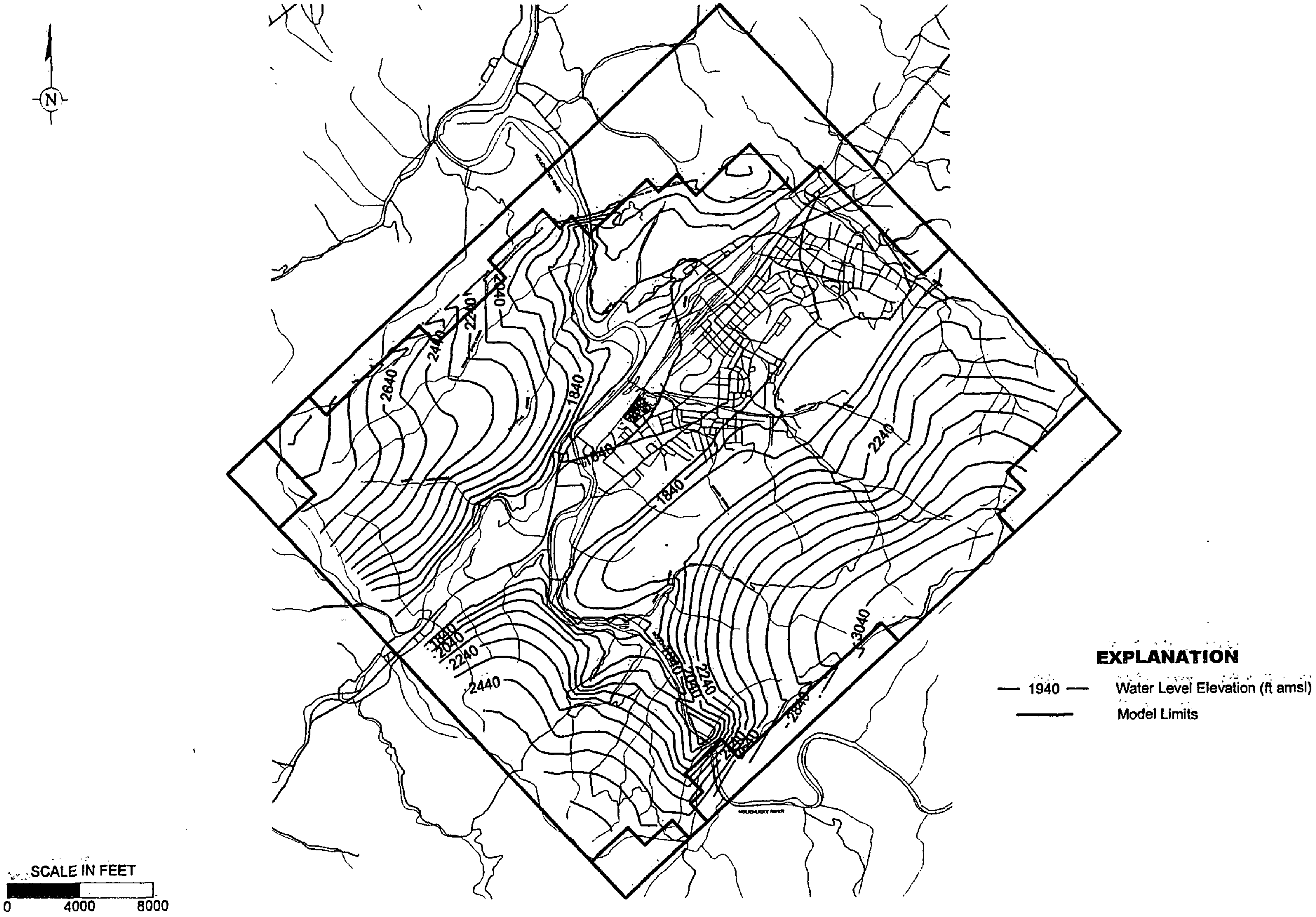
Simulated Regional Hydraulic Head Distribution in Model Layer 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

3-10

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-11A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



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GERAGHTY & MILLER

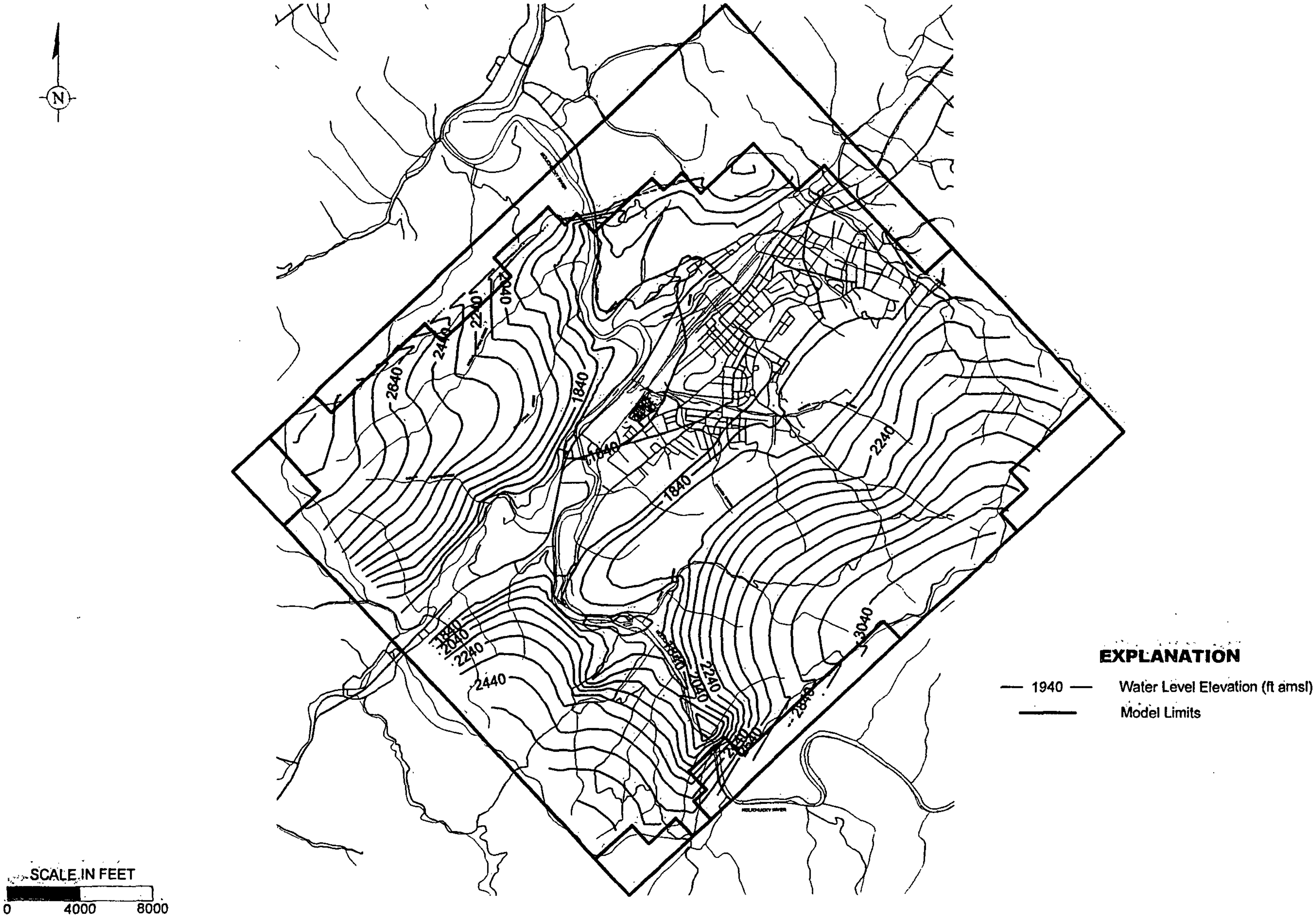
Simulated Regional Hydraulic Head Distribution in Model Layer 3

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

3-11

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-12A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



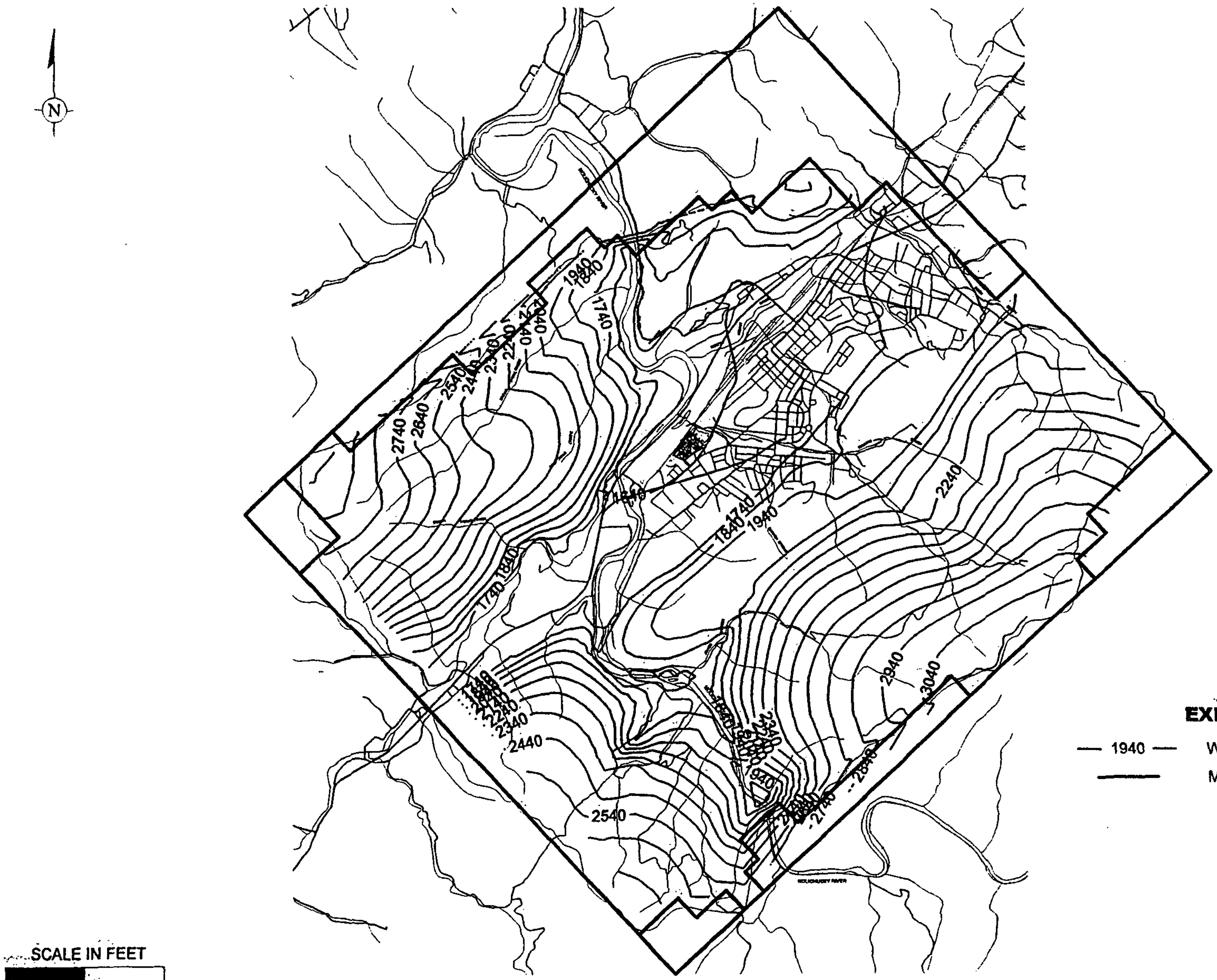
ARCADIS
GERAGHTY & MILLER

Simulated Regional Hydraulic Head Distribution in Model Layer 4

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
3-12

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-13A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



EXPLANATION

— 1940 — Water Level Elevation (ft amsl)

——— Model Limits

SCALE IN FEET

0 4000 8000

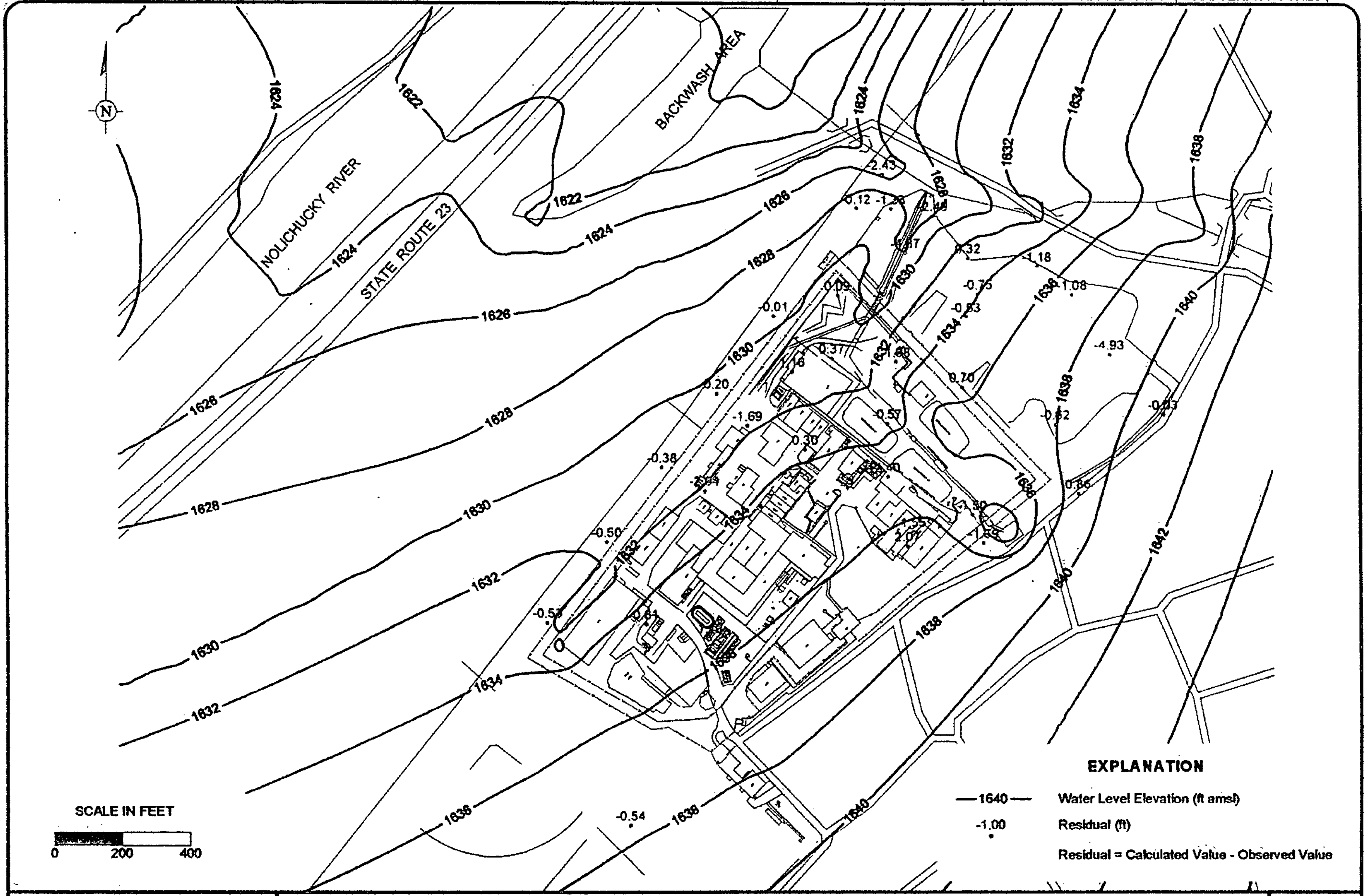
ARCADIS GERAGHTY&MILLER

Simulated Regional Hydraulic Head Distribution in Model Layer 5

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE 3-13

DWG. DATE: 30NOV98 JH	PROJ. NO.:TN000487.0004.0001	RPT NAME: MODEL	DRAWING: FIG3-13.SRF	PROJ. MANAGER: B. MOORE	PROJ. OFFICER: B. ILGNER	DRAFTER: J. HUGHES



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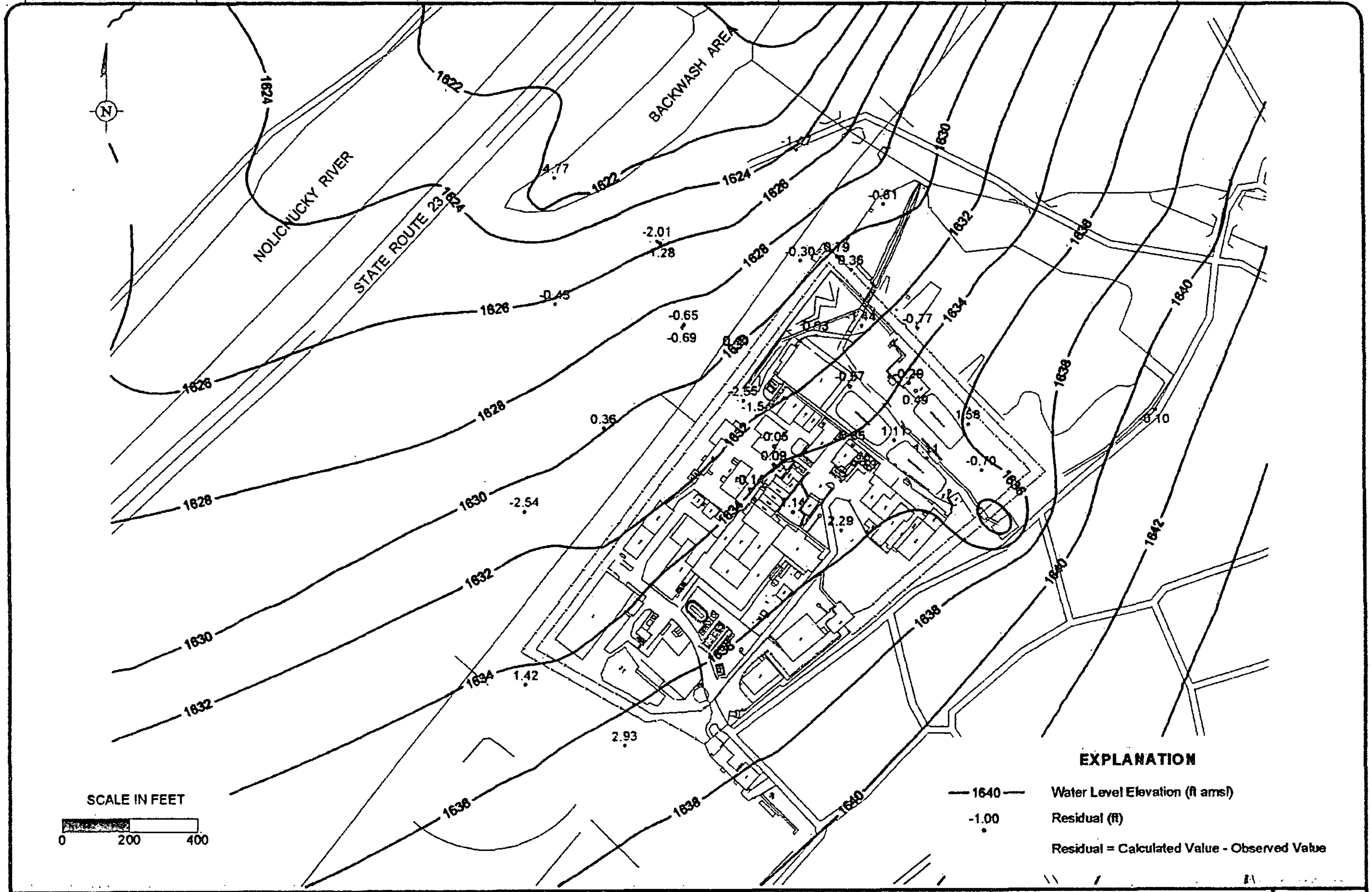
Simulated Hydraulic Head Distribution and Residuals in Model Layer 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

3-14

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-15A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
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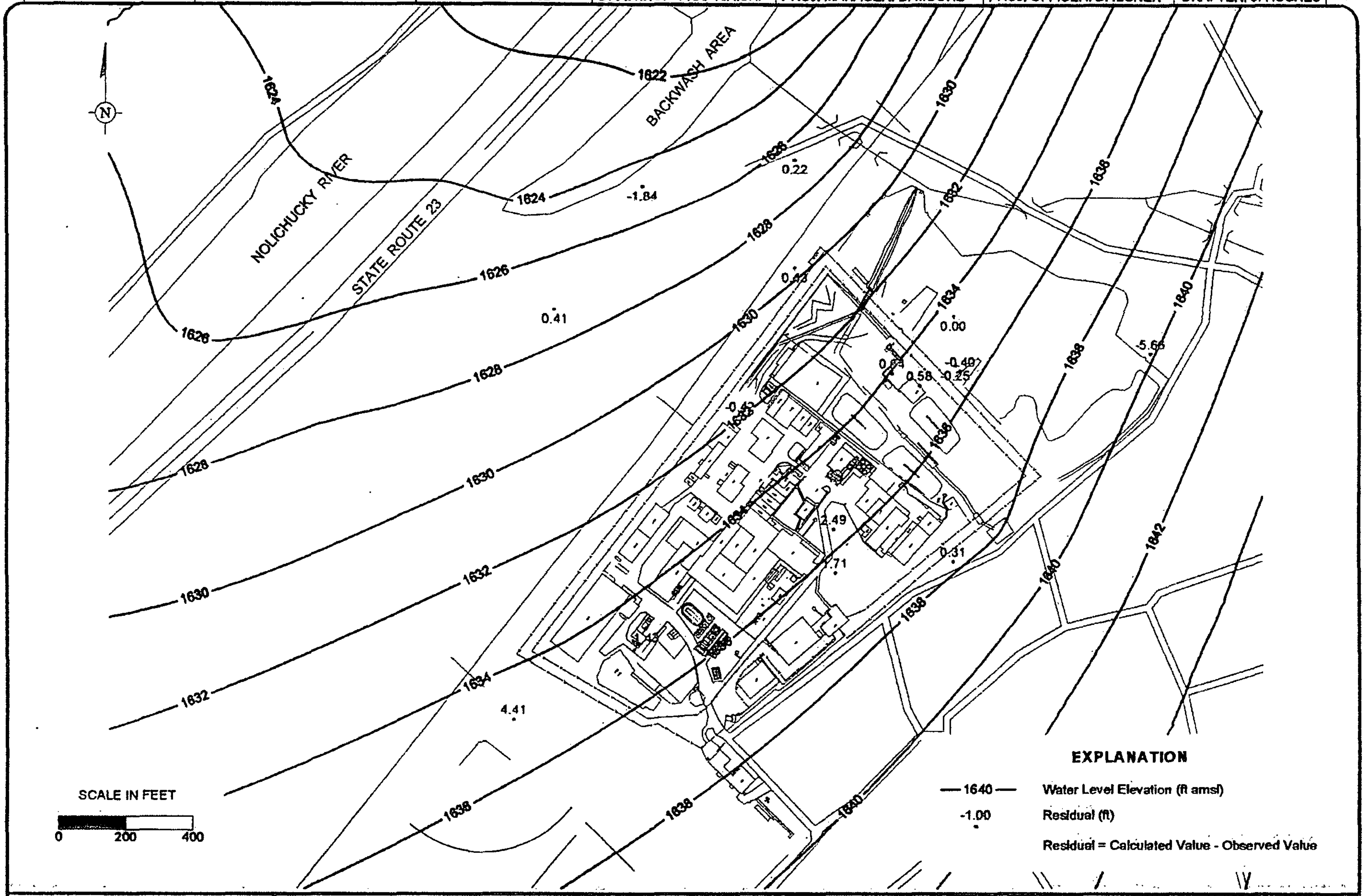
Simulated Hydraulic Head Distribution and Residuals in Model Layer 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
3-15

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG3-16A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
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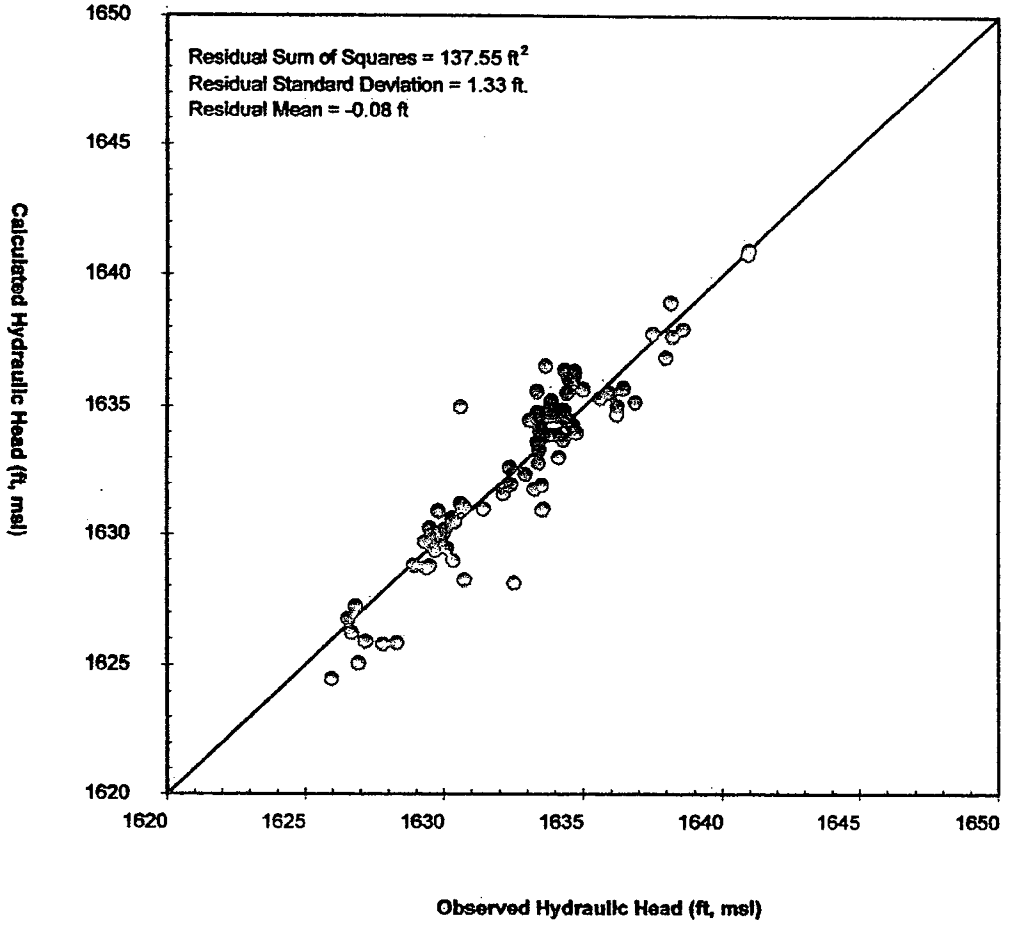
Simulated Hydraulic Head Distribution and Residuals in Model Layer 3

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
3-16

DWG. DATE: 01DEC98 MD | PROJ. NO.: TN000487.0004.00001 | FILE NAME: MODEL RPT | DRAWING: D32743.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



Residual Sum of Squares = 137.55 ft^2

Residual Standard Deviation = 1.33 ft.

Residual Mean = -0.08 ft

ARCADIS
GERAGHTY & MILLER

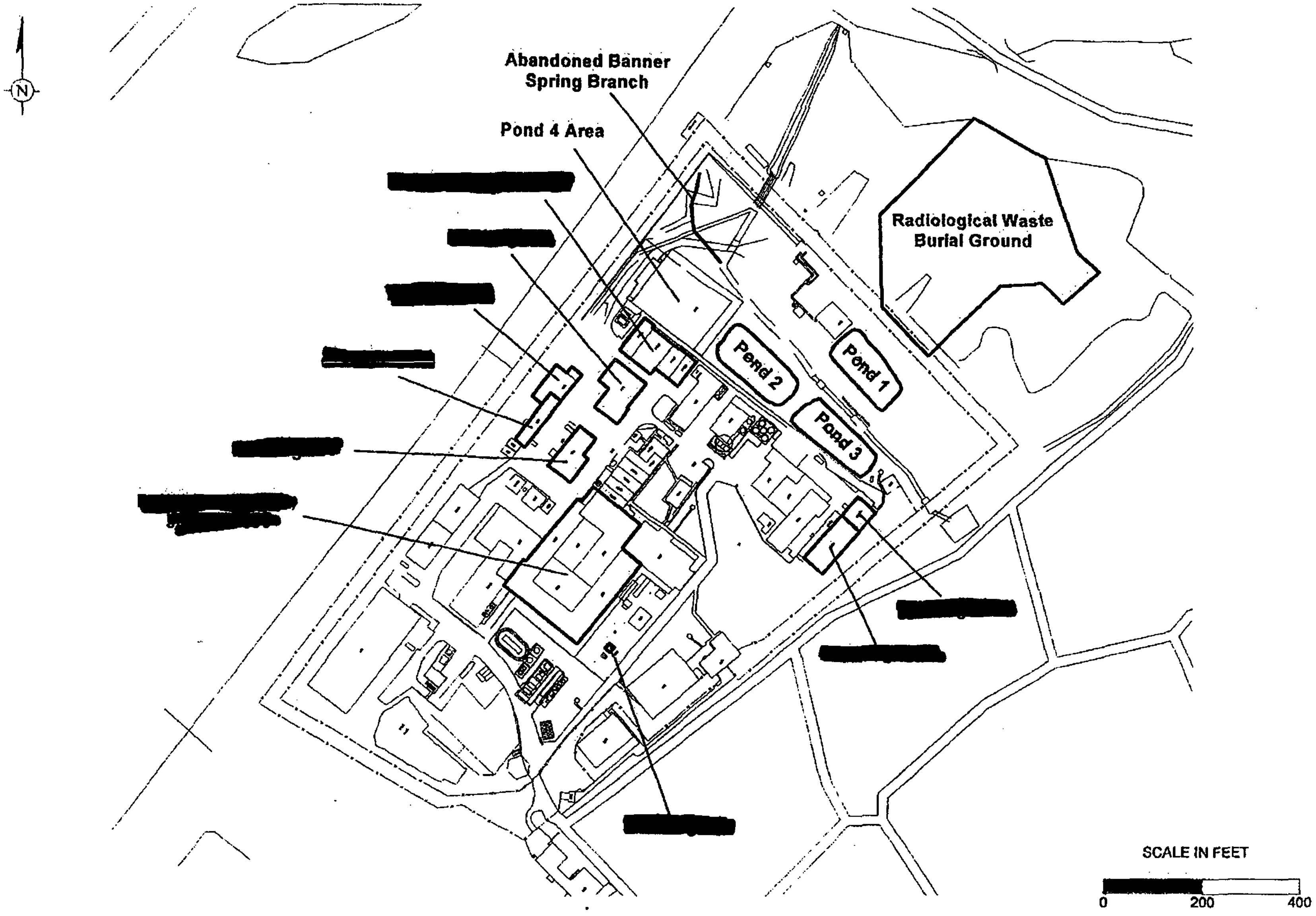
Relationship Between Observed and Simulated Water Levels

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

3-17

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-1A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY&MILLER

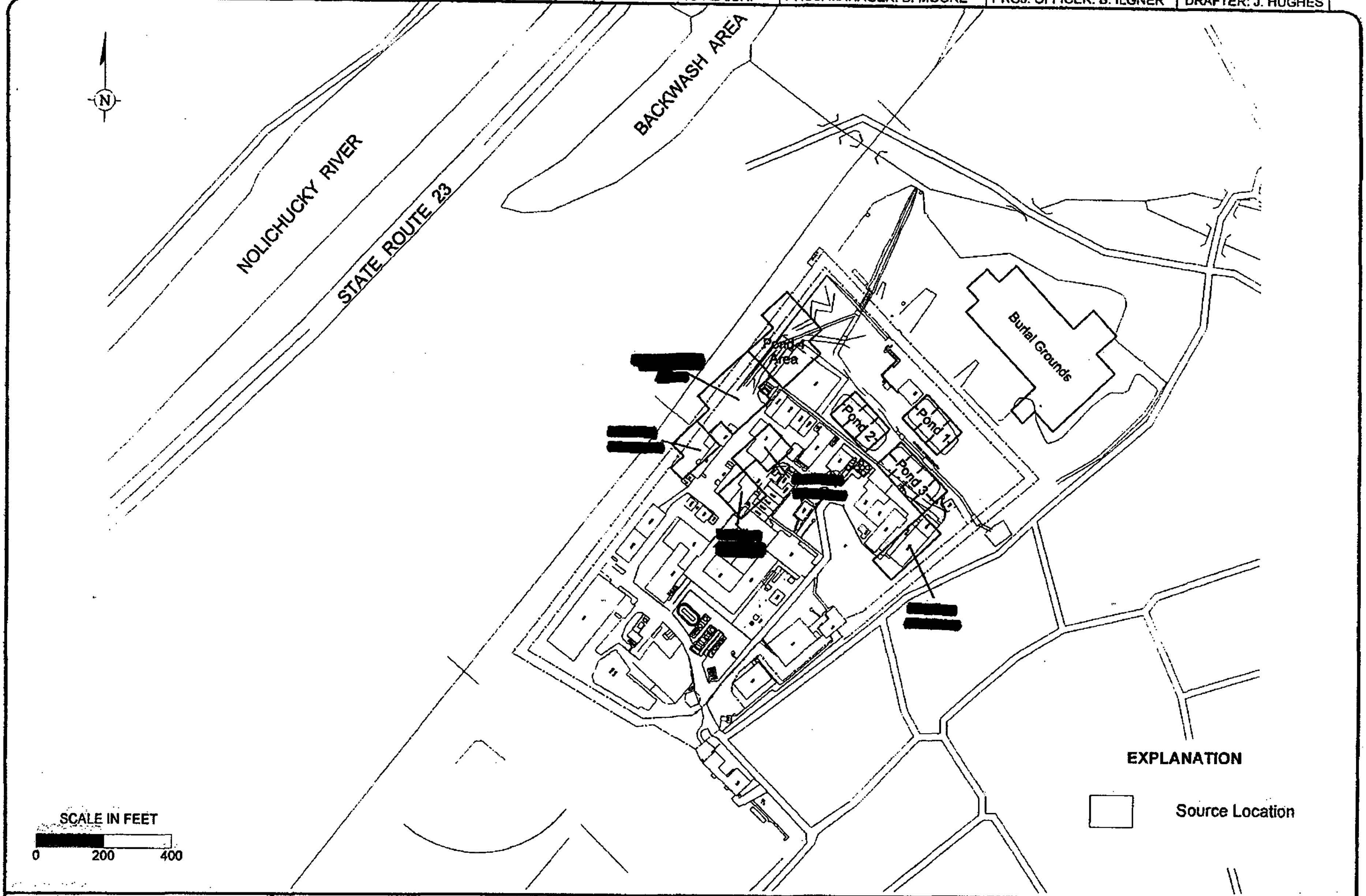
Potential Source Areas

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

4-1

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-2A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

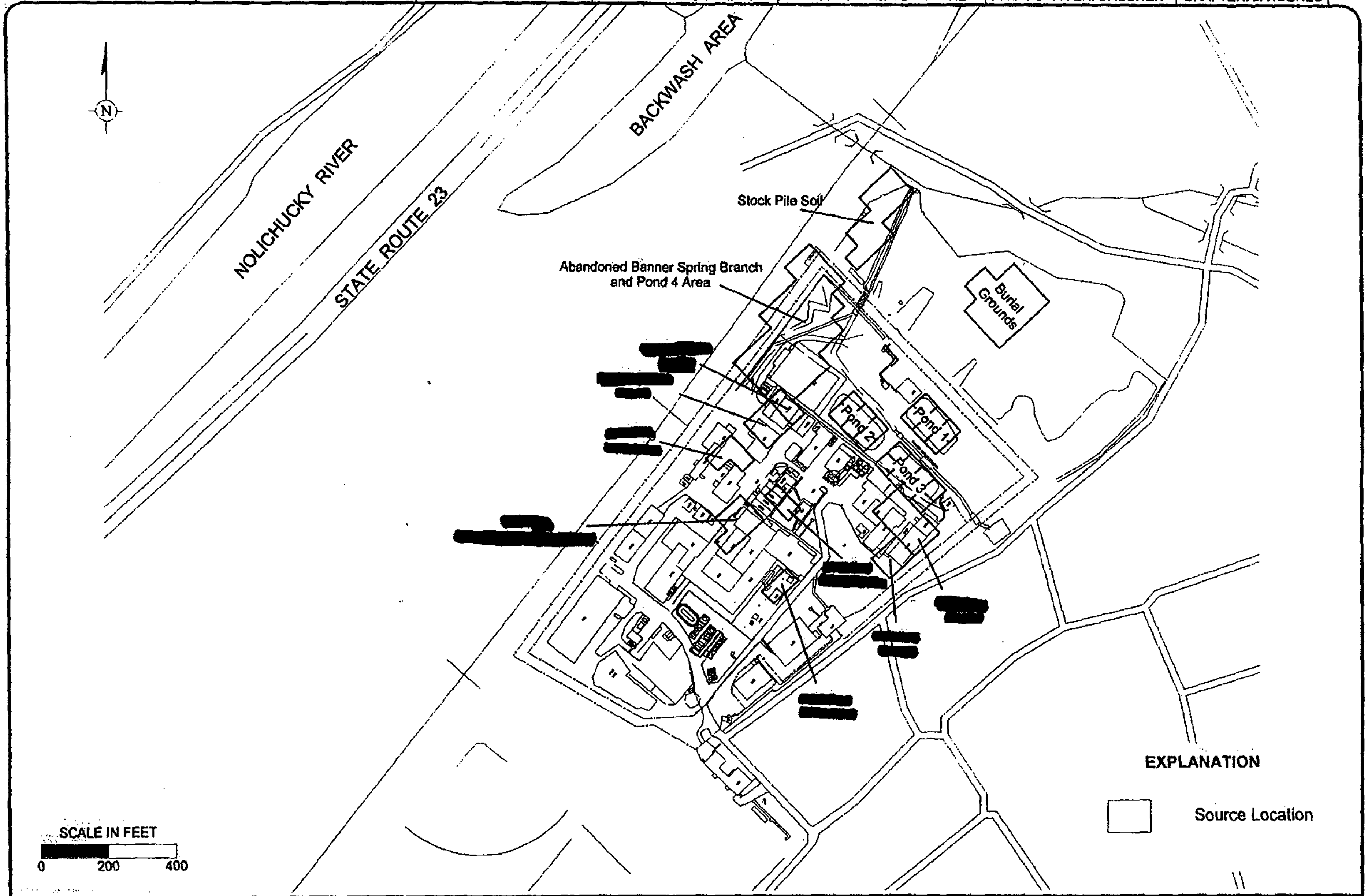
Distribution of PCE Sources

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

4-2

DWG DATE: 30NOV98 JH | PROJ. NO.: TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-3A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



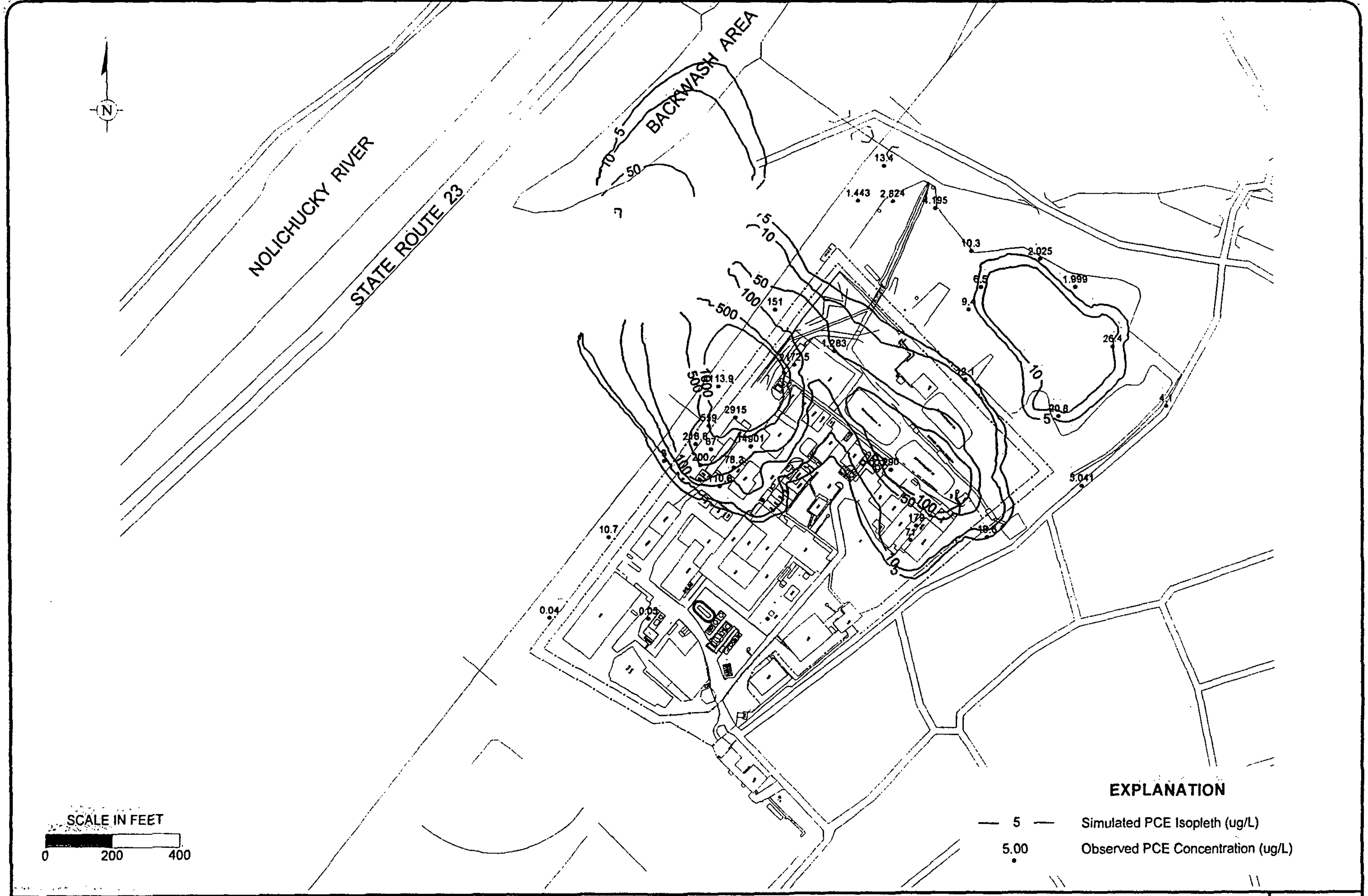
ARCADIS
GERAGHTY&MILLER

Distribution of Uranium Sources

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
4-3

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-4A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

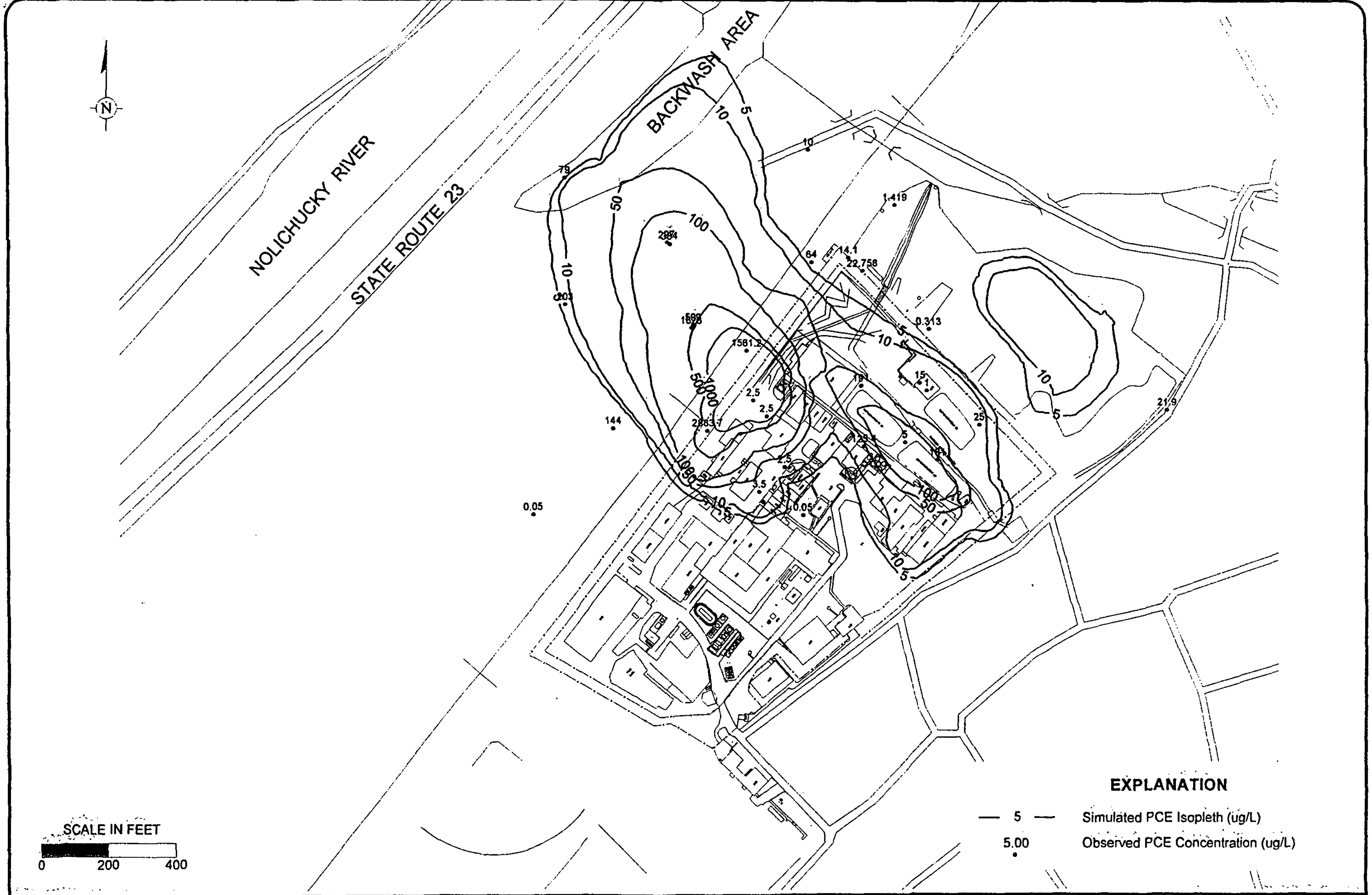
Simulated 1998 PCE Concentrations in Model Layer 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

4-4

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-5A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



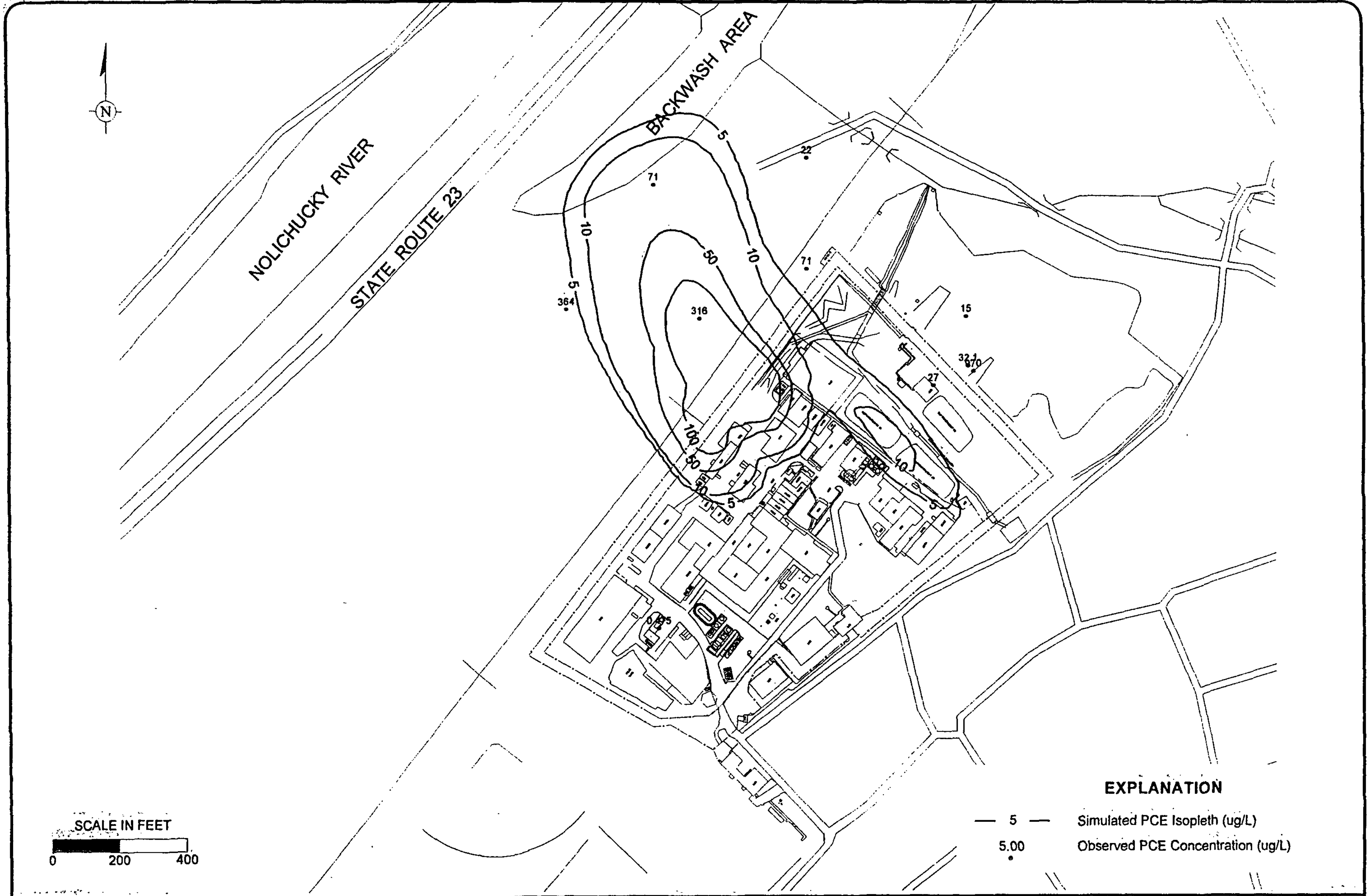
ARCADIS
GERAGHTY & MILLER

Simulated 1998 PCE Concentrations in Model Layer 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
4-5

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-6A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

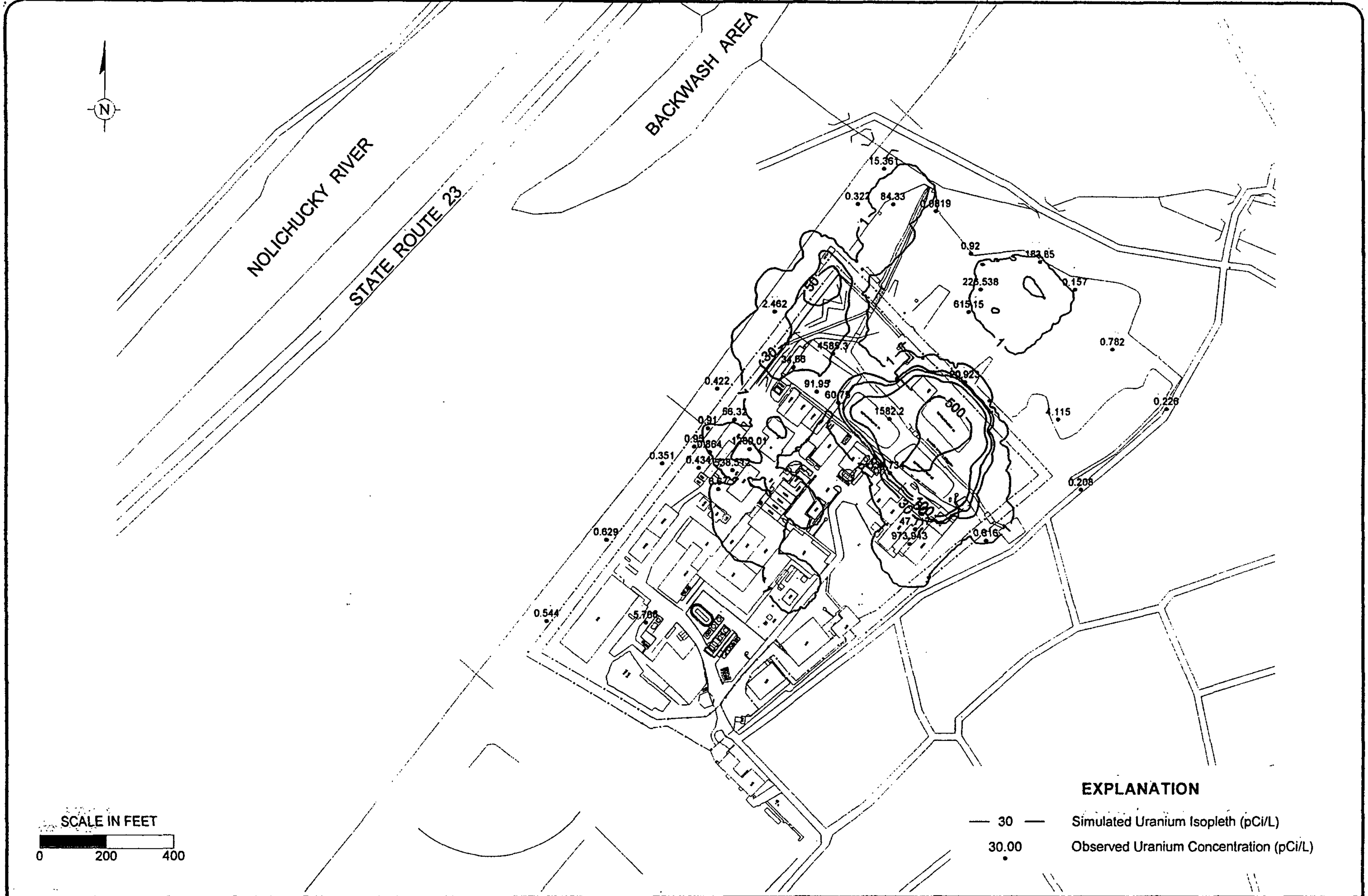
Simulated 1998 PCE Concentrations in Model Layer 3

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

4-6

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-7A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

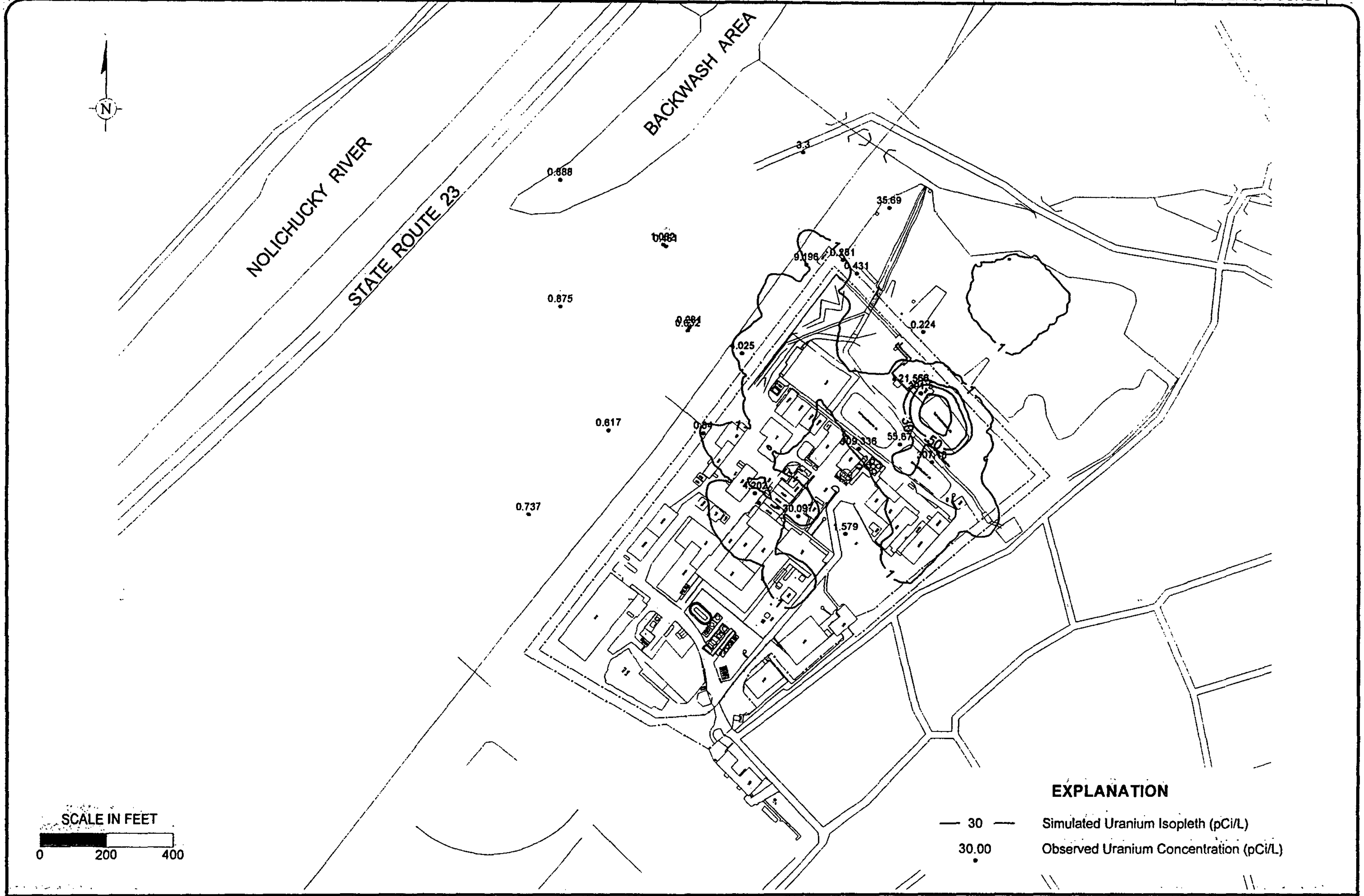
Simulated 1998 Uranium Concentrations in Model Layer 1

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

4-7

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-8A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



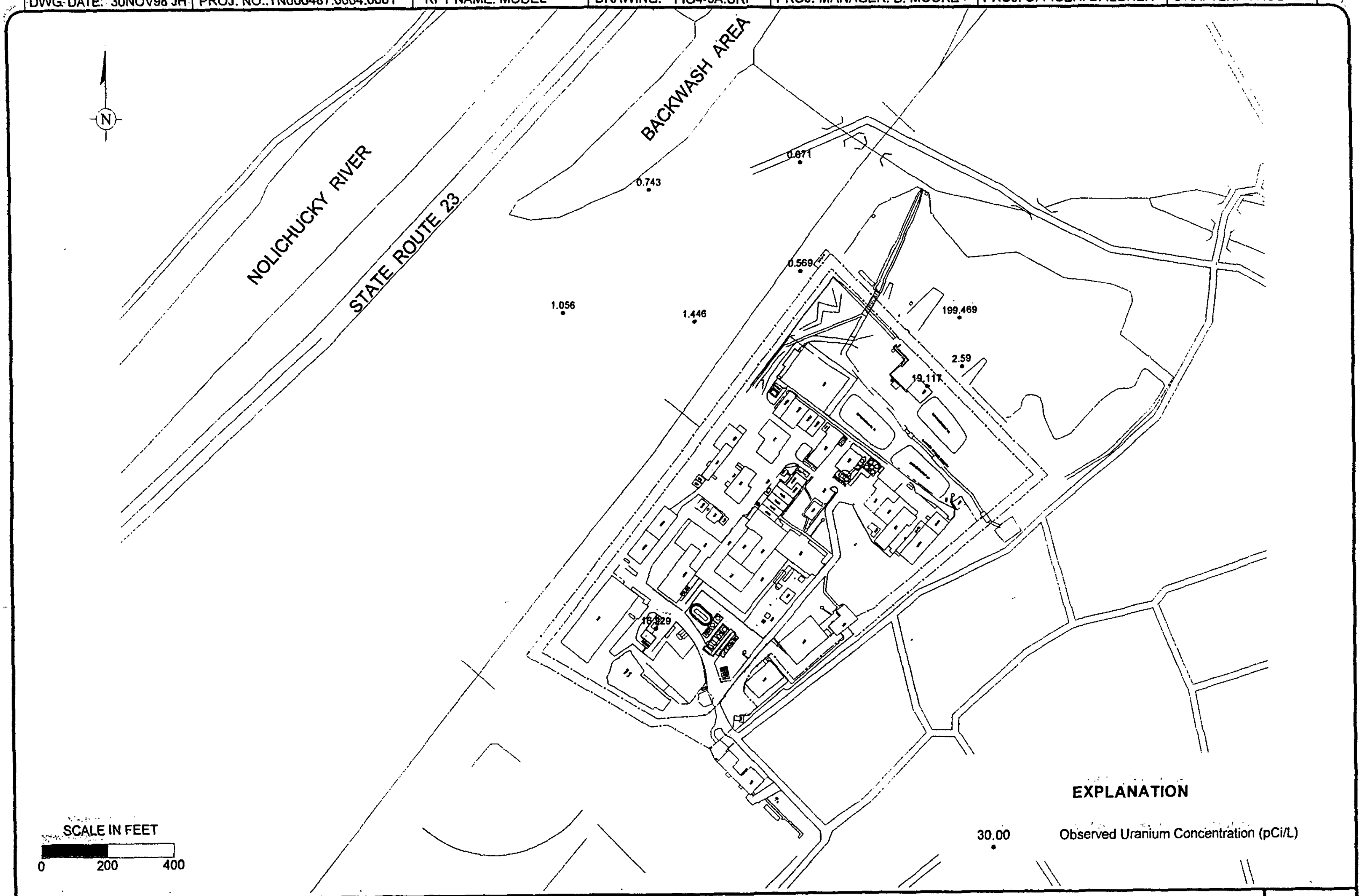
ARCADIS
GERAGHTY & MILLER

Simulated 1998 Uranium Concentrations in Model Layer 2

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
4-8

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-9A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY&MILLER

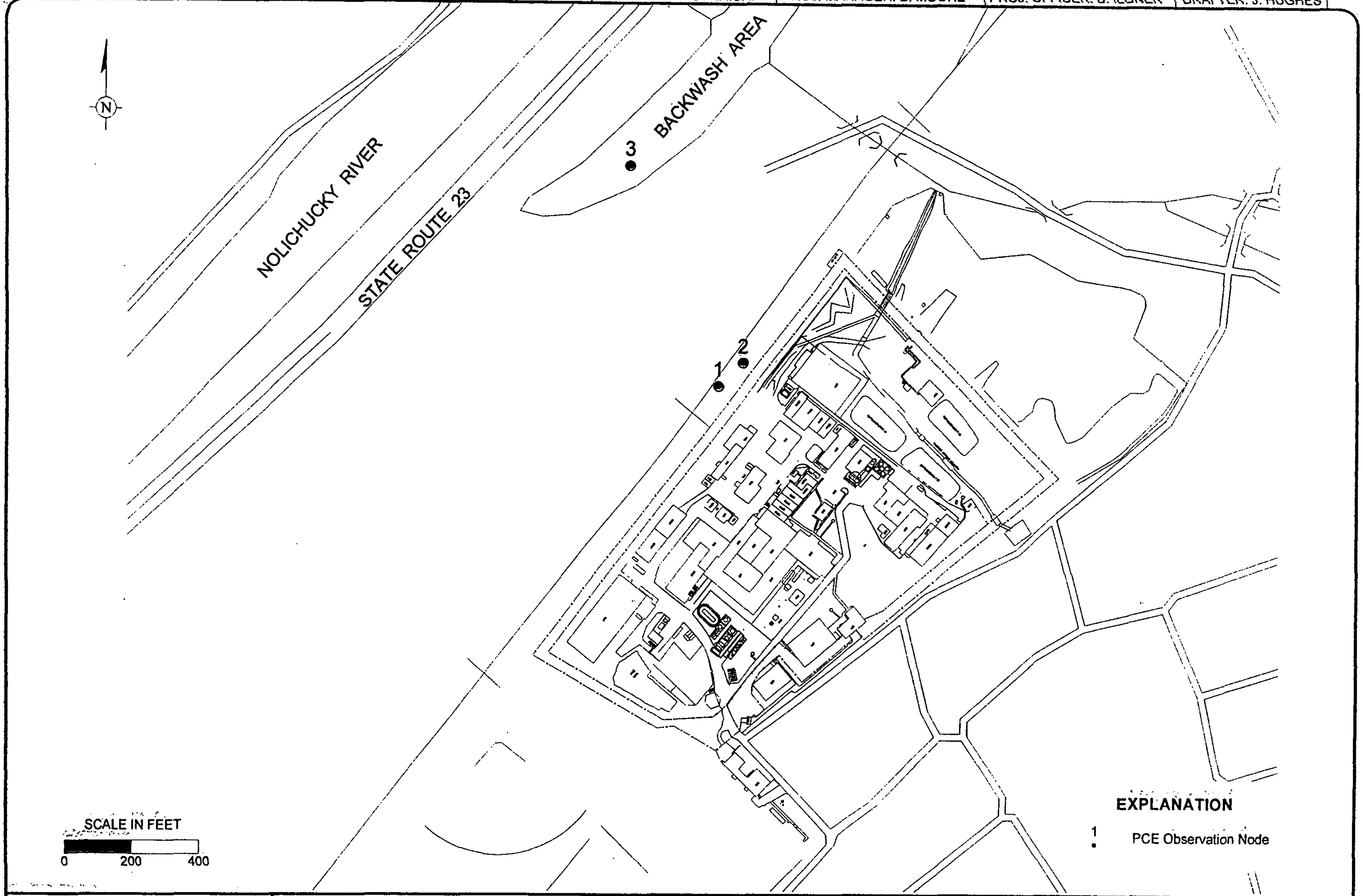
Simulated 1998 Uranium Concentrations in Model Layer 3

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

4-9

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-1A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



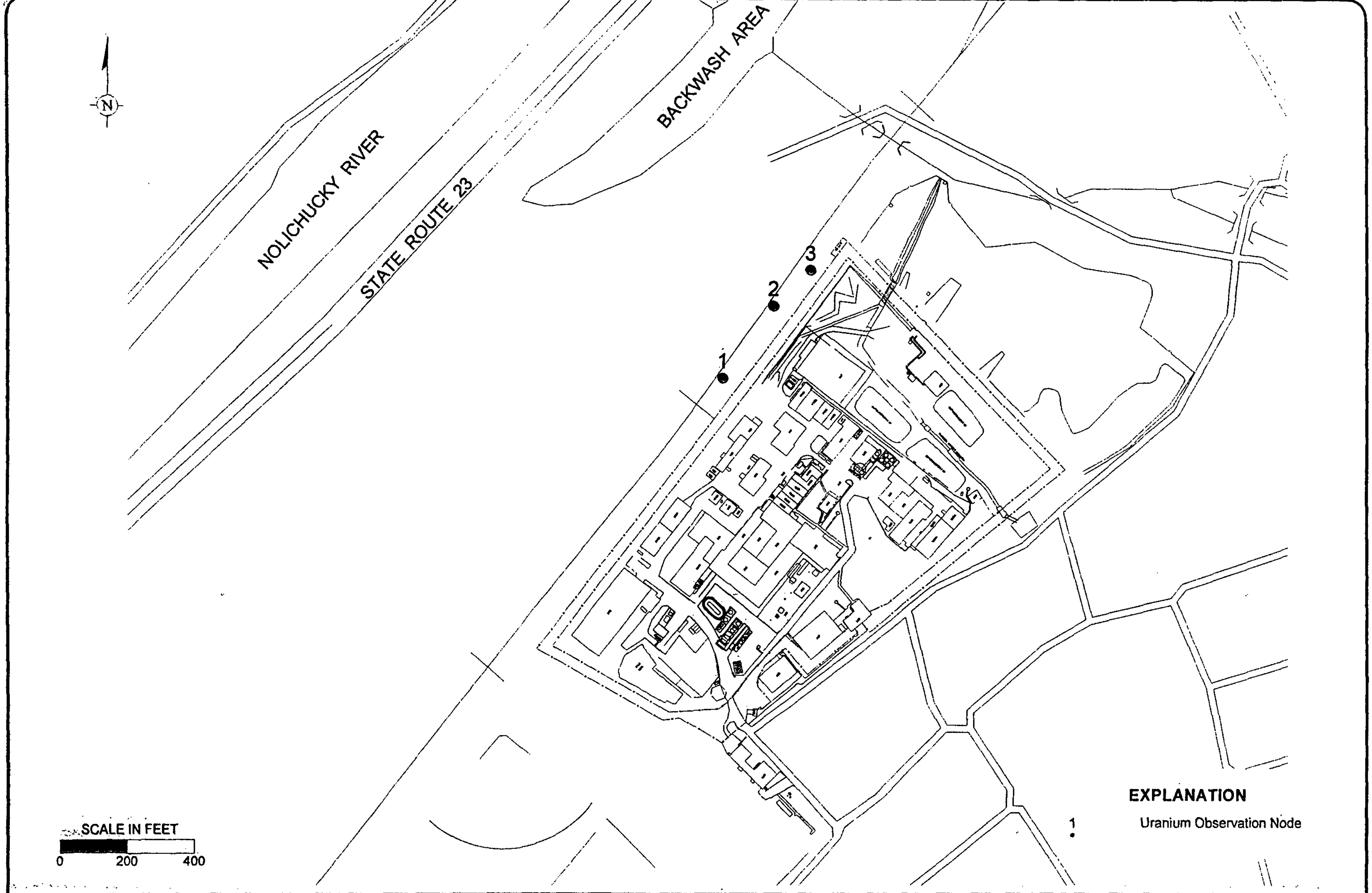
ARCADIS
GERAGHTY & MILLER

Location of PCE Observation Nodes

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-1

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG4-17.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



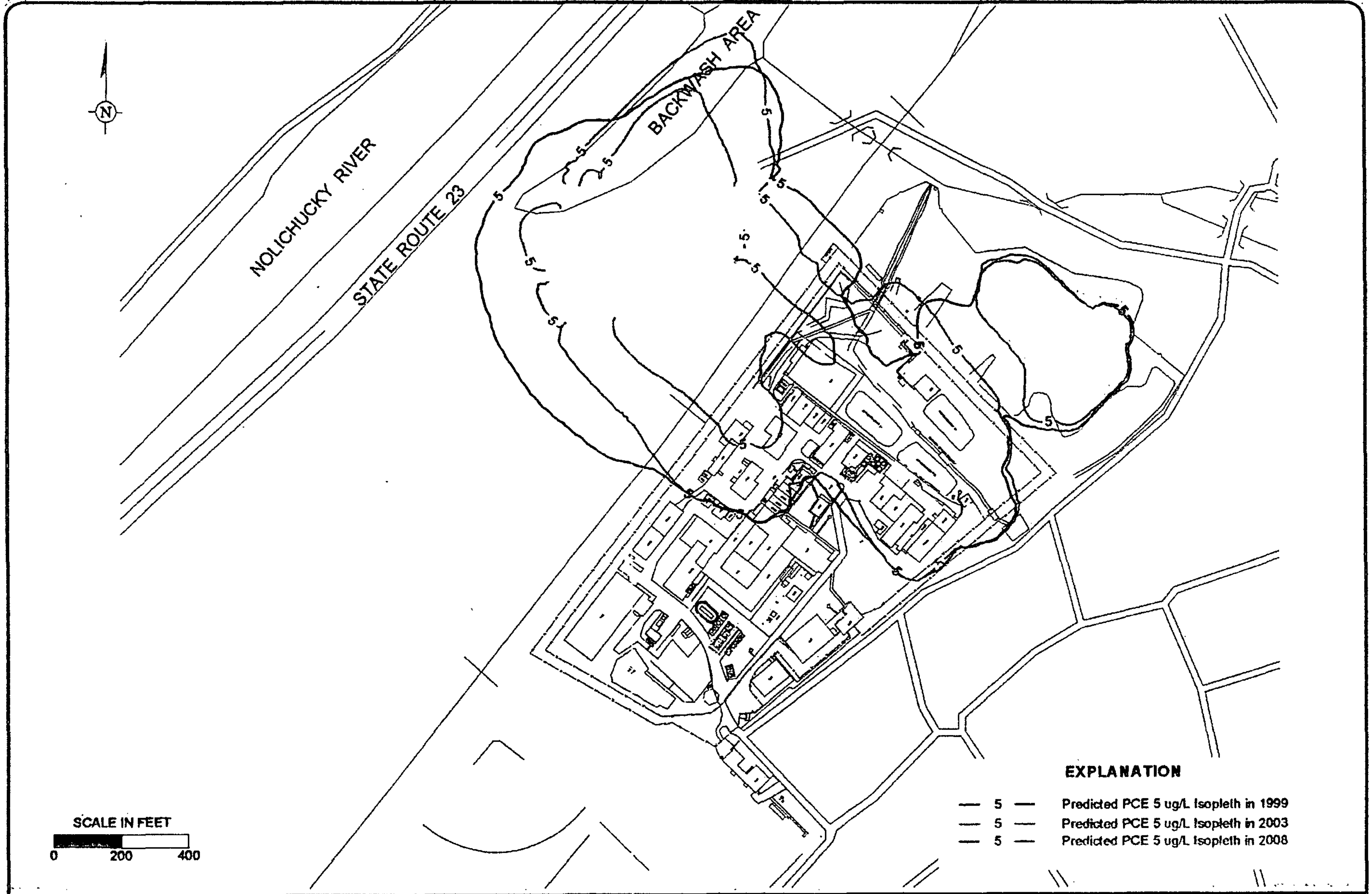
ARCADIS
GERAGHTY & MILLER

Location of Uranium Observation Nodes

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-2

DWG DATE: 30NOV98 JH
PROJ. NO.:TN000487.0004.0001
RPT NAME: MODEL
DRAWING: FIG5-3A.SRF
PROJ. MANAGER: B. MOORE
PROJ. OFFICER: B. ILGNER
DRAFTER: J. HUGHES



ARCADIS
GERAGHTY&MILLER

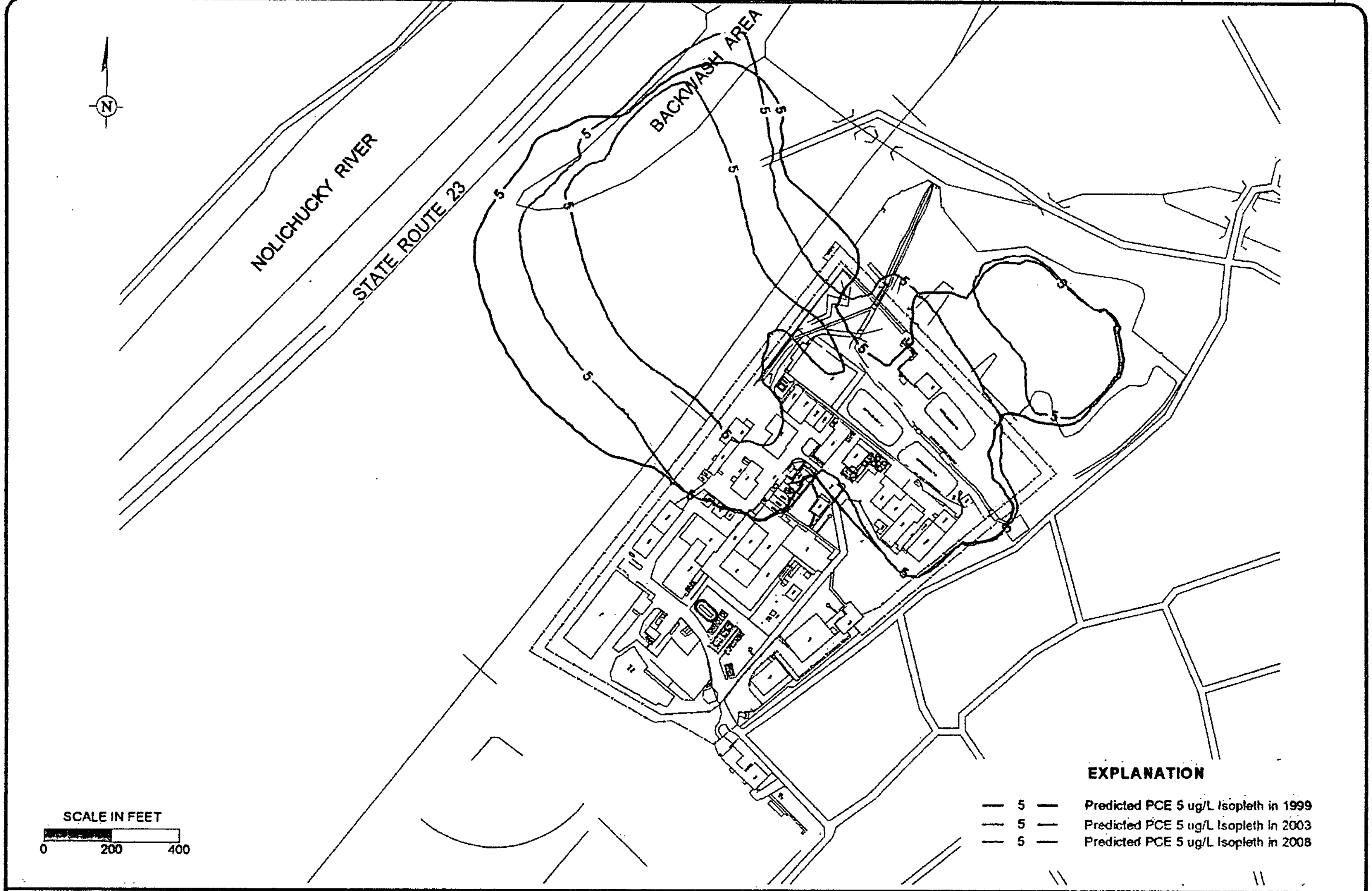
Predicted PCE Concentrations with Discontinuous Sources in 1999, 2003, and 2008 (Model Layer 1)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

5-3

DWG. DATE: 30NOV98 JH | PROJ. NO.: TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-4A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



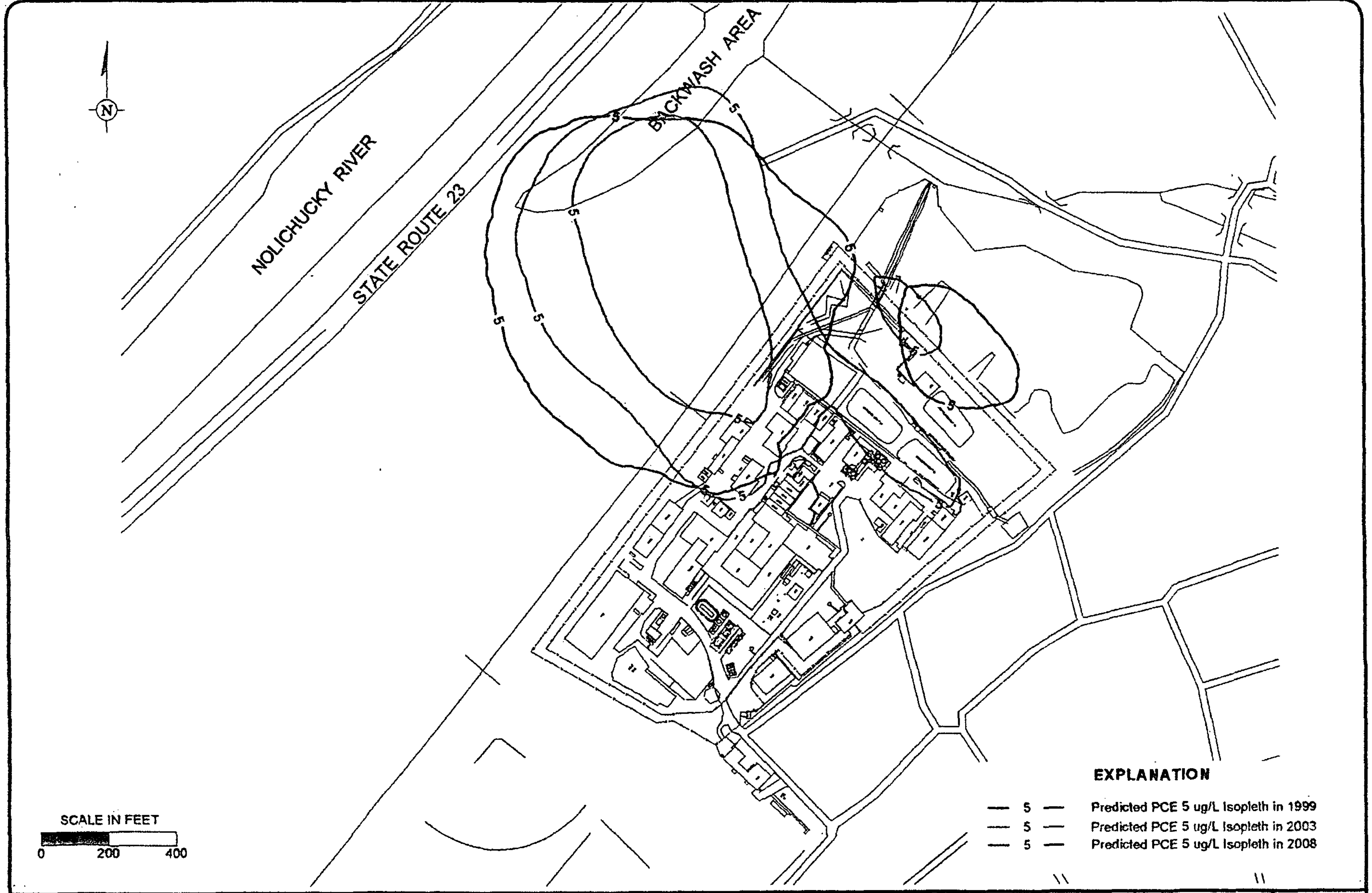
ARCADIS
GERAGHTY & MILLER

Predicted PCE Concentrations with Discontinuous Sources in 1999, 2003, and 2008 (Model Layer 2)

Nuclear Fuel Services, Inc.   Erwin, Tennessee

FIGURE
5-4

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-5A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



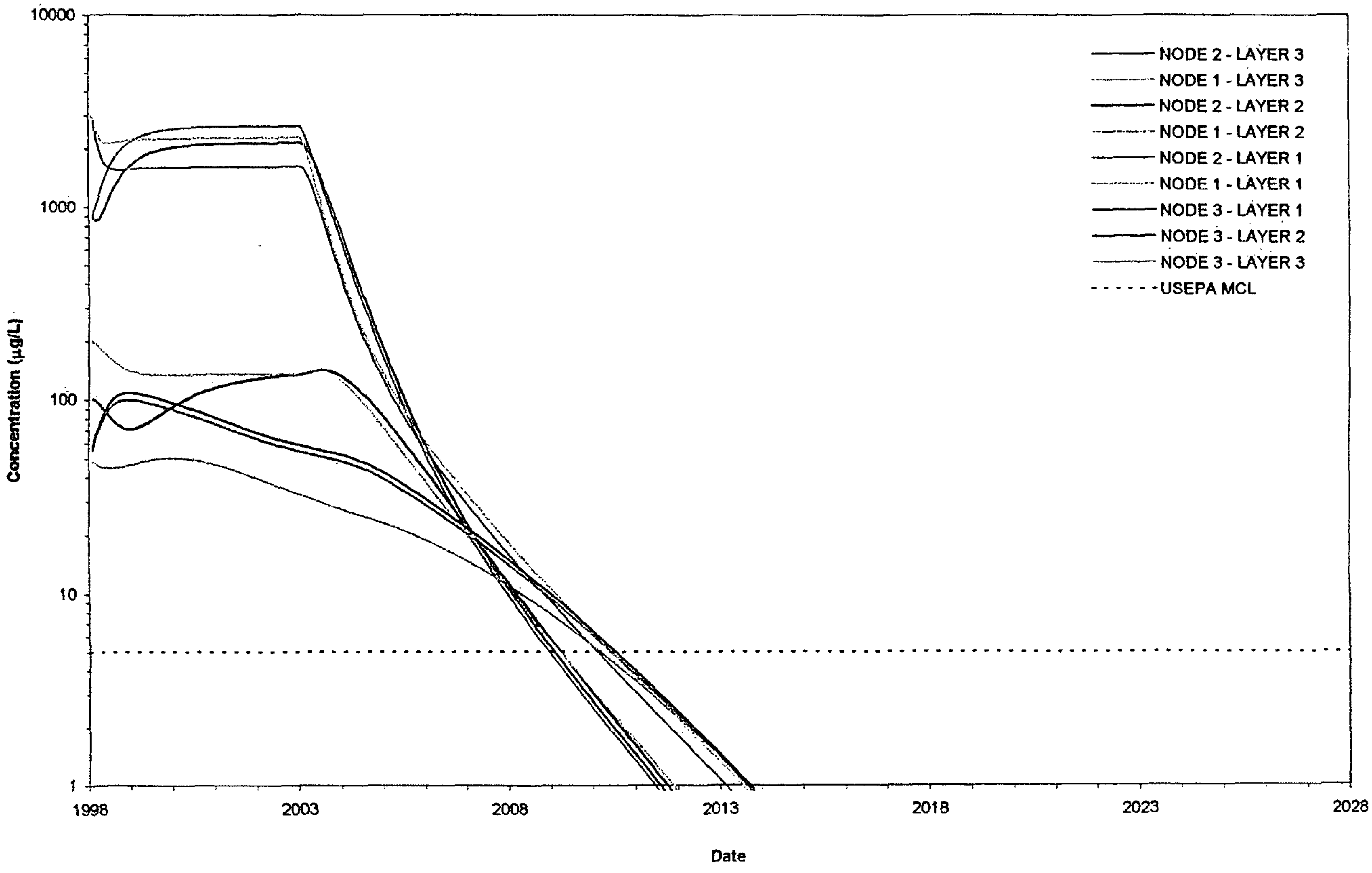
ARCADIS
GERAGHTY&MILLER

Predicted PCE Concentrations with Discontinuous Sources in 1999, 2003, and 2008 (Model Layer 3)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-5

DWG. DATE: 01DEC98 MD | PROJ. NO.: TN000487.0004.00001 | FILE NAME: MODEL RPT | DRAWING: D32744.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



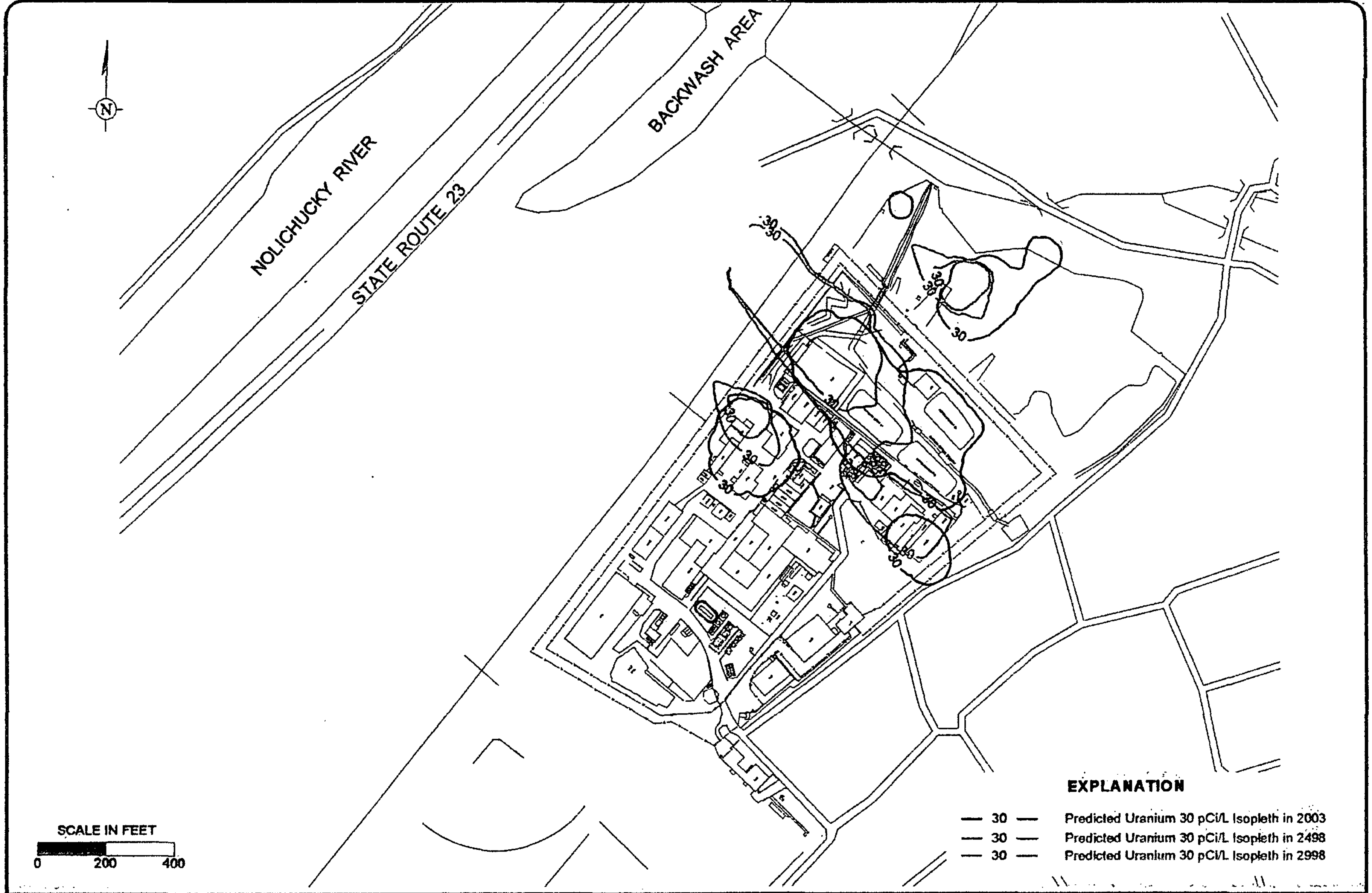
ARCADIS
GERAGHTY & MILLER

Predicted PCE Concentration at Observation Nodes (Discontinuous Source Release Scenario)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-6

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-7A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



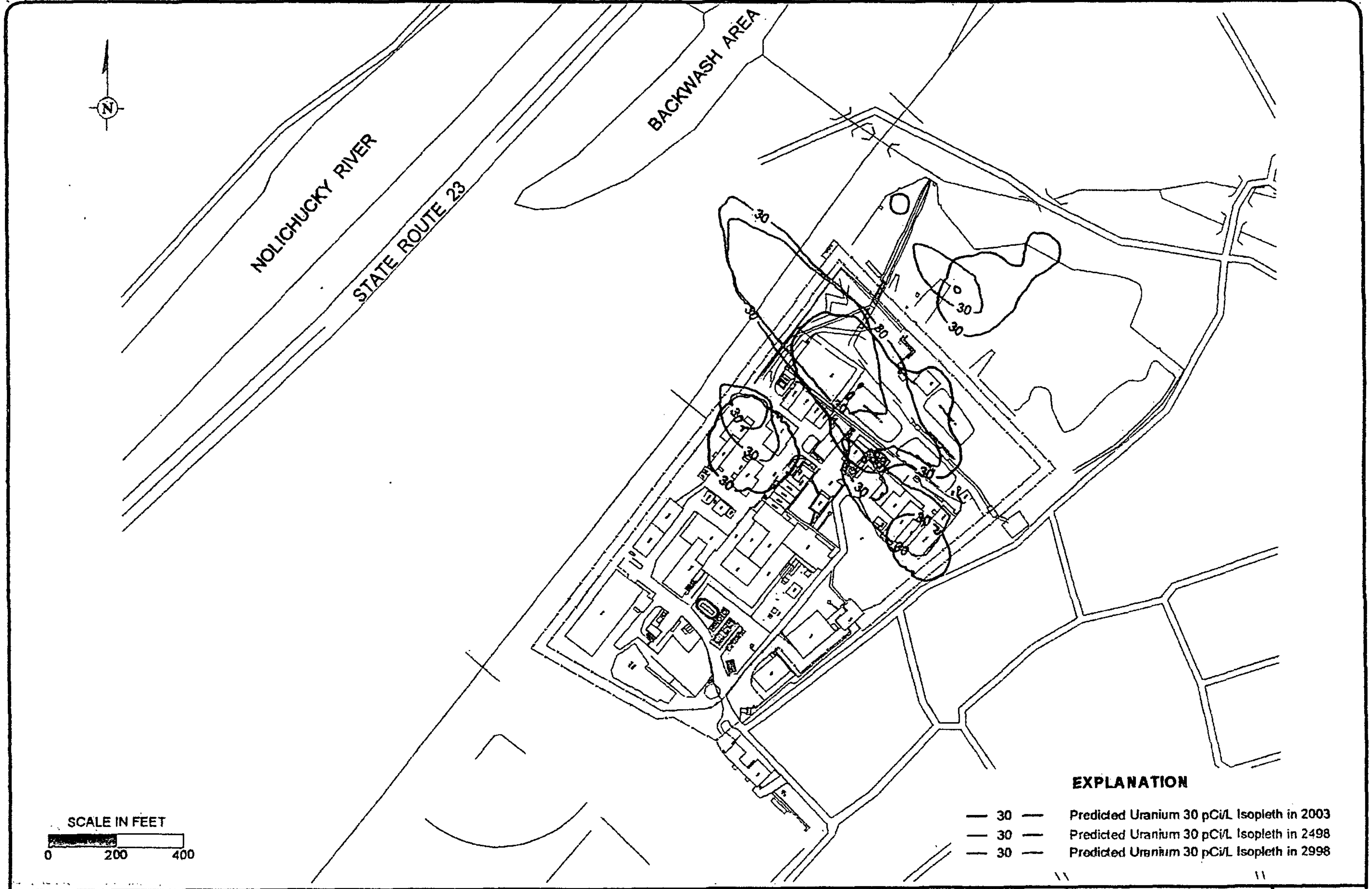
ARCADIS
GERAGHTY & MILLER

Predicted Uranium Concentrations with Discontinuous Sources in 2003, 2498, and 2998 (Model Layer 1)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-7

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-8.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



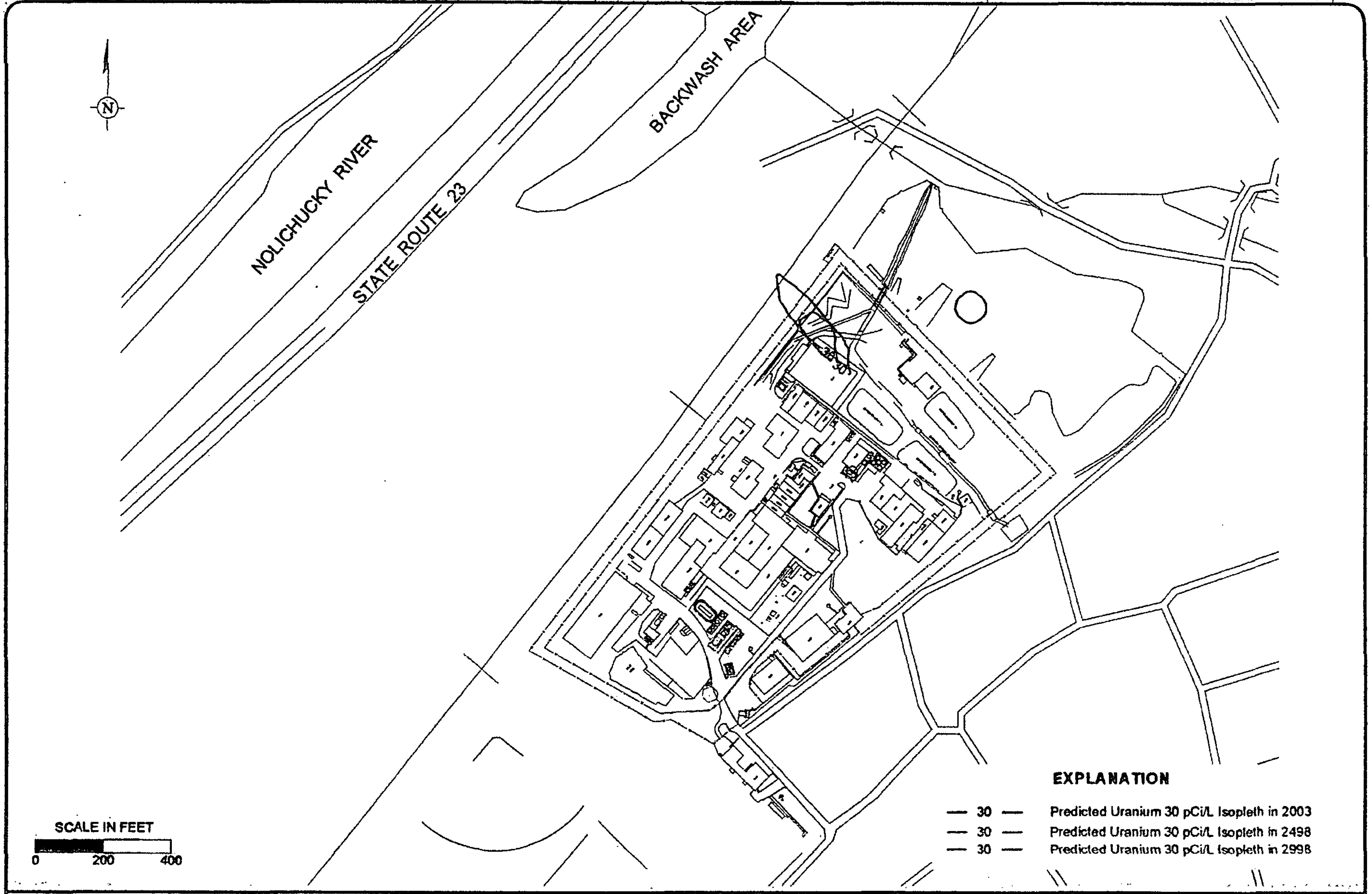
ARCADIS
GERAGHTY & MILLER

Predicted Uranium Concentrations with Discontinuous Sources in 2003, 2498, and 2998 (Model Layer 2)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-8

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-9A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



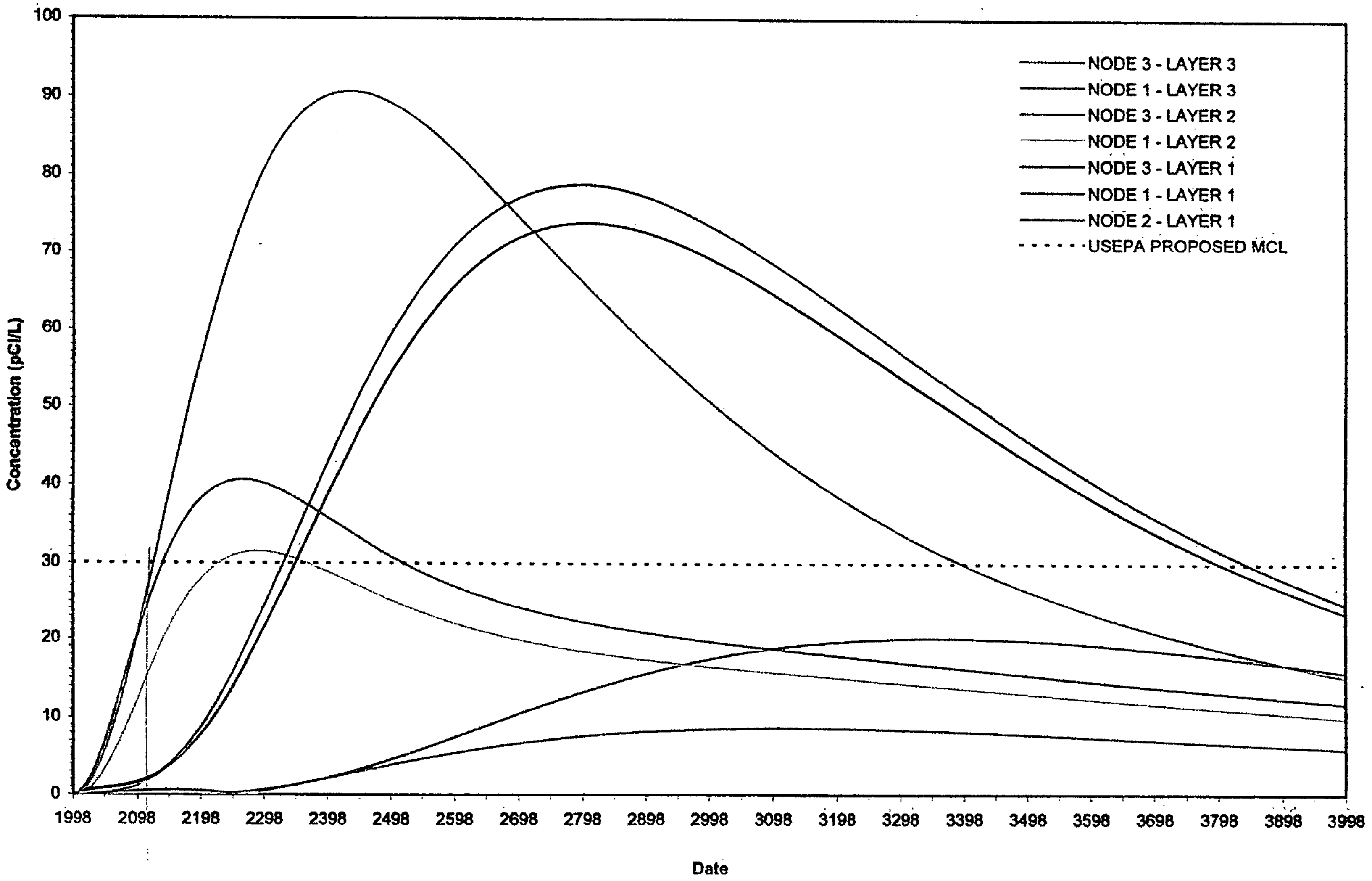
ARCADIS
GERAGHTY & MILLER

Predicted Uranium Concentrations with Discontinuous Sources in 2003, 2498, and 2998 (Model Layer 3)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-9

DWG. DATE: 14DEC98 MD | PROJ. NO.: TN000487.0004.00001 | FILE NAME: MODEL RPT | DRAWING: D32744.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



ARCADIS
GERAGHTY & MILLER

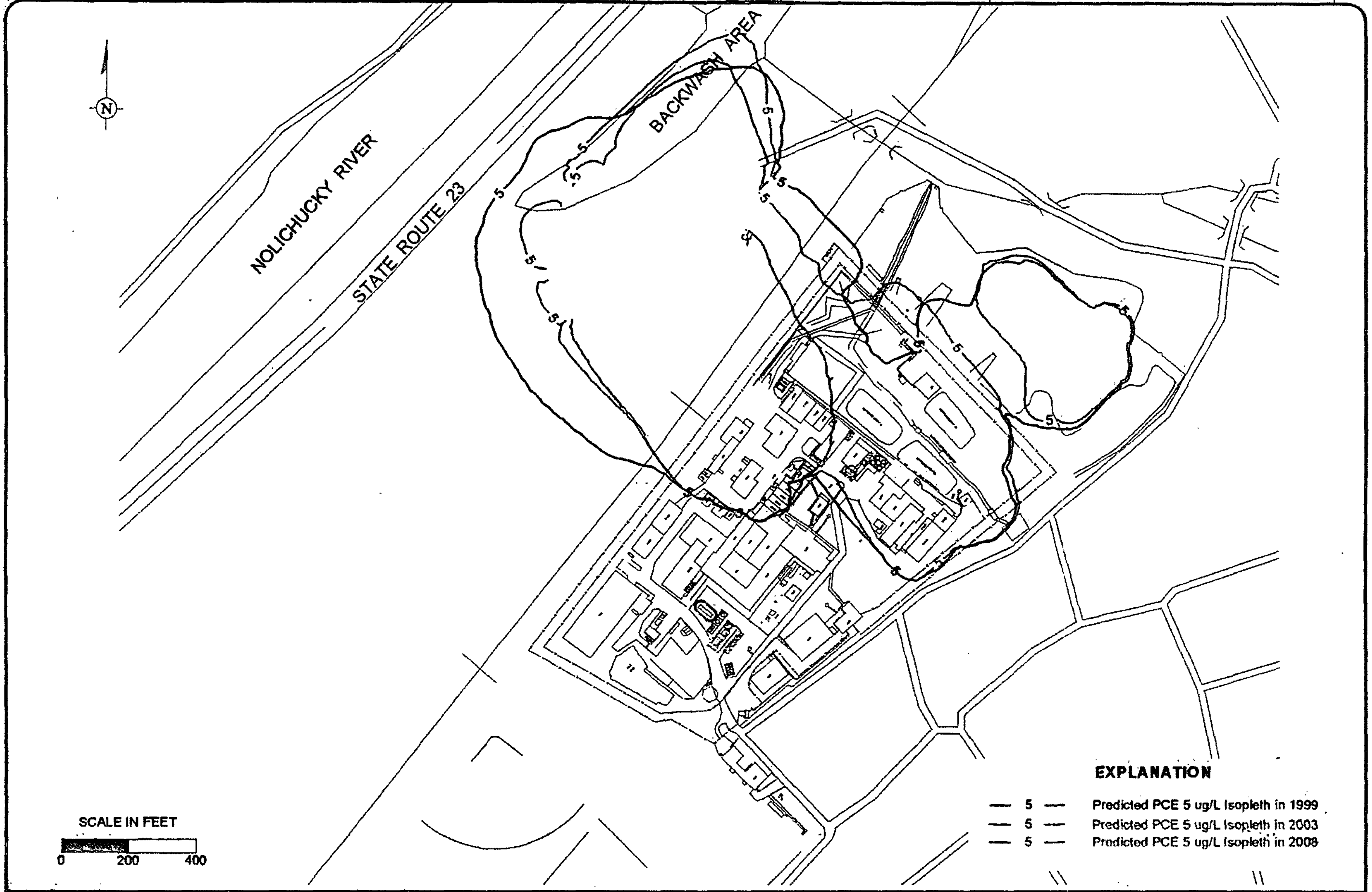
Predicted Uranium Concentration at Observation Nodes (Discontinuous Source Release Scenario)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

5-10

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-11.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
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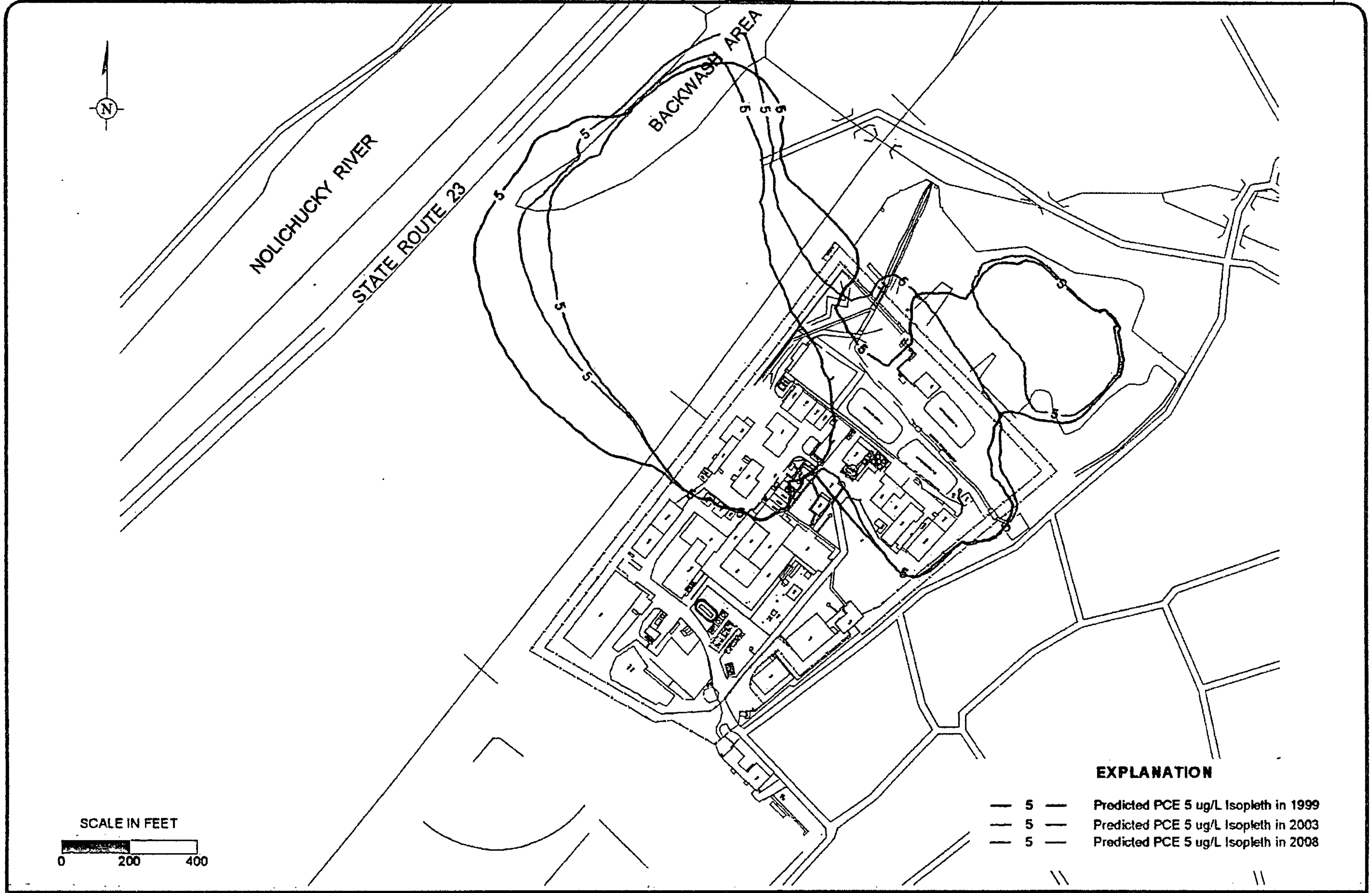
Predicted PCE Concentrations with Continuous Sources in 1999, 2003, and 2008 (Model Layer 1)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

5-11

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-12A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



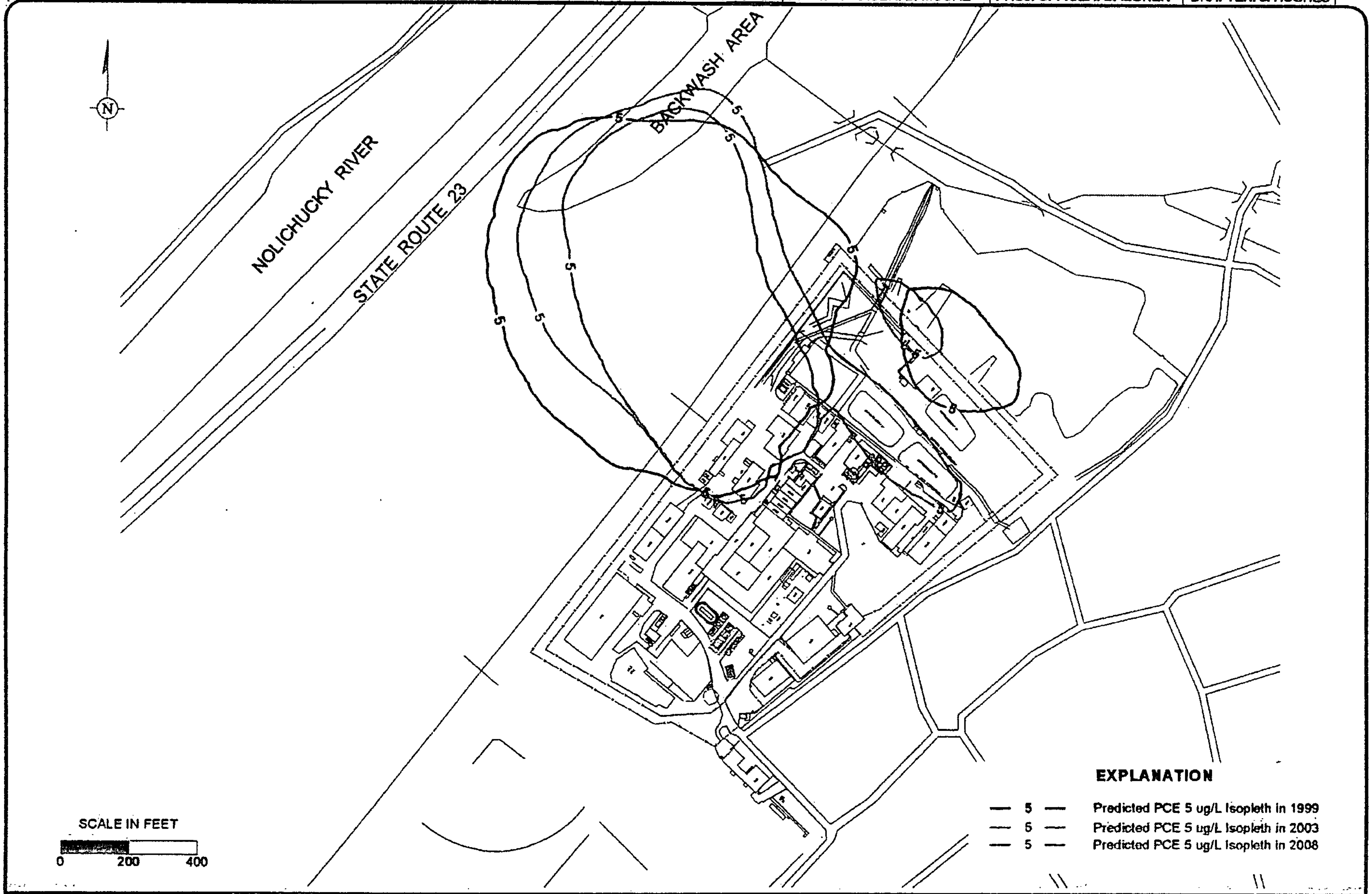
ARCADIS
GERAGHTY & MILLER

Predicted PCE Concentrations with Continuous Sources in 1999, 2003, and 2008 (Model Layer 2)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-12

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-13A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

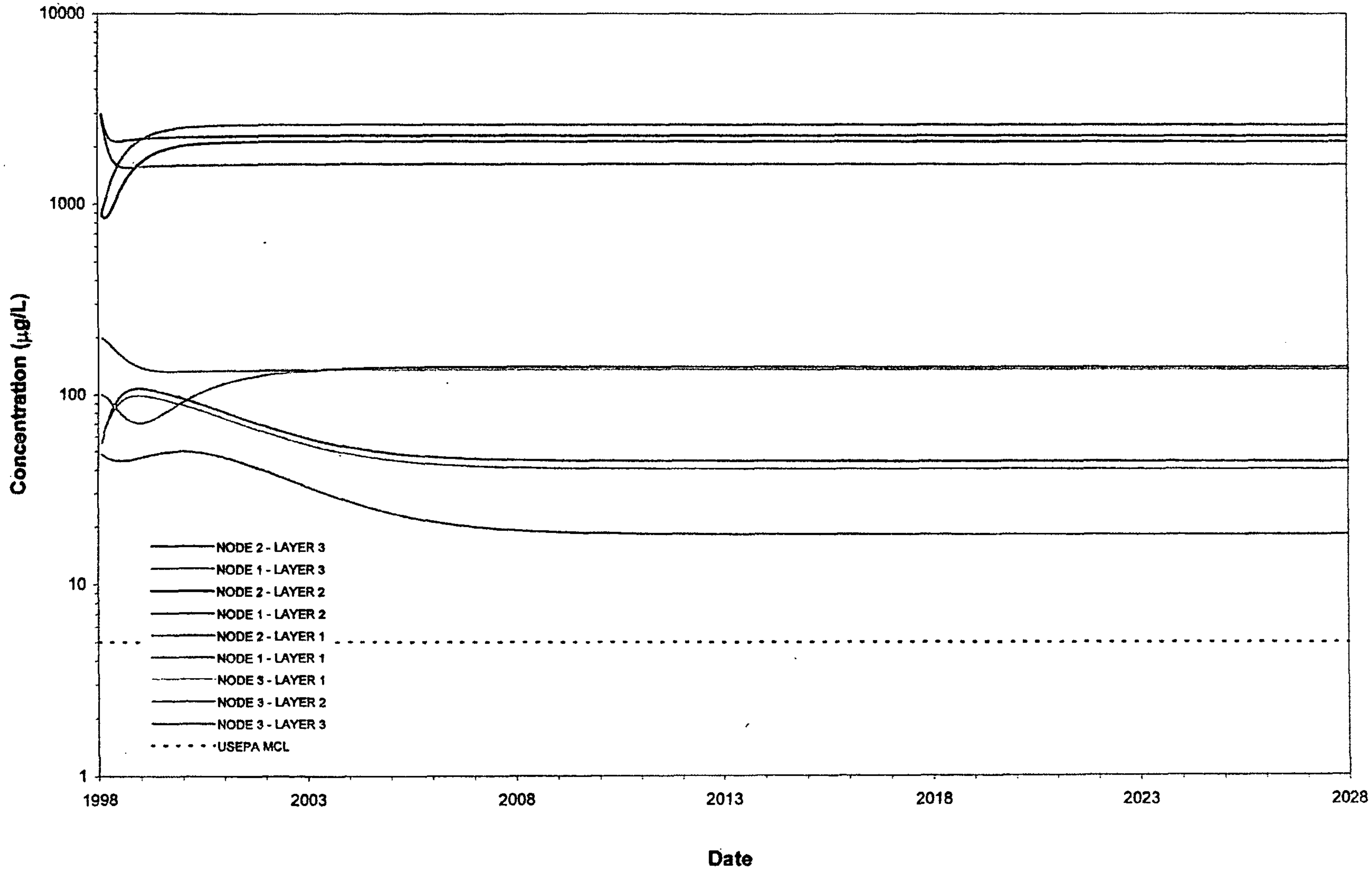
Predicted PCE Concentrations with Continuous Sources in 1999, 2003, and 2008 (Model Layer 3)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

5-13

DWG. DATE: 14DEC98 MD | PROJ. NO.: TN000487.0004.00001 | FILE NAME: MODEL RPT | DRAWING: D32744.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



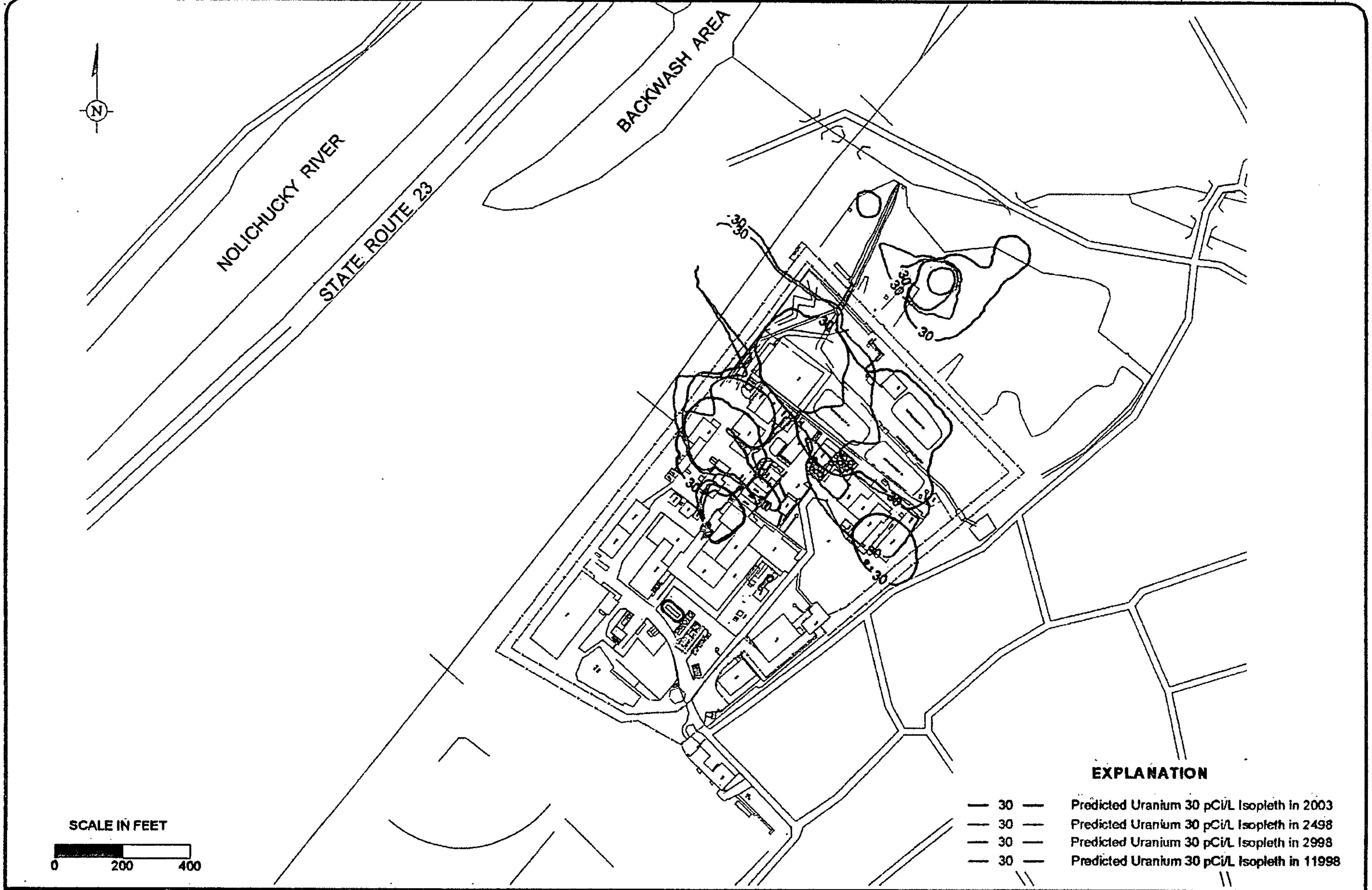
ARCADIS
GERAGHTY & MILLER

Predicted PCE Concentration at Observation Nodes (Continuous Source Release Scenario)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE
5-14

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-15A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

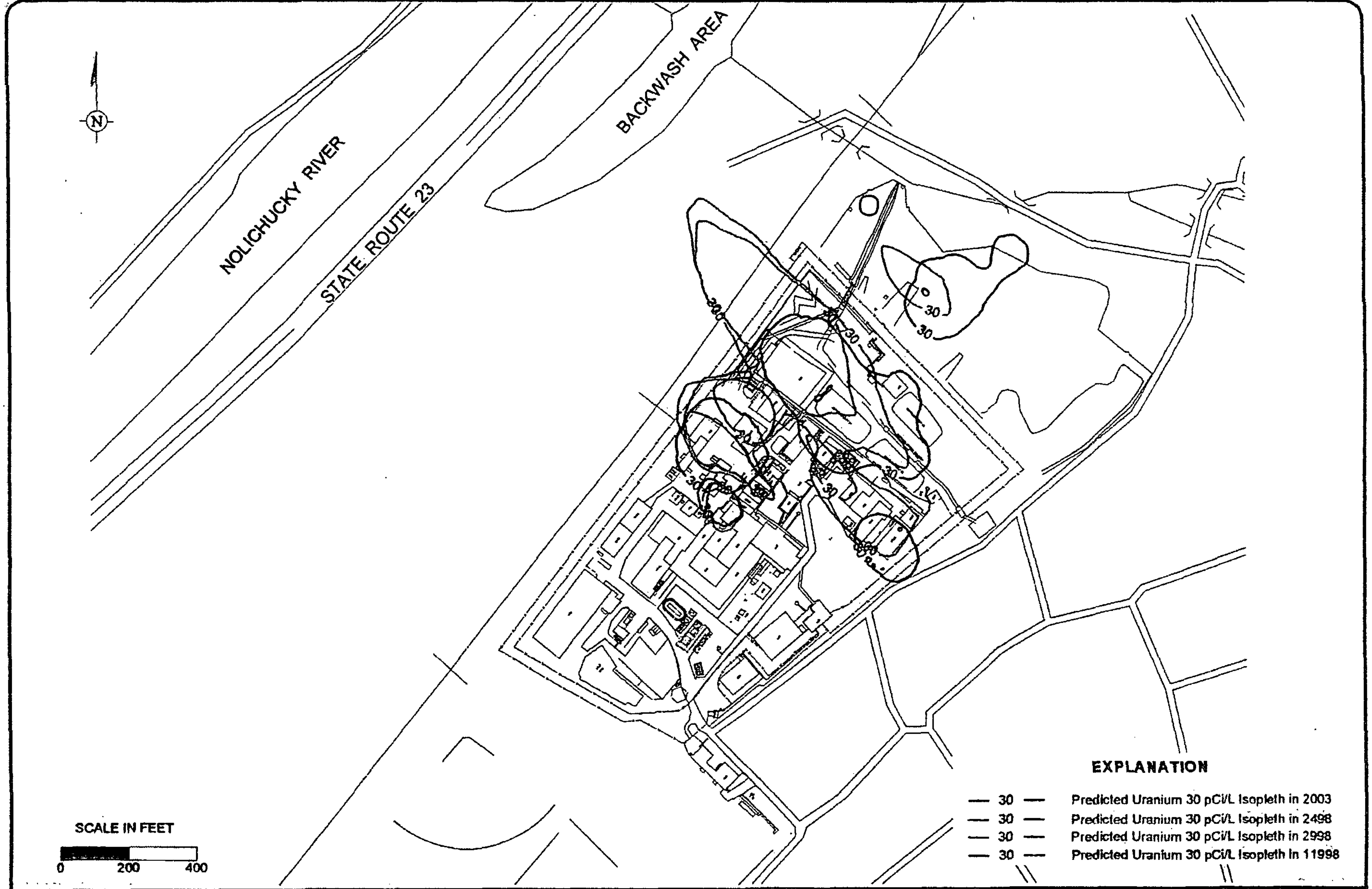
Predicted Uranium Concentrations with Continuous Sources in 2003, 2498, 2998, and 11998 (Model Layer 1)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

5-15

DWG DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-16A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

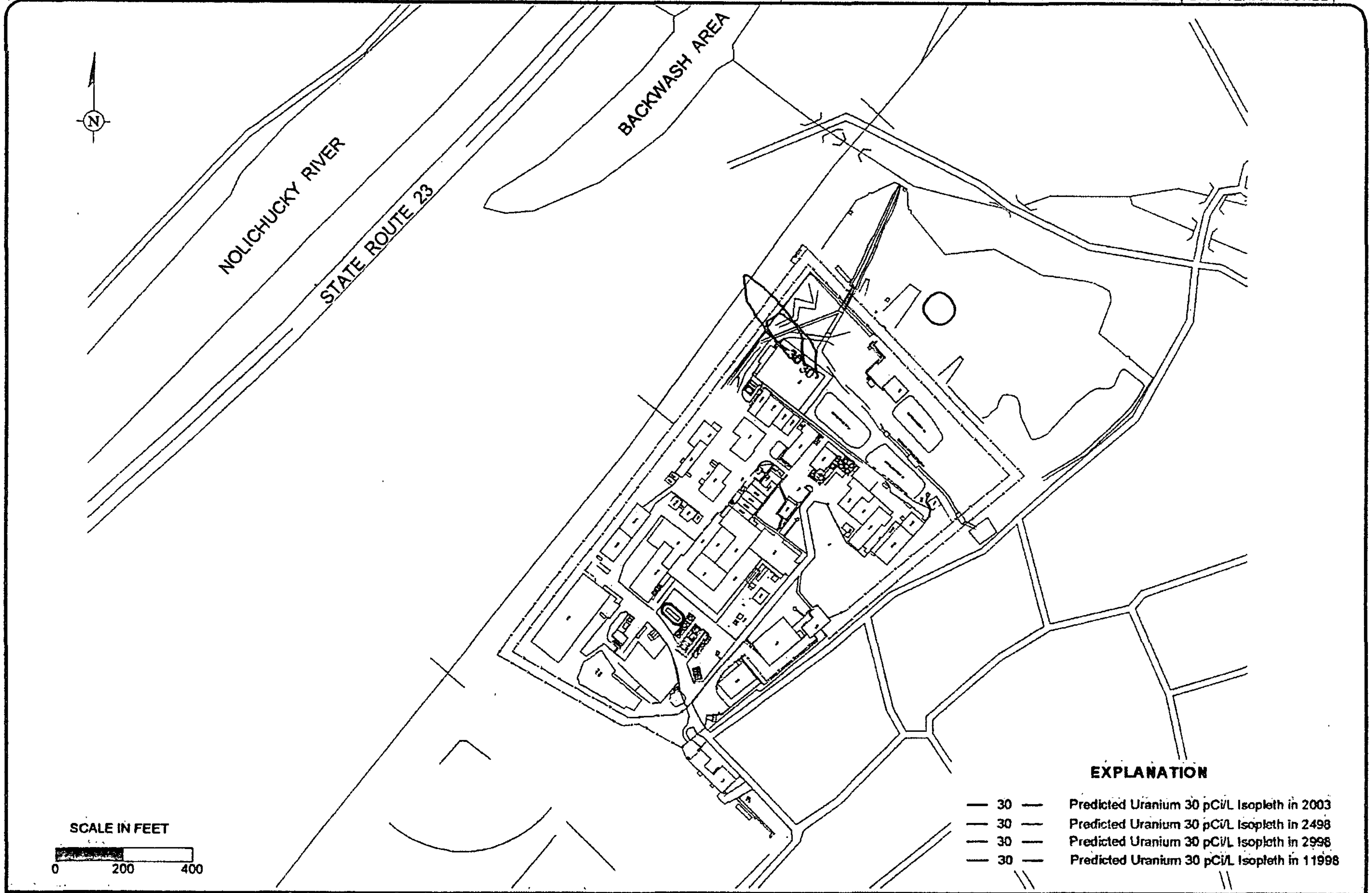
Predicted Uranium Concentrations with Continuous Sources in 2003, 2498, 2998, and 11998 (Model Layer 2)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

5-16

DWG. DATE: 30NOV98 JH | PROJ. NO.:TN000487.0004.0001 | RPT NAME: MODEL | DRAWING: FIG5-17A.SRF | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: J. HUGHES



ARCADIS
GERAGHTY & MILLER

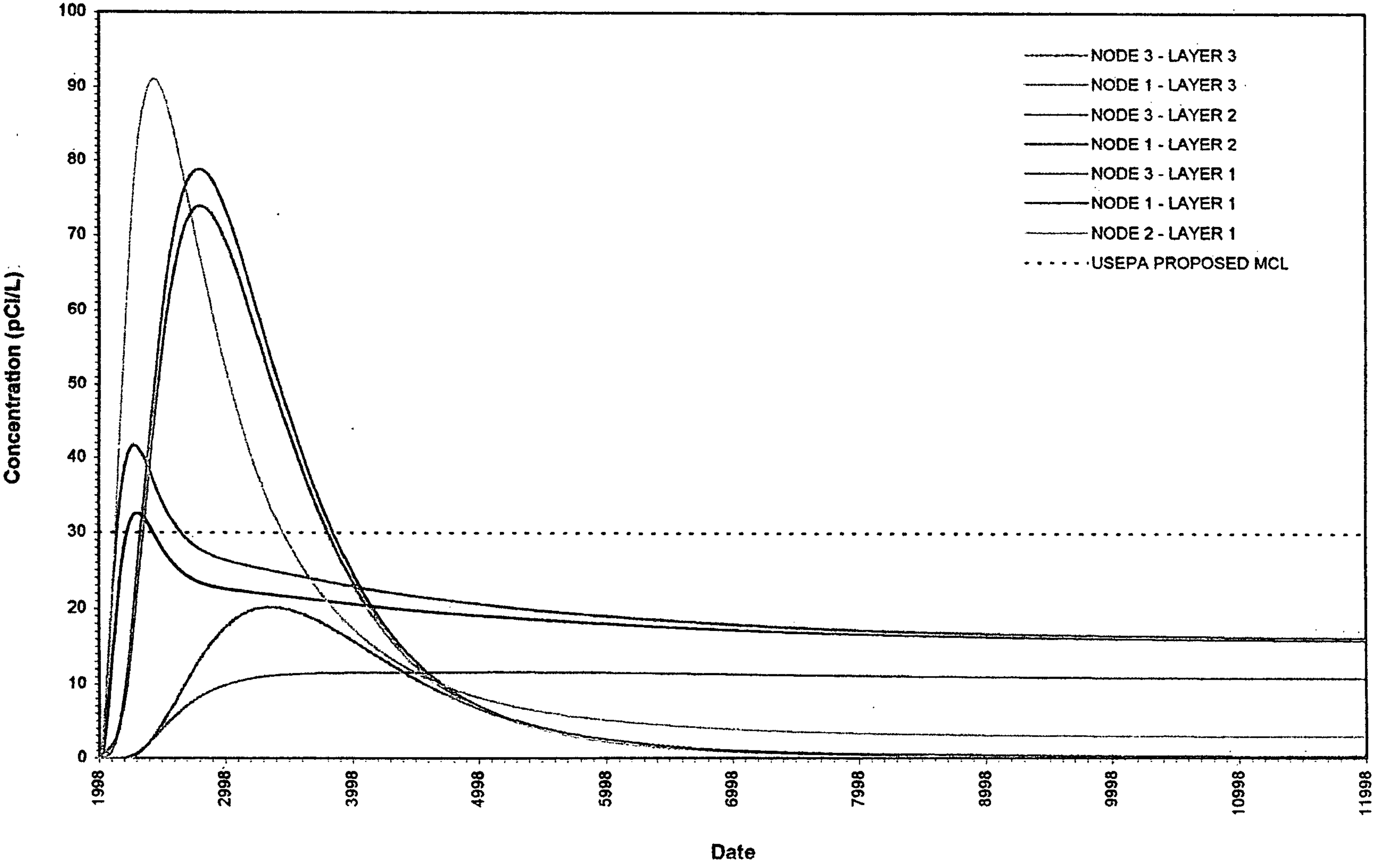
Predicted Uranium Concentrations with Continuous Sources in 2003, 2498, 2998, and 11998 (Model Layer 3)

Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

5-17

DWG. DATE: 14DEC98 MD | PROJ. NO.: TN000487.0004.00001 | FILE NAME: MODEL RPT | DRAWING: D32744.CDR | PROJ. MANAGER: B. MOORE | PROJ. OFFICER: B. ILGNER | DRAFTER: M. DAY



ARCADIS
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Predicted Uranium Concentration at Observation Nodes
(Continuous Source Release Scenario)

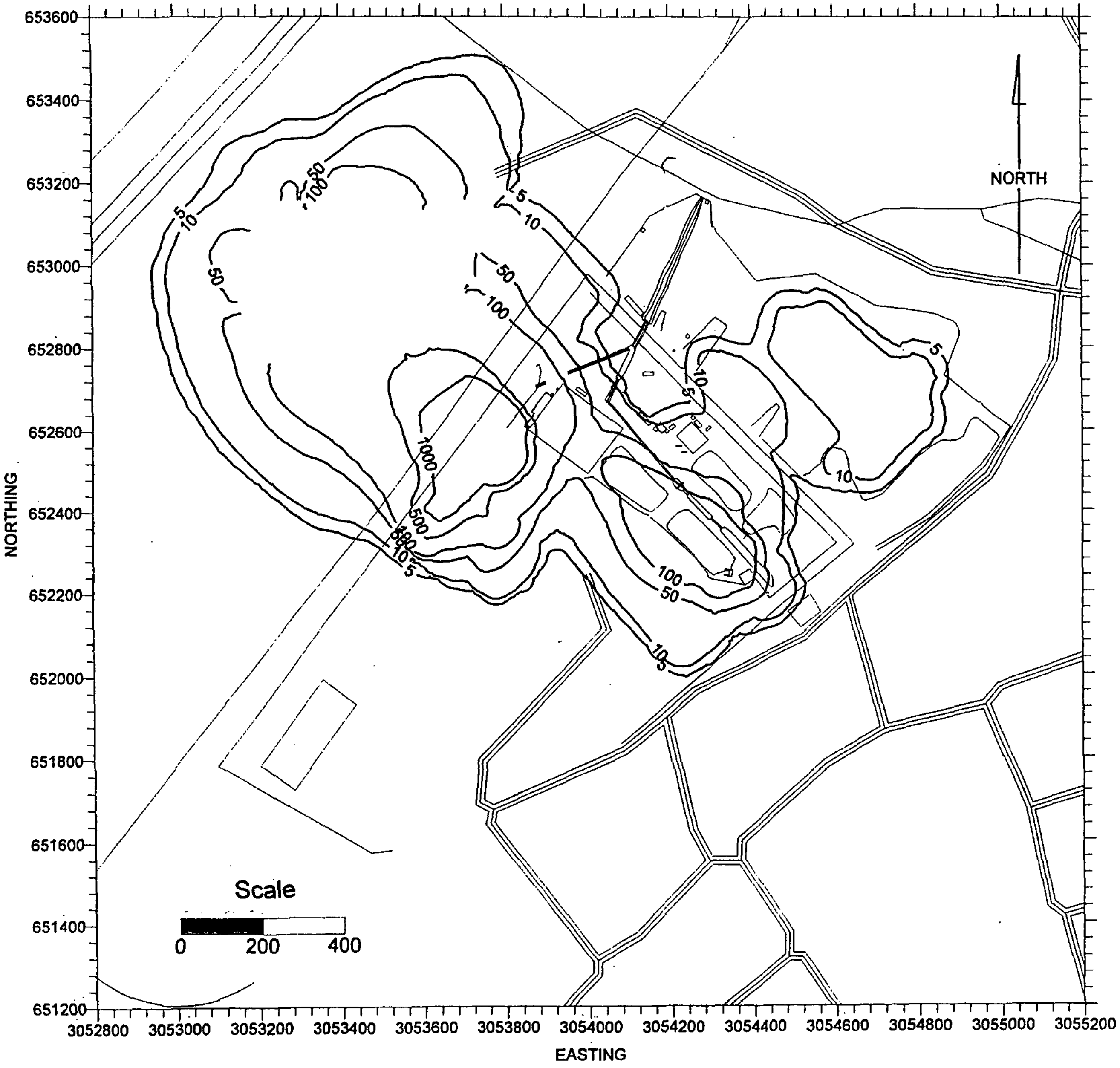
Nuclear Fuel Services, Inc. Erwin, Tennessee

FIGURE

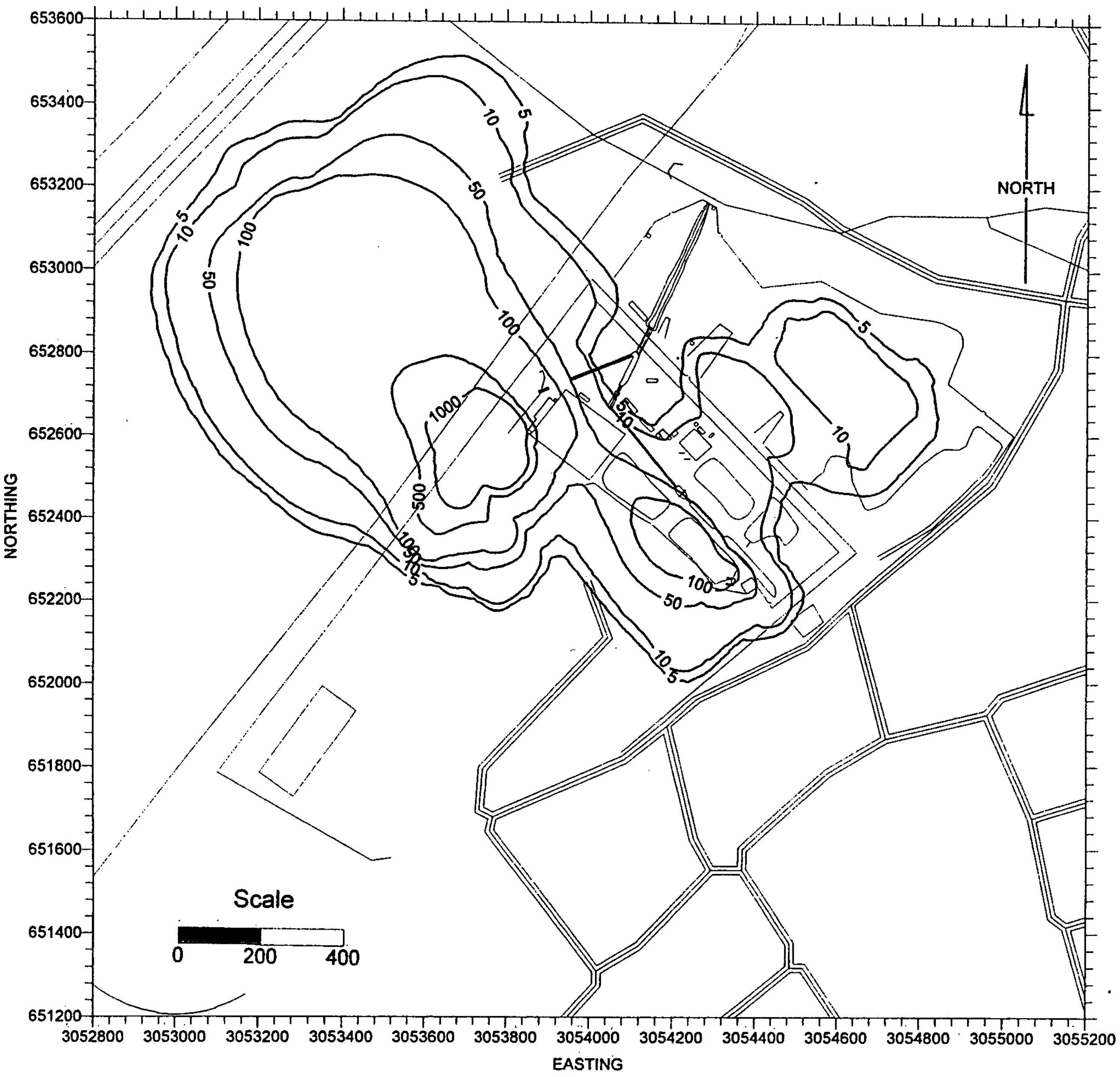
5-18

APPENDIX A

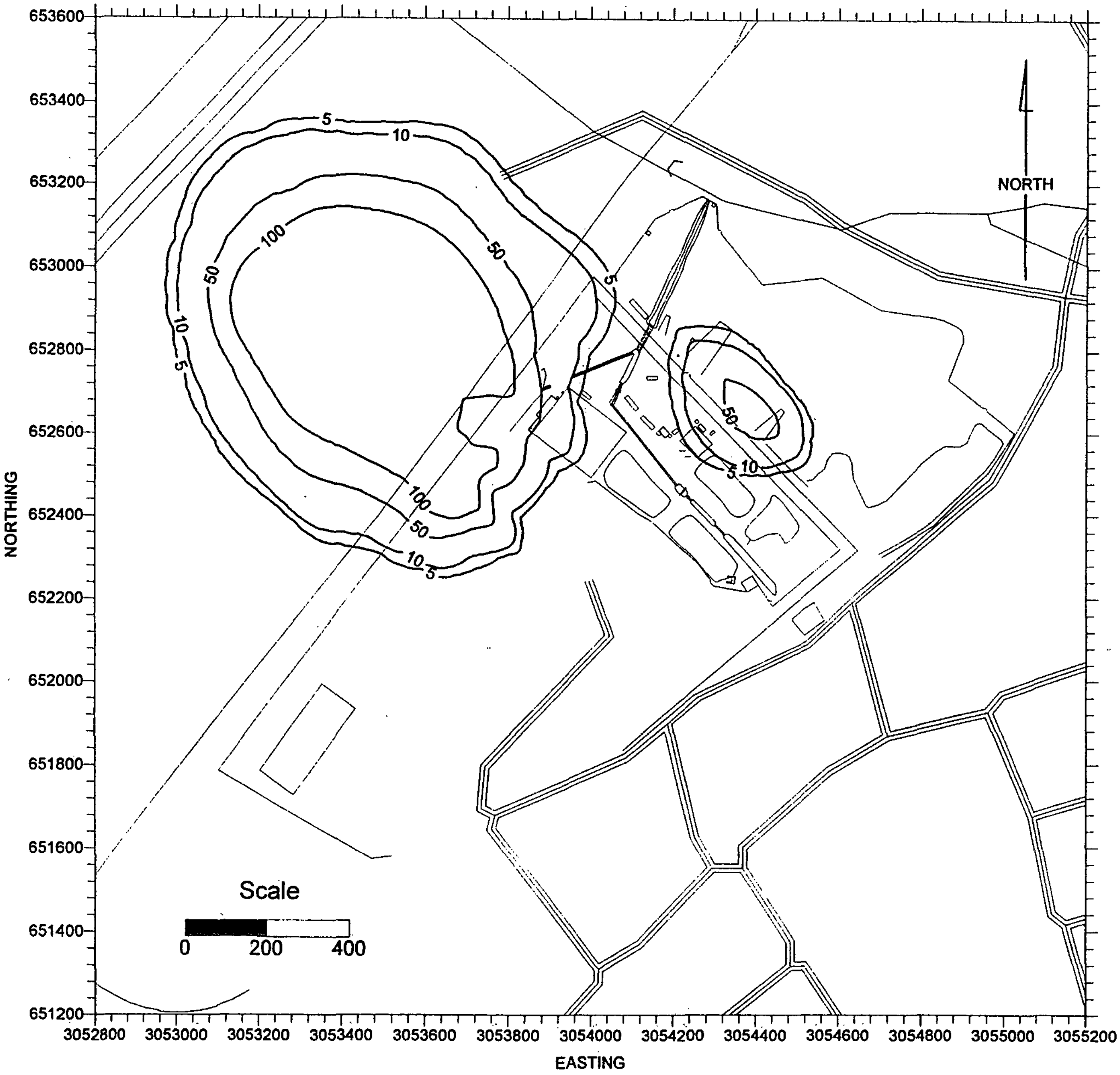
ADDITIONAL PREDICTIVE SIMULATIONS CONTOUR MAPS



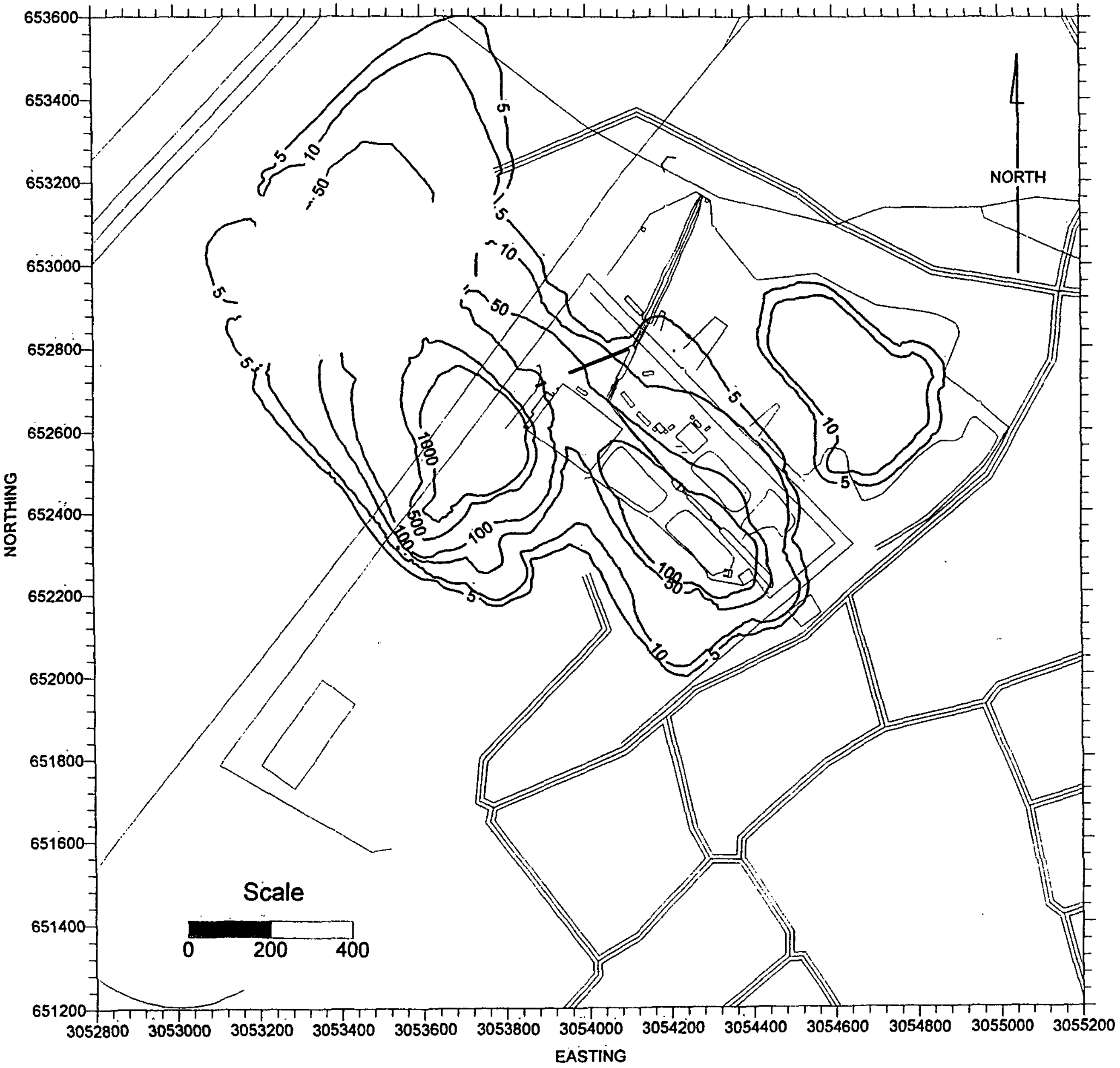
PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 1998
IN THE SHALLOW ALLUVIAL AQUIFER
WITH CONTINUOUS SOURCES



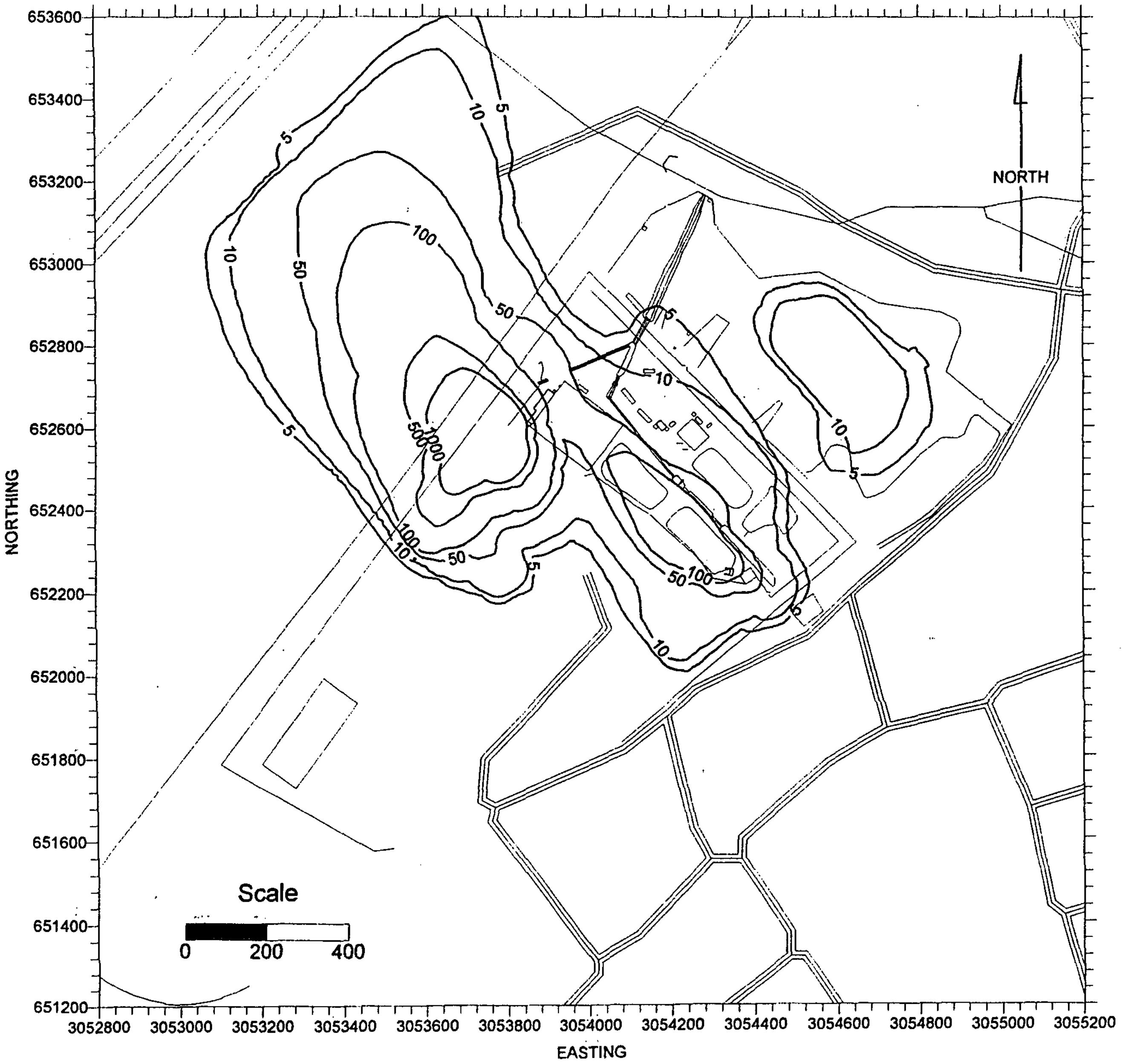
PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 1998
IN THE DEEP ALLUVIAL AQUIFER
WITH CONTINUOUS SOURCES



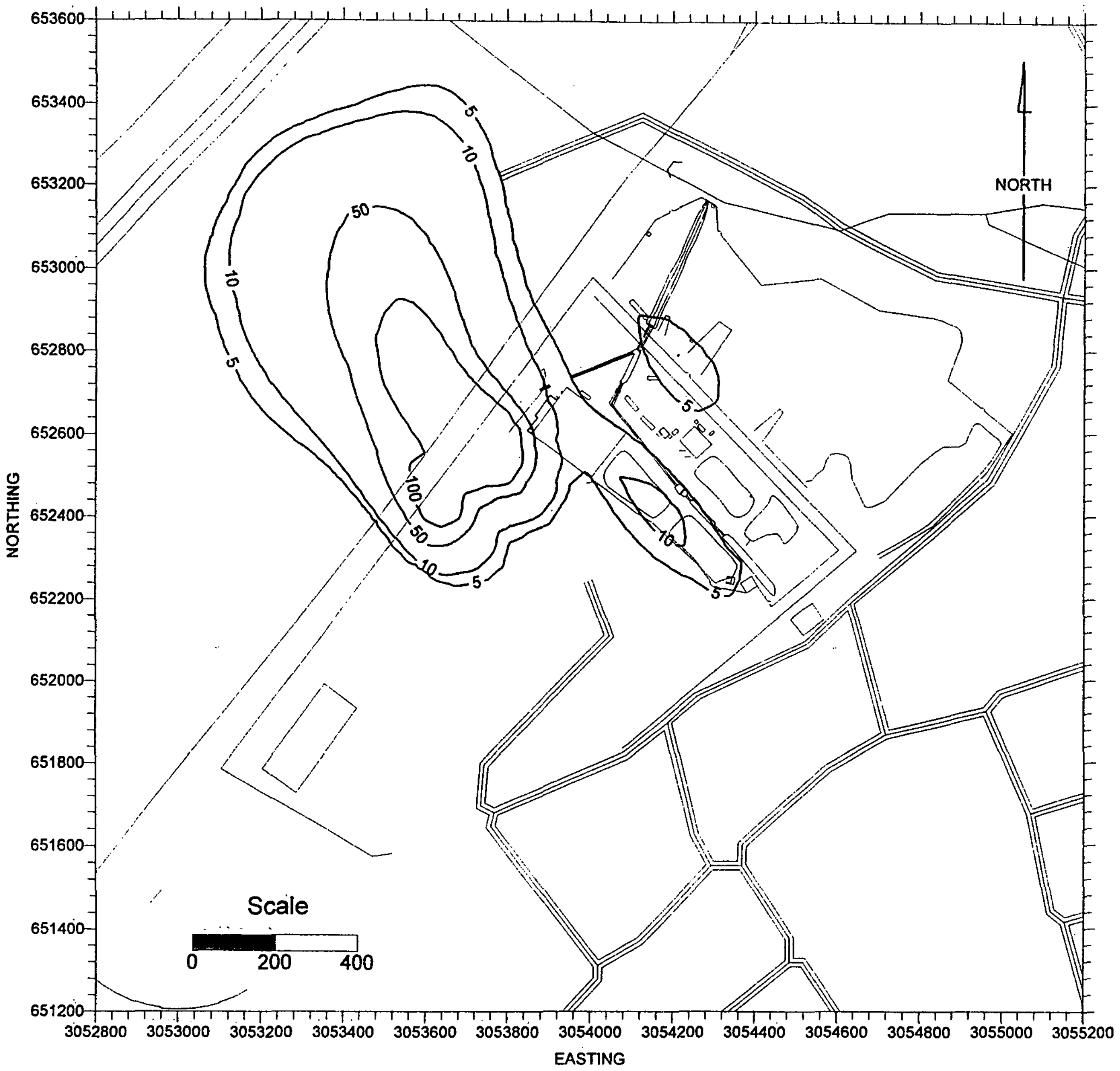
PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 1998
IN THE SHALLOW BEDROCK AQUIFER
WITH CONTINUOUS SOURCES



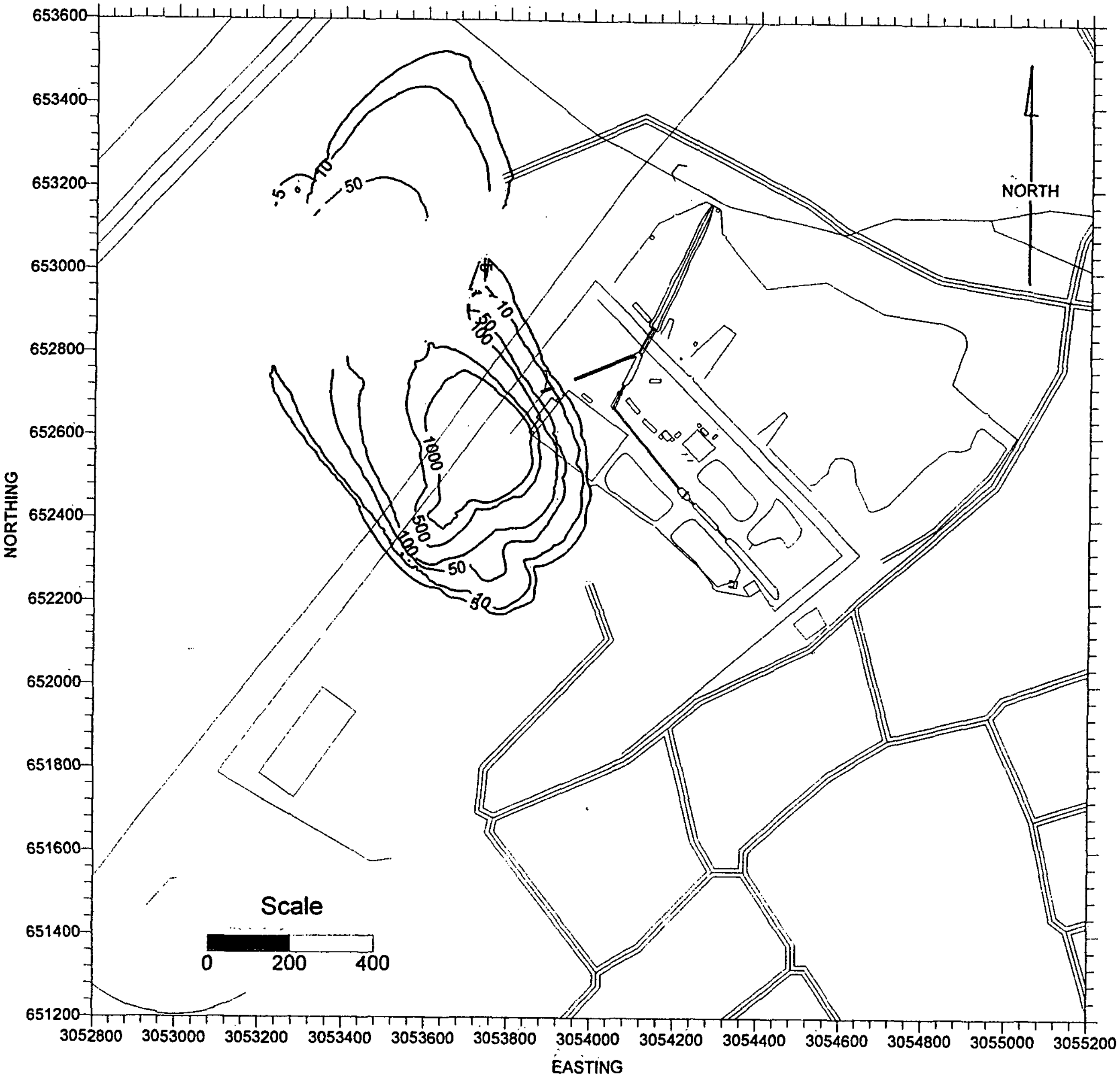
PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 2003
IN THE SHALLOW ALLUVIAL AQUIFER
WITH CONTINUOUS SOURCES



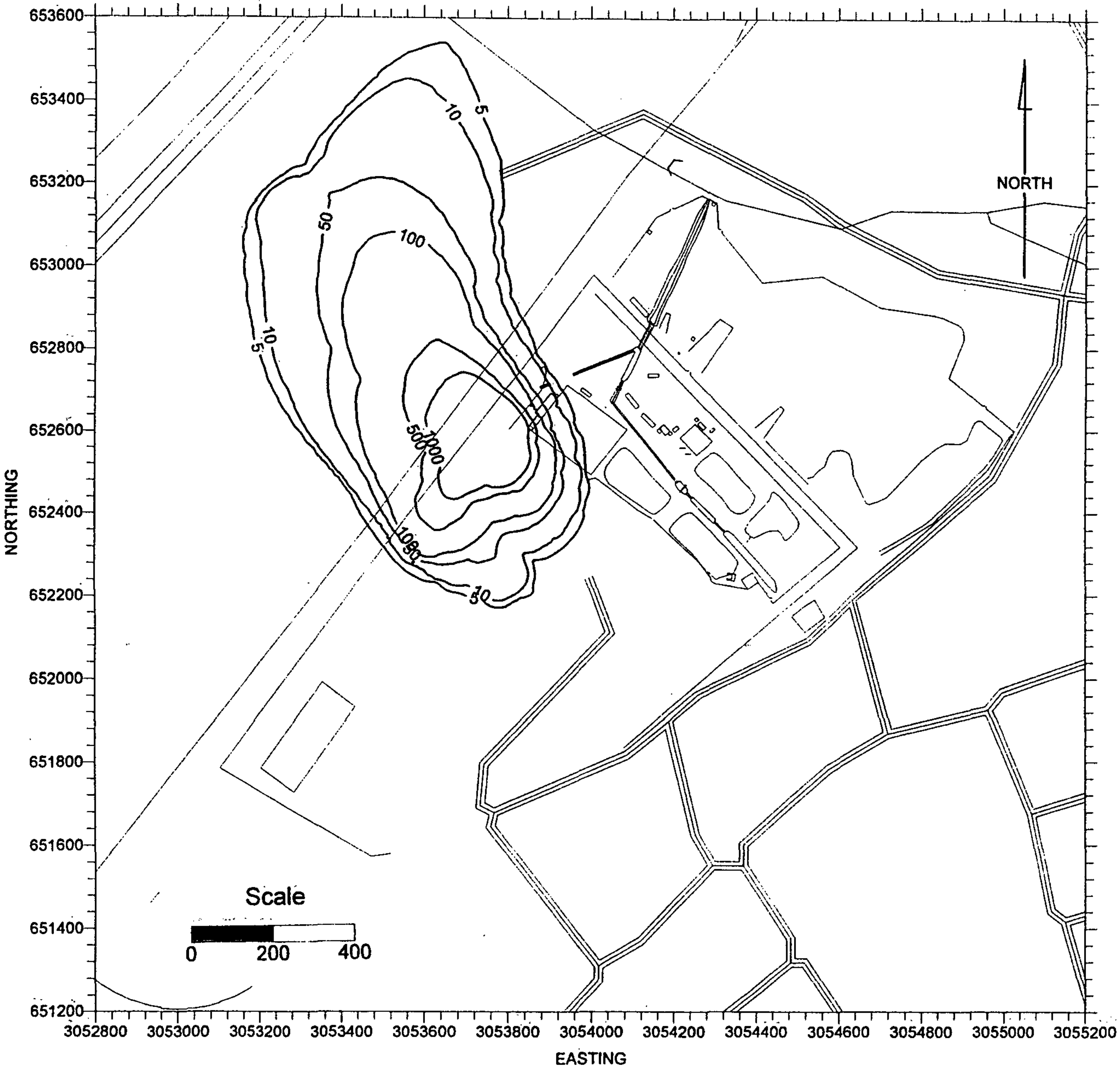
PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 2003
IN THE DEEP ALLUVIAL AQUIFER
WITH CONTINUOUS SOURCES



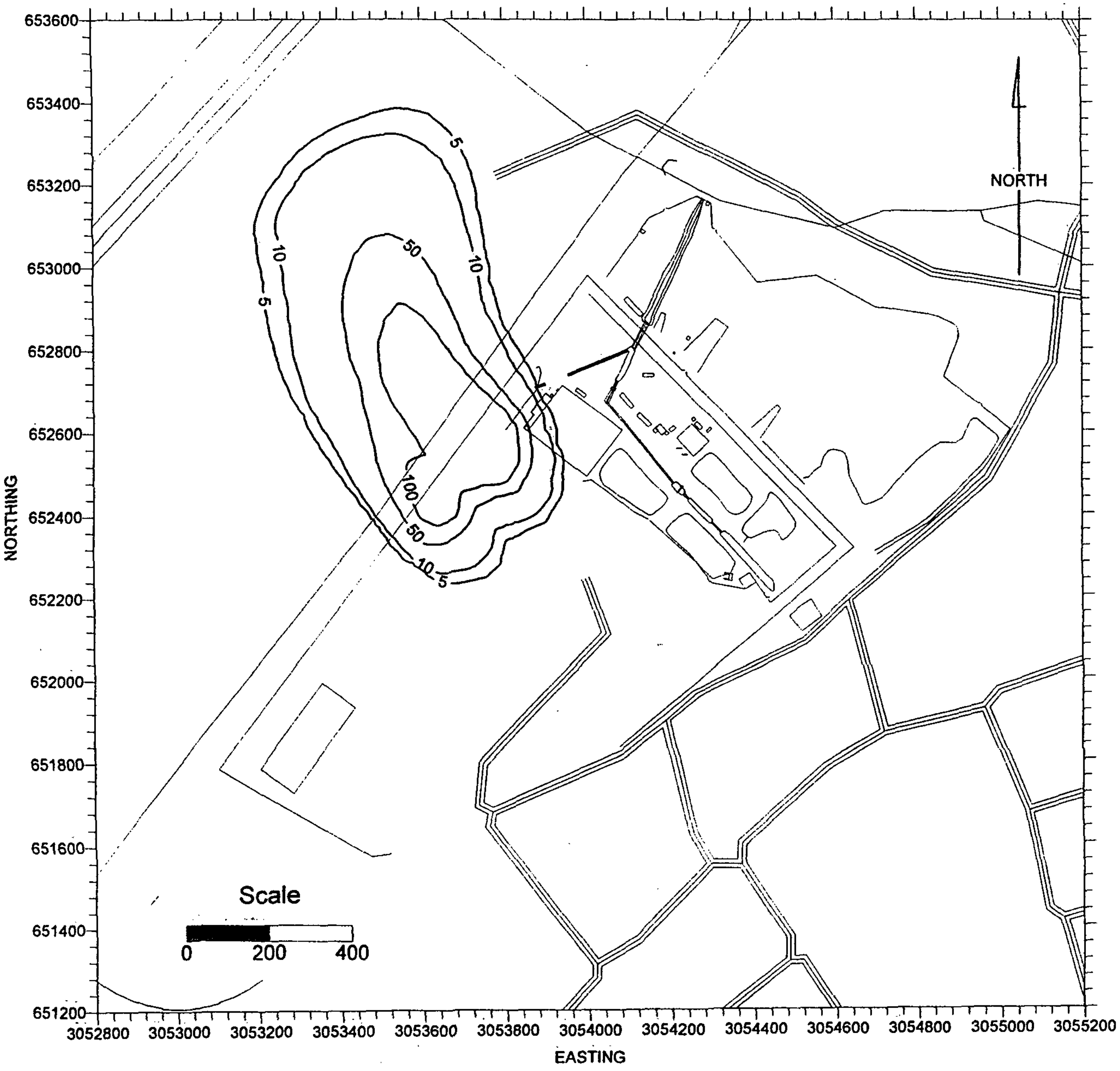
PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 2003
IN THE SHALLOW BEDROCK AQUIFER
WITH CONTINUOUS SOURCES



PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 2008
IN THE SHALLOW ALLUVIAL AQUIFER
WITH CONTINUOUS SOURCES



PREDICTED TETRACHLOROETHENE CONCENTRATIONS (ug/l) AT 2008
IN THE DEEP ALLUVIAL AQUIFER
WITH CONTINUOUS SOURCES



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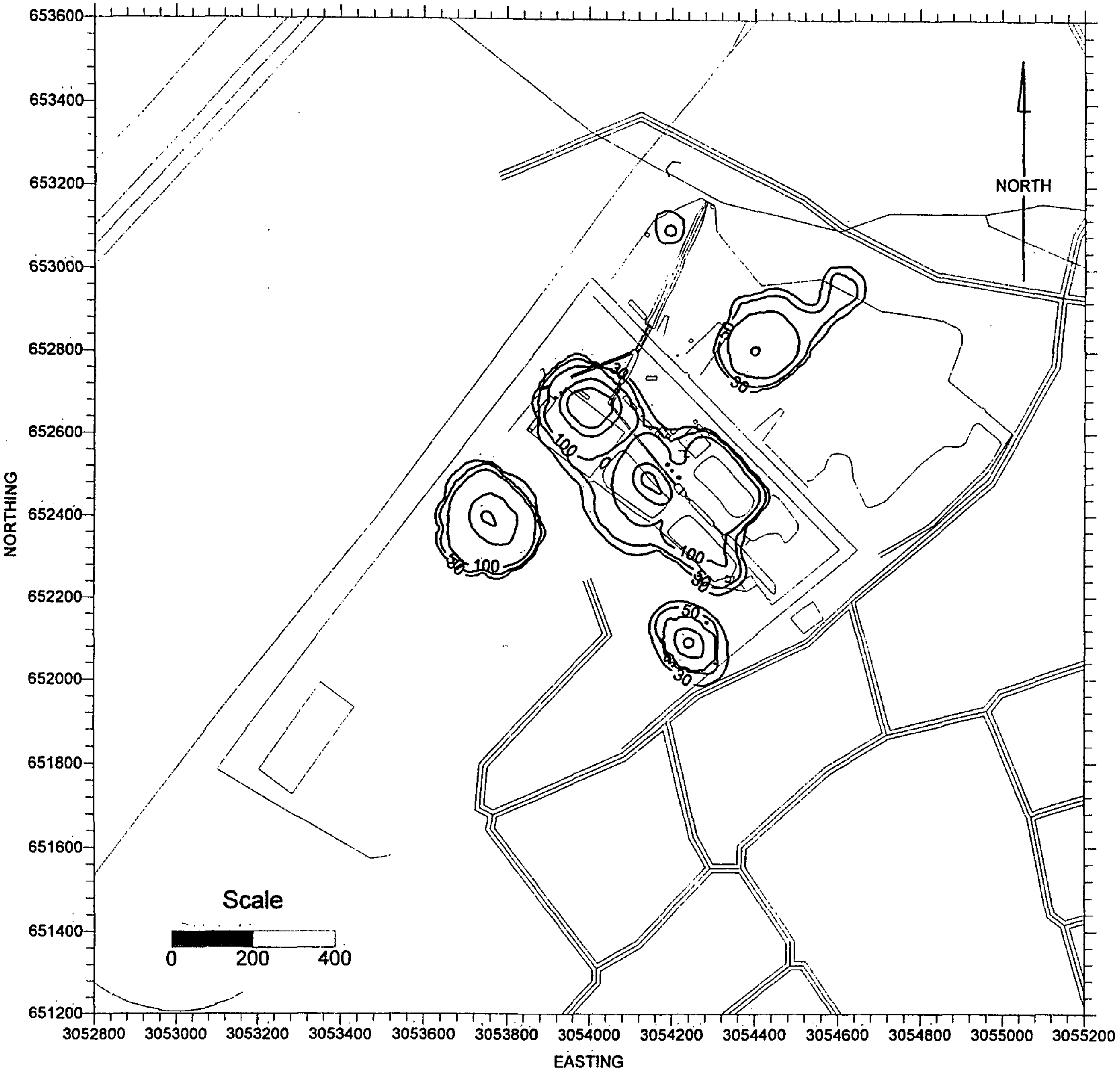

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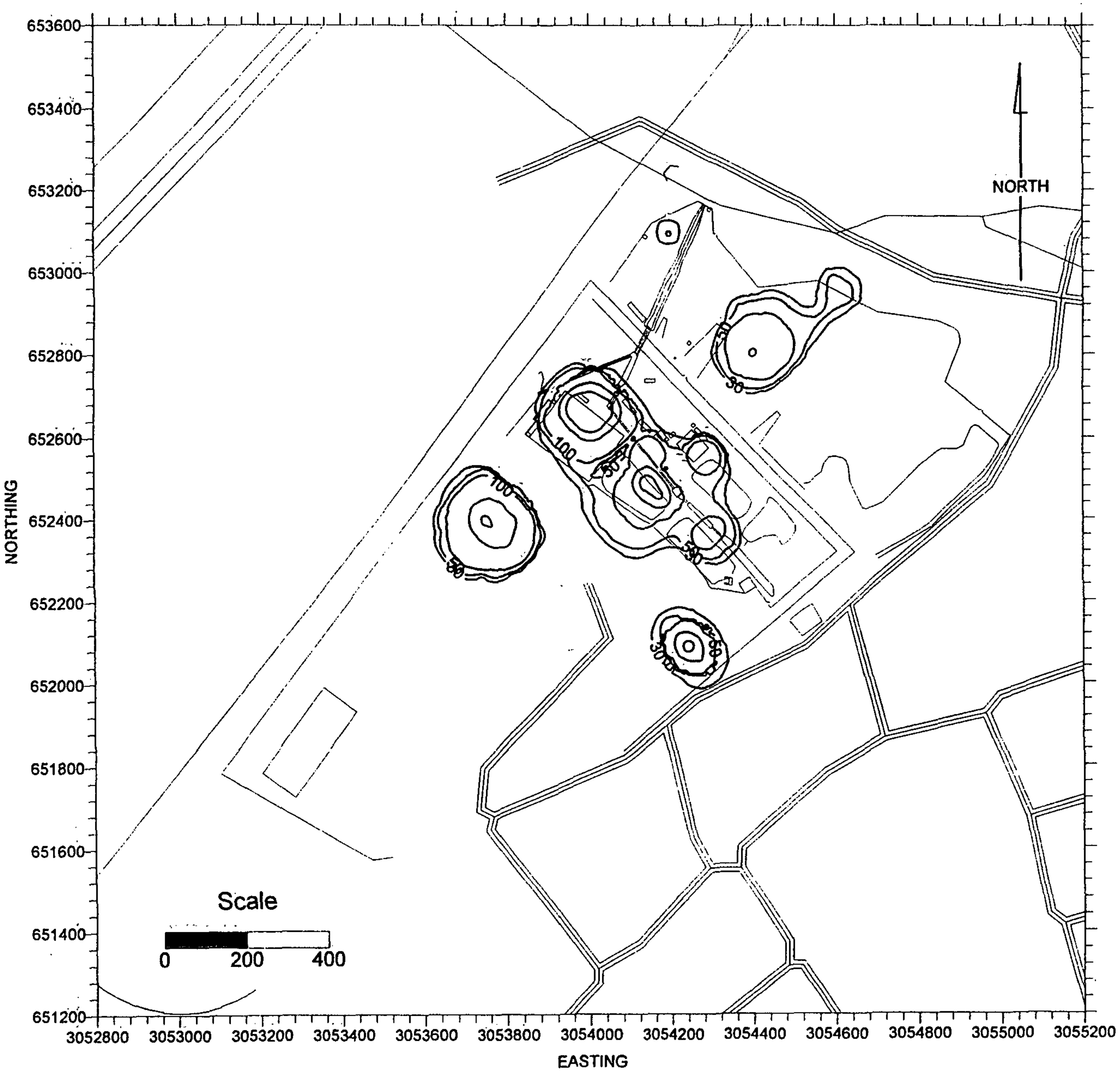

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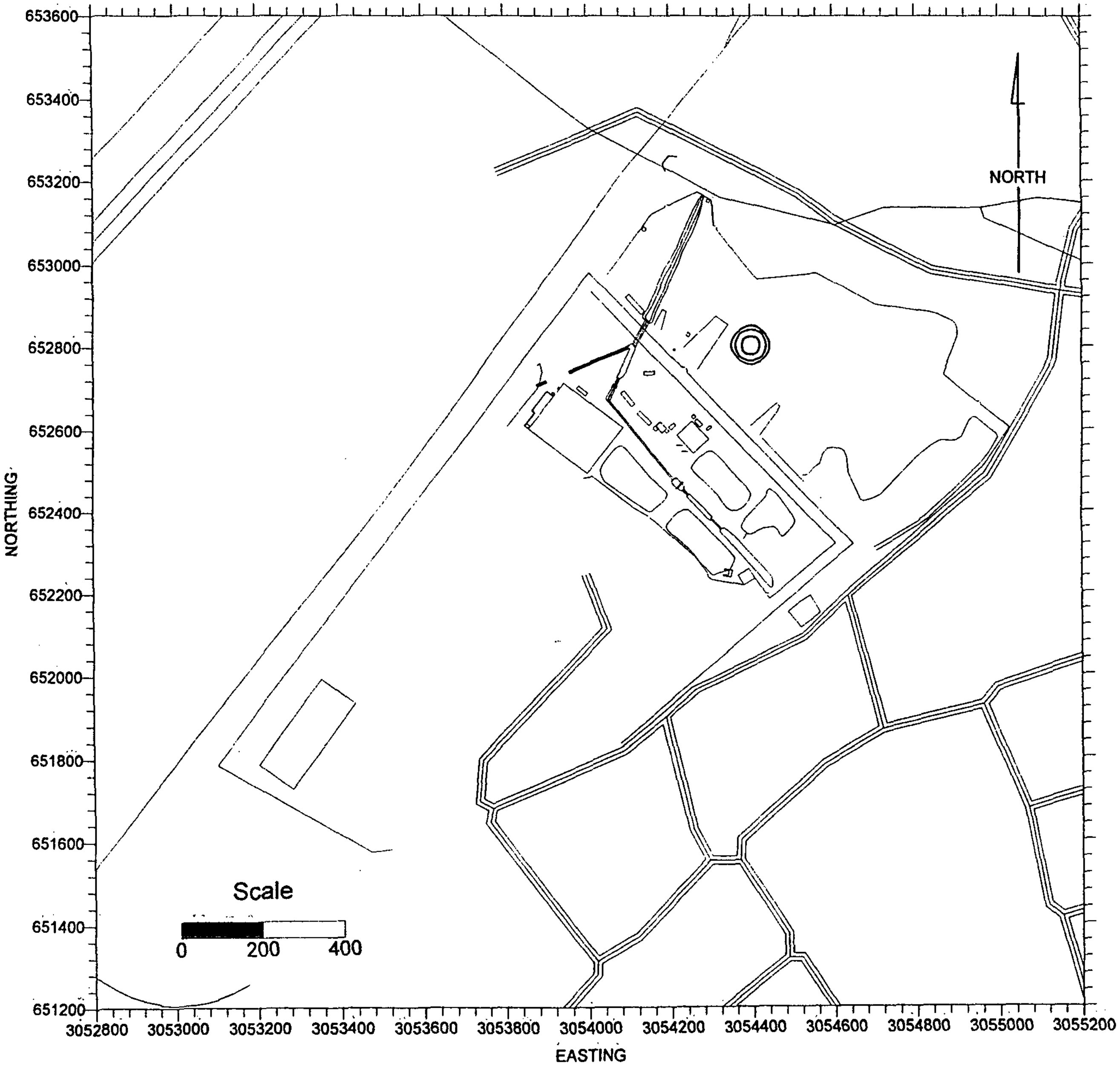

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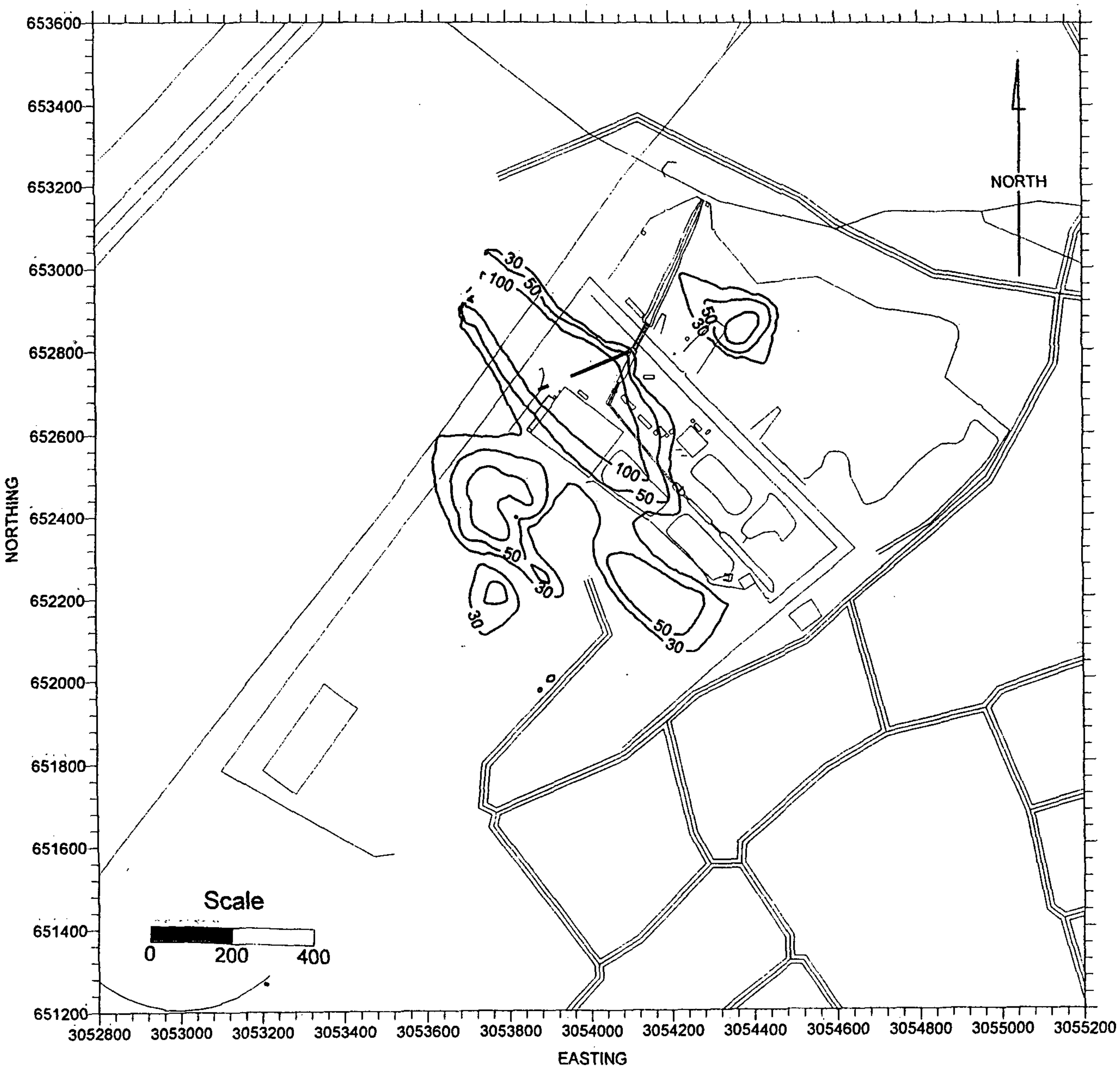

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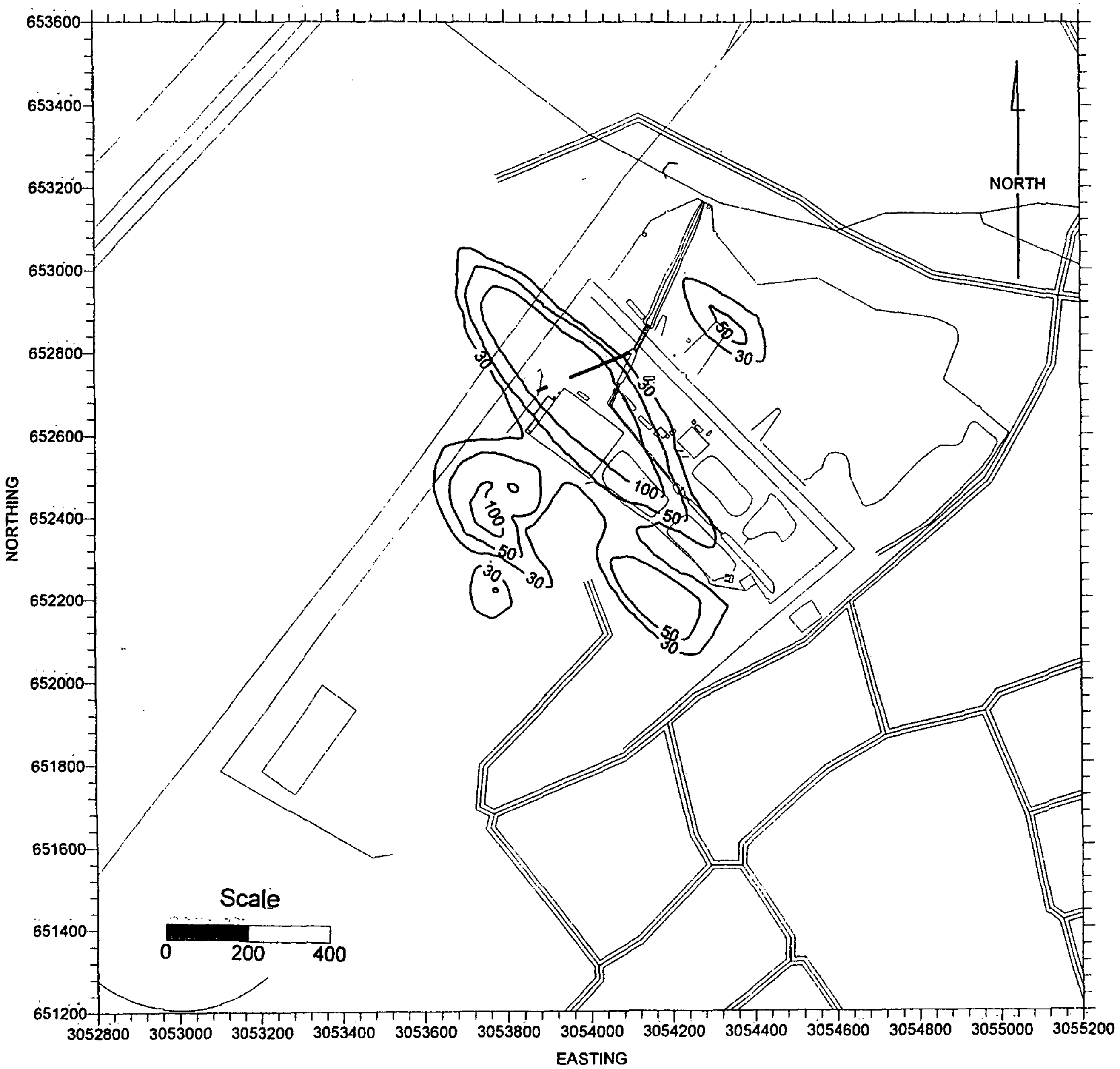

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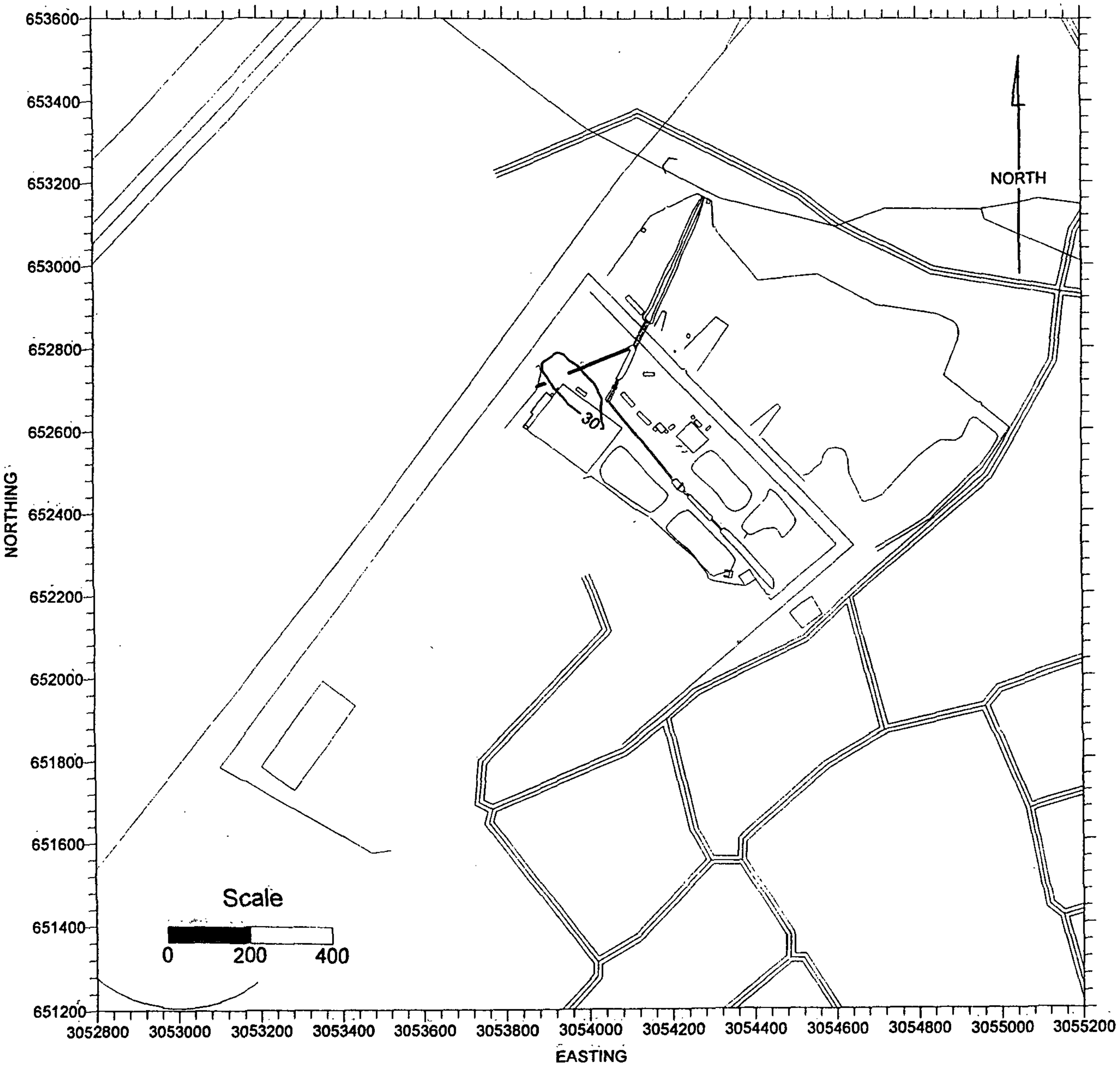

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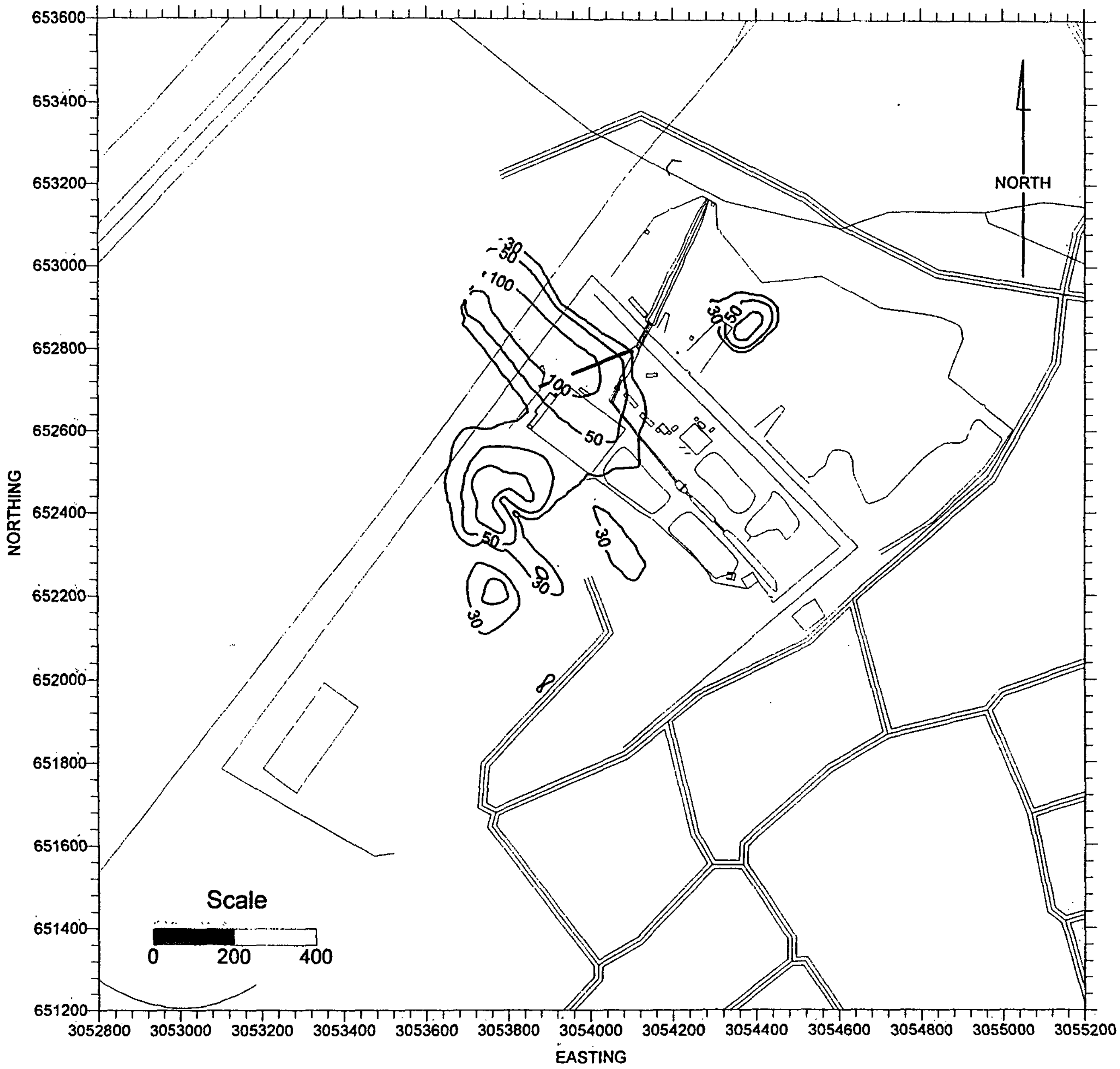

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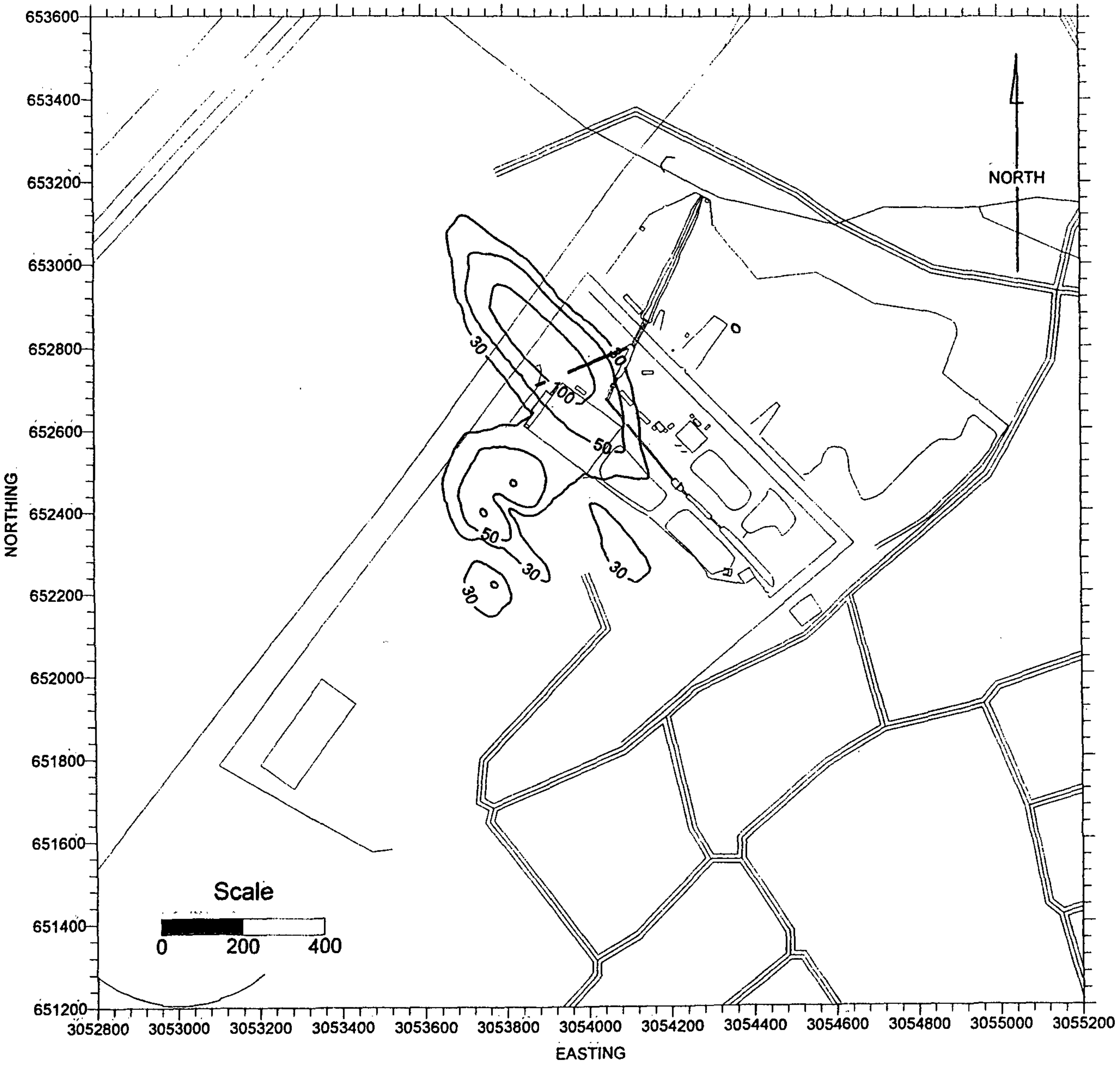

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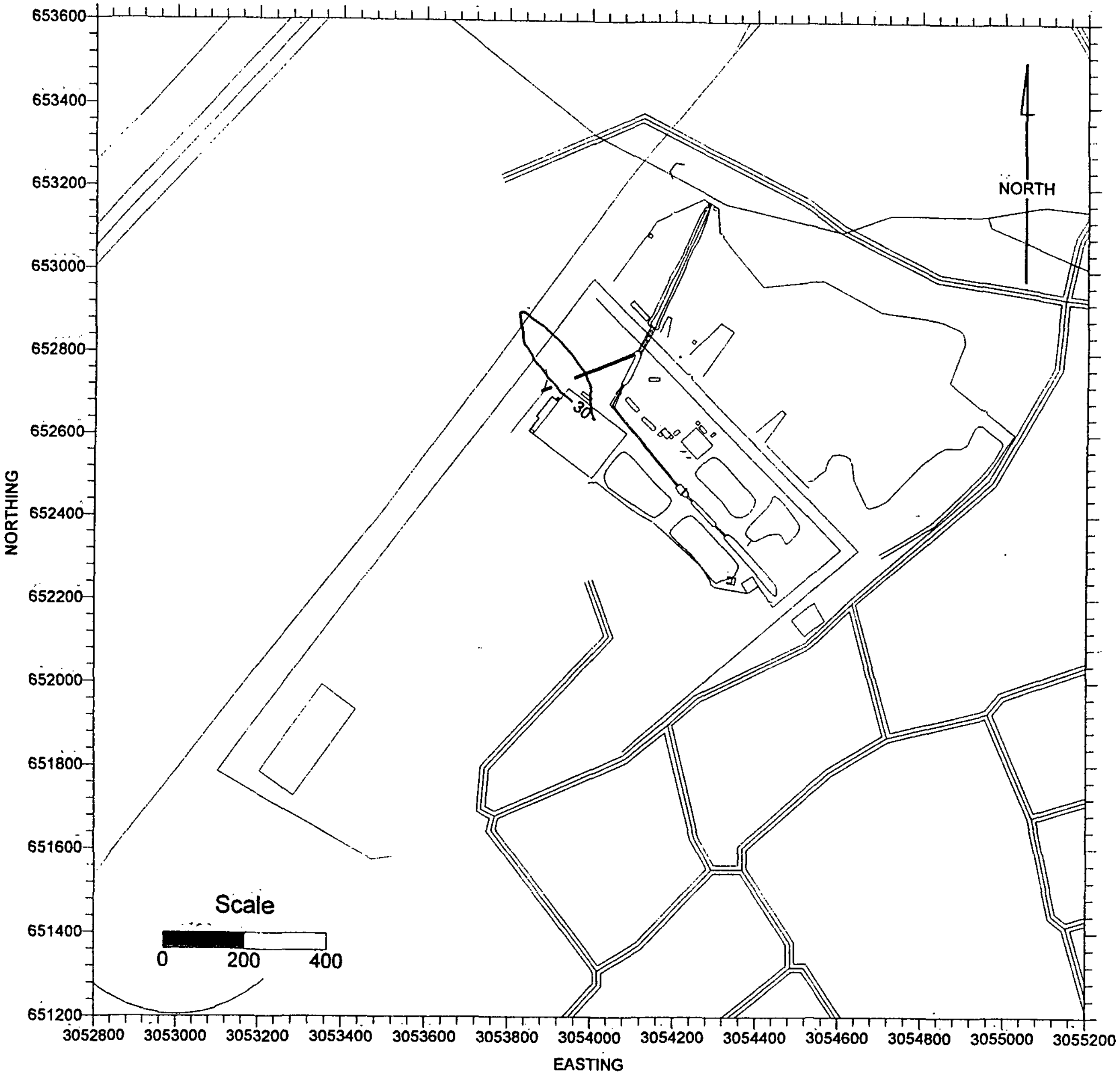

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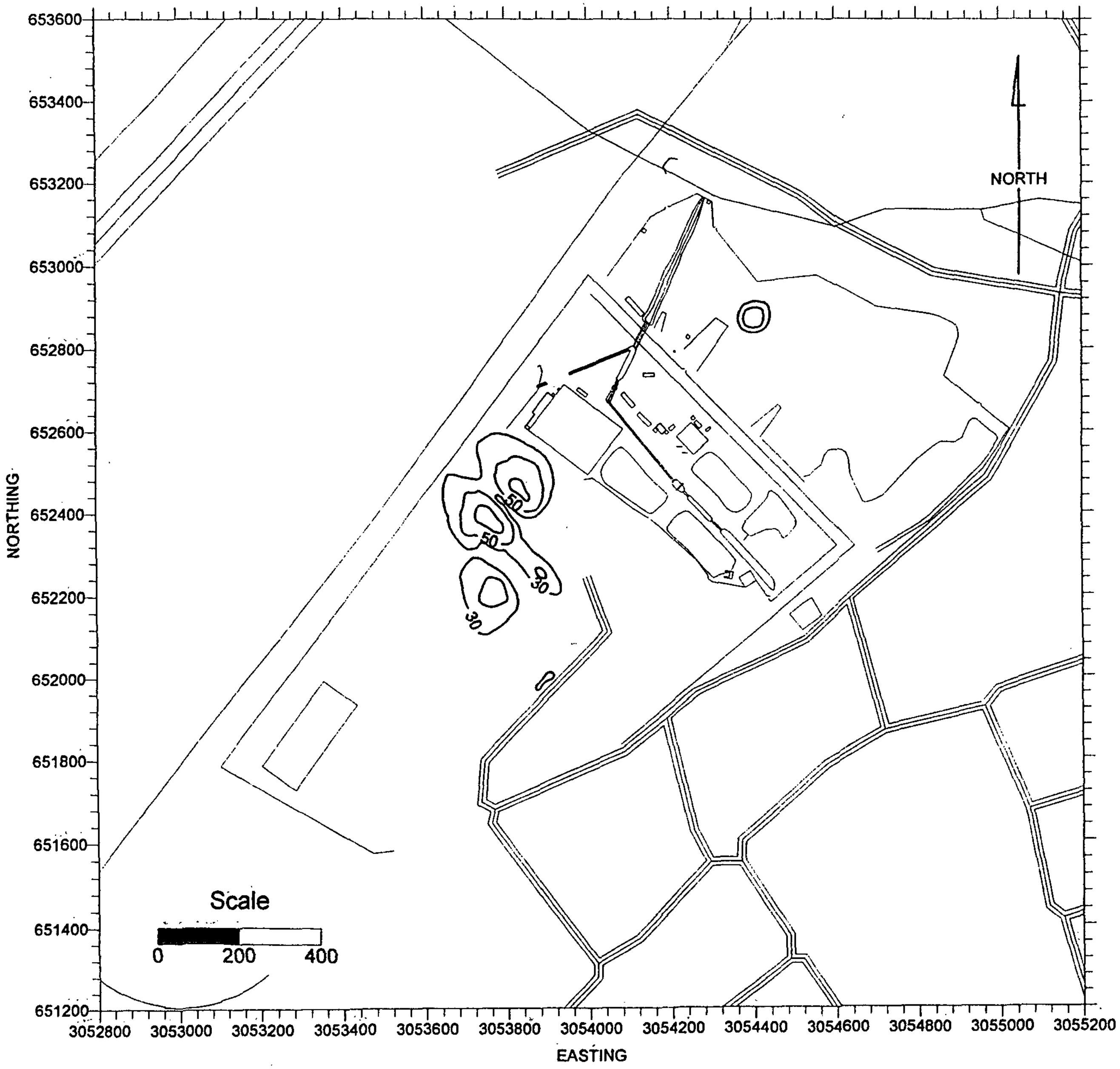

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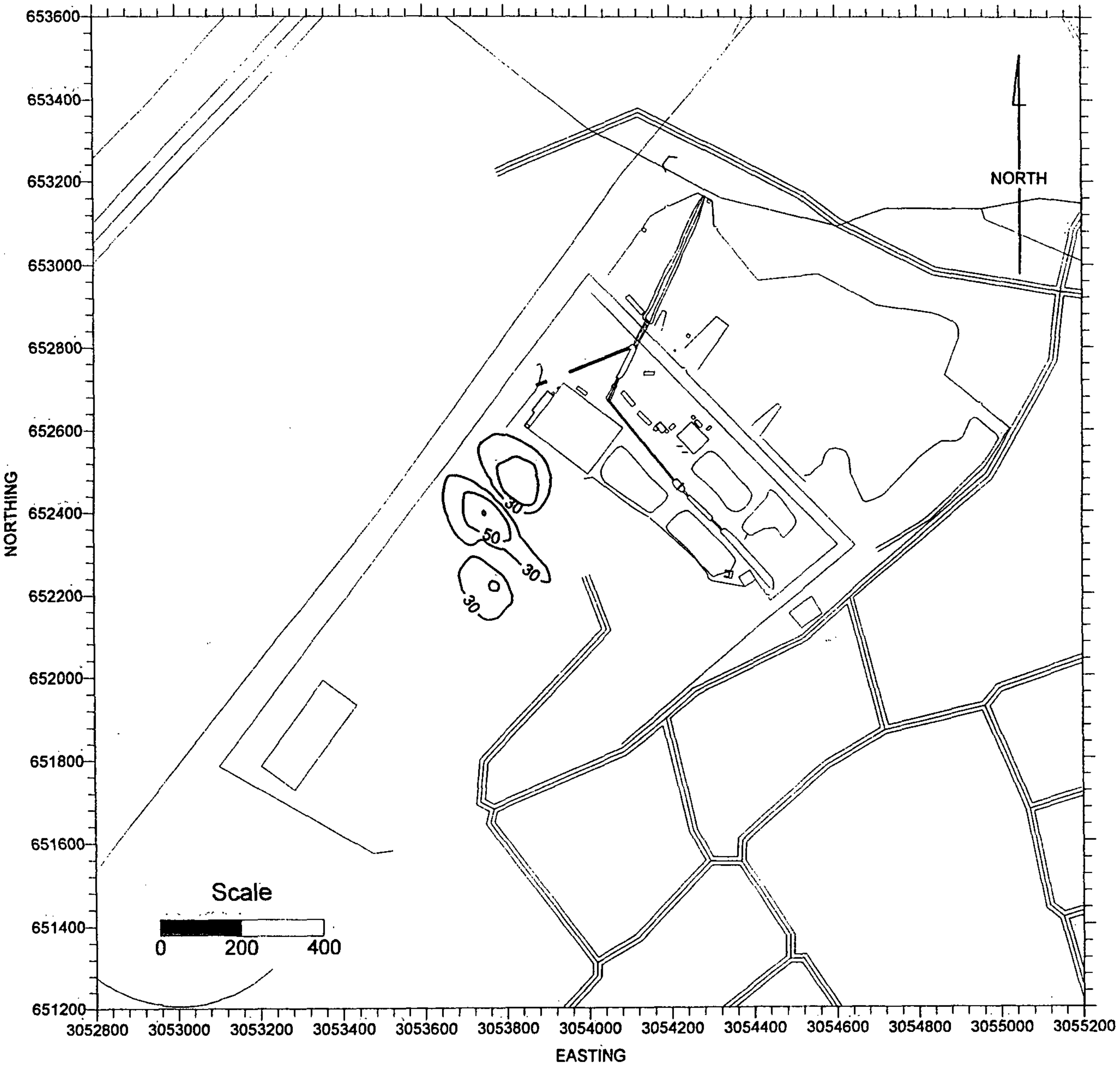

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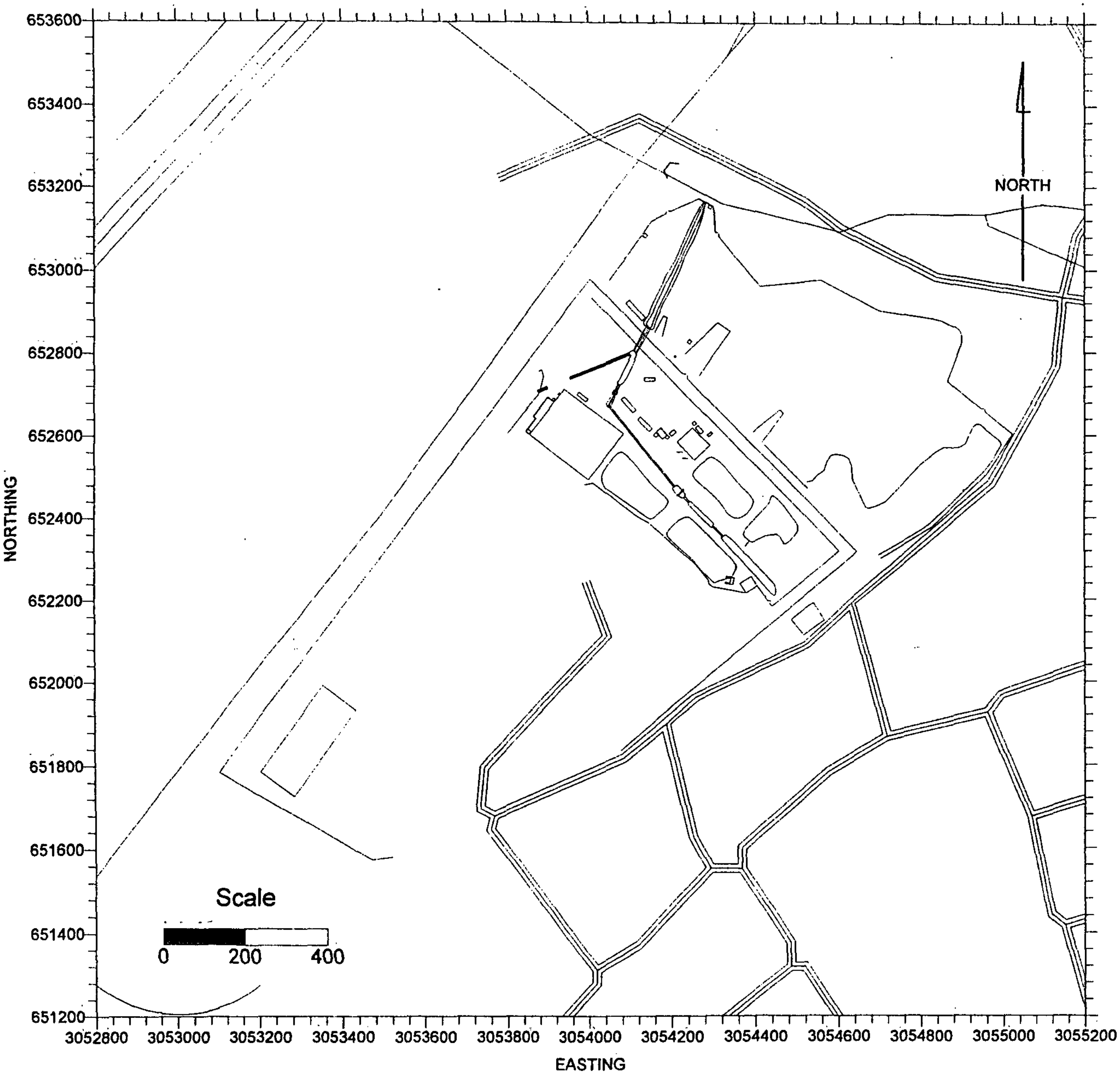

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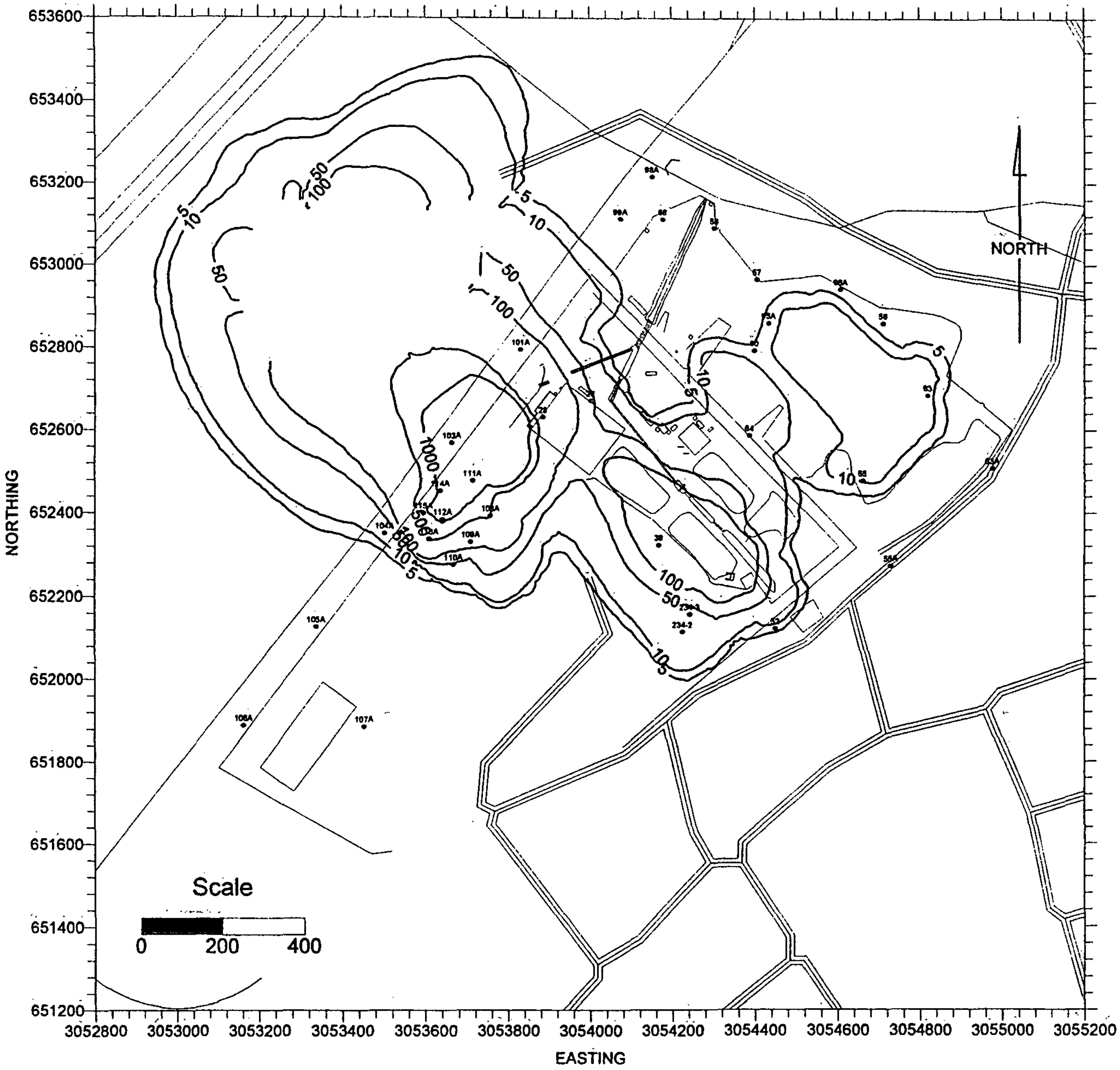

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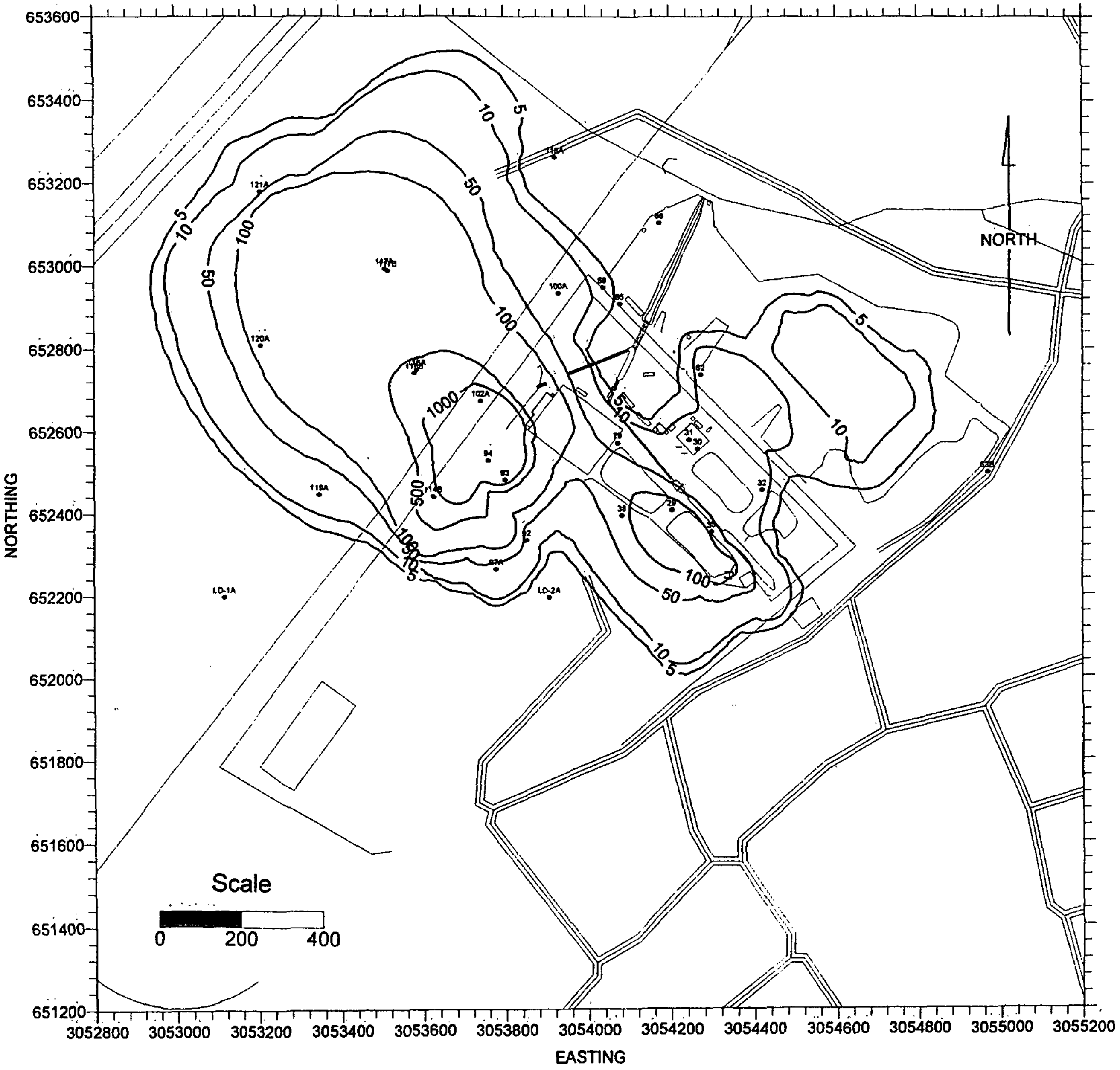

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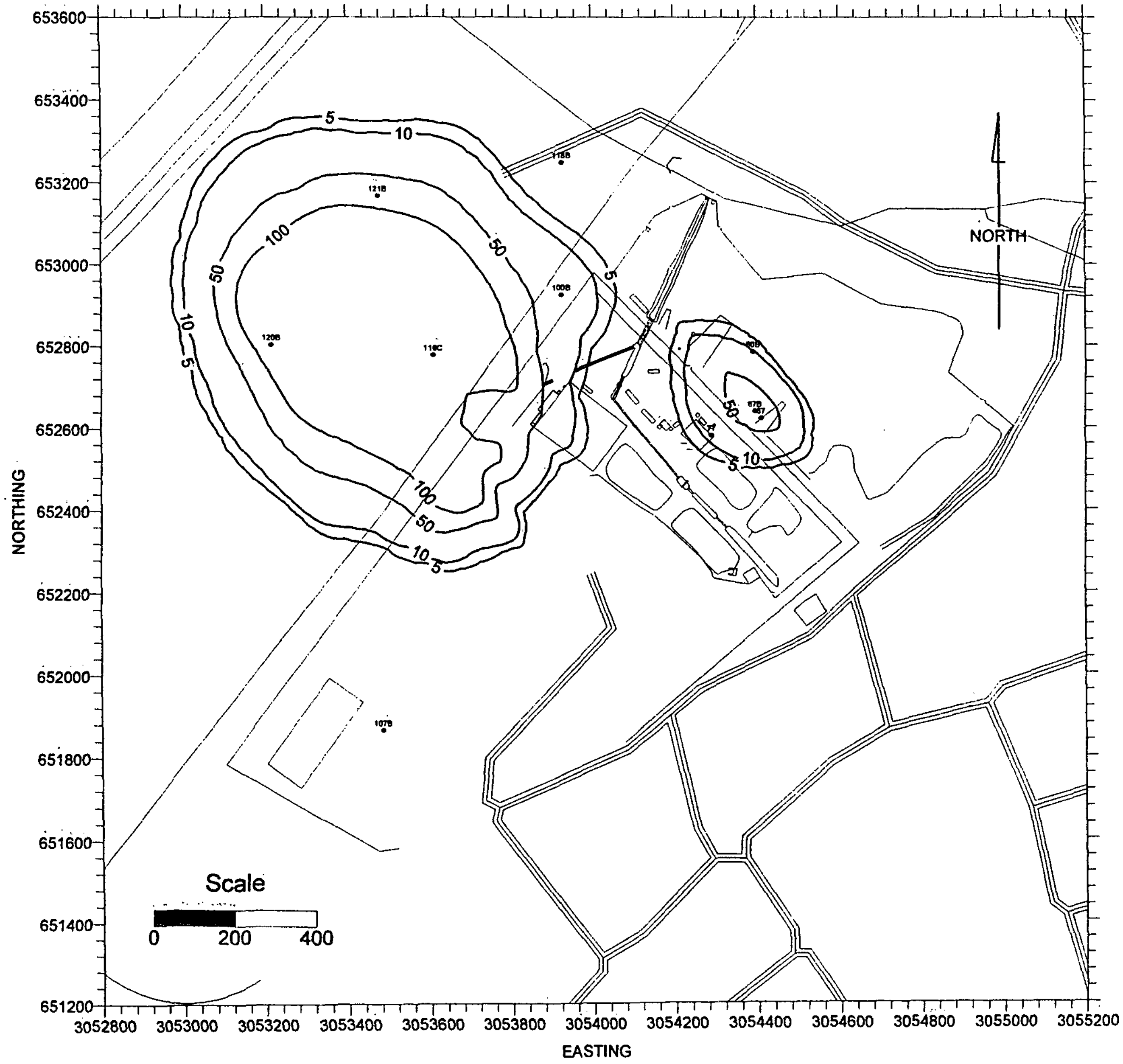

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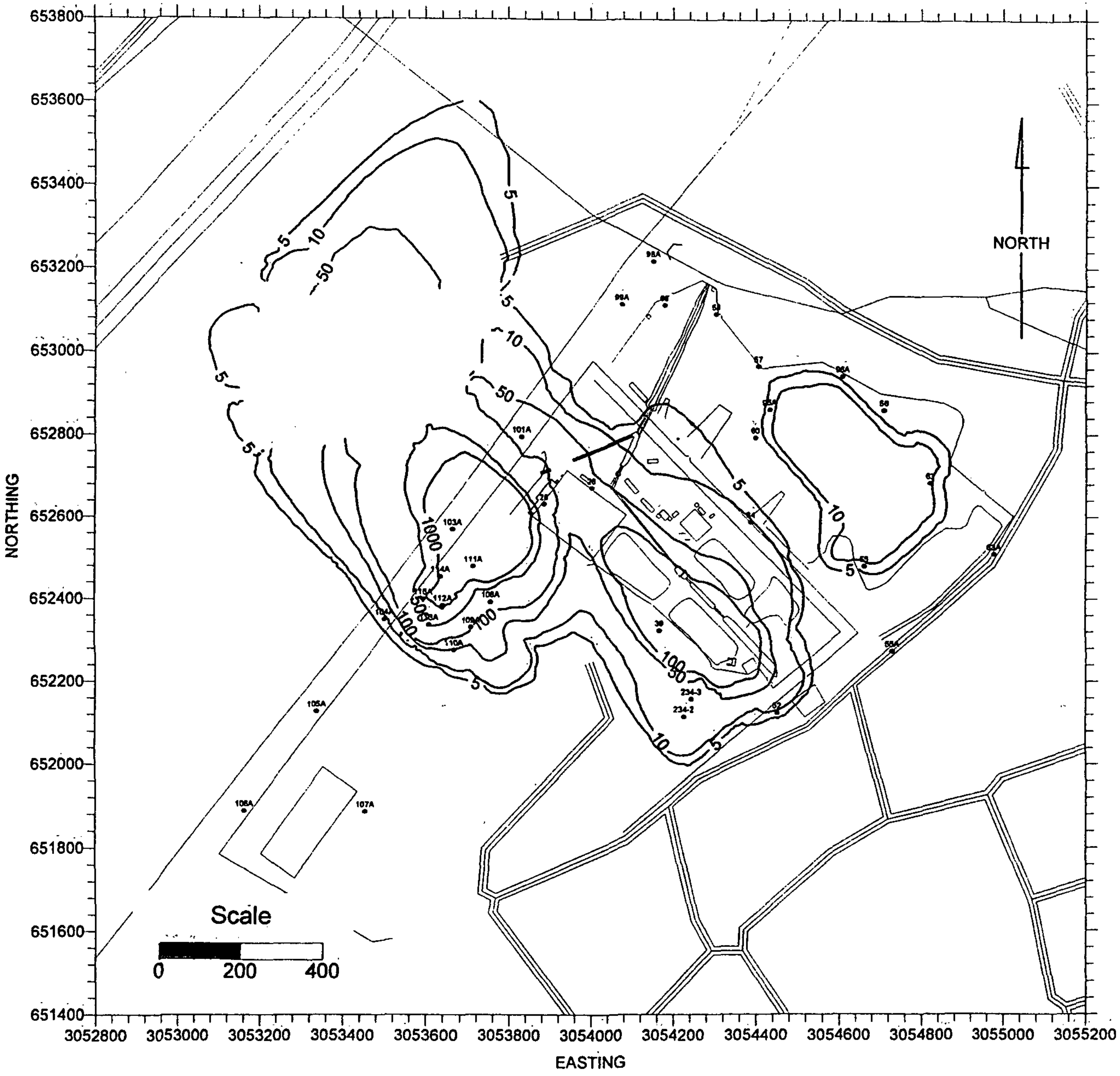

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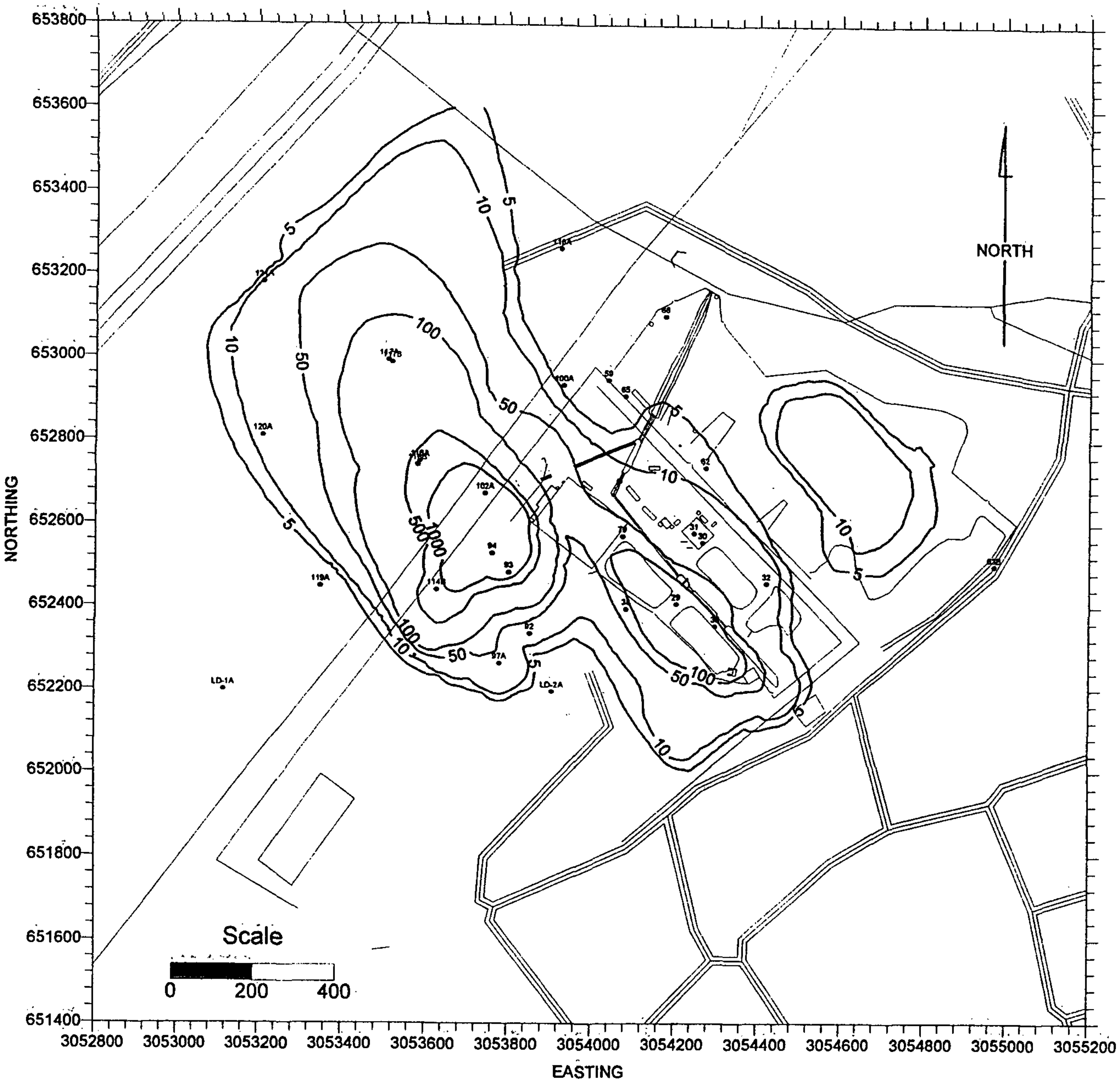

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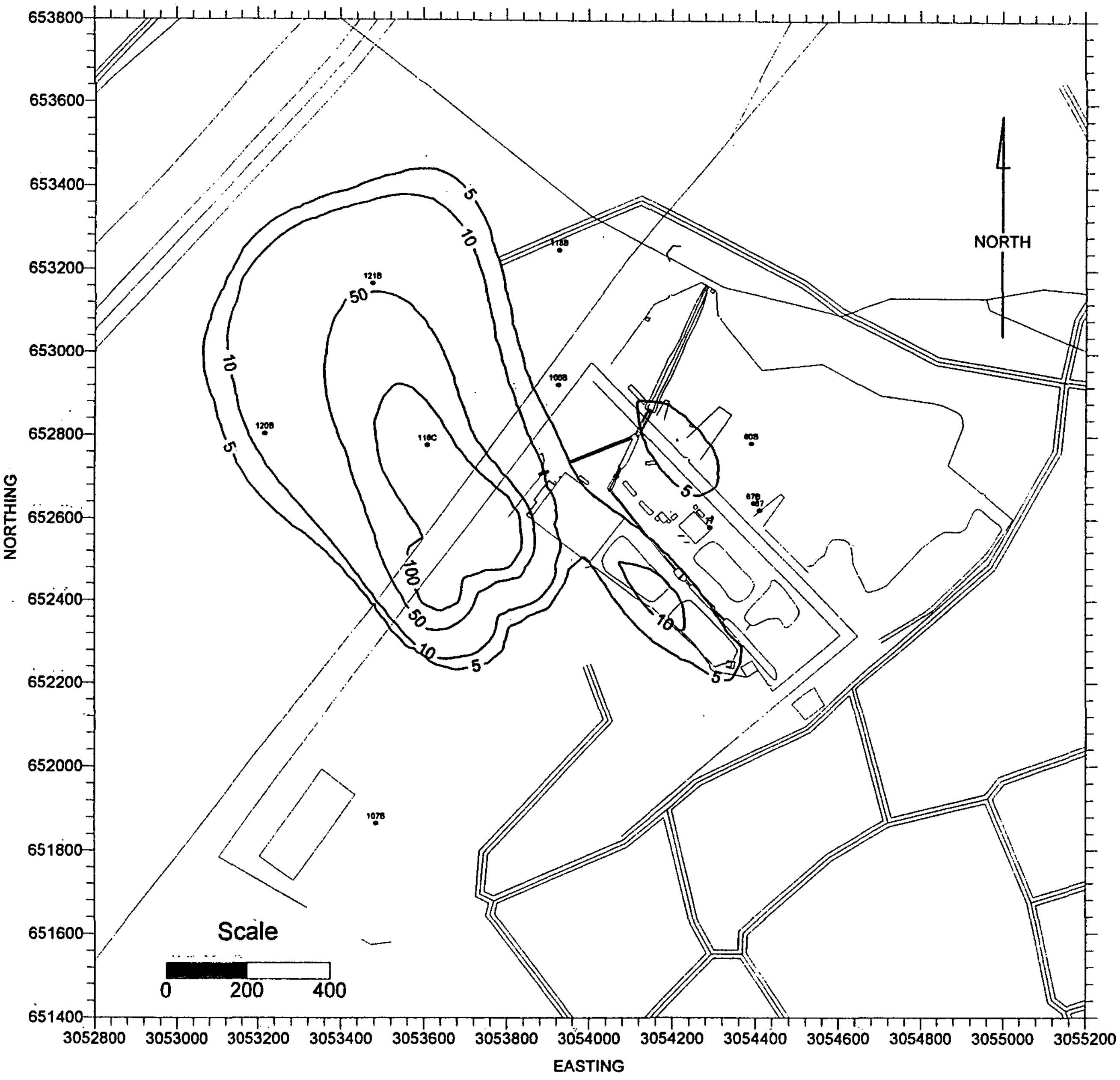

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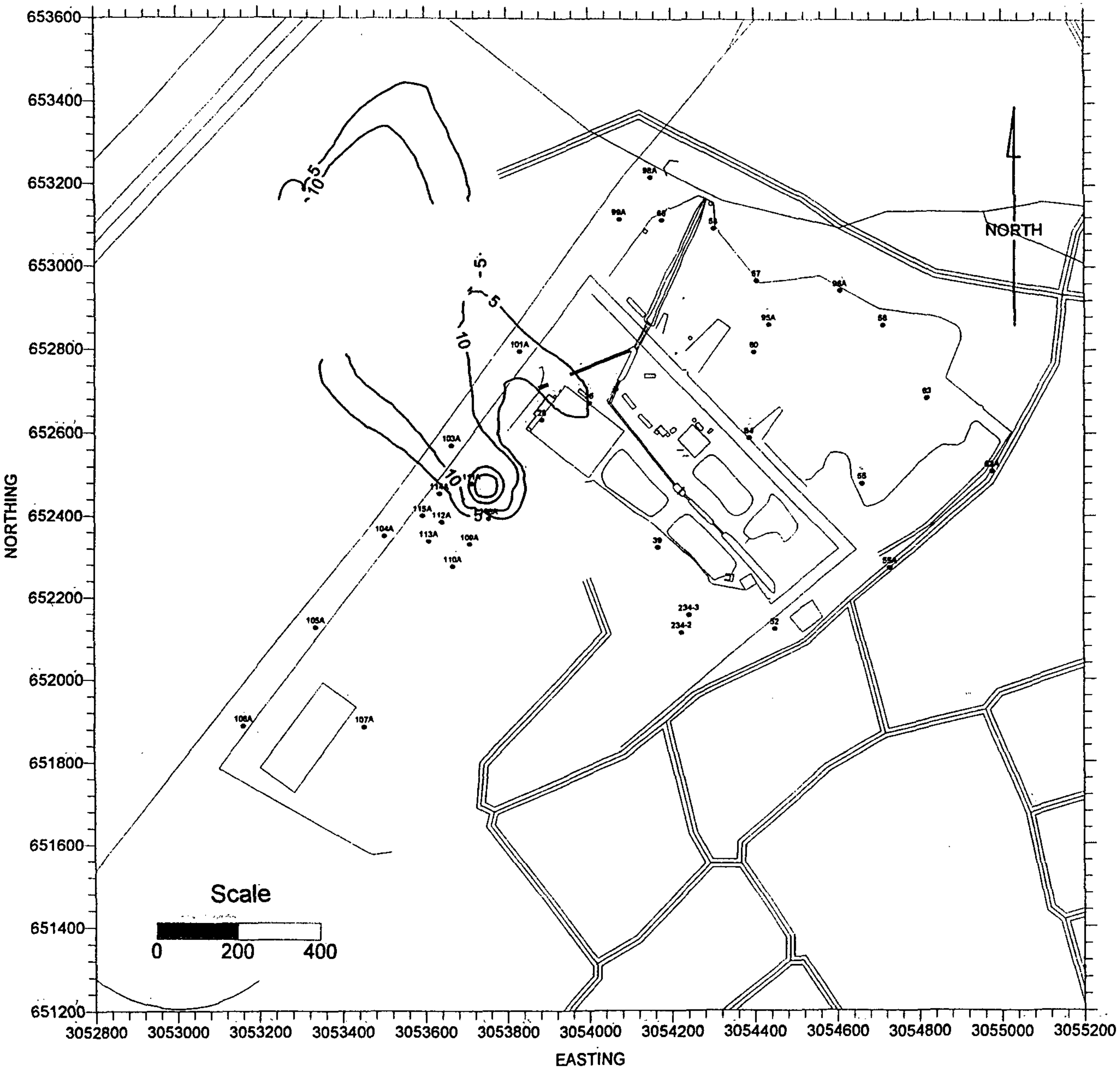

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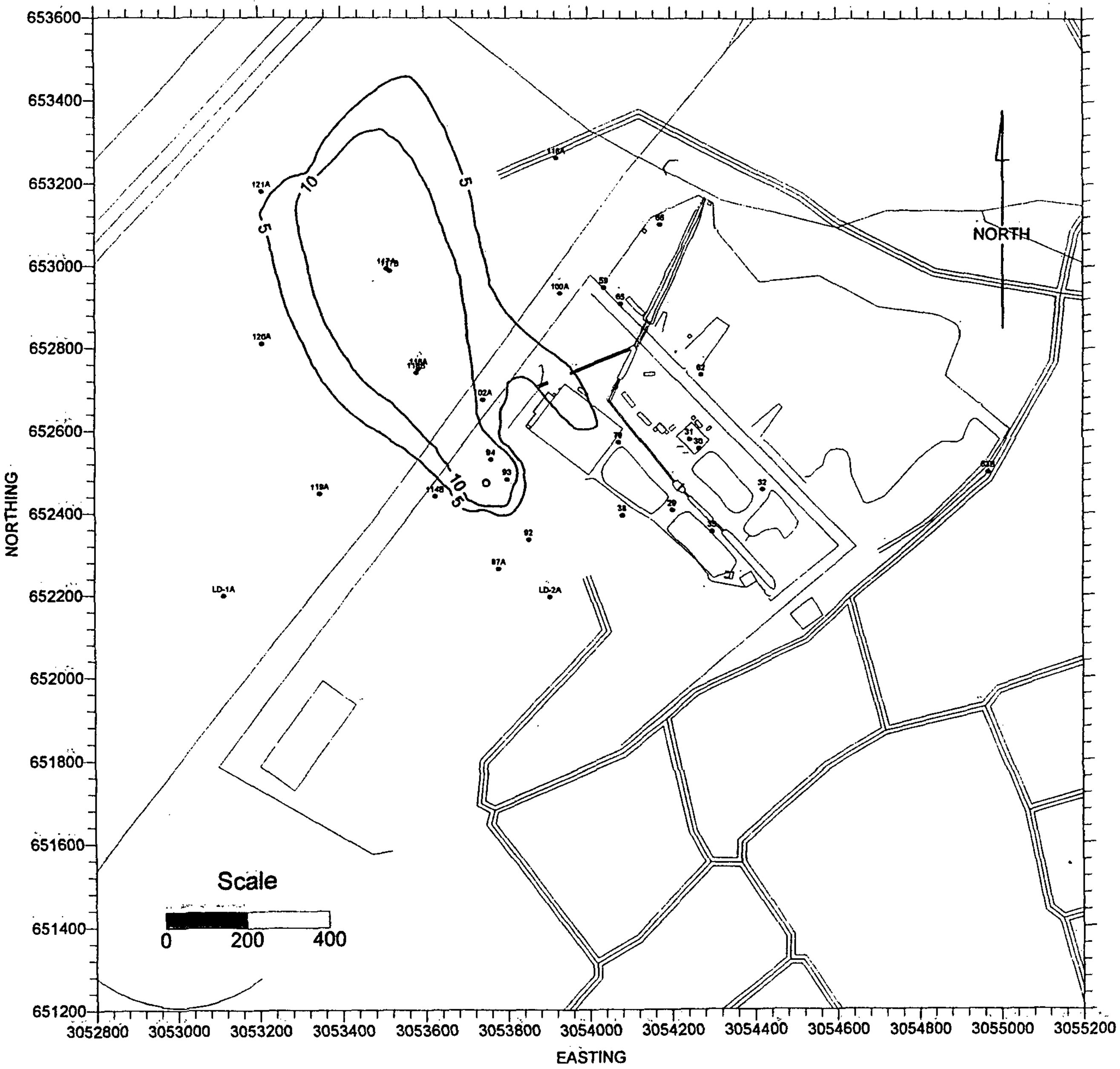

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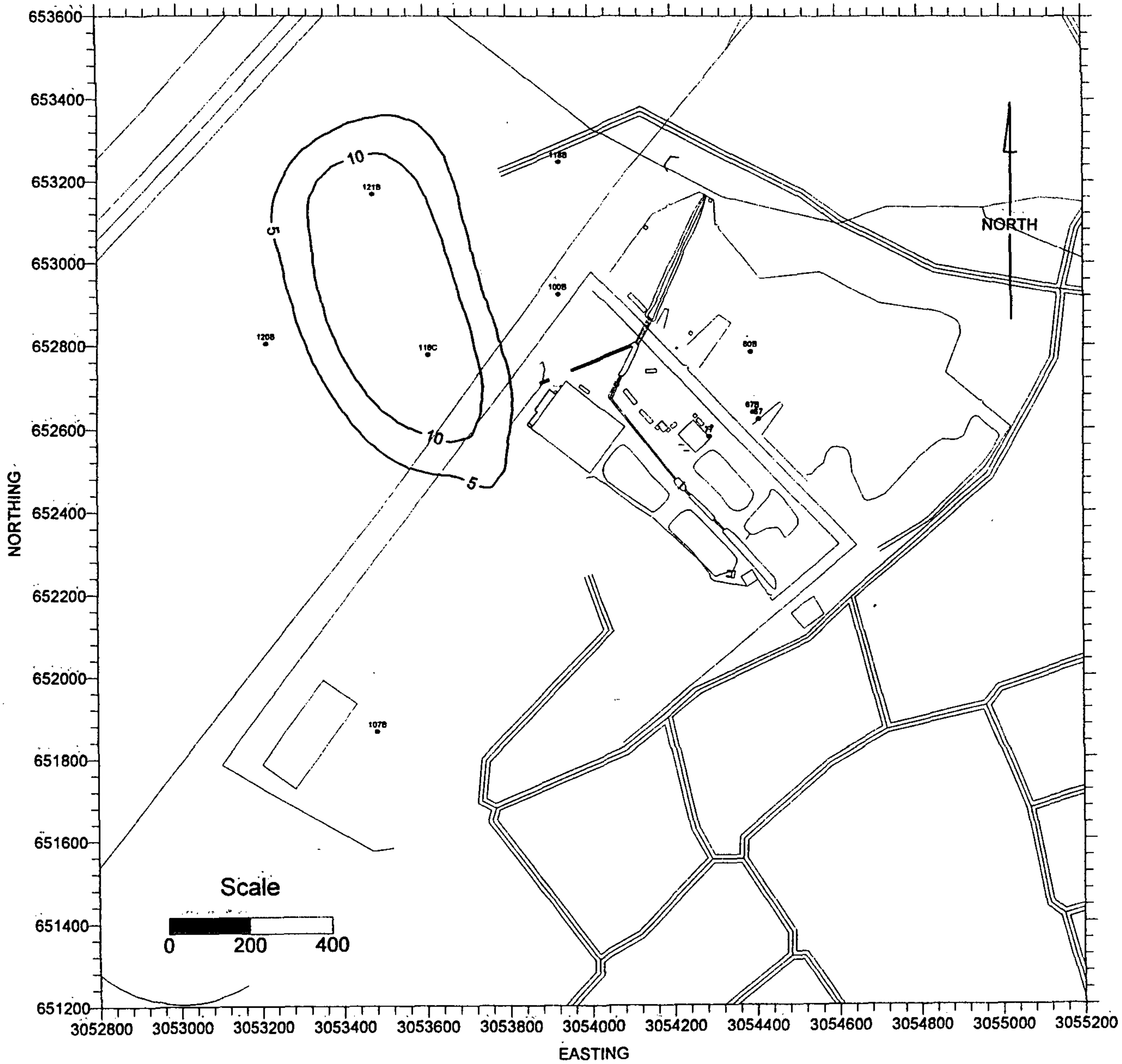

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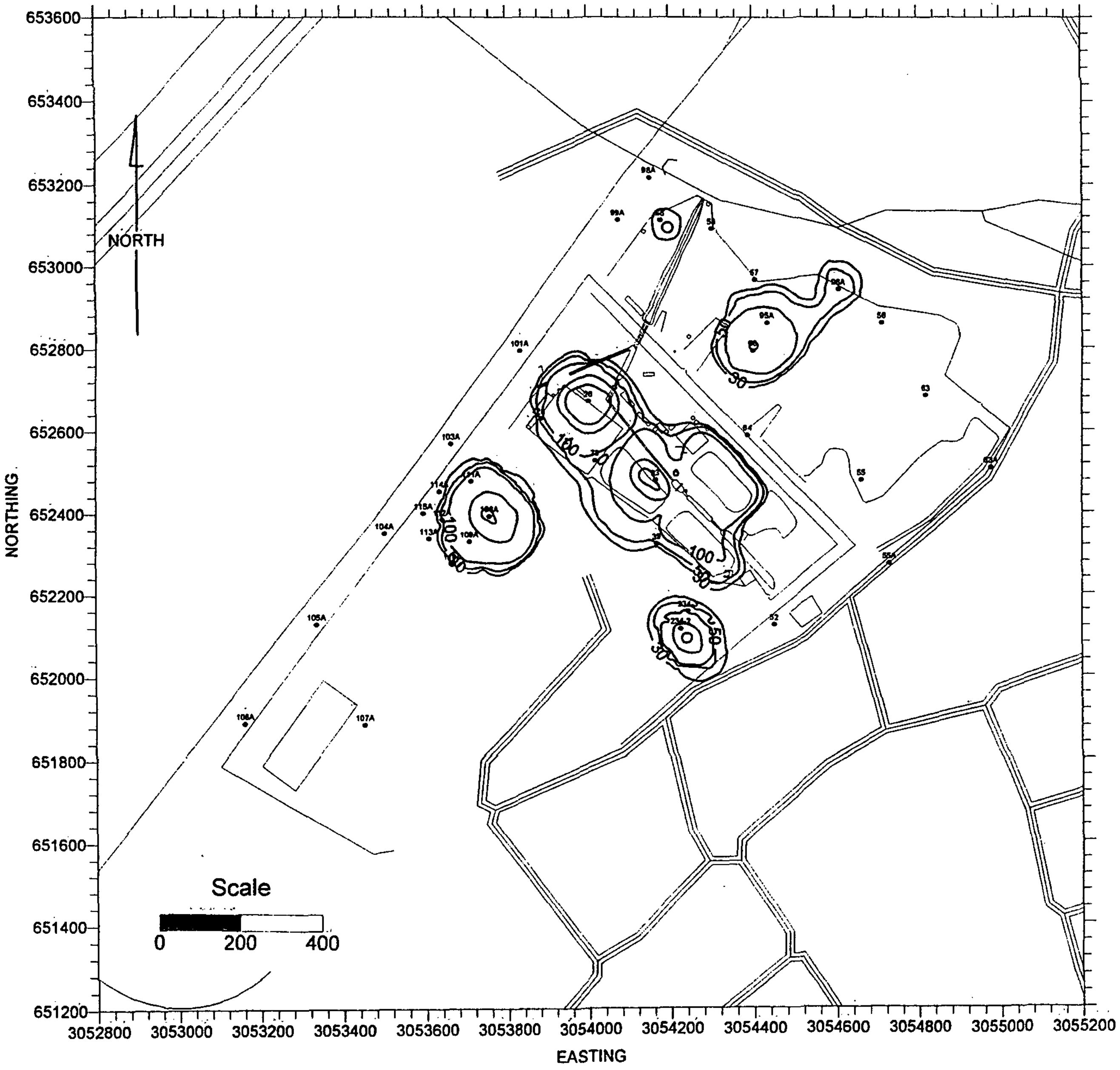

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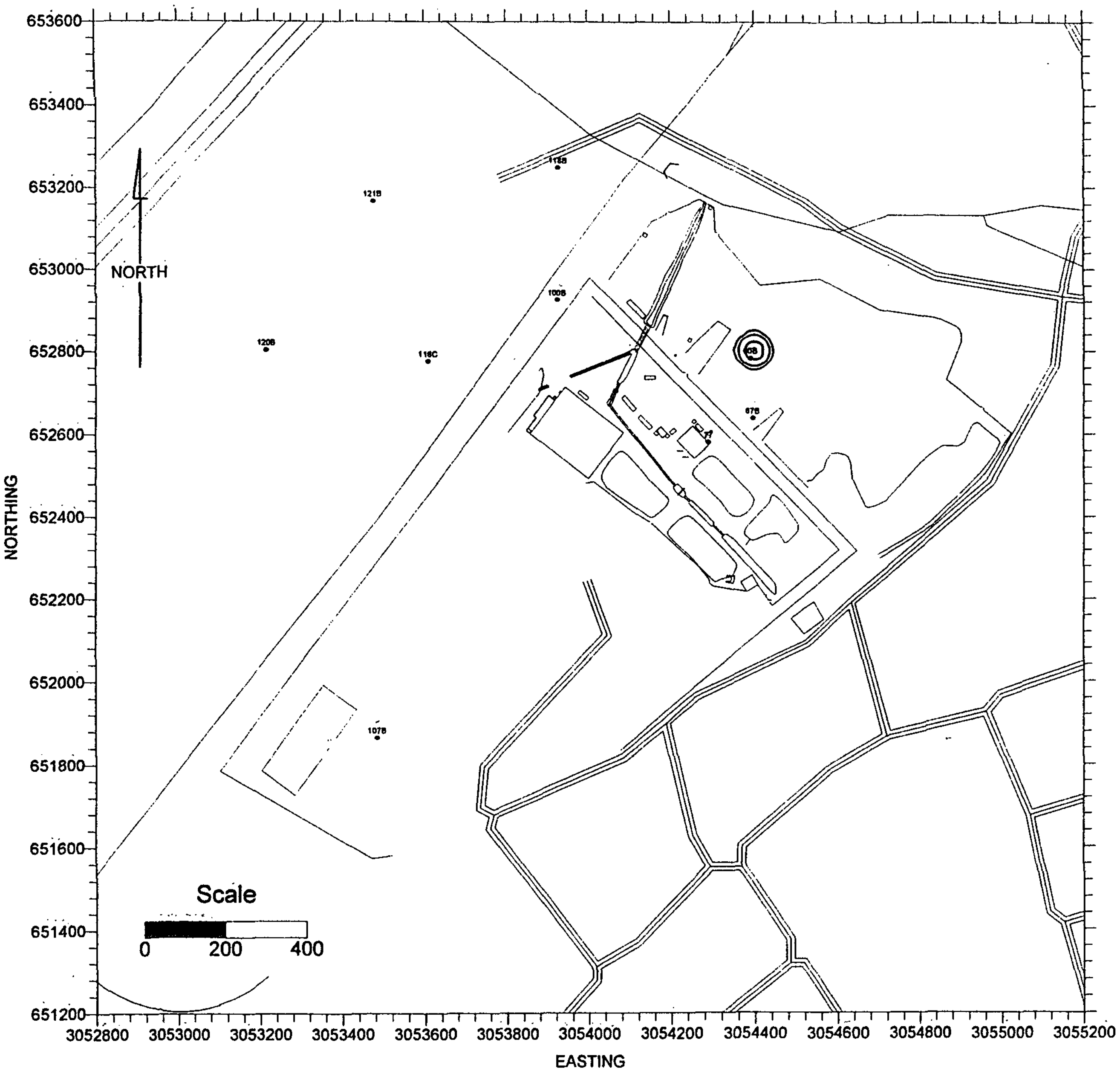

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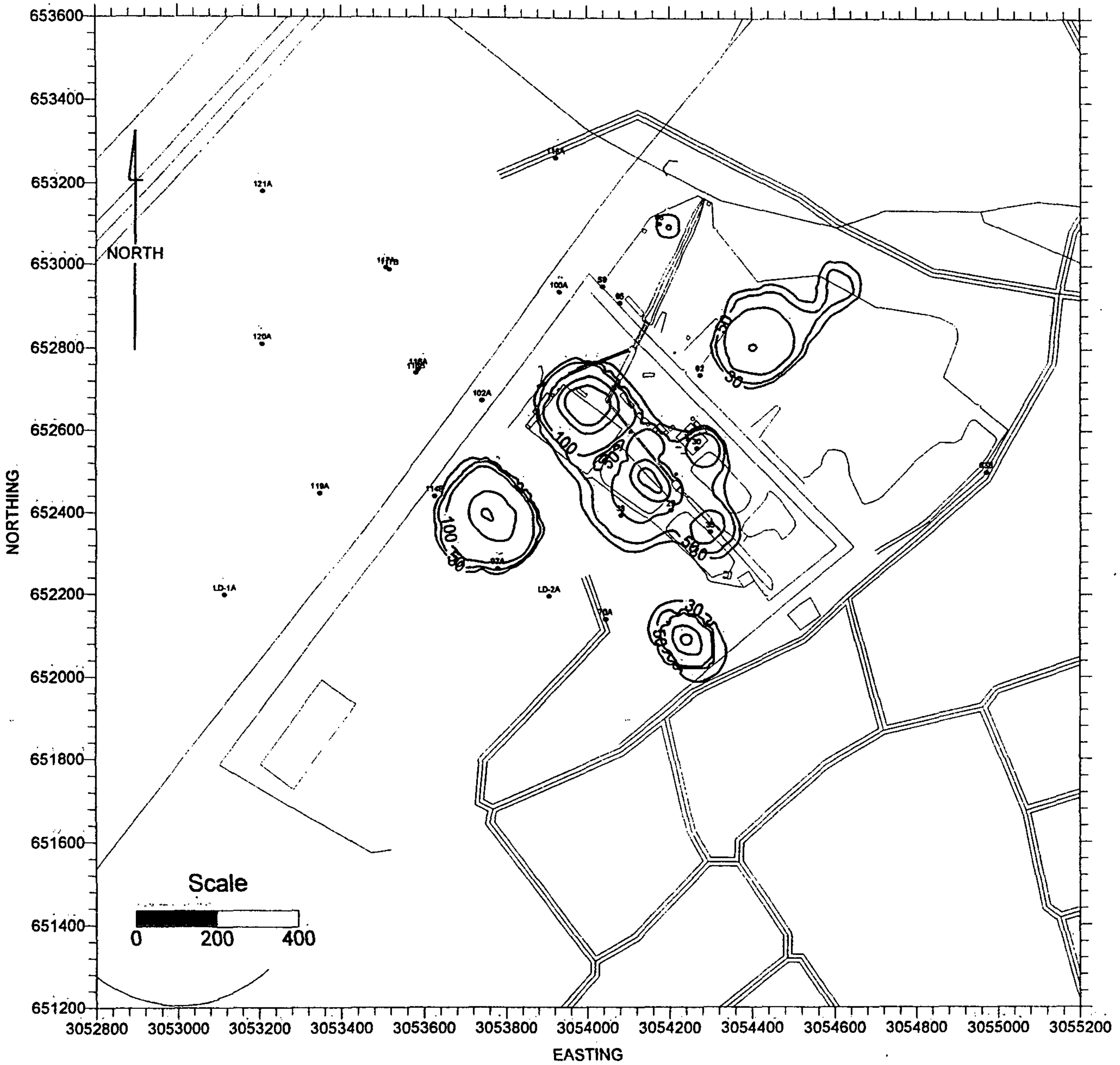

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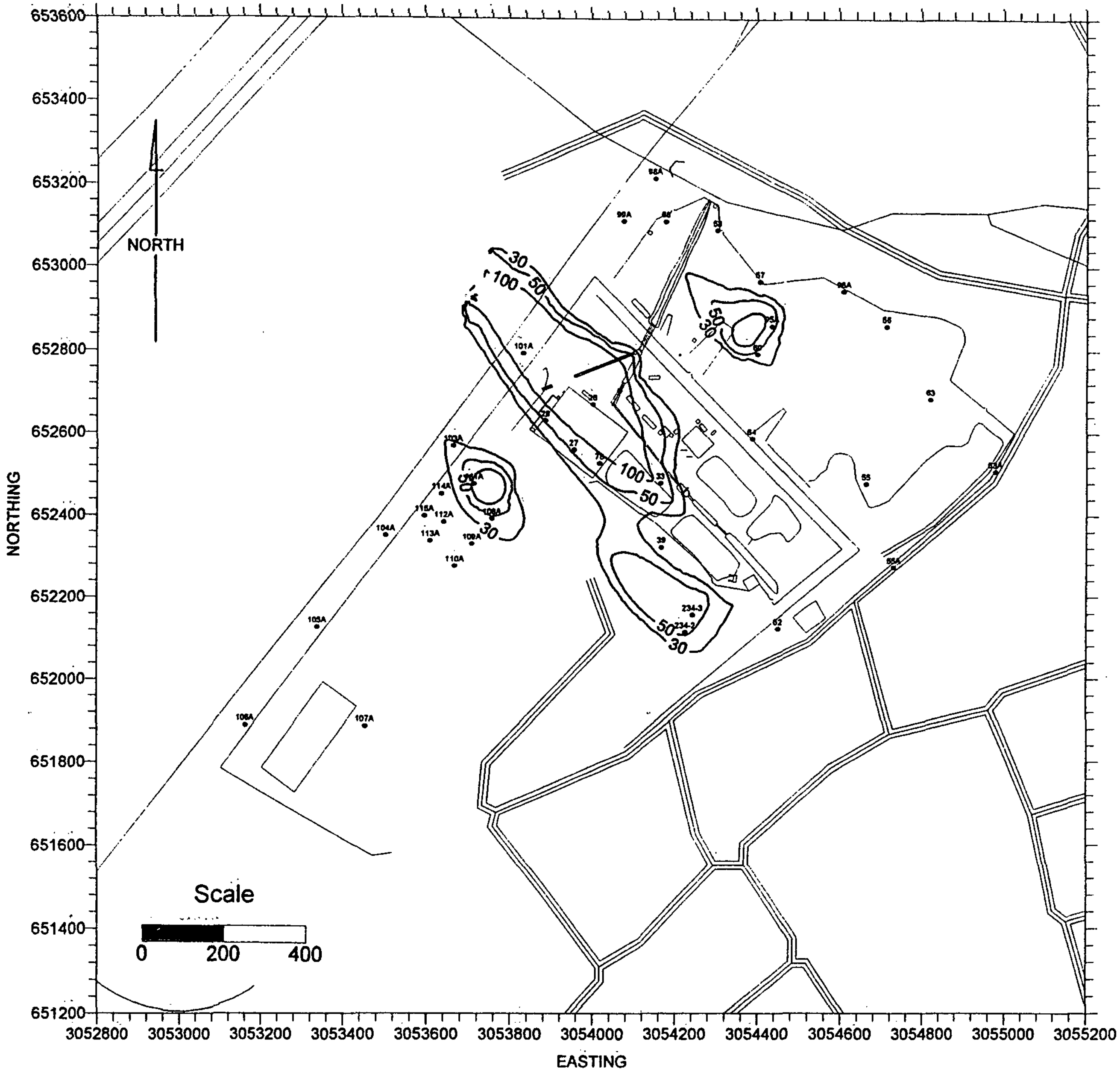

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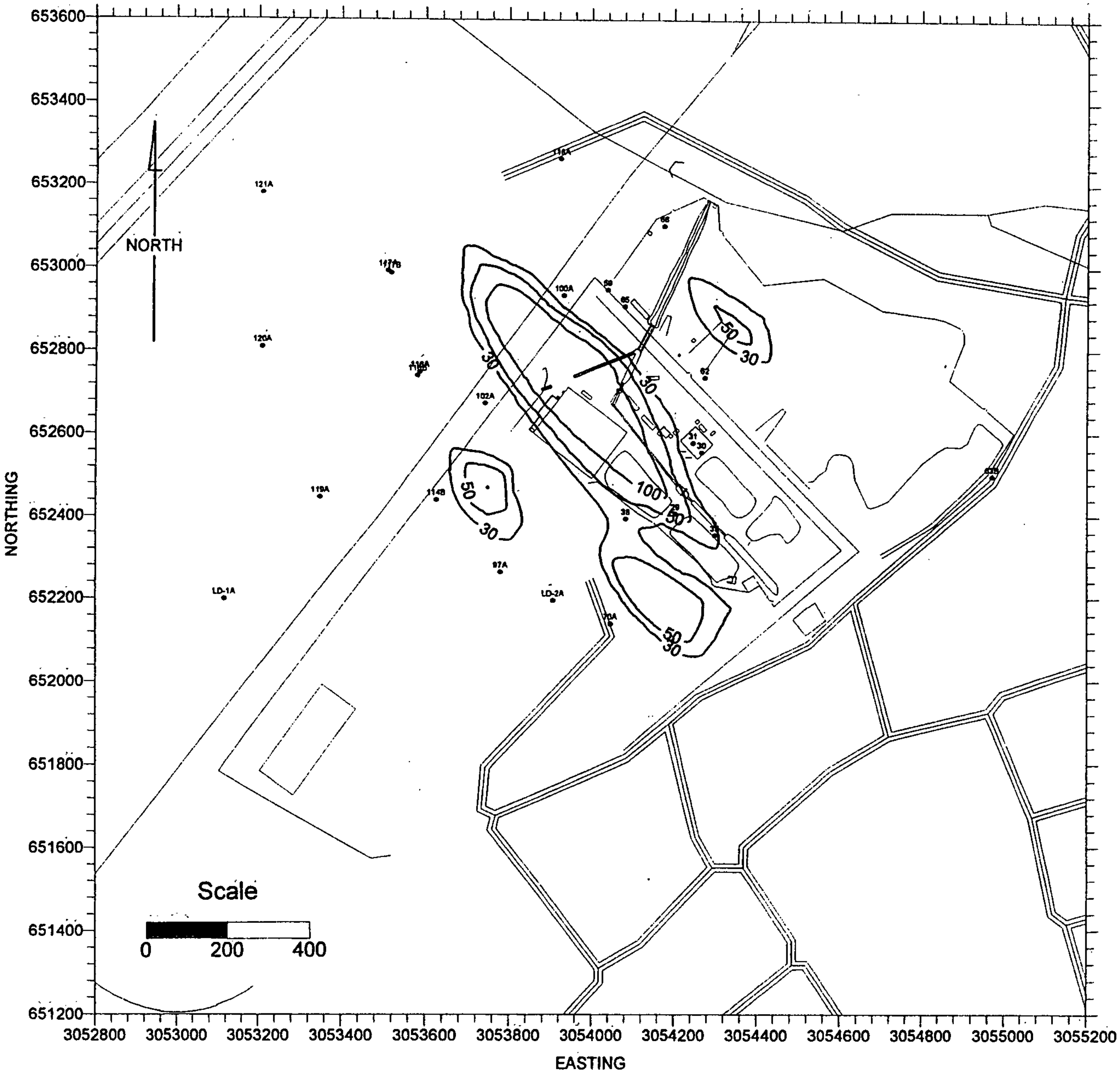

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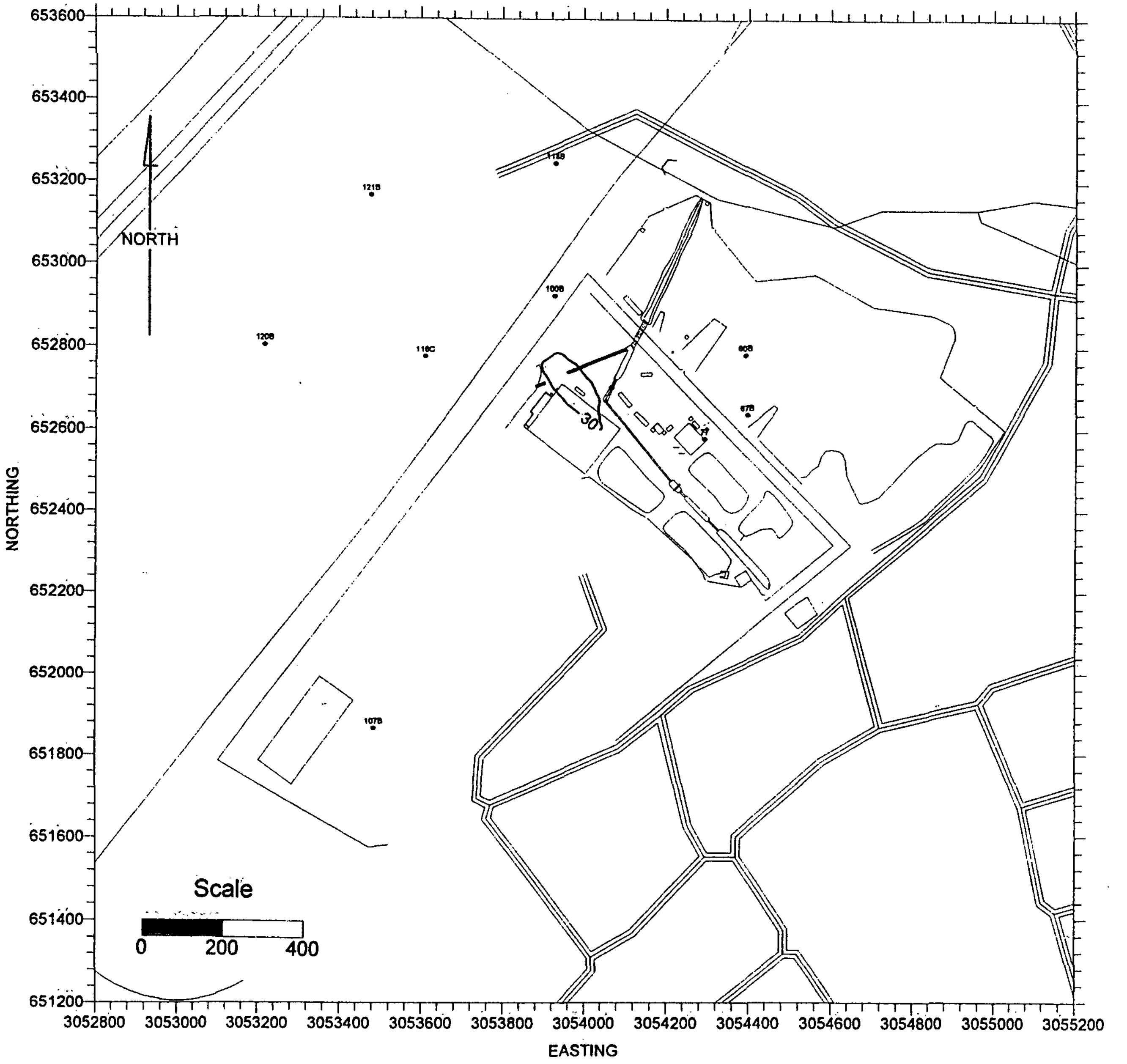

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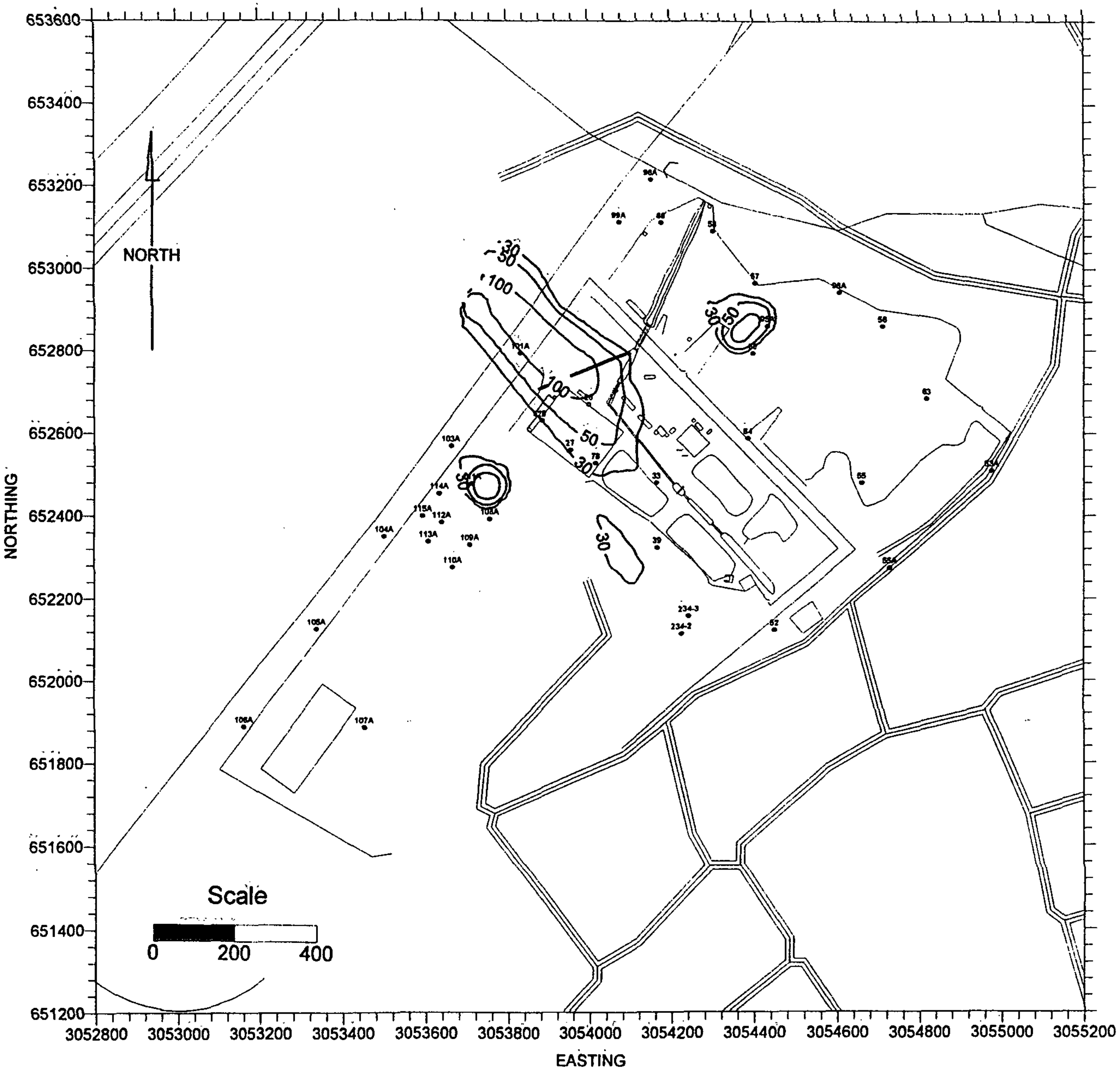

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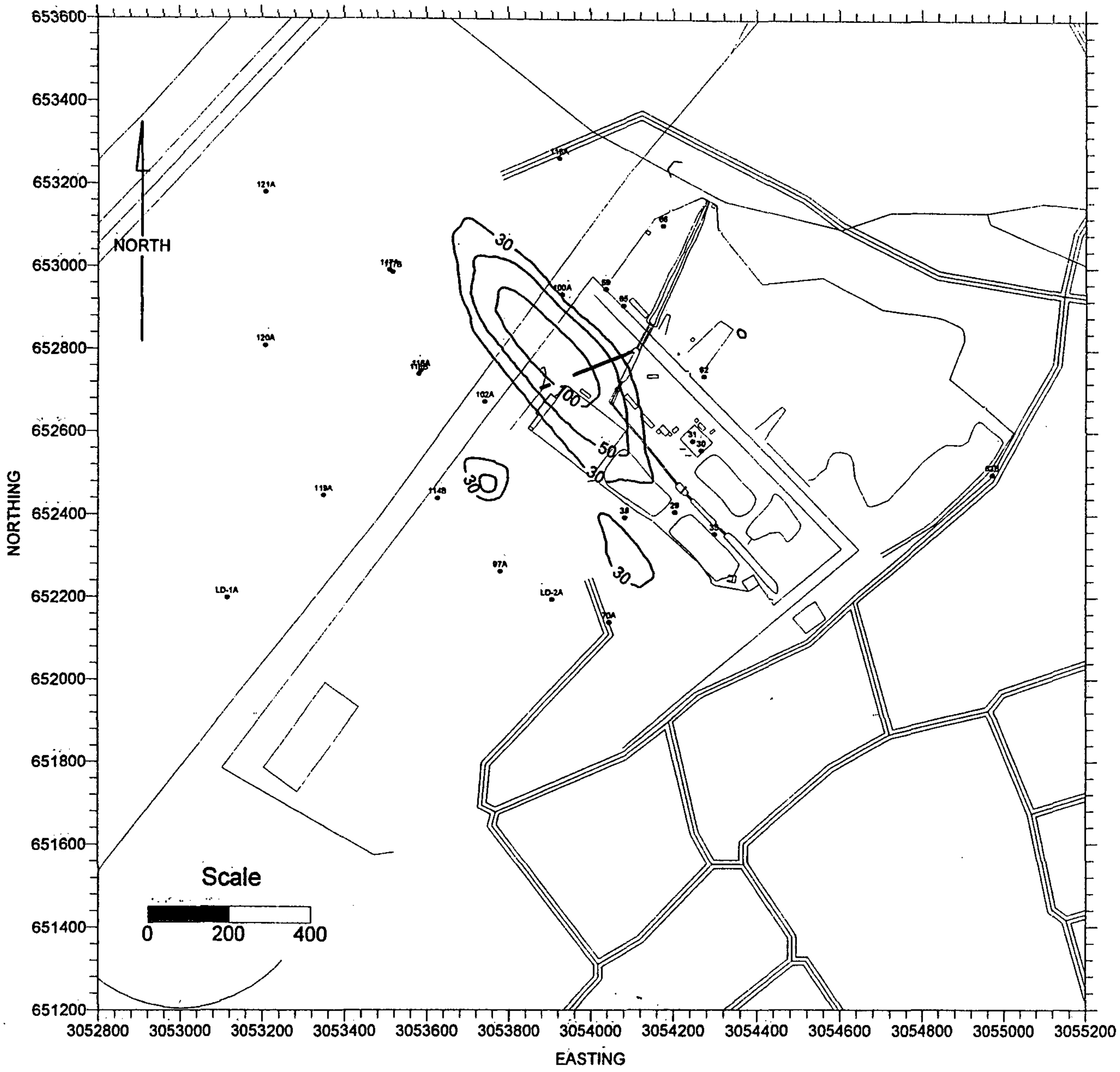

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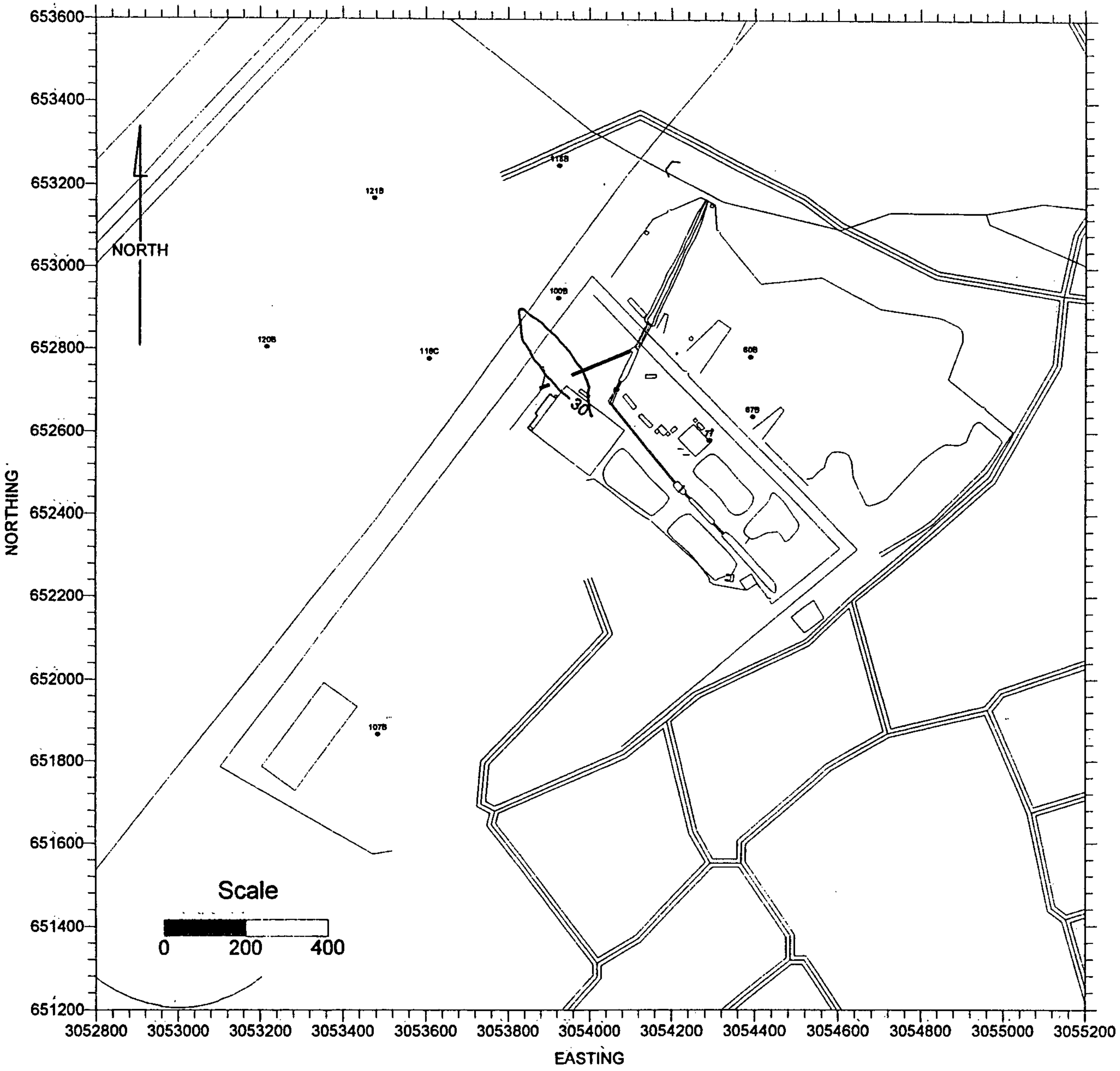

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RAI 9

Attachment 5

Revised Groundwater Flow and Solute-Transport Modeling Report, February 2010

ARCADIS

Infrastructure, environment, buildings

Imagine the result

NFS

Revised Groundwater Flow and Solute-Transport Modeling Report

Erwin, Tennessee

February 2010

100118-TNNFS-RPT-014

ARCADIS

Michael Kladias, PG
Principal Hydrogeologist

Paul Preston, PE
Project Manager

Berny D. Ilgner, PG
Principal In Charge

Revised Groundwater Flow and Solute-Transport Modeling Report

Erwin, Tennessee

Prepared for:
Nuclear Fuel Services, Inc.

Prepared by:
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Our Ref.:
TNNFS0903.MODL

Date:
February 18, 2010

[redacted]

Tables

Figures

Acronyms

amsl	above mean sea level
aNGVD	above National Geodetic Vertical Datum
AOC	area of concern
bgs	below ground surface
COC	constituents of concern
CVOC	chlorinated volatile organic compound
D&D	decommissioning and decontamination
DCE	dichloroethene
f_{oc}	fraction of organic carbon
ft	feet
ft/d	feet/day
ft^3	cubic feet
gpm	gallons per minute
HEU	High Enriched Uranium
HMOC	Hybrid Method of Characteristics
IRZ	in-situ reactive zone
K_d	partitioning coefficient
Koc	octinal carbon ratio
L/kg	liters per kilogram
MCLs	maximum contaminant levels
µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MMOC	Modified Method of Characteristics
MOC	Method of Characteristics
NFS	Nuclear Fuel Services, Inc.
PCE	tetrachloroethene
ppb	parts per billion
RSS	residual sum of squares
RSTD	residual standard deviation
Site	NFS facility located in Erwin, Tennessee
SWMU	Solid Waste Management Unit
TCE	trichloroethene
TCLP	Toxicity Characteristic Leaching Procedure
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey
VC	vinyl chloride

1. Introduction

ARCADIS was retained by Nuclear Fuel Services, Inc. (NFS) to revise the existing numerical groundwater flow and solute-transport model for the NFS facility located in Erwin, Tennessee (Site). The existing model was initially developed in 1996 (Geraghty & Miller, Inc. 1995 and 1996) and then was modified in 1999 (ARCADIS Geraghty & Miller, Inc. 1999). Revision of the existing groundwater flow and solute-transport model was designed to incorporate recently collected geologic, hydrogeologic, and water-quality data, as well as the impacts of site-specific remedial activities. The purpose of this report is to provide a detailed summary of the improvements made to the site groundwater model and present an updated evaluation of the fate and transport of site-related constituents of concern (COCs).

Although recently collected field data have refined the understanding of site conditions in several key locations, the hydrogeologic conceptual model that was developed during the original modeling effort (Geraghty & Miller, Inc. 1995 and 1996) is still applicable and, therefore, these elements were utilized in the model revision. Key aspects of this conceptual model are summarized in this document; however, a more complete description of the site conceptual model is presented in previous reports (Geraghty & Miller, Inc. 1995 and 1996).

1.1 Site Location and History

NFS is a nuclear fuel fabrication and uranium recovery facility that has been operational since the late 1950s. The NFS facility, approximately 64 acres in size, is located in the mountainous region of east Tennessee, east of the Nolichucky River and adjacent to the CSX Railroad (Figure 1-1). The NFS Erwin site, located in Unicoi County, is within the city limits of Erwin and is immediately west of the community of Banner Hill. Situated in a narrow valley surrounded by rugged mountains, the Site occupies a relatively level area approximately 20 to 30 feet (ft) above the elevation of the Nolichucky River. To the west, east, and south, the mountains rise to elevations of 3,500 to 5,000 ft within a few miles of the Site. The CSX Railroad adjoins the Site on the northwest boundary. A light industrial park is located opposite the Site on the northwest side of the railroad (Figure 1-2). Residential, commercial, and industrial lands constitute 19 percent of the surrounding area, with about 7 percent covered by farms and suburban homes (U.S. Nuclear Regulatory Commission 1991). The remaining area is forested.

1.2 Project Objectives and Methodology

Revisions to the exiting groundwater flow and solute-transport model for the Site were made with the following goals in mind:

- To revise and recalibrate the existing groundwater flow model based on recent site investigation work performed since development of the previous site models;
- To perform qualitative recalibration of the solute-transport model based on water-quality data and remedial activities; and
- To utilize the solute-transport model with current water-quality data to predict the migration, extent, and concentration of site-related COCs.

2. Geologic and Hydrogeologic Setting

The Site is located within the Nolichucky River floodplain. Over time, the meandering river has migrated across the valley floor targeting different geologic layers for erosion and deposition. In response to periodic episodes of increased streamflow, the channel has incised the underlying bedrock at different rates depending on the bedrock composition. The bedload, carrying particles ranging from clay to large boulders, effectively scoured the bottom of the channel cutting deep grooves (up to 60 ft bgs) into the less resistant carbonate bearing units while the more resistant shale beds remained intact. After increased discharge events, the river deposited its bedload in fining upward succession due to decreased stream competence and capacity. The remaining channel fill deposits are oriented in a linear pattern beneath the Site and are nearly parallel to the river. The depositional geometry and vertical succession of the deposits allows for increased transmissivity within the abandoned channels on the Site.

2.1 Geologic Framework

Several regional geologic studies have been published for the area of Tennessee in which the NFS Erwin plant is located. Detailed discussions of these studies and the geologic setting of the Erwin area are presented in the previous modeling reports (Geraghty & Miller, Inc. 1996; ARCADIS Geraghty & Miller, Inc. 1999).

2.1.1 Bedrock

Unicoi County lies within the Blue Ridge Physiographic Province. Mountains surrounding Erwin are underlain primarily by quartzite and other clastic rocks of Cambrian and pre-Cambrian age (Figure 2-1). They project 1,000 to 2,500 ft above the adjacent lowlands. The Erwin valley is underlain chiefly by the Honaker Dolomite, Rome Formation, and Shady Dolomite, all of Cambrian age (DeBuchananne and Richardson 1956).

The NFS Erwin plant is underlain by Cambrian and Ordovician sedimentary rocks which have been folded and thrust faulted. No faults have been mapped through or adjacent to the plant site (EcoTek, Inc. 1994a).

The Rome Formation, which underlies the NFS site, is described as red, maroon, or brown silty shale. Coring at the Site has shown that the Rome dips at steep angles, to nearly vertical, and contains highly weathered zones (Figure 2-2). Alternating layers of dolomite and shales are present beneath the Site (Figure 2-3).

2.1.2 Unconsolidated Sediments

Bedrock exposed within the mountains surrounding Erwin has been weathered to produce a blanket of residuum. Residuum is also present in the Erwin valley away from the depositional influences of the Nolichucky River; however, accumulations tend to be thinner over the Rome or away from the Nolichucky River. The bedrock surface (Figure 2-3) mimics topography in only the most general sense as there is a perceptible westward increase in depth to bedrock toward the Nolichucky River. The depth to bedrock from the surface varies from 0 to 60 ft at the facility, as evidenced by historical drilling activities (Figure 2-3).

Alluvial overburden of varying thickness is present across the Site. In general, the overburden sediment coarsens downward. The overburden consists of 2 to 4 ft of brown to dark brown, fine- to medium-grain clay/silt rich sand. Below the cohesive alluvial material is a zone of medium- to coarse-grain, light to medium gray, micaceous sand, or orange to brown quartzitic sand. The sand extends to a depth of 10 to 15 ft. A sharp contact does not exist between the clayey unit and underlying sand, but rather the change is gradational to a coarser texture with depth. Underlying the sand is a bed of rounded pebbles coarsening with depth into poorly sorted cobbles and boulders (EcoTek, Inc. 1994a). Thickness of the alluvium ranges from 0 ft, at an outcrop of shale (possible alluvial terrace) along the eastern plant perimeter road, to 60 ft to the northwest of the Site near the Nolichucky backwater area (Figure 2-4).

The coarsest material (cobbles/boulders) lies directly on the bedrock surface. The cobble/boulder zone occupies a similar horizon across the Site, but its thickness and elevation varies (Figure 2-4). The origin of this material is probably channel fill brought into the valley by the Nolichucky River and its tributaries; therefore, its continuity and thickness is variable across the floodplain occupied by the NFS site (EcoTek, Inc. 1994a).

The surface of the cobble/boulder zone is variable with a high elevation of 1,642 ft above mean sea level (amsl) to a low of 1,620 ft amsl. The cobble/boulder zone is highest in the southern corner of the Site with a high feature extending to the approximate center of the Site. A high also is evident northeast of the burial ground. Low elevations occur along the CSX Railroad property and in the vicinity of well 234A. Cobbles are apparently non-existent near Building 234, at the shale outcrop below the contractors' parking lot, around the Building 105 Complex, along the northeastern reach of Banner Spring Branch, and in the vicinity of wells 59 and 65 (northern corner of the fenced portion of the Site) (EcoTek, Inc. 1994a).

2.2 Hydrologic Framework

The aquifer underlying the NFS site is composed of two principal hydrostratigraphic units: an unconsolidated unit and a bedrock unit. The water-table aquifer occurs in the unconsolidated surficial sediments at the Site, which are predominantly alluvial in origin. This alluvial aquifer is limited in areal extent and is found mainly in the lowland areas. The alluvial aquifer pinches out just north and south of the Site due to the presence of shallow bedrock.

Alluvial deposits are generally very heterogeneous in sediment size, composition, and depositional pattern, causing varying degrees of anisotropy throughout these deposits. The presence of large amounts of clay in suspended and mixed-load stream deposits commonly causes the vertical hydraulic conductivity to be orders-of-magnitude less than in a horizontal direction.

The bedrock aquifer beneath the Site occurs in the Rome Formation. Even though the alluvial aquifer is of greater permeability than the bedrock aquifer, regional groundwater flow patterns exist in the bedrock aquifer beneath the Site to a depth of at least 350 ft. Groundwater originating in the upland areas flows through the Shady and Honaker Dolomite before exiting the groundwater flow system through surface water in the valley.

Previous investigations have determined that water in the Rome Formation in the site area occurs under weak artesian conditions for the range of depths investigated. Locally, the Rome bedrock surface is shallow and intersects the water table in several areas.

2.2.1 Groundwater Usage

Wells and springs are the principal source of water supply for several communities in the Erwin region. Erwin Utilities uses a combination of wells and springs for its water supply. A total of six public groundwater wells are located within a 5-mile radius of the Site. Average pumping rates for these wells are known, but specific pumping rates over time are not available. Little is known about the usage of most of the private water wells within the 5-mile radius of the NFS site. The nearest public water intake downstream from the NFS facility along the Nolichucky River is at Jonesborough, approximately 8 miles in distance (EcoTek, Inc. 1989).

In relation to the NFS site, the nearest water withdrawal well used by Erwin Utilities is approximately 1/2 mile north of the northern NFS facility boundary ("Railroad Well"). In addition to Erwin Utilities, other users of groundwater in Unicoi County consume approximately 3 million gallons per day (EcoTek, Inc. 1994a). Most public and industrial supply wells tap the fractures and solution cavities in the limestone and occasionally in shale aquifers. Domestic water supplies generally obtain water from the shallow bedrock (EcoTek, Inc. 1994a). Surface water in the Erwin area is not used for water supplies. Table 2-1 summarizes the water supply wells in the vicinity of the NFS facility and identifies the geologic formation in which they are completed.

2.2.2 Water Levels

The Erwin valley is characterized as a discharge zone for groundwater as evidenced by the number of springs in the valley and along its hillsides. Groundwater occurs beneath the Site in both the unconsolidated alluvium and bedrock lithologies. The water table is present in the alluvium from where it intersects the land surface to as much as 17 ft below ground surface (bgs) in the southwestern area of the plant. Water-level data is available throughout the Site.

Monitoring wells at the NFS site are completed in four hydrostratigraphic zones: 1) across the water table in the shallow alluvium; 2) the deep alluvium (cobble zone); 3) shallow bedrock; and 4) in the intermediate depth bedrock, from 50 to 120 ft bgs (EcoTek, Inc. 1994a). Generally, groundwater flows in a northwest direction towards the Nolichucky River (Figure 2-5). The general groundwater flow direction in the cobble/boulder zone and shallow bedrock is roughly uniform to that in the shallow alluvium zone, exhibiting flow toward the northwest.

Water-level data from well clusters (wells located nearby and screened at various depths) indicate that consistent upward gradients exist in at least the northeast area of the Site. This upward gradient is most likely due to regional discharge of groundwater (typically from the mountains) to large sinks like the Nolichucky River.

2.2.3 Hydraulic Properties

Several aquifer tests have been performed to define the hydraulic properties at the Site. The subsurface lithologies have been partitioned into three distinct zones on the basis of their hydraulic properties as described below.

- Alluvium: This unit is fine- to coarse-grained unconsolidated sediments with hydraulic conductivity increasing with depth. Hydraulic conductivity values range from 0.51 feet/day (ft/d) to 114.0 ft/d. Cobble/boulder zone hydraulic conductivity estimates range from 0.54 to 168 ft/d.

Coring across the Site revealed no laterally continuous aquitard separating the bedrock from the alluvium. The groundwater in the bedrock is therefore considered to be unconfined (EcoTek, Inc. 1989).

- Shallow Bedrock: Analysis of hydraulic tests indicate that shallow bedrock displays variable hydraulic conductivity as low as 0.05 ft/d in competent dolomite and as high as 27.64 ft/d in weathered shale (EcoTek, Inc. 1989).
- Deeper Bedrock: Five wells and piezometers are screened in intermediate or deeper bedrock down to a maximum depth of 120 ft. Hydraulic conductivity is estimated to be 33.0 ft/d.

Fractures between the beds of the nearly vertically-dipping dolomite probably provide the easiest pathways for water to flow. Flow through fractures across the beds may be more restrictive relative to flow-through fractures along the bedding planes. This may help explain the consistent north-northwest groundwater flow directions and elliptical drawdowns (observed during well 80 pumping test) along strike during pumping. Consequently, the primary effect of pumping is expressed asymmetrically in a northeast-southwest direction, following strike of the beds (EcoTek, Inc. 1993).

2.2.4 Surface Water

There were three surface water bodies in the vicinity of the NFS Erwin site: Banner Spring Branch, Martin Creek, and the Nolichucky River (Figure 1-2). Banner Spring Branch, re-routed during site remediation, was a small (1.5 to 3.0 ft wide) spring-fed stream lying entirely within the NFS Erwin plant boundaries. Banner Spring Branch originates on NFS property at Banner Spring which flows at a rate of about 300 gallons per minute (gpm) and flows underground within concrete piping around the east and north of the Site until it empties into Martin Creek at the northwest corner of the Site, about 1,200 ft from its source. The former Banner Spring Branch was confined to a straight, incised channel which flowed between Ponds 1, 2, and 3, which were also removed during site remediation. Prior to creation, the Ponds area was marshy with the Banner Spring channel exiting the area along its western boundary. The former Banner Spring Branch was generally a gaining stream in its upper man-made reaches and was a losing stream west of the Ponds area until its confluence with Martin Creek. Historically, the ponds had altered groundwater flow directions on site. The ponds generally acted as additional recharge sources to the groundwater as indicated by historical observed mounding of the water table in the vicinity of the ponds.

Martin Creek, fed by mountain springs, groundwater, and runoff, runs nearly parallel to the northern property line of the Site, crossing the property for just a few yards at the northwest corner. The width of Martin Creek varies from 8 to 15 ft, with depth varying from a few inches to pools of 3 to 4 ft deep. The flow rate varies seasonally from 1,000 to 5,000 gpm.

Monthly stage data for the Nolichucky River were obtained from the United States Geological Survey (USGS) at the gauging station near Embreeville, roughly 2.5 miles northwest of the Site. Based on this data, the average river stage is approximately 1,521 ft above National Geodetic Vertical Datum (aNVGD) 1929 (United States Geological Survey 2009).

There are several large springs in the vicinity of the NFS site. The majority of springs exhibit quick response (within about 1 day) to local precipitation. In particular, many of the springs show a measurable increase in flow and the water often becomes turbid. Banner Spring water rarely has storm-related turbidity, signifying relatively deep groundwater circulation. Groundwater pumping can influence spring flow rates indicating good hydraulic communication exists in the fractured bedrock units.

2.2.5 Precipitation and Ground Recharge

The average annual mean precipitation for Erwin is approximately 45 inches (Erwin Utilities 2009). It is estimated that 19 to 25 percent of the precipitation in eastern Tennessee is expected to infiltrate as groundwater recharge (Zarawski 1978).

The unconsolidated aquifer is primarily recharged by infiltration of rainfall, as well as upward seepage of water into the unconsolidated deposits from the bedrock beneath. A secondary local source of groundwater recharge is seepage/infiltration from the ponds, marshes, and streambeds. Groundwater recharge may also occur on an intermittent basis from leaking storm drains and pipelines (EcoTek, Inc. 1989).

The Rome aquifer beneath the facility is primarily recharged by subsurface movement of water from beneath the adjacent upland areas. Rainfall directly infiltrates into aquifers on the upland areas and moves downgradient in the subsurface through fractures. The higher elevations of the recharge areas help to create the hydraulic head that creates the artesian pressures in the valley. A secondary localized source of recharge to the Rome aquifer beneath the facility is downward infiltration of water from the unconsolidated aquifer into the Rome (Geraghty & Miller, Inc. 1995).

2.3 Constituent Distributions

Operations at the NFS plant have resulted in the presence of radionuclides and organic constituents in the groundwater below the facility. The prime source areas: 1) three former unlined surface impoundments (Ponds 1, 2, and 3) [Solid Waste Management Unit (SWMU) 1]; 2) the "Pond 4" disposal area (SWMUs 2, 4,and 6); 3) the radiological waste burial grounds (SWMU 9); and 4) the areas associated with Buildings 110, 111, 130, 120/131 (SWMUs 13, 14, and 20) and the Building 200 Complex, all of which are located in the northern portion of the NFS site (Figure 2-6). The initial solute-transport model was developed for two types of constituents, one radioactive (uranium) and one representative chlorinated solvent [tetrachloroethene (PCE)]. Dissolved uranium concentrations are present primarily on site, situated within the unconsolidated sediments and extending into shallow bedrock. Elevated uranium concentrations are present throughout the central and northern area of the Site near known source areas (Figure 2-6). PCE concentrations in the alluvium and shallow bedrock encompass the northwestern portions of the NFS site and extend off site toward the Nolichucky River.

Concentrations of dissolved uranium and PCE have exceeded their respective U.S. Environmental Protection Agency (USEPA) maximum contaminant levels (MCLs) of 30 micrograms per liter (µg/L) and 5 µg/L. Exceedances have been encountered primarily in the areas within or downgradient of the source areas (Figure 2-6). Since 2000, NFS has undergone extensive decommissioning and decontamination (D&D) modifications. Many source areas have been removed or remediated since that time. Of primary interest are the areas that were major contributors to distribution of the two constituents of concern. At the time of this report the source areas in the vicinity of the ponds and the burial grounds have been excavated. Further, *in-situ* reactive zone (IRZ) treatment technology has been applied to the source material in the SWMU 20 area. However, suspected additional sources of both uranium and PCE remain in the vicinity of the Building 200 and 300 Complexes and potentially beneath Buildings 111, 110, and 130. In addition, chlorinated daughter products, such as trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride (VC) have recently been detected in the same areas as PCE and are the result of reductive dechlorination. The observed dissolved uranium concentrations, when compared to PCE and the daughter products concentrations, indicate that uranium moves very slowly in the alluvial aquifer material.

3. Groundwater Flow Model Development

A three-dimensional numerical model was initially developed in 1996 (Geraghty & Miller, Inc. 1996) and subsequently modified in 1999 (ARCADIS Geraghty & Miller, Inc. 1999) that simulates regional groundwater flow in the vicinity of the NFS site. The groundwater flow model was constructed and calibrated for a 38-square mile area surrounding the NFS facility for the purpose of simulating groundwater flow on a regional scale in a multi-unit system, consisting of alluvium (unconsolidated material) and underlying bedrock.

Based on data collected since the 1996 and 1999 groundwater flow model development, the hydrogeologic conceptual model for the NFS site was refined. The data were also used to revise the representation of stratigraphic units assigned in the model (i.e., thickness and geometry of stratigraphic units), to revise the delineation of hydraulic conductivity zones in the model, and to better delineate the current extent of uranium and PCE constituent concentrations. In addition, October 2009 water-level data were used to recalibrate groundwater flow characteristics.

For the current study, the existing model was revised primarily within the site area to incorporate data collected after 1999. These data were used to make significant changes to the groundwater flow model within the NFS property boundary and directly northwest of the NFS facility. New regional data were not available for the area outside the immediate vicinity of the NFS facility; therefore, regional changes were not warranted. Further, data collected since 1999 did not enhance the original understanding of groundwater sources and sinks. Therefore, with the exception of pumping rates assigned to several of the on-site and off-site wells, the boundary conditions assigned in the model were not altered except where site activities have resulted in the removal of ponds and some site drainage features, and where boundary conditions coincided with the areas of grid refinement. In summary, the following features were revised during the recent modeling investigation:

- Model discretization
- Thickness, elevation, geometry, and hydraulic properties associated with the unconsolidated aquifer units and top of bedrock in the vicinity of the NFS facility
- Solute-transport model parameters

The following sections provide a description of the groundwater flow model developed for the NFS facility with recent changes highlighted.

3.1 Regional Model Description

3.1.1 Code Selection

The MODFLOW code, a publicly available groundwater flow simulation program, was used in both existing and recent modeling investigations to simulate groundwater flow at the NFS site. MODFLOW was developed by the USGS (McDonald and Harbaugh 1988). It is thoroughly documented, widely used by consultants, government agencies and researchers, and is consistently accepted by the regulatory and scientific communities. In addition, ARCADIS has developed utilities for use with MODFLOW to ease in the construction and calibration of groundwater models. Given the intended use for the NFS site groundwater flow model as a decision-making tool, regulatory acceptance is vital for any code selected for this study.

In addition to its attributes of widespread use and acceptance, MODFLOW was also selected because of its versatile simulation features. MODFLOW can simulate transient or steady-state saturated groundwater flow in one, two, or three dimensions and offers a variety of boundary conditions including specified head, aerial recharge, injection or extraction wells, evapotranspiration, drains, rivers or streams, and horizontal flow barriers. Aquifers simulated by MODFLOW can be confined or unconfined, or convertible between confined and unconfined conditions. For the NFS site, which consists of a multi-unit system with variable hydrogeologic unit thickness and boundary conditions, MODFLOW's three-dimensional capability and boundary condition versatility are essential for the proper simulation of groundwater flow conditions.

3.1.2 Model Discretization

The finite-difference technique employed in MODFLOW to simulate hydraulic head distributions in multi-aquifer systems requires aerial and vertical discretization or subdivision of the continuous aquifer system into a set of discrete blocks that forms a three-dimensional model grid. In the block-centered, finite-difference formulation used in MODFLOW, the center of each grid block corresponds to a computational point or node. When MODFLOW solves the set of linear algebraic finite-difference equations for the complete set of blocks, the solution yields values of hydraulic head at each node in the three-dimensional grid.

Water levels computed for each block represent an average water level over the volume of the block. Thus, adequate discretization (i.e., a sufficiently fine grid) is required to resolve features of interest, and yet not be computationally burdensome. MODFLOW allows the use of variable grid spacing such that a model may have a finer grid in areas of interest where greater accuracy is required and a coarser grid in areas requiring less detail.

The aerial discretization of the revised model was revised during the recent modeling effort to enhance the accuracy of the model in the study area. The three-dimensional model grid developed for the NFS groundwater flow model extends over an area covering approximately 38 square miles. The grid boundaries were specified to coincide with natural boundaries, when possible, and to minimize the influence of model boundaries on simulation results at the Site. The model domain extends approximately 6.6 miles from the east to west boundaries and 5.7 miles from the north to south boundaries. The finite-difference grid in the revised model consists of 346 columns and 259 rows with five layers for a total of 448,070 grid cells or nodes. The model grid was enhanced by introducing a uniform 10-ft aerial grid spacing in the vicinity of the NFS facility to provide increased computational detail in the area of interest and grades to larger grid spacing at greater distances from the Site. The earlier versions of the model utilized a 50-ft grid cell spacing in the area of the Site. The finer grid cell spacing was enhanced to take advantage of increased computing power to enable more accurate delineation of structure in the model and to improve simulation accuracy.

The boundaries of the finite-difference grid and variable grid spacing at the NFS site were selected for the purpose of accurately simulating both regional and local groundwater flow around the Site. The extent selected for the grid ensured adequate incorporation of regional groundwater flow features that affect site conditions. The groundwater flow model was also oriented such that a principal axis of the model grid conforms to regional groundwater flow directions (northwest to southeast). The strike of the bedrock units (northeast to southwest) is also roughly perpendicular to the average groundwater flow direction.

The regional groundwater flow model uses five layers to simulate groundwater flow in the hydrogeologic units encountered within the study area. Within each model layer, the hydraulic parameters assigned in the model represent the various lithologies found beneath the Site. In the vicinity of the Nolichucky River and the NFS facility, model layers are represented as follows:

- Model Layer 1 – shallow alluvium
- Model Layer 2 – cobble/boulder zone
- Model Layer 3 – shallow bedrock
- Model Layers 4 and 5 – deeper bedrock

Information from the previous investigations on the Site, public water supply well logs, and published reports by USGS and other agencies were used to help define the total model depth which corresponds to the assumed depth of the active groundwater flow system. In areas where the alluvium pinches out (i.e., outside the vicinity of the NFS facility), Model Layers 1 and 2 also represent bedrock. Even though the NFS facility is underlain by the Rome Formation, the model domain extends to areas where the Honaker Dolomite, Shady Dolomite, Erwin, Hampton, Unicoi, and Snowbird Formations outcrop. Differences in the material properties associated with the bedrock formations are represented in the model by the assignment of differing hydraulic properties. The use of multiple model layers corresponding to the bedrock allows for the simulation of vertical gradients within the bedrock and for more accurate representation of the steeply dipping beds.

Lithologic descriptions from on-site wells were used to define the structural top and bottom elevations of the shallow alluvial sediments and top of bedrock in the vicinity of the Site. In more distant areas of the model domain, land surface elevation data were used to define the bottom elevations for Model Layers 1 and 2 such that the layer bottoms were a subdued reflection of topography (Model Layer 2 eventually graded to a horizontal plane in Model Layers 3 through 5). The bottom elevations specified for Model Layers 3, 4, and 5 are 1,525, 1,450, and 1,325 ft amsl, respectively.

In the vicinity of the NFS facility, the elevation and thickness of shallow alluvium, cobble/boulder zone, and the shallow bedrock were updated in the revised model based on lithologic logs developed for the new monitor wells and information from site investigation of nearby sites. As part of this effort, significant changes were made to the model in structure associated with the cobble/boulder zone. These changes to the model were facilitated by developing contour maps illustrating the elevation of the top of bedrock (Figure 2-3) and the thickness of the cobble/boulder zone (Figure 2-4). The base of the shallow alluvium (i.e., the top of the cobble/boulder zone) was determined by adding the cobble/boulder zone thickness to the bedrock surface elevation. In the vicinity of the new monitor wells, the thickness of the boulder/cobble zone was determined to be greater than the thickness assigned in the original model. The elevation of Model Layers 1, 2, and 3 were adjusted to better correspond to this new lithologic data.

3.1.3 Boundary Conditions

MODFLOW features a variety of boundary condition options, facilitating the incorporation of natural and anthropogenic boundaries in the model. The model uses various types of mathematical boundary conditions to represent natural boundaries. Natural boundaries simulated by the regional model include groundwater divides, precipitation recharge, rivers, and streams. As discussed in Section 3, the specification of boundary conditions in the revised model is identical to the boundary conditions specified in the previous groundwater flow models developed for NFS (Geraghty & Miller, Inc. 1996; ARCADIS Geraghty & Miller, Inc. 1999). These boundary conditions are summarized below.

Within the model domain, external model boundaries coincide with well-defined, natural flow system boundaries where possible. Within the regional model, no-flow boundaries were assigned to represent barriers to groundwater flow, including groundwater divides and regional groundwater flowlines. Groundwater flow divides were delineated by locating topographic highs from topographic maps in the general model area. Model extents are defined to correspond to the divides, or in some cases actual grid nodes were set to "no flow" to better represent the actual groundwater divide.

The model simulates precipitation recharge using a prescribed flux boundary condition in the uppermost active layer of the model. A uniform precipitation recharge rate of 6 inches/year is assigned throughout the model domain. This rate was estimated during the model calibration process. This is slightly lower than previous estimates by Zarawski (1978); however, when realistic hydraulic parameter values were assigned in the model, precipitation recharge rates greater than 6 inches/year caused the model to calculate water-level elevations that were much higher than those observed in the field.

Head-dependent flux conditions represent rivers and tributary streams, such as the Nolichucky River, South and North Indian Creek, Broad Shoal Creek, Rock Creek, Martin Creek, drainage ditches, and the on-site ponds. The model simulates these head-dependent fluxes using "river and drain cells", a boundary condition option provided by MODFLOW to represent rivers and streams. River cells allow the model to compute the flow into or out of a surface water feature as a function of the head difference between the stream elevation and the hydraulic head simulated in the aquifer. An advantage of this type of boundary condition is that the model can simulate influent or effluent conditions along different reaches of a stream depending on local head relationships between the stream and aquifer. River cells are used in Model Layer 1 to represent larger tributary streams, the Nolichucky River, and the ponds. Minor tributaries are simulated with drain cells to allow groundwater to flow only into the tributary. If the simulated water level falls below the drain elevation, the drain becomes inactive. Springs such as Banner Spring, Erwin Spring, and Love Spring were simulated using drain cells.

The elevations of the various head-dependent boundary conditions were derived from actual field measurements or were taken from topographic maps. The Nolichucky River stage was determined from monthly stage data at the gauging station near Embreeville, roughly 2.5 miles northwest of the Site. The average stage is 1,521.65 ft aNGVD at Embreeville. The grade of the river was determined from topographic maps to determine the actual river stage throughout the model domain. The elevations of the on-site ponds were assigned in the model based on measurements made in August 1995. The elevations for the former Ponds 1, 2, and 3 were defined in the model as 1,633.39, 1,636.24, and 1,638.11 ft amsl, respectively. The conductance term associated with the river and drain cells was generally calculated using the current estimated hydraulic parameters of the underlying aquifer material.

A total of three groundwater supply wells and ten groundwater dewatering wells (i.e., around former Pond 4) are represented in the model using prescribed flux boundary conditions. The dewatering wells were discontinued when the ponds were removed during site remediation and were set to inactive in the model after 2002. Average pumping rates for the public supply wells (Railroad Well, Birchfield Well, and the O'Brien Well) were determined from Erwin Utilities pumping records. The above-mentioned off-site wells did not produce any significant effects on simulated groundwater flow directions in the vicinity of the Site.

3.1.4 Hydraulic Conductivity Zonation

In the previous versions of the groundwater flow model, the hydraulic conductivity of the shallow alluvium, cobble/boulder zone, and the bedrock formations were simulated by assigning zones of differing hydraulic conductivity in each model layer. In the upper model layers, the distribution of hydraulic conductivity was simulated to be heterogeneous to reflect the contrast between relatively high permeability alluvial material and the steeply-dipping bedrock units. Distinct hydraulic conductivity zones were prescribed in the model to represent the Rome Formation, the Honaker Dolomite, and the Shady Dolomite. In each model layer, a single hydraulic conductivity zone was assigned to represent the Erwin, Hampton, Unicoi, and Snowbird Formations. The representation of the unconsolidated units was modified slightly in the current model. In Model Layer 1, two hydraulic conductivity zones were assigned to represent the shallow alluvium and portions of the cobble/boulder zone, and two hydraulic conductivity zones were also assigned in Model Layer 2 to represent the cobble/boulder zone and other alluvial material. These zones were delineated based on slug test and packer test data collected at the Site.

3.2 Groundwater Flow Model Recalibration

3.2.1 Model Calibration Methodology

During the model calibration process, model parameters and/or boundary conditions are adjusted to obtain a satisfactory match between observed and simulated water-level elevations, which are referred to as calibration targets. For best calibration results, a model should rely on discrete water-level measurements to produce answers free of contouring interpretations and artifacts. In the calibration of a groundwater flow model, use of point data eliminates the potential for interpretive bias that may result from attempting to match a contoured potentiometric surface (Konikow 1978; Anderson and Woessner 1992).

As a further goal for the calibration of a model, the principle of parameter parsimony should be used that seeks to achieve an adequate model calibration through the use of the fewest number of model parameters. It should be noted that the use of greater numbers of model parameters during model calibration creates a situation in which many combinations of model parameter values produce equivalent calibration results. In this case, the model calibration parameters are called non-unique. Following the principle of parameter parsimony reduces the degree of non-uniqueness and results in more reliable calibrated parameter values. The information gathered for the conceptual model guides any decision to add model parameters (e.g., zones of hydraulic conductivity) to the model during the calibration process. Therefore, in the absence of hydrogeologic evidence, the simpler model is preferred.

The primary criterion for evaluating the calibration of a groundwater flow model is the difference between simulated and observed water levels at a set of calibration targets (i.e., typically monitor wells). A residual or model error, e_i, is defined as the difference between the observed ($\hat{h}_i$) and simulated (h_i) hydraulic head measured at a target location:

$$e_i = h_i - \hat{h}_i \qquad \text{(Eq.3-1)}$$

The automatic parameter estimation procedure seeks to minimize an objective function defined by the residual sum of squares (RSS):

$$RSS = \sum_{i=1}^{n} \left(h_i - \hat{h}_i\right)^2 \qquad \text{(Eq.3-2)}$$

A residual with a negative sign indicates over-prediction by the model (i.e., the simulated head is higher than the measured value). Conversely, a positive residual indicates under-prediction.

The residual standard deviation (RSTD), which normalizes the RSS by the number of calibration targets and number of estimated parameters (p), is defined as follows:

$$RSTD = \sqrt{\frac{RSS}{n - p}} \qquad \text{(Eq.3-3)}$$

The RSTD is useful for comparing model calibrations with different numbers of calibration targets and estimated parameters. Another calibration measure is the mean of all residuals ($\bar{e}$):

$$\bar{e} = \frac{1}{n} \sum_{i=1}^{n} e_i \qquad \text{(Eq.3-4)}$$

A mean residual significantly different from zero indicates model bias. The Gauss-Newton parameter estimation procedure produces a near zero residual mean at the minimum RSS.

Calibration of the revised model required numerous individual computer simulations. The values and shapes of the various parameter zones in the model were gradually varied until a reasonable solution was achieved and was in agreement with the conceptual site model. Calibration of the revised model was achieved using both trial-and-error and parameter estimation techniques designed for use with MODFLOW.

The statistical goals of model calibration included the following:

- *RSTD* less than 10 percent of the total head change observed across the model domain. The total observed head change for the monitor wells in the model domain is approximately 13.67 feet; and
- A residual mean close to zero (indicating little or no bias) and the majority of calculated residuals are less than 10 percent of the range in observed water-level elevations.

3.2.2 Calibration Targets

Calibration targets are a set of field measurements, typically groundwater elevations, used to test the ability of a model to reproduce observed conditions within a groundwater flow system. For the calibration of a steady-state (time-invariant) model, the goal in selecting calibration targets is to define a set of water-level measurements that represent the average elevation of the water table or potentiometric surface at locations throughout the Site.

Following refinement, the flow model was first verified against the historical water-level measurements used in the previous model. Afterwards, the revised model was recalibrated using the 2009 water-level data set (Table 3-1). This set of calibration targets consists of a total of 37 monitor wells screened in relevant model layers with water-level elevations measured in 2009.

3.2.3 Recalibration Results

3.2.3.1 Hydraulic Conductivity Estimates

Precipitation recharge, horizontal hydraulic conductivity, and hydraulic conductivity anisotropy ratios were adjusted in the model to obtain a satisfactory match between observed and simulated water levels. During the recent modeling investigation, the precipitation recharge rate and hydraulic conductivity anisotropy ratios assigned in the original model were not altered. Horizontal hydraulic conductivity values were adjusted within the range of measured values to obtain a satisfactory match between simulated and observed water levels. Because the horizontal to vertical anisotropy ratios were not altered during the calibration process, the vertical hydraulic conductivity values changed as the horizontal hydraulic conductivity was adjusted during the calibration process.

The hydraulic conductivity values assigned to the model in Layers 1 and 2 were the primary variables that were adjusted during the model calibration process. Because new lithologic, hydraulic conductivity and water-level data are only available in the vicinity of the Site, the model calibration was focused on this area. Outside the immediate vicinity of the Site, the bedrock hydraulic conductivity zones assigned in the model were not modified. Figures 3-1, 3-2, and 3-3 illustrate the hydraulic conductivity zones assigned in the model for Model Layers 1, 2, 3, 4, and 5, respectively. Note that the hydraulic conductivity zones that represent the bedrock formations exhibit a northeast-southwest trend that corresponds to the direction of geologic strike. The bedrock hydraulic conductivity zonation was entered into the model directly from published geologic maps. During the original model calibration (Geraghty & Miller, Inc. 1996), it was found that three of the rock formations contained different hydraulic properties (Rome Formation, Shady Dolomite, and Honaker Dolomite), but that the Hampton, Erwin, Unicoi, and Snowbird Formations are hydraulically similar. Thus, the latter four formations were simulated as a combined hydraulic zone in the model. Descriptions of groundwater flow from USGS literature (DeBuchananne and Richardson 1956) support the model finding that these units have similar flow characteristics.

In the vicinity of the NFS facility, recently collected field data were used to adjust the hydraulic conductivity zonation in Model Layers 1 and 2. As part of this effort, hydraulic conductivity measurements determined from slug tests were evaluated to improve the delineation of the hydraulic conductivity to be consistent with spatial trends in estimated hydraulic conductivity and with lithologic descriptions. As part of this evaluation, hydraulic conductivity values determined through slug tests were overlain onto site maps and compared to hydraulic conductivity zones assigned in the original model. These hydraulic conductivity maps were used during the model calibration process to revise the hydraulic conductivity zones representing the shallow alluvium and the cobble/boulder zone. Additionally, detailed structural maps of the thickness of the cobble/boulder zone were reviewed and integrated into the model. Because there are relatively high measurement uncertainties associated with hydraulic conductivity values measured using slug tests, the hydraulic conductivity zones and values were not prescribed in the model based solely on the measured hydraulic conductivity values. Instead, these values were used to guide the delineation of hydraulic conductivity zones during the model calibration process.

Figures 3-1, 3-2, and 3-3 illustrate the revised delineation of hydraulic conductivity zones and calibrated hydraulic conductivity values in the vicinity of the NFS facility (i.e., Model Layers 1, 2, and 3). In Model Layers 1 and 2, the spatial orientation of a high hydraulic conductivity zone (i.e., Zones 7 and 9) were delineated to the southwest and to the north to better match a hydraulic conductivity measurement obtained in well 107A and to improve the model calibration. In these model layers, the higher hydraulic conductivity zones were assigned in the model to primarily represent the cobble/boulder zone (i.e., Zones 7 and 9). The hydraulic conductivity zonation in Model Layer 3 was not modified during the recent modeling investigation.

3.2.3.2 *Simulated Hydraulic Heads*

As a part of evaluating the revised model recalibration, simulated potentiometric surface maps were prepared for the entire modeled region (Figure 3-4) to ensure that simulated groundwater flow patterns were reasonable relative to observed conditions (Figure 2-5). Simulated local potentiometric surface maps were also prepared to depict groundwater flow conditions in the site vicinity (Figure 3-5). The simulated hydraulic head surfaces for Model Layers 1 and 2 show regional water levels declining from all areas surrounding the NFS site toward the Nolichucky River and Indian Creek (Figure 3-4). The water table significantly flattens in the higher permeability units, specifically the alluvial and cobble zones and in the Rome Formation along the Nolichucky River and Indian Creek.

In the upland areas, decreasing hydraulic heads are simulated with depth. This indicates downward flow of recharge in the upland areas. Groundwater originating in the highland areas ultimately flows towards the valleys, exiting the groundwater system via the rivers. In the lowland areas, beneath the rivers, upward hydraulic gradients are simulated by the model. Simulated head contours in the bedrock beneath the Site indicate a northwest groundwater flow direction towards the Nolichucky River.

3.2.3.3 *Analysis of Model Residuals*

A primary model recalibration objective for the NFS groundwater flow model was to minimize the residual sum of squares (Eq. 3-2) computed for the 37 water-level calibration targets. Table 3-1 lists the simulated water elevations and model residuals for each calibration target. Figure 3-5 shows the spatial distribution of the residuals across the Site in Model Layer 2. Furthermore, Figure 3-6 shows the agreement between observed and simulated water levels graphically for the calibration targets. Overall, the model shows a very good match to the measured water levels at the Site when compared to an R-squared value of 1.

Residual statistics for the recalibrated groundwater flow model also indicate very good agreement between simulated and measured groundwater elevations (Table 3-1). Most of the calculated residuals are less than 1.4 ft, which is 10 percent of the range of observed changes in water-level elevations. The residual standard deviation is calculated to be 1.74 ft or about 12.4 percent of the range of observed water-level elevations for the entire model domain. Additionally, the residual mean is close to zero (0.53 ft) indicating that a satisfactory degree of model recalibration has been achieved. All data points are within 15 percent of the range of the residuals between the observed and simulated groundwater levels. The trend of data calculated for Model Layer 2 possessed an R-square value of 0.83.

4. Solute-Transport Model Calibration

A solute-transport model for the NFS facility was initially developed in 1996 (Geraghty & Miller, Inc. 1996) and subsequently modified in 1999 (ARCADIS Geraghty & Miller, Inc. 1999) using the MT3D code. This model was used to predict the current and future extent of uranium and PCE constituents in groundwater. The results of the original predictive solute-transport simulations were used to assist NFS in the refinement of their groundwater monitoring network. The current study updated the historical period utilized for model calibration to include current 2009 conditions.

Similar to the earlier modeling studies, a qualitative solute-transport calibration was completed by specifying historic source terms in the model and simulating conditions from 1957 to 2002. The groundwater flow model was used to simulate groundwater flow conditions for this same time period, and the groundwater velocities and volumetric flow terms computed by the flow model were input into the MT3D solute transport model. The effects of historical changes in groundwater pumping rates at on-site and off-site pumping wells were incorporated into the flow model by specifying several stress periods in the MODFLOW model that correspond to periods where the average groundwater pumping conditions remained relatively constant. During the solute-transport calibration process of the original model, source concentrations and transport parameters were adjusted until the site-specific chlorinated volatile organic compound (CVOC, such as PCE, TCE, cis-1,2-DCE, and VC) and uranium concentrations computed by the MT3D model for the last stress period (i.e., corresponding to December 2009) reasonably matched those observed in the field. The purpose of the calibration is to enable predictive analysis that will aid NFS in the development and evaluation of environmental remedies at the Site.

Compared to the previous modeling efforts, the following modifications were made in the revised solute-transport model:

- Extents and concentrations of various sources were adjusted during the qualitative recalibration process
- Two-stage qualitative calibrations were performed
    - pre-remediation period between 1957 and 2000 and pilot test 2000-2002
    - remediation period between 2002 and 2009
- Dual-domain mass transfer was simulated

- Transport parameters (i.e., distribution coefficients, degradation rates, and porosity values) were adjusted during the recalibration process
- Chain decay of chlorinated COCs (i.e., PCE, TCE, cis-1,2-DCE, and VC) was incorporated

4.1 Description of PCE and Uranium Source Areas

Operations at the NFS plant have resulted in the presence of radionuclide and organic constituents in the groundwater beneath the facility. The primary sources of these constituents were: 1) three former unlined surface impoundments (Ponds 1, 2, and 3) (SWMU 1); 2) former "Pond 4" disposal area (SWMUs 2, 4, and 6); 3) radiological waste burial grounds (SWMU 9); and 4) Buildings 110, 111, 130, 120/131 (SWMUs 13, 14, and 20) and the Building 200 Complex. Many of the PCE and uranium releases within the main plant area occurred near the buildings that are identified on Figure 2-6. The following subsections describe the primary sources of PCE and uranium in groundwater at the NFS site that were represented in the solute-transport model.

4.1.1 Ponds 1, 2, and 3 (SWMU 1)

SWMU 1 and area of concern (AOC) 5 are located north of plant production facilities and include former Ponds 1, 2, and 3 and the Former Banner Spring Branch. These were unlined impoundments built from 1957 to 1963; ponds received process waste waters associated with the production of nuclear materials. These ponds received fluids until 1978, when a wastewater treatment plant was built to treat wastewater. The three ponds contained approximately 91,000 cubic feet (ft^3) of waste material. The predominant radiological waste COCs were isotopes of uranium and thorium. PCE was also detected among other COCs in the waste samples. Waste from Pond 2 was also identified as characteristically hazardous for PCE and cadmium (Advanced Recovery Systems, Inc. 1994).

Waste removal began in August 1991 at Pond 3 with dredging to remove most of the contaminated sediments. Removal of waste from Ponds 1, 2, and 3 was completed in September 1993, August 1994, and May 1994, respectively (Advanced Recovery Systems, Inc. 1994). Waste from Pond 2 was treated to reduce PCE and cadmium concentrations below Toxicity Characteristic Leaching Procedure (TCLP) regulatory levels in an on-site treatment unit prior to disposal.

The historical discharge rates of contaminated water to the ponds were calculated using the NFS Lagoon Historical Data Report (Nuclear Fuel Services, Inc. 1985).

Information on various buildings at the facility, the chemical processes for which these buildings were used, operating periods, and quantities of wastewater discharged (flow rates) to the ponds has been detailed in previous reports. These flow rates were calculated for appropriate time stress periods, defined in Section 4.3, and incorporated into the solute-transport model.

Since 2000, NFS began excavation of these areas and has removed the remaining source material that was adhered to soils surrounding the former impoundments and channel. Remediation of the area is ongoing and for the purposes of the model are not continuous sources.

4.1.2 Pond 4 (SWMU 2)

SWMU 2 (Pond 4) was originally a marshy or low-lying area located in the western portion of the facility (underneath the former 410 Building footprint) and received waste material. The types and forms of materials placed in the Pond 4 area have been identified as the following: press cake, incinerator ash, sludge, drums (empty), buckets, (empty), conduit, pipes, old equipment, and general trash. No records of these materials and disposal activities are available. SWMU 2 was identified as a potential source for uranium and PCE (EcoTek, Inc. 1994b). Since 2000, NFS began excavation of these areas and has removed the remaining source material that was adhered to soils surrounding the former impoundments and channel. Remediation of the area is ongoing and for the purposes of the model are not continuous sources.

4.1.3 Banner Spring Abandoned Stream Bed Channel

SWMU 6 designates one of the abandoned channels of Banner Spring Branch which received supernatant from the three NFS impoundments. This channel was located north of the main plant facilities in the former Pond 4 area. Stream sediments were contaminated with isotopes of uranium and thorium. In 1967, the lower portion of the channel of Banner Spring Branch had been relocated approximately 200 ft east/southeast leaving the existing channel abandoned. Sediments from this portion of the abandoned channel were left in place and then backfilled. SWMU 6 was located within the boundary of SWMU 2 and was identified as a potential source for uranium only (EcoTek, Inc. 1994b). Since 2000, NFS began excavation of these areas and has removed the remaining source material that was adhered to soils surrounding the former impoundments and channel. Remediation of the area is ongoing and for the purposes of the model are not continuous sources.

4.1.4 Building 130 Scale Pit (SWMU 20) and Adjoining Buildings 131 and 120

Building 130 was constructed in the late 1950s. Operations in Building 130 include thorium processing, High Enriched Uranium (HEU) processing, and cleaning uranium hexafluoride cylinders. Potential COCs may include uranium, PCE, and TCE. Building 120 was constructed in the late 1950s. Building 131 was constructed in the early 1960s adjacent to Building 120. The Building 120/131 area has been used for maintenance, product storage, and as a pilot plant. Currently, the Building 120/131 Complex houses the maintenance department and a research and development laboratory. Chlorinated solvents were thought to have been used and stored in the vicinity of Buildings 120 and 131 (Nuclear Fuel Services, Inc. 1995a).

4.1.5 Radiological Waste Burial Ground (SWMU 9)

NFS disposed of low-level radioactive waste on site in a shallow burial ground referred to as the radiological waste burial ground (SWMU 9). The waste included contaminated equipment, construction debris, laboratory waste, and process waste. The waste was buried in units 120 to 160 ft long, 25 to 26 ft wide, and no greater than 10 ft deep with 3 to 6 ft of overburden. This SWMU was active from 1966 to 1977, and is a potential source for both uranium and PCE constituents (Nuclear Fuel Services, Inc. 1995b). Remediation of the area is ongoing and for the purposes of the model are not continuous sources for SWMU 9.

4.1.6 Bulk Chemical Storage Area at Building 111 (SWMU 13)

Building 111 was used as a storage area for processed chemical products, operating from 1957 to 1979. This building is thought to be a potential source for both uranium and PCE (Nuclear Fuel Services, Inc. 1995c).

4.1.7 Miscellaneous Potential Source Areas

In addition to the above described sources, the Building 200 Complex and Buildings 110, 302, 303, 304, 306, and 309 were identified as potential source areas for uranium.

4.2 Solute-Transport Model Description

4.2.1 Code Description

The NFS solute-transport model was constructed using the MT3D code, a modular three-dimensional solute-transport program. MT3D was originally developed by Zheng (1990) at S.S. Papadopulos & Associates, Inc., and subsequently documented for the Robert S. Kerr Environmental Research Laboratory of the USEPA. The MT3D code uses the flow terms and velocities computed by MODFLOW in its transport calculations. MT3D also uses the same finite-difference grid structure and boundary conditions as the groundwater flow model (MODFLOW), minimizing the effort necessary to construct a solute-transport model. The MT3D code was further updated in 1999 (Zheng and Wang 1999) and is referred to as MT3DMS, where MS denotes the multi-species component for accommodating add-on reaction packages. MT3DMS has a comprehensive set of options and capabilities for simulating advection, dispersion/diffusion, and chemical reactions of COCs in groundwater flow systems under general hydrogeologic conditions. The MT3DMS code was selected over previous versions of MT3D and RT3D (which was used in the original transport modeling analysis) to revise the solute-transport model because it more readily accounts for multi-species transport, transformation, and incorporates the dual-domain formulation. ARCADIS has also incorporated the chain-decay reactions into MT3DMS (i.e., PCE→VC), making it the most up-to-date platform for state of the art transport modeling. MT3DMS is publicly available, features extensive code documentation and verification, and was developed to be used in conjunction with MODFLOW.

For the revised transport modeling evaluation, the dual-domain mass transfer model, an alternative to the classical single-domain advection-dispersion equation, was utilized. As previously mentioned, the dual-domain model is an incorporated option in the widely-used transport modeling code MT3DMS (Zheng and Wang 1999).

In a dual-domain model, two porosity terms need to be specified: mobile and immobile porosity. Mobile porosity represents the more mobile portion of the formation where advective transport dominates, whereas the immobile porosity represents the less mobile portions of the formation where diffusion is dominant. The dual-domain model more accurately explains the classic movement of COCs in the subsurface than the single-domain model. Typically, as a pulse of contamination migrates through the porous media, portions of the plume move quickly in the migratory pore space while other portions of the plume diffuse and migrate into less mobile zones. Eventually, as the bulk of the plume mass migrates past a point in the system, mass stored in the less mobile zones diffuses or contributes mass back into the more active pore space through diffusion (Gillham, et al. 1984). Mass transfer into and out of the less mobile zone is generally slow because the process is controlled by diffusion. This effect is described clearly in the literature, as well as the mathematics to support the concept (Gillham, et al. 1984; Molz, et al. 2006; Flach, et al. 2004; Harvey and Gorelick 2000; Feehley, et al. 2000; Julian, et al. 2001; Zheng and Bennett 2002).

$$\theta_m \frac{\partial C_m}{\partial t} + \theta_{im} \frac{\partial C_{im}}{\partial t} = \frac{\partial}{\partial x_i}(\theta_m D_{ij} \frac{\partial C_m}{\partial x_j}) - \frac{\partial}{\partial x_i}(q_i C_m) + q_s C_s \qquad \text{(Eq. 4-1)}$$

$$\theta_{im} \frac{\partial C_{im}}{\partial t} = \beta(C_m - C_{im}) \qquad \text{(Eq. 4-2)}$$

Where C_m is the solute concentration in the mobile domain, C_{im} is the solute concentration in the immobile phase, θ_m is the porosity of the mobile domain, θ_{im} is the porosity of the immobile domain, and β is the first-order mass transfer coefficient between the mobile and immobile domains. Note: $\theta_{total} = \theta_{im} + \theta_m$

MT3DMS has four methods for solving the advection-dispersion equation: the Method of Characteristics (MOC), the Modified Method of Characteristics (MMOC), the Hybrid Method of Characteristics (HMOC), and conventional explicit finite-difference. The finite-difference technique uses a Taylor-series to approximate the derivatives, and is susceptible to numerical dispersion. Based upon the concentration gradients that have been observed in the field, the explicit finite-difference procedure was used.

4.2.2 Transport Parameters

The simulation of COC fate and transport requires specification of various transport parameters that control the rate, movement, mixing, and absorption of site-specific COCs (such as CVOCs and uranium) in the subsurface. For the updated transport modeling analysis, the fate and transport of the site COCs was simulated incorporating the processes of adsorption, advection, and degradation. Table 4-1 summarizes the transport parameters as obtained from the two-stage qualitative recalibration of the solute-transport model.

A limitation of the finite-difference scheme applied by MT3DMS is that some numerical dispersion is inherent in the simulation results. Numerical dispersion is a function of the size of the grid cell spacing, hydrogeologic properties assigned in the model, simulated water levels, and the time step size. It should be noted that while numerical dispersion is an artifact of the solution process, there is no mathematical difference between physical and numerical dispersion. The numerical dispersivity can be computed on a block-by-block basis in models solved using finite difference methods (Zheng and Bennett 2002). Application of the equations reported by Zheng and Bennett (2002) indicates that the numerical dispersivity is approximately one-half the modeled grid size (approximately 5 ft for this analysis in the site area). This dispersivity value is similar in scale to the values reported by Xu and Eckstein (1995). Therefore, dispersion coefficients were not explicitly defined in the revised transport model.

4.2.2.1 Adsorption

Adsorption is the process by which a solute adheres to a solid surface. Adsorption results in the solute, which was originally in solution, to become distributed between the solution and the solid phase, a process called partitioning. As a result of adsorption, a solute will move slower through the aquifer than the groundwater. This effect is called retardation. Adsorption is mathematically represented using a partitioning coefficient (K_d) which is the ratio of the concentration of the constituent in the sorbed (i.e., solid) phase to the concentration of the constituent in the dissolved phase (Eq. 4-3).

$$K_d = \frac{C_s}{C_d} \qquad \text{(Eq. 4-3)}$$

where:

C_s = the concentration of the constituent in the sorbed phase [milligrams per kilogram (mg/kg)]; and

C_d = the concentration of the constituent in the dissolved phase [milligrams per liter (mg/L)].

The site-specific COCs are adsorbed by the geologic materials during transport; therefore, a K_d was assigned in the model for each constituent during the transport simulations. The distribution coefficient for organic compounds is calculated using the following equation:

$$Kd = f_{oc} * Koc \qquad \text{(Eq. 4-4)}$$

where:

f_{oc} = the fraction of organic carbon; and

Koc = the octinal carbon ratio.

Based on previous modeling reports (Geraghty & Miller, Inc. 1996; ARCADIS Geraghty & Miller, Inc. 1999) and USEPA guidance (U.S. Environmental Protection Agency 2009), a f_{oc} of 0.1 percent was utilized in the revised transport model. Similarly, K_{oc} values of 240 liters per kilogram (L/kg), 87 L/kg, 49 L/kg, 30 L/kg, and 10,700 L/kg were assigned for PCE, TCE, cis-1,2-DCE, VC, and uranium, respectively.

4.2.2.2 Decay and Degradation

Radioactive decay and biodegradation are simulated by specifying a degradation or decay rate in the MT3D model. Radioactive decay was simulated for uranium by specifying a decay rate of 1.2×10^{-8} days^{-1} (i.e., corresponds to a half life of 1.6×10^{5} years) in the solute-transport model. PCE, as well as its daughter products, are degraded by microbial activity. Under ambient conditions, the half life for PCE and TCE can range from 6 months to 2 years, while that for cis-1,2-DCE and VC can range from 3 months to 8 years (Howard, et al. 1991). During the pre-remediation period (1957 to 2002) model recalibration, the corresponding degradation rates were varied within the ranges, and values of 9 months, 9 months, 6 years, and 6 years (Table 4-2) were found to produce the best match between observed and calculated PCE, TCE, cis-1,2-DCE, and VC concentrations, respectively.

However, during the full-scale remediation period (2002 through 2009) model recalibration, an enhanced degradation zone was delineated based on site-specific data and observations. Table 4-2 shows the degradation rates of various constituents within this zone as obtained from the qualitative recalibration process. The enhanced degradation zone has been the result of *in-situ* remedial activities targeted to reduce source mass concentrations and accelerate the attenuation process.

4.2.2.3 Effective Porosity

As mentioned before, the revised solute-transport simulations for the Site were performed using the dual-domain formulation. This option requires assignment of two porosity terms: mobile and immobile porosity. The total porosity measured at the Site is 41 percent (Nuclear Fuel Services, Inc. 1995d). However, site-specific mobile and immobile porosity values are not currently known, and therefore, were estimated during the recalibration process. Accordingly, the total porosity of 41 percent was estimated to be partitioned into a 15 percent mobile porosity and a 26 percent immobile porosity (Table 4-1). These values are consistent with literature value as well as ARCADIS experiences at similar sites.

Because of the suspected age of the plume, it was assumed that the mobile and immobile domains are in equilibrium. Therefore, the immobile domain concentrations were assumed to be equal to the mobile domain concentrations (i.e., dissolved-phase concentrations). A mass transfer coefficient of 0.001 day^{-1} was utilized in this revised transport modeling analysis and was based on the recalibration process as well as current research (Zheng and Bennett 2002).

4.3 Transport Model Recalibration

The solute-transport model was recalibrated to estimate transport parameter values that control the migration of site-specific COCs. As a result of recent on-site remedial activities, the recalibration process consisted of two stages: 1) pre-remediation period between 1957 and 2002, and 2) remediation period between 2002 and 2009.

The model was recalibrated first by simulating site-specific COC migration from January 1957 through December 2002 (i.e., before on-site remedial activities including *in-situ* reactive treatment). Recalibration to this time-frame enabled estimation of basic transport parameters such as natural degradation rates and adsorption characteristics of site-specific COCs, mobile porosity, mass transfer coefficient, etc. Afterwards, the recalibrated model was further adjusted (particularly the COC degradation rates within the remedial impacted zone) for the remediation period between 2002 and 2009. Further descriptions of the recalibration processes during these two stages are discussed in the following sections.

Due to uncertainties regarding the distribution and release history associated with COC sources at the NFS facility, rigorous transport calibrations were not performed. Instead, the calibration processes were performed to ensure that the specified transport parameters produce the general shape and extent of the observed COC plumes. Consequently, residual statistics were not used to describe the transport calibrations. Instead, observed COC concentrations were compared with simulated distribution of COC concentrations to allow for quick determination of the quality of the fit between observed and computed values. Model adjustments were performed to minimize, to the extent possible, the difference between computed and observed constituent concentrations.

4.3.1 Pre-Remediation Period (1957 to 2002)

Prior to performing the solute-transport simulations, the recalibrated groundwater flow model was used to simulate flow conditions for the time period corresponding to January 1957 through December 2002. The flow model was set up to simulate eight stress periods which correspond to periods associated with pumping conditions in the vicinity of the NFS facility. The velocities and volumetric flow rates calculated by the flow model were then input into the solute-transport model, and the solute-transport model was used to simulate the site-specific COCs. The pumping schedules for the supply wells were used to define the stress periods presented below.

- Stress Period 1: This first stress period covers the time period extending from January 1957 through December 1970. During this period, only two supply wells within the model domain, the Birchfield Well and the O'Brien Well, were actively pumping. The Birchfield Well is screened in Model Layers 3, 4, and 5, while the O'Brien Well is screened only in Model Layer 3. The daily average pumping rates were calculated from recorded monthly pumping totals. Additionally, effluent was discharged to the three impoundments during this period from plant operations which were simulated by 20 (number of model cells encompassing ponds) injection wells continuously discharging into the ponds at a constant rate of 132.35 ft^3/day/well.

- Stress Period 2: The second stress period extends from January 1971 through December 1975. This period uses the same pumping wells and average rates used in Stress Period 1, except that the injection rate of processed wastewater effluent sent to the impoundments was reduced to 49.47 ft^3/day/well.

- Stress Period 3: This stress period extends from January 1976 through December 1978 and was included in the model to simulate an increase in pumping rates for the Birchfield Well and O'Brien Well. This period maintained the injection rate of processed wastewater effluent sent to the impoundments as used in Stress Period 2.

- Stress Period 4: The fourth stress period extends from January 1979 through December 1985 and was included to account for additional pumping rate increases at both the Birchfield Well and O'Brien Well. This period was also modified to remove wastewater effluent entering the impoundments as effluent to the ponds was stopped in 1978.

- Stress Period 5: The fifth stress period extends from January 1986 through December 1990. During this time, the Railroad Well started pumping in addition to the other wells. The Railroad Well withdraws all its water from Model Layers 3, 4, and 5.

- Stress Period 6: The sixth stress period extends from January 1991 through December 1993. This stress period incorporates changes in the pumping rates of the three supply wells in the model domain.

- Stress Period 7: The seventh stress period extends from January 1994 through July 1994. This stress period was specified in the model to incorporate changes in the pumping rates at the three water supply wells.

- Stress Period 8: The last stress period extends from July 1994 through December 2002. At the beginning of this time period, ten dewatering wells were put into service around the Pond 4 area.

The following PCE and uranium sources were assigned in the model: 1) Ponds 1, 2, and 3 (SWMU 1); 2) Pond 4 disposal area (SWMUs 2, 4, and 6); 3) radiological waste burial grounds (SWMU 9); and 4) the areas associated with Buildings 110, 111, 130, 120/131 (SWMUs 13, 14, and 20) and the Building 200 Complex. The timing and constituent concentrations associated with these sources was estimated from disposal records and conversations with NFS personnel during the original solute-transport model calibration. During the recalibration process, the source extents and strengths were adjusted to match the observed COC concentrations in 2002. Pond sources were simulated by assigning concentrations to the river cells in the model, and the sources around the buildings and the radiological waste burial grounds were simulated by assigning a concentration to precipitation recharge entering the source area. Figure 2-6 illustrates the distribution of the initial groundwater sources assigned in Model Layers 1 and 2. The concentrations assigned to these sources are summarized in Table 4-3.

4.3.2 Remediation Period (2002 to 2009)

In order to reduce the source mass concentrations, full-scale *in-situ* remedial activities (e.g., source mass removal and IRZ system) started at the NFS site. The full-scale *in-situ* reactive remedial measure created a reactive zone, where enhanced degradation of the site-specific COCs was attained. As a result, the recalibrated transport model from the first stage was further adjusted to reflect the impact of the remedial activities on the site-specific COCs. Accordingly, during the remediation period recalibration process, a reactive zone of enhanced degradation was delineated based on site-specific data and observations.

As part of remedial activities, source mass was removed from the following locations: 1) Ponds 1, 2, and 3 (SWMU 1); 2) Pond 4 (SWMU 2); 3) radiological waste burial grounds (SWMU 9); and 3) stock pile area (SWMU 7) (Figure 2-6). Accordingly, continuous sources of uranium and PCE in the unsaturated zone at these locations were eliminated from the transport model during the remedial period recalibration process. However, simulated COC groundwater concentrations at these locations from the first stage recalibration were assigned as initial concentrations in the transport model for the second stage. In addition, individual COC plume maps were prepared using the 2002 analytical data and the initialized plumes were assigned to the model. Because there is a high degree of hydraulic interconnection between the shallow alluvium and cobble/bedrock zones, the same initialized plume was assigned to both Model Layers 1 and 2. Few data were available to define the spatial distribution of COCs in the shallow bedrock, and therefore, no plume maps were prepared and initialized in Model Layers 3, 4, and 5.

4.4 Re-Calibration Results

Initially, the solute-transport simulations for the pre-remediation period were performed using the transport parameters that were assigned in the existing model. However, the spatial distribution of site-specific COCs predicted by the model did not adequately match the constituent distribution observed in December 2002 and December 2009. Consequently, the source extent and magnitude, as well as the transport parameters were adjusted individually and in combination until an adequate match were achieved.

After numerous transport simulations, the parameter values summarized in Table 4-1 were found to produce the best match between the observed and simulated plume geometry from 2002 and 2009. Figures 4-1 through 4-10 illustrate simulated COC concentrations with the observed concentrations posted on the maps. Since most of the water-quality data and simulated mass are in Model Layer 2, only the plume maps for this layer are presented.

In general, the observed COC data compare well with the simulated plume distribution. During the recalibration process, more emphasis was given to match monitor wells with higher concentrations. Because the recalibrated model is slightly biased towards higher concentrations, the model uses conservative estimates of various transport parameter values. In locations where the predicted constituent concentrations do not closely match those observed in the field, the discrepancy can be attributed to localized heterogeneities as well as uncertainties associated with the extent and release history for COC source areas within the NFS facility. Nonetheless, the shape and extent of the COC plumes suggest that a satisfactory degree of qualitative calibration and estimate of the transport parameters have been achieved.

5. Predictive Simulations

As part of the current modeling investigation, the recalibrated solute-transport model was used to predict the future migration and attenuation of site-specific COC plumes under current (2009) conditions (flow and water quality) at the Site. Initial COC plumes for each of the site COCs were developed based on current (2009) water quality. Since there is a high degree of hydraulic interconnection between the shallow alluvium and cobble/bedrock zones, same initialized plume was assigned to both Model Layers 1 and 2. In addition, simulated COC concentration distributions from the remediation period (2002 to 2009) recalibration process were assigned to the locations in Model Layers 1 and 2 where current quality data were not available. Source terms were adjusted in the model to account for completed and/or ongoing remedial activities at the Site. Accordingly, a continuous source in the unsaturated zone for PCE and uranium was assigned only to the Building 200 Complex, where the extent and magnitude of the continuous source was kept similar to the recalibration process. No continuous source zone was assigned for TCE, cis-1,2-DCE, and VC.

Furthermore, two predictive solute-transport simulation scenarios, with and without continued remediation, were completed. The purpose of such scenarios was to evaluate the impact of site remedial activities on the COC migration and attenuation timeframe. Under the continued remediation scenario, it was assumed that the *in-situ* reactive zone will be active in the future, and hence, will allow continuous enhanced degradation of site-specific COCs within the reactive zone. The reactive zone was eliminated during the "without continued remediation" scenario, and thereby, allowing only natural degradation of the constituents across the Site.

Transport simulations for uranium were conducted for a period of 1,000 years, whereas those for PCE, TCE, cis-1,2-DCE, and VC were carried out for 50 years. The simulated concentration distributions over time were used to evaluate the effects of natural attenuation of site COCs. The CVOC results are presented as simulated concentration distributions at current (initialized distribution in 2009), 10 (2019), and 50 (2059) years into the future for Model Layer 2 and dissolved uranium results are presented as current (initialized distribution in 2009), 100 (2109) and 1,000 (3009) years (Figures 5-1 through 5-10). Since most of the water-quality data and simulated mass are in Model Layer 2, only the plume maps for this layer are presented.

Simulation results indicate significant degradation or attenuation of COCs and limited migration to off-site locations under continued remediation scenario. Without active remediation in the future, uranium and PCE plumes generally expand and remain above the regulatory limits at on-site locations. Interestingly though limited or no cis-1,2-DCE and VC concentrations above the regulatory limits [70 parts per billion (ppb) and 2 ppb, respectively] were observed after 10 years of simulated time due to limited degradation of PCE (and TCE) under ambient conditions. The following sections describe the predictive simulation results of the COCs under the two scenarios – with and without future remediation.

5.1 PCE, TCE, cis-1,2-DCE, and VC

As described in previous section, PCE concentration distributions were initialized in Model Layers 1 and 2 based on current (2009) and simulated water-quality data. In addition, a continuous source in the unsaturated zone near Building 234 area was assigned. Simulation results for PCE under continued remediation scenario (Figure 5-1) indicate a significant decrease in simulated PCE concentrations as a result of enhanced degradation in the on-site reactive zone. Only a small PCE plume with concentrations between 10 to 100 ppb is observed on site after 50 years of transport time. PCE concentrations beyond north-west of the rail-line boundary attenuate below the regulatory limit of 5 ppb in 50 years. In addition, limited or no off-site migration of PCE is observed within the simulated time. On the other hand, without continued remediation and enhanced degradation zone, significantly elevated concentrations of PCE (between 100 and 500 ppb) remain on site after 50 years of transport simulation (Figure 5-6). Furthermore, continued migration of PCE concentrations ranging between 10 and 100 ppb are observed beyond the rail-line boundary and towards the Nolichucky River.

Similar to PCE, initial concentrations of TCE were assigned in Model Layers 1 and 2 based on current (2009) and simulated water-quality data. But unlike PCE, no continuous source of TCE in the unsaturated zone was present. Under continued remediation scenario (Figure 5-2), TCE concentrations initially increased due to enhanced degradation of PCE to TCE; however, the plume mass concentration decreased rapidly afterwards due to enhanced degradation in the reactive zone. On the contrary, without continued remediation, a long narrow TCE plume with concentrations between 5 and 100 ppb expanded to off-site locations, and persisted throughout the 50-year simulation period (Figure 5-7).

Based on recent (2009) and simulated water-quality data, cis-1,2-DCE and VC concentrations were initialized in Model Layers 1 and 2, with no continuous sources of these compounds. Results from predictive simulations with and without continued remediation scenarios depict an interesting phenomenon. A small concentration plume of cis-1,2-DCE above the regulatory limit of 70 ppb is observed on site after 10 years of predictive simulation with continued remediation (Figure 5-3), whereas no cis-1,2-DCE above the regulatory limit is observed after 10 years under ambient conditions (Figure 5-8). Similar results are also observed for VC under the two scenarios (Figures 5-4 and 5-9). These results indicate that while enhanced degradations of PCE and TCE within the reactive zone helped reduce the parent concentration mass, it also produced the daughter products (cis-1,2-DCE and VC) through the degradation pathway. The source area of parent product and remedial activities were helping to sustain daughter product distribution. Although no daughter products above the regulatory limits are observed under the ambient condition, it should be realized that the source mass of parent products are not degrading fast enough, and hence, poses a potential risk of persisted elevated concentrations and subsequent off-site migration.

5.2 Uranium

Uranium concentration distributions were initialized in Model Layers 1 and 2 based on current (2009) and simulated water-quality data. In addition, a continuous source in the unsaturated zone near the Building 234 area was assigned (Figure 2-6). Simulation results suggest that continued on-site remediation will completely degrade uranium concentration below the regulatory limit of 30 ppb in approximately 100 years within the reactive zone (Figure 5-5). However, without continued remediation, simulated uranium concentration distributions throughout 1000 years are almost identical to the initial condition (Figure 5-10). This observation can be attributed to the extremely low natural attenuation rate of uranium. Furthermore, *Figures 5-5 and 5-10 indicate* that the shape and extent of uranium plumes outside the reactive zone are quite stable over time as a result of the low mobility of uranium in groundwater. Modeling results after 1,000 years of simulated transport suggest that uranium concentrations between 30 and 500 ppb remain on site and migrate to off-site location beyond the rail-line boundary, with or without continued remediation.

6. Model Assumptions and Limitations

The NFS groundwater flow and solute-transport models assume that the fractured media present at the Site and within the surrounding bedrock aquifer system can be represented as an equivalent porous media. Representation of the fractured bedrock aquifer system as a porous media is valid as long as the fractures are closely spaced relative to the scale of the problem that is being evaluated with the model. The equivalent porous media approach adequately represents the behavior of a regional flow system, but may poorly reproduce local conditions on a scale of several meters.

In areas of the model where specific data are lacking, the model may not accurately simulate local flow conditions. The model may also be less accurate away from the Site due to the relatively large grid spacing used in these areas which requires averaging hydrologic parameters over a larger area. The accuracy of the model away from the Site has not been evaluated due to a lack of detailed hydraulic information outside the NFS plant area. However the accuracy in model parameters in the vicinity of the Site was addressed through the model recalibration process and the completion of a detailed sensitivity analysis.

It should be noted that even though the estimated biodegradation rates for various site-specific COCs were the best value determined during the qualitative recalibration of the transport model, more emphasis was given to match the monitor wells with higher concentrations. Therefore, the estimated biodegradation rates are slightly biased, and thus overestimated the concentrations of daughter products (i.e., TCE, cis-1,2-DCE, and VC) at some locations.

Although the current solute-transport model accurately simulates the large-scale migration of dissolved CVOC and uranium plumes, finer discretization in the vicinity of the site may increase the resolution and accuracy of the model predictions. The current model utilizes a 10-ft grid spacing in the site area which can sometimes be greater than the scale of changes in observed concentrations. Although the on-site grid spacing in the revised model is much finer than the previous models, averaging of observed groundwater concentrations and concentrations associated with source areas over individual grid cells may lead to some inaccuracies.

The accuracy of the NFS flow model was determined by comparing the simulated results with observed values. This does not necessarily indicate the model will perform with the same level of accuracy for long-term predictions use. The predictive simulations discussed in the report contain the same aquifer recharge rates and similar flow system stresses as for the calibration period. Thus, assuming that significant changes to the aquifer system water balance do not occur, the predictions should have a level of reliability similar to the calibrated flow model. It should be noted, however, that as predictive simulation time increase, confidence in the applicability of the present water balance and aquifer conditions (e.g., porosity, stream downcutting or meandering, climate changes, etc.) to future conditions continues to decrease with increasing simulation time. Therefore, predictive simulations far into the future may be inaccurate due to the inability to predict long-term climatic trends, changes in groundwater divide locations, etc., which can occur over time.

7. Summary and Conclusions

A regional groundwater flow model (MODFLOW) for the NFS site was originally developed in 1996, and subsequently modified in 1999. The model was used to simulate groundwater flow in an unconsolidated and bedrock aquifer system. In conjunction with the flow model, a solute-transport model was developed (MT3D) to evaluate fate and transport of uranium and PCE. Primary source areas in the unsaturated zone were developed as part of solute-transport model development. These source areas are represented by three former unlined surface impoundment ponds (SWMU 1), the former "Pond 4" disposal area (SWMUs 2, 4, and 6), the radiological waste burial grounds (SWMU 9), and Buildings 110, 111, 130, 120/131 (SWMUs 13, 14, and 20), and the Building 220 Complex. Additionally, model simulation incorporated the production history of nearby Erwin Utility supply wells and infiltration at the ponds to define individual aquifer stress periods.

Based on recently collected site-specific data, the hydrogeologic conceptual model for the NFS site was refined. The data were also used to revise the representation of stratigraphic units assigned in the model (i.e., thickness, elevation, and geometry of stratigraphic units), to revise the delineation of hydraulic conductivity zones in the model, and to better delineate the extent of uranium and PCE constituent concentrations through model discretization. In addition, the new water-level data were used to recalibrate groundwater flow characteristics, and the calibration results indicate that a satisfactory degree of calibration was achieved.

Following recalibration of the flow model, the existing solute-transport model was revised based on recent groundwater sampling data. Flow conditions simulated using the recalibrated groundwater flow model were used in the revised transport model. In general, the following modifications were made in the revised solute-transport model:

- Extents and concentrations of various sources were adjusted during qualitative recalibration process
- Qualitative calibrations were performed in two stages
    - pre-remediation period between 1957 and 2002
    - remediation period between 2002 and 2009
- Dual-domain mass transfer was simulated
- Transport parameters (i.e., distribution coefficients, degradation rates, and porosity values) were adjusted during the recalibration process

- Chain decay of chlorinated COCs (i.e., PCE, TCE, cis-1,2-DCE, and VC) was incorporated

The revised transport model was recalibrated first by simulating site-specific COC migration from January 1957 through December 2002 (i.e., before on-site remedial activities). Recalibration to this time-frame enabled to estimate basic transport parameters such as natural degradation rates and adsorption characteristics of site-specific COCs, mobile porosity, mass transfer coefficient, etc. Afterwards, the recalibrated model was further adjusted (particularly the COC degradation rates within the remedial impacted zone) for the remediation period between 2002 and 2009.

Due to uncertainties regarding the distribution and release history associated with COC sources at the NFS facility, only a qualitative recalibration of the solute-transport model was carried out by comparing observed COC concentrations with simulated distribution of COC concentrations. In general, the shape and extent of the COC plumes suggest that a satisfactory degree of qualitative calibration and estimate of the transport parameters have been achieved.

The recalibrated solute-transport model was used to predict the future migration and attenuation of site-specific COCs under two scenarios – with and without continued remediation. Simulation results indicate significant degradation or attenuation of COCs and limited migration to off-site locations under continued remediation scenario. Without active remediation in the future, uranium and PCE plumes were found to be expanding and consistently remaining above the regulatory limits.

Predictive simulation results for uranium without continued remediation scenario revealed a similar concentration distribution to the initial condition, which can be attributed to the extremely low natural attenuation rate of uranium. Furthermore, the stable shape and extent of uranium plumes (outside the reactive zone) up to approximately 1,000 years of transport simulation are the result of a high retardation factor associated with uranium.

The ability of the model to perform predictive simulations has helped to predict the current and future extent the COCs at the Site. The model can be a powerful tool to evaluate the effectiveness of the current remedial systems, for risk assessment, and to develop a cost-effective monitor well program. These models can be utilized as a tool to enhance the understanding of site conditions as new site information is gathered.

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9. Certification

I certify under penalty of law, including but not limited to penalties for perjury, that the information contained in this *Revised Groundwater Flow and Solute-Transport Modeling Report* for the Nuclear Fuel Services, Inc. facility in Erwin, Tennessee, and on any attachment is true, accurate, and complete to the best of my knowledge, information, and belief. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for intentional violation.

Berny D. Ilgner, PG
PG (Print Name)

Signature

2/18/10
Date

TN000250
Tennessee Registration #

BERNY D. ILGNER
#250

Paul M. Preston, PE
PE (Print Name)

Signature

2/18/2010
Date

TN109506
Tennessee Registration #

STATE OF TENNESSEE

COUNTY OF KNOX

Sworn to and subscribed before me by Berny D. Ilgner and Paul M. Preston

on this date 2-18-10. My commission expires 3-26-11

Benita A. Ferrell
Notary Public (Print Name)

Benita A. Ferrell
Signature

Stamp

BENITA A. FERRELL

Table 2-1. Public and Private Groundwater Supplies in the Unicoi County Area

Nuclear Fuel Services, Inc. Erwin, Tennessee

Public Groundwater Supplies in Unicoi County

Source	Geologic Horizon[1]	Depth (ft)	Potential Yield (gpm)	Location in Relation to NFS
Erwin Utility District				
Anderson-McInturff Spring	Cu/Chk	—	450	Approx. 3.8 mi. NE of NFS
Birchfield Well and Spring	Cu/Chk/Cs	222	1,500	Approx 1.5 mi. N or NFS
O'Brien Well and Spring	Ce (spring)	606	630	Approx 1.3 mi. NE of NFS
Railroad Well	Cr/Chk	240	315	Approx 3,500 ft NE of NFS
Plassco Well	Chk	350	—	Approx 2.5 mi. ENE of NFS
Elk's Club Well	Chk	305	1,200	Approx 1.6 mi. NE of NFS
Ambrose Well	Chk	270	1,100	Approx 1.5 mi. N of NFS
Johnson City Water Department				
Unicoi Springs (3)	Cu	—	2,500	Approx. 6 mi. NE of NFS

SOURCE: First Tennessee Development District, March 1987 and Bradfield Environmental Services, Inc.

Private Groundwater Supplies Within a 5-mile Radius of NFS

Owner and/or Name	Geologic Horizon[1]	Depth (ft)	Potential Yield (gpm)[3]	Use
Crystal Ice, Coal & Laudry (well)	Chk	135	75	Industrial
Love Spring	Cs	---	500	---
Grady Ledford (well)	Ce	122	N/A	Domestic
Sam Tipton (well)	Ce	80	N/A	Domestic
E.L. Lewis (spring)	Ce	—	5	Domestic
Unaka Springs	Cu	—	N/A	Domestic
U.S. Dept. of the Interior (spring)	Chk	—	916	Industrial
Fess Radford (well)	Chk	30	N/A	Domestic
Kelley Rice (well)	Cs	24	N/A	Domestic
Charles Erwin (well)	Chk	323	N/A	Domestic
Yates Spring	Cu	—	10	Domestic
W.B. Walker	Ch	N/A	3	Domestic

NOTES:

1. Chk - Honaker Dolomite Cs - Shady Dolomite Ce - Erwin Formation
   Cu - Unicoi Formation Cr - Rome Formation Ch - Hampton Formation
2. Banner Spring was listed as a potential water supply source in the Survey of Public Groundwater Supplies published by the First Tennessee Development District in March 1987. Banner Spring is owned by Nuclear Fuel Services, Inc. and is not a water supply.
3. N/A - Not Available

SOURCE: EcoTek Inc., Hydrogeologic Characterization Study of NFS Facility, Vol. I, March 1989

Table 3-1. Calibration Targets and Calculated Residuals for Regional Model

Nuclear Fuel Services, Inc., Erwin, Tennessee

Well ID	Model Layer	Model Row	Model Column	Simulated Heads (ft MSL)	Observed Heads [(1)] (ft MSL)	Residual (ft)
52	1	219	260	1636.11	1635.99	0.12
58	1	145	314	1631.89	1630.27	1.62
74	1	191	182	1636.75	1634.83	1.92
103A	1	139	233	1632.19	1631.02	1.17
104A	1	144	207	1632.95	1632.02	0.93
105A	1	149	180	1633.68	1635.51	-1.83
106A	1	155	150	1634.50	1629.43	5.07
107A	1	175	171	1635.87	1634.89	0.98
108A	1	159	228	1633.99	1633.63	0.36
111A	1	150	231	1633.22	1634.56	-1.34
112A	1	151	219	1633.34	1634.85	-1.51
113A	1	153	214	1633.58	1635.05	-1.47
234-2	1	210	243	1637.24	1633.01	4.23
39R	1	180	253	1635.65	1633.27	2.38
98A	1	126	312	1629.27	1628.48	0.79
99A	1	128	301	1630.61	1629.27	1.34
91	2	170	240	1635.09	1633.74	1.35
92	2	169	231	1635.04	1634.46	0.58
93	2	155	237	1633.70	1633.75	-0.05
94	2	149	238	1633.09	1634.43	-1.34
100A	2	131	278	1631.24	1630.12	1.12
102A	2	137	246	1631.95	1631	0.95
109A	2	160	220	1634.10	1634.97	-0.87
110A	2	161	214	1634.32	1638.08	-3.77
116A	2	121	240	1629.89	1631.1	-1.21
116B	2	121	240	1629.89	1631.02	-1.13
117A	2	98	251	1627.38	1627.95	-0.57
117B	2	99	252	1627.56	1627.76	-0.20
118A	2	107	300	1627.64	1626.82	0.82
118B	2	108	299	1627.92	1627.76	0.16
119A	2	127	202	1630.99	1631.58	-0.59
120A	2	92	217	1627.24	1624.41	2.83
38R	2	180	253	1635.65	1633.45	2.20
97A	2	170	221	1635.14	1634.93	0.21
OW-1	2	156	231	1633.74	1633.72	0.02
120B	3	91	217	1628.04	1625.45	2.59
SC-4	3	206	223	1637.36	1635.58	1.78

(1) - Data collected on October 23, 2009.
MSL - mean sea level

Total Targets Used =	**37.00**
Mean =	**0.53**
Variance =	**3.01**
Standard Deviation =	**1.74**
Residual Sum of Squares =	**118.82**
Range of Observed Water-Level Elevations Model Layer 1=	**7.51**
Range of Observed Water-Level Elevations Model Layer 2 =	**13.67**
Range of Observed Water-Level Elevations Model Layer 3 =	**10.13**
Range of Simulated Water-Level Elevations Model Layer 1 =	**7.97**
Range of Simulated Water-Level Elevations Model Layer 2 =	**8.41**
Range of Simulated Water-Level Elevations Model Layer 3 =	**9.31**

Table 4-1. Parameters Assigned in the Solute-Transport Model

Nuclear Fuel Services, Inc., Erwin, Tennessee

Parameters	Symbol	Uranium	PCE	TCE	DCE	Vinyl Chloride
Distribution Coefficient (L/kg)	Kd	107	0.24	0.07	0.039	0.024
Mass Transfer Coefficient		1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
Mobile Porosity (%)	σ_m	15	15	15	15	15
Total Porosity (%)	σ_{total}	41	41	41	41	41
Background Degradation Rate (day - 1)		1.20E-08	2.57E-03	2.57E-03	3.17E-04	3.17E-04
Enhanced Degradation Rate (day - 1)		6.69E-04	4.62E-02	4.62E-02	4.62E-02	4.62E-02

DCE - cis-1,2-dichloroethene

kg - kilograms

L - liters

PCE - tetrachloroethene

TCE - trichloroethene

Table 4-2. Half-Lives of Site-Specific Contituents of Concern

Nuclear Fuel Services, Inc. Erwin, Tennessee

Site-Specific COCs	Background (years)	Enhanced (days)
PCE	0.75	15
TCE	0.75	15
DCE	6	15
Vinyl Chloride	6	15
Uranium	158,253	1,051

COCs - constituents of concern
DCE - cis-1,2-dichloroethene
PCE - tetrachloroethene
TCE - trichloroethene

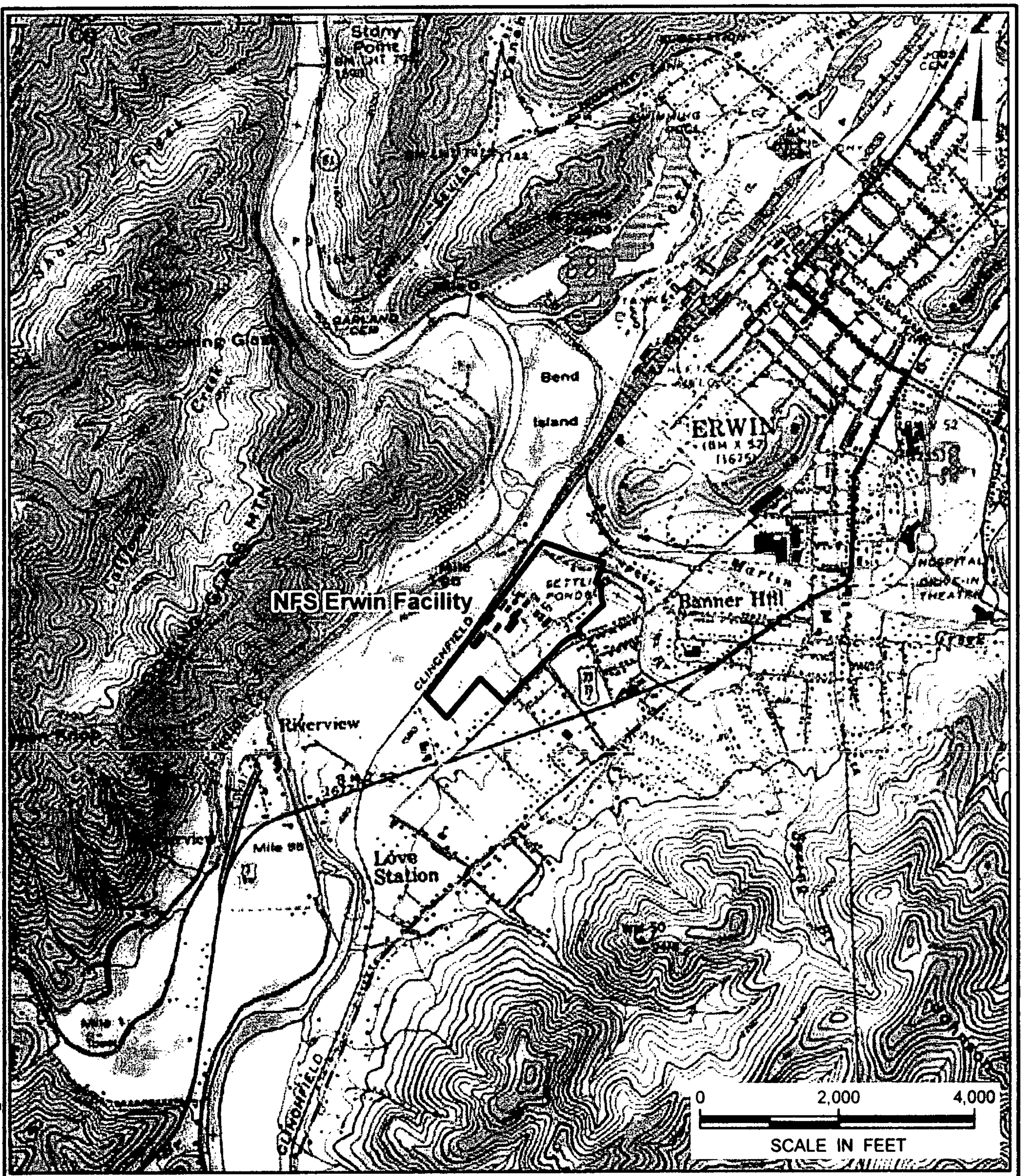
Table 4-3. Source Concentrations Used in the Historical Solute-Transport Model

Nuclear Fuel Services, Inc.   Erwin, Tennessee

Source Distribution Areas	PCE Concentration (ppb)	Uranium Concentration (ppb)
Ponds 1, 2, and 3	450	750
Pond 4	1,000	250
Burial Grounds	200	560
Stock Pile	--	450
Building 110	--	250
Building 111	20,000	250 to 1,350
Building 120	50,000	--
Building 130	20,000	2,500
Building 131	1,000	--
Building 300 Complex		
302, 304, 306	--	450
303	--	450
309	--	450
Building 200 Complex		
234A	1,000	840
234C	1,000	560

PCE - tetrachloroethene

ppb - parts per billion



REFERENCE: http://services.arcgisonline.com/arcgis/services
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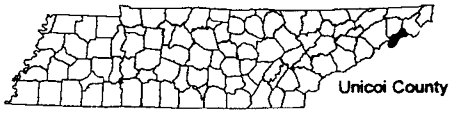
TENNESSEE



NUCLEAR FUEL SERVICES, INC.
ERWIN, TN
REVISED GROUNDWATER FLOW AND SOLUTE-TRANSPORT MODELING REPORT

REGIONAL LOCATION MAP

ARCADIS

FIGURE
1-1

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGNER PM: P.PRESTON TM: R.MCKINNEY
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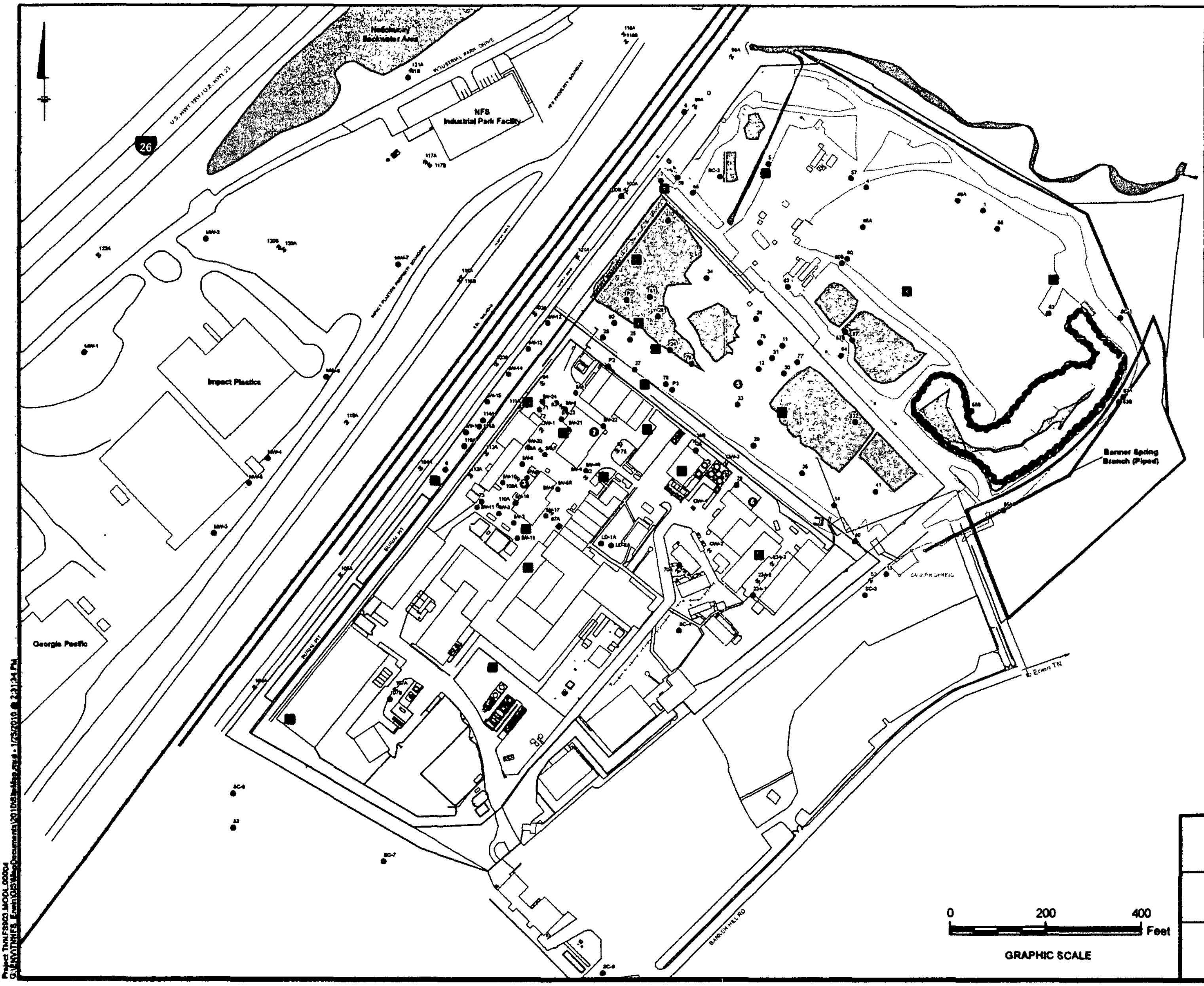

Type	Name	Description
SWMU	1	Ponds 1, 2, and 3
SWMU	2	Pond 4
SWMU	3	Underground Storage Tank at Bldg. 110
SWMU	4	Yard Incinerator
SWMU	5	Abandoned Banner Spring Branch Channel
SWMU	7	Contaminated CSX Soil Stockpile
SWMU	8	Soil Excavation Site on CSX Property
SWMU	9	Radiological Waste Burial Ground
SWMU	10	Demolition Landfill
SWMU	11	Burial Trenches on CSX Property
SWMU	12	310 Warehouse
SWMU	13	Bulk Chemical Storage at Bldg. 111
SWMU	14	LNAPL Plume (Well 72)
SWMU	15	WWTF
SWMU	16	Radiological Incinerator (Bldg. 302)
SWMU	17	Calciner
SWMU	18	Bldg. 105 UST
SWMU	19	Bldg. 106 UST
SWMU	20	Bldg. 130 Scale Pit
SWMU	21	No. 2 Fuel Oil AST
AOC	2	Boiler Blowdown & Backwash Water Bldg. 111
AOC	3	Cooling Water Tower Bldg. 130
AOC	5	Former Banner Spring Branch Channel
AOC	6	Mercury Contaminated Area

Legend

- ● AOC
- ■ SWMU
- ✦ Active Groundwater Monitoring Well
- ● Injection
- ● Abandoned Groundwater Monitoring Well
- ▨ SiteFeatures
- Building
- ▨ Water
- ▨ BannerSpringBranch_pipe
- Area of Interest

Notes:
Base Map created by merging NFS Drawing 21Kout-2 (11/5/2009) and ARCADIS xref_NFS_bas.dwg.

0 200 400 Feet
GRAPHIC SCALE

NFS
ERWIN, TENNESSEE
Revised Groundwater Flow and Solute-Transport Modeling Report

Site Map

ARCADIS

FIGURE
1-2

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGNER PM: P.PRESTON TM: M. KLADIAS
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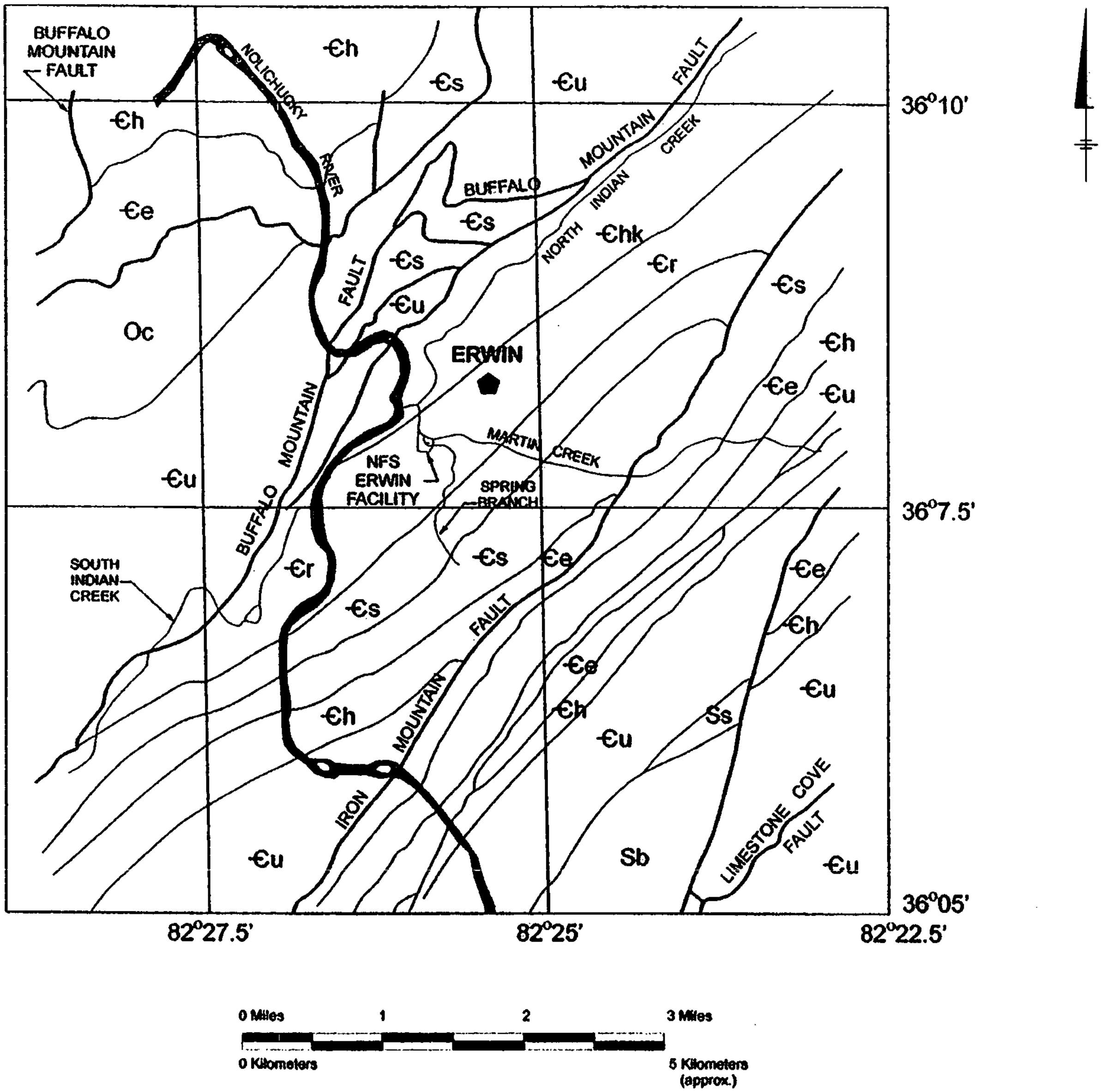

EXPLANATION

PRECAMBRIAN (p€)		CAMBRIAN (€)	
O c	Ocoee Group	€ hk	Honaker Dolomite
S s	Sandsuck Shale	€ r	Rome Formation
S b	Snowbird Formation	€ s	Shady Dolomite
		€ e	Erwin Formation
		€ h	Hampton Formation
		€ u	Unicoi Formation

NUCLEAR FUEL SERVICES, INC.
ERWIN, TN
REVISED GROUNDWATER FLOW AND SOLUTE-TRANSPORT MODELING REPORT

GEOLOGIC MAP OF THE ERWIN REGION

ARCADIS

FIGURE
2-1

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PROJECT: TNNFS901.FS07.00001 PATH: G:\ENV\TNNFS_Erwin\GIS\MapDocuments\2010\Regional Geo Erwin.mxd SAVED: 13JAN2010

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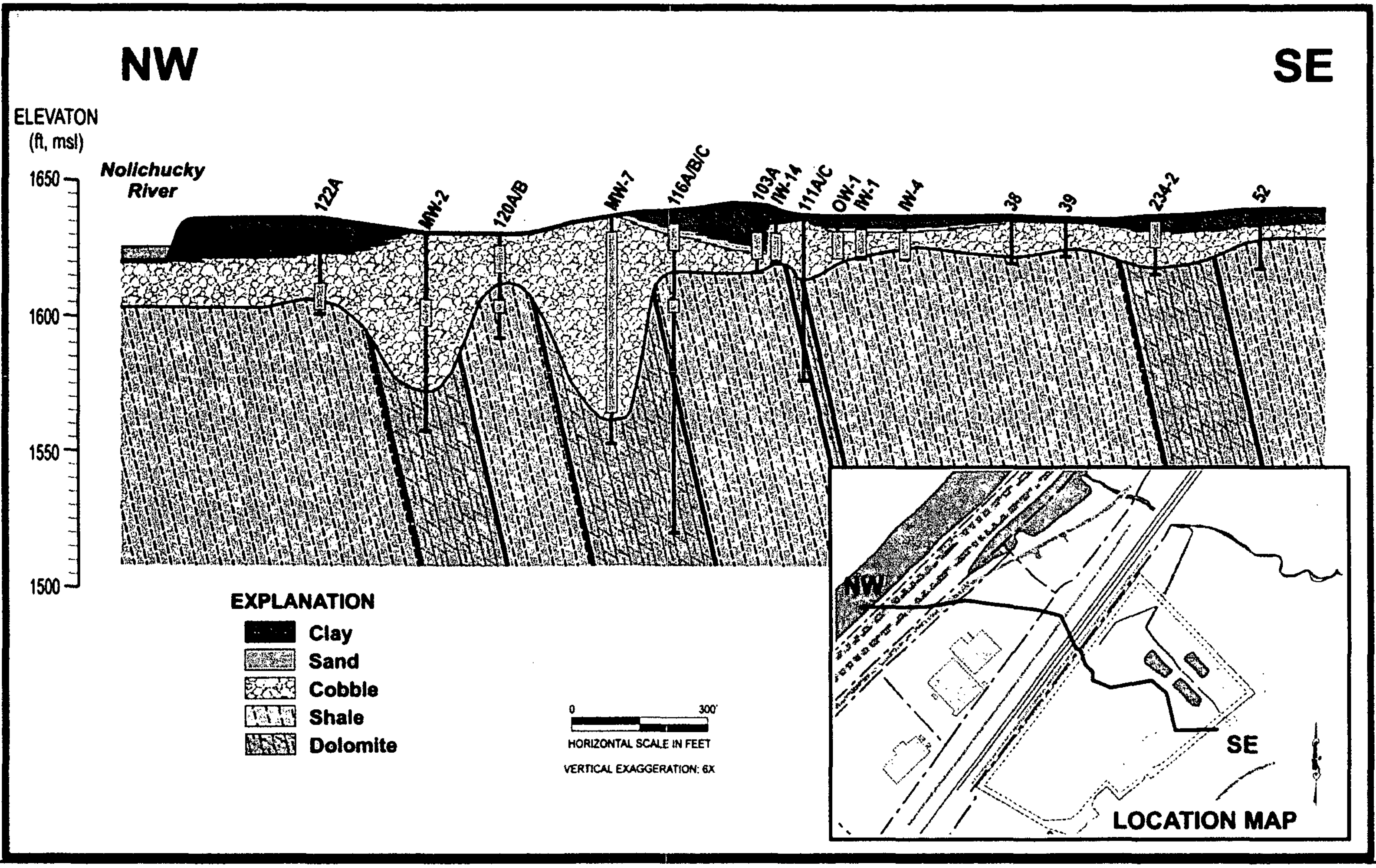

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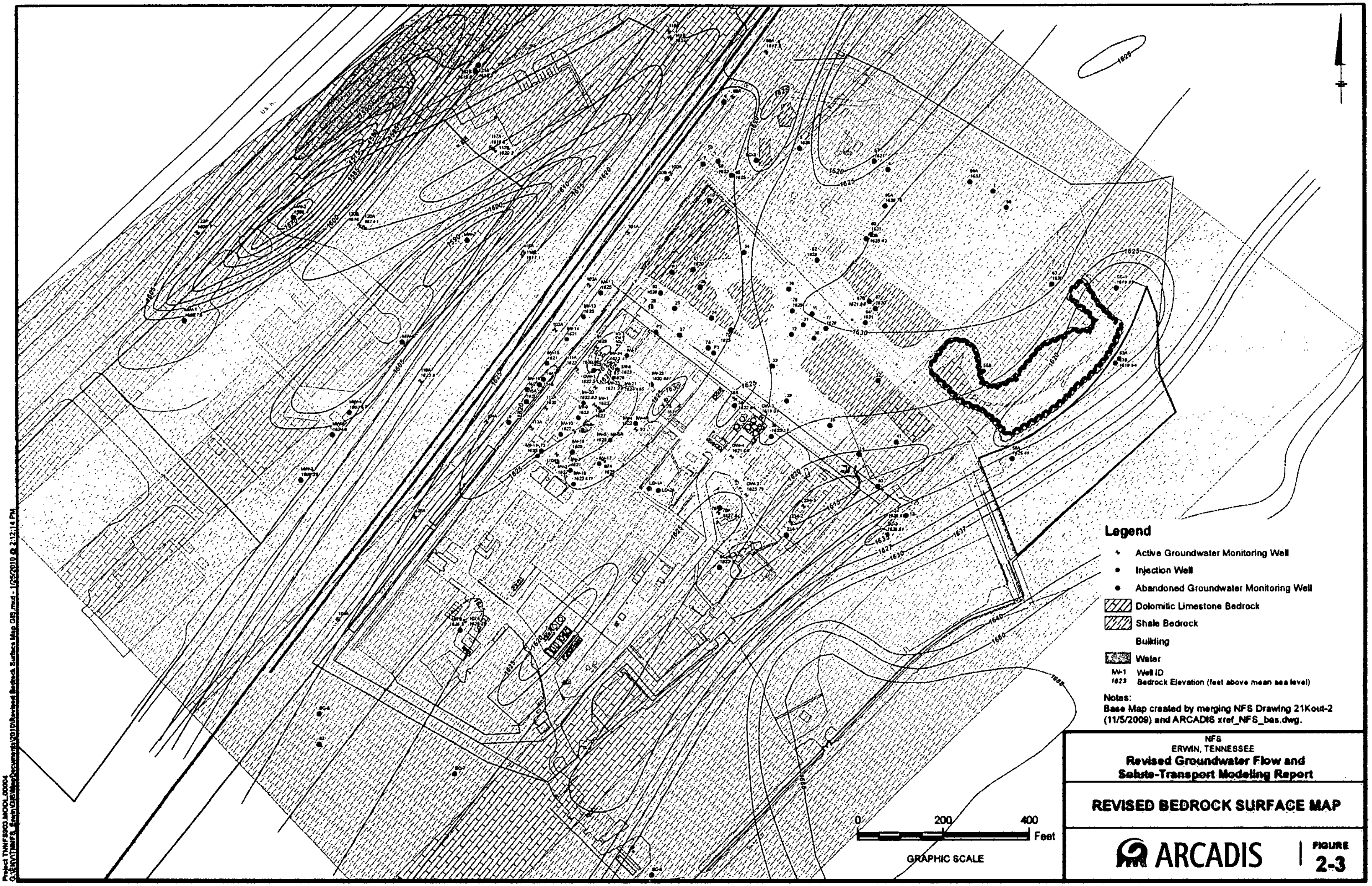
ERWIN, TENNESSEE

Revised Groundwater Flow and Solute-Transport Modeling Report

Geologic Cross Section

ARCADIS

FIGURE
2-2



Notes:
Base Map created by merging NFS Drawing 21Kout-2 (11/5/2009) and ARCADIS xref_NFS_bas.dwg.

NFS
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Revised Groundwater Flow and Solute-Transport Modeling Report

REVISED BEDROCK SURFACE MAP

ARCADIS

FIGURE
2-3

CITY: KNX DIV/GROUP: ENV DB: B.ALTON PIC: B.ILGNER PM: P.PRESTON TM: M. KLADIAS
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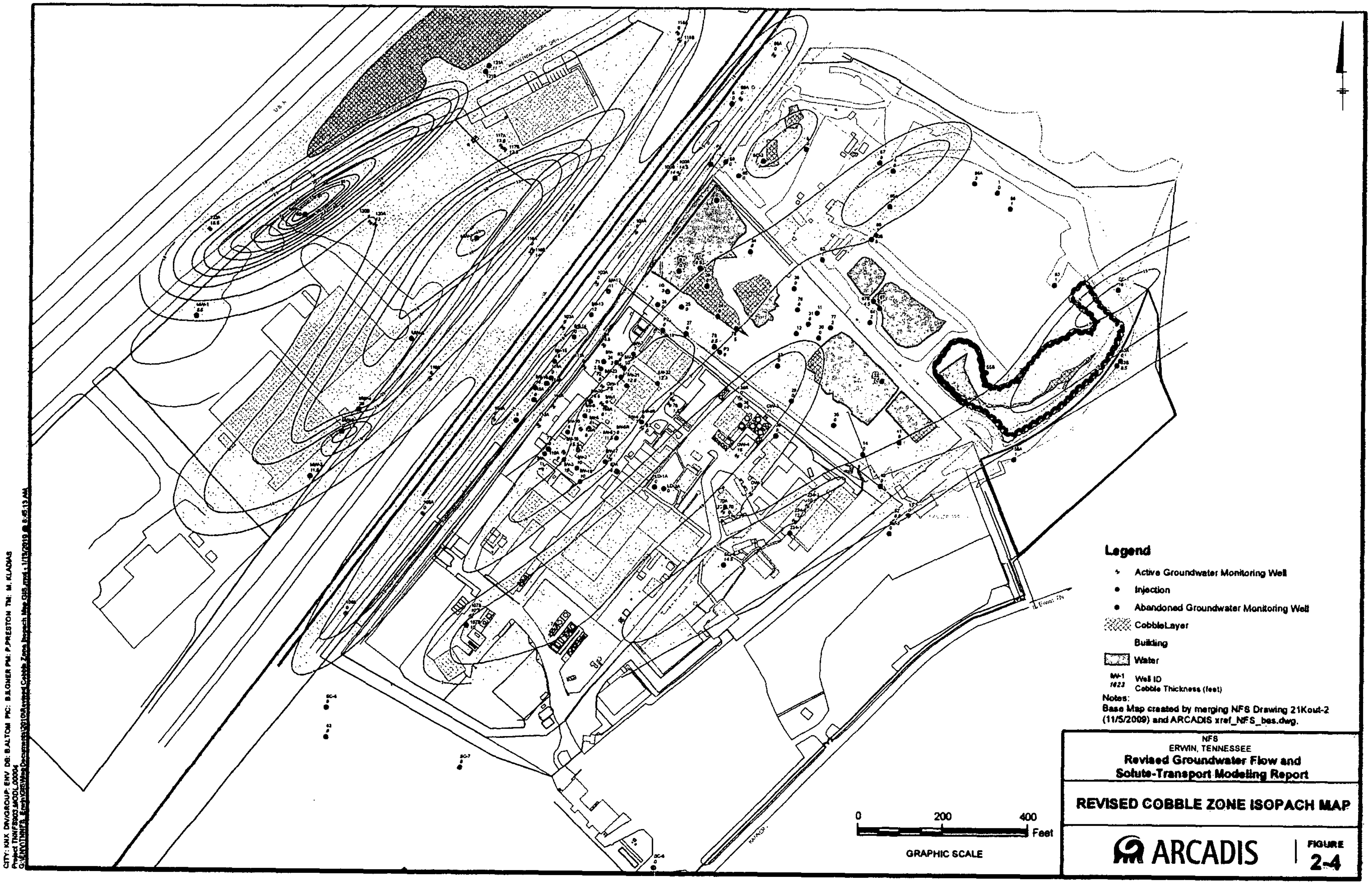

Legend

- ⁎ Active Groundwater Monitoring Well
- ● Injection
- ● Abandoned Groundwater Monitoring Well
- ▨ CobbleLayer
- Building
- ▨ Water
- MW-1 Well ID
- 1623 Cobble Thickness (feet)

Notes:
Base Map created by merging NFS Drawing 21Kout-2 (11/5/2009) and ARCADIS xref_NFS_bes.dwg.

NFS
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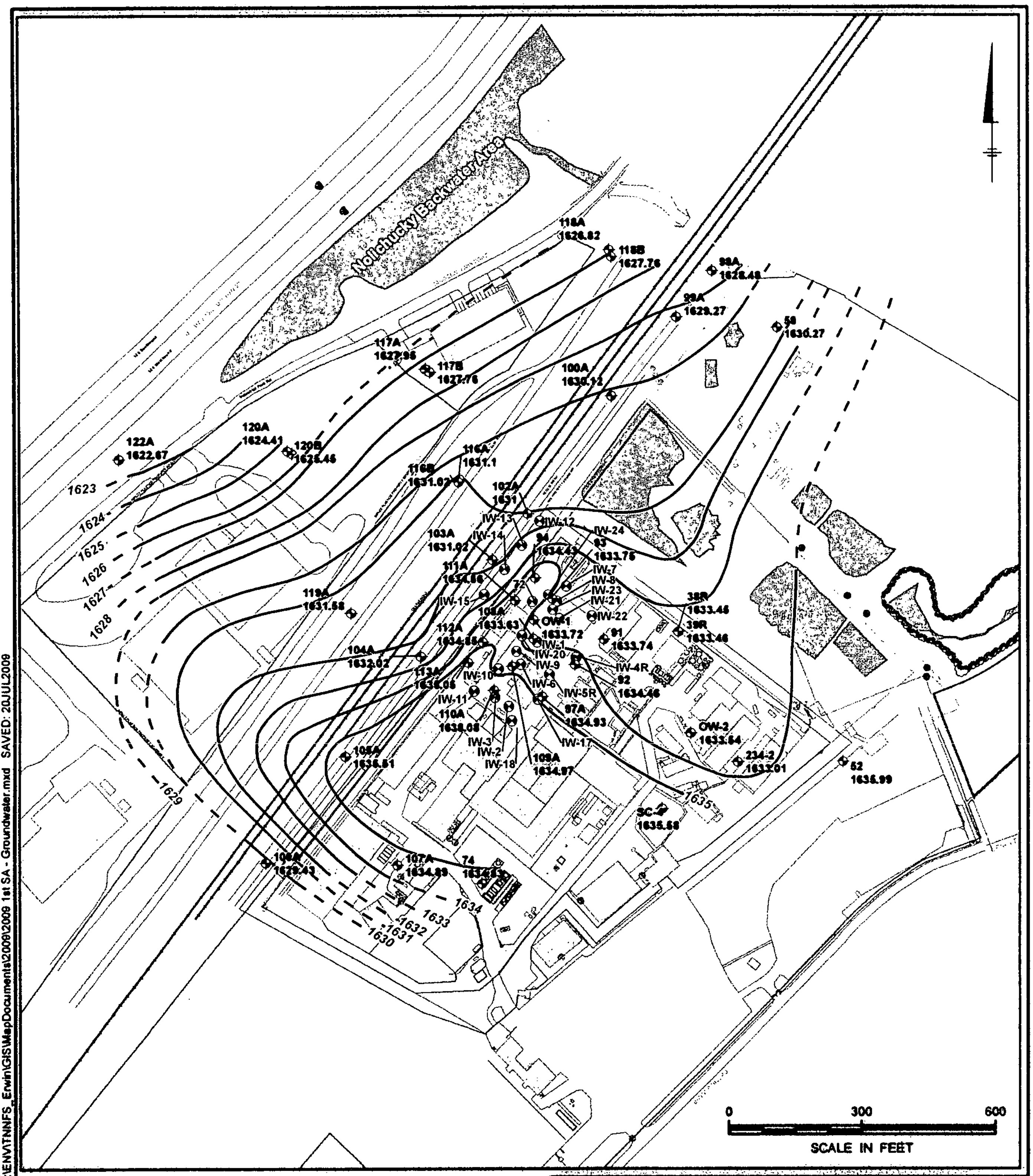
Revised Groundwater Flow and Solute-Transport Modeling Report

REVISED COBBLE ZONE ISOPACH MAP

ARCADIS

FIGURE
2-4

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.AGNER PM: P.PRESTON TM: M. KLADIAS
Project TNNF5903.MODL.00004
G:\ENV\TNNFS_Erwin\GIS\Map Documents\2010\Revised Cobble Zone Isopach Map GIS.mxd - 1/15/2010 @ 8:45:13 AM



LEGEND:

- ⊕ Monitor Well/Groundwater Elevation
- ⊗ Injection Well

October 2009 Potentiometric Contours (ft-amsl)

- ——— Approximate
- – – Inferred

NOTES:

a) Groundwater depth to water collected on October 23, 2009 and was subtracted from NFS reference elevations.

b) Injection wells were not measured during this sampling event.

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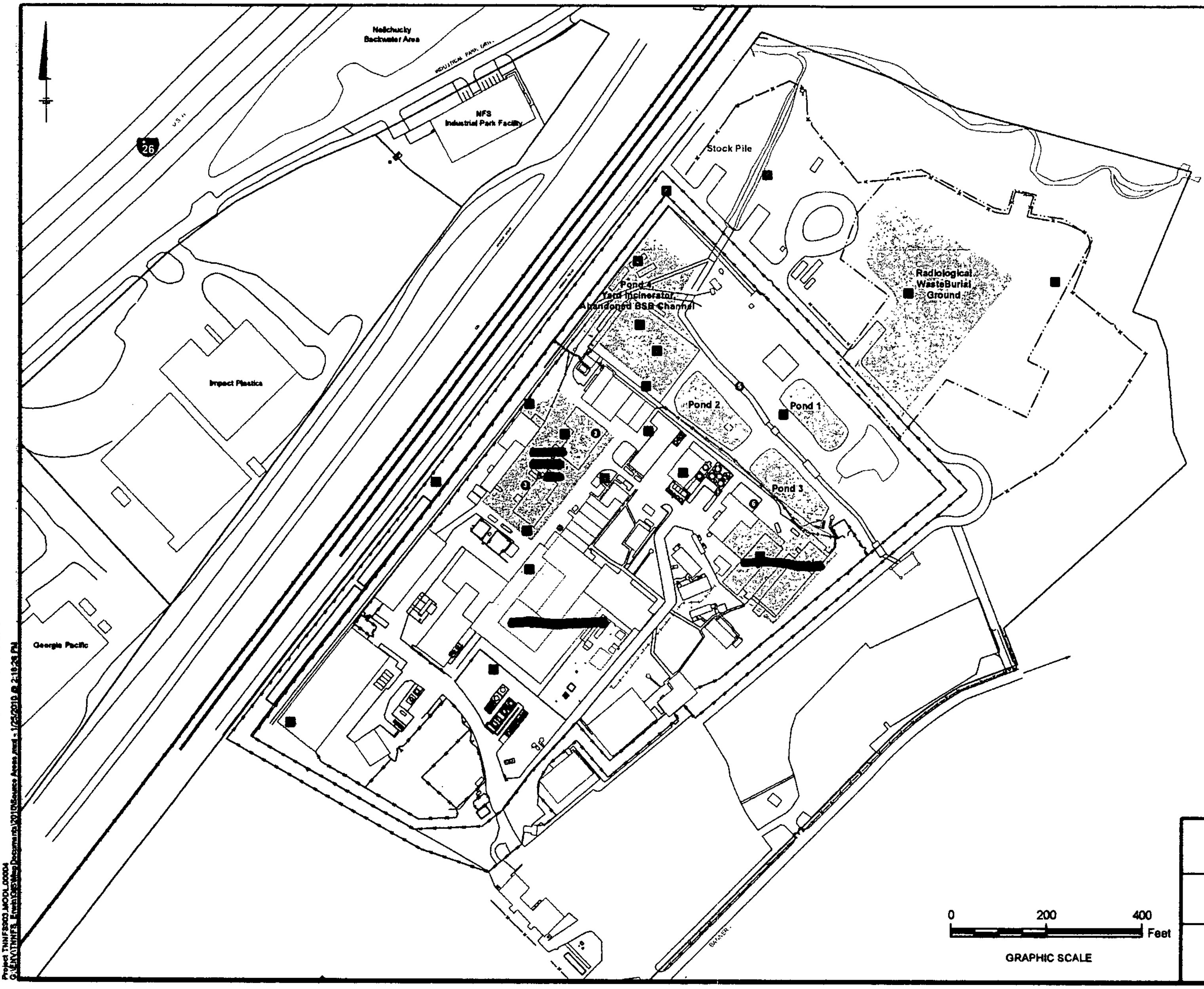
REVISED GROUNDWATER FLOW AND SOLUTE-TRANSPORT MODELING REPORT

Water-Level Elevation in the Cobble/Boulder Zone

ARCADIS

FIGURE
2-5

CITY: (KNOXVILLE) DIV/GROUP:(ENV) DB:(B.ALTOM) LD:(R.MCKINNEY) PIC:(B.ILGNER) PM:(P.PRESTON) TM:(B.BAILEY)
PROJECT: TNNFS901.FS07.00003 PATH: G:\ENV\TNNFS_Erwin\GIS\MapDocuments\2009\2009 1st SA - Groundwater.mxd SAVED: 20JUL2009



[redacted]

[redacted]

[redacted]

Type	Name	Description
SWMU	1	Ponds 1, 2, and 3
SWMU	2	Pond 4
SWMU	3	Underground Storage Tank at Bldg. 110
SWMU	4	Yard Incinerator
SWMU	6	Abandoned Banner Spring Branch Channel
SWMU	7	Contaminated CSX Soil Stockpile
SWMU	8	Soil Excavation Site on CSX Property
SWMU	9	Radiological Waste Burial Ground
SWMU	10	Demolition Landfill
SWMU	11	Burial Trenches on CSX Property
SWMU	12	310 Warehouse
SWMU	13	Bulk Chemical Storage at Bldg. 111
SWMU	14	LNAPL Plume (Well 72)
SWMU	15	WWTF
SWMU	16	Radiological Incinerator (Bldg. 302)
SWMU	17	Calciner
SWMU	18	Bldg. 105 UST
SWMU	19	Bldg. 100 UST
SWMU	20	Bldg. 130 Scale Pit
SWMU	21	No. 2 Fuel Oil AST
AOC	2	Boiler Blowdown & Backwash Water Bldg. 111
AOC	3	Cooling Water Tower Bldg. 130
AOC	5	Former Banner Spring Branch Channel
AOC	6	Mercury Contaminated Area

Legend

- ● AOC
- ■ SWMU
- ▨ Uranium And Chlorinated Solvent Source Area
- Uranium Source Area
- Building

Notes:
Base Map based on pre-remediation layout of NFS (<2002).

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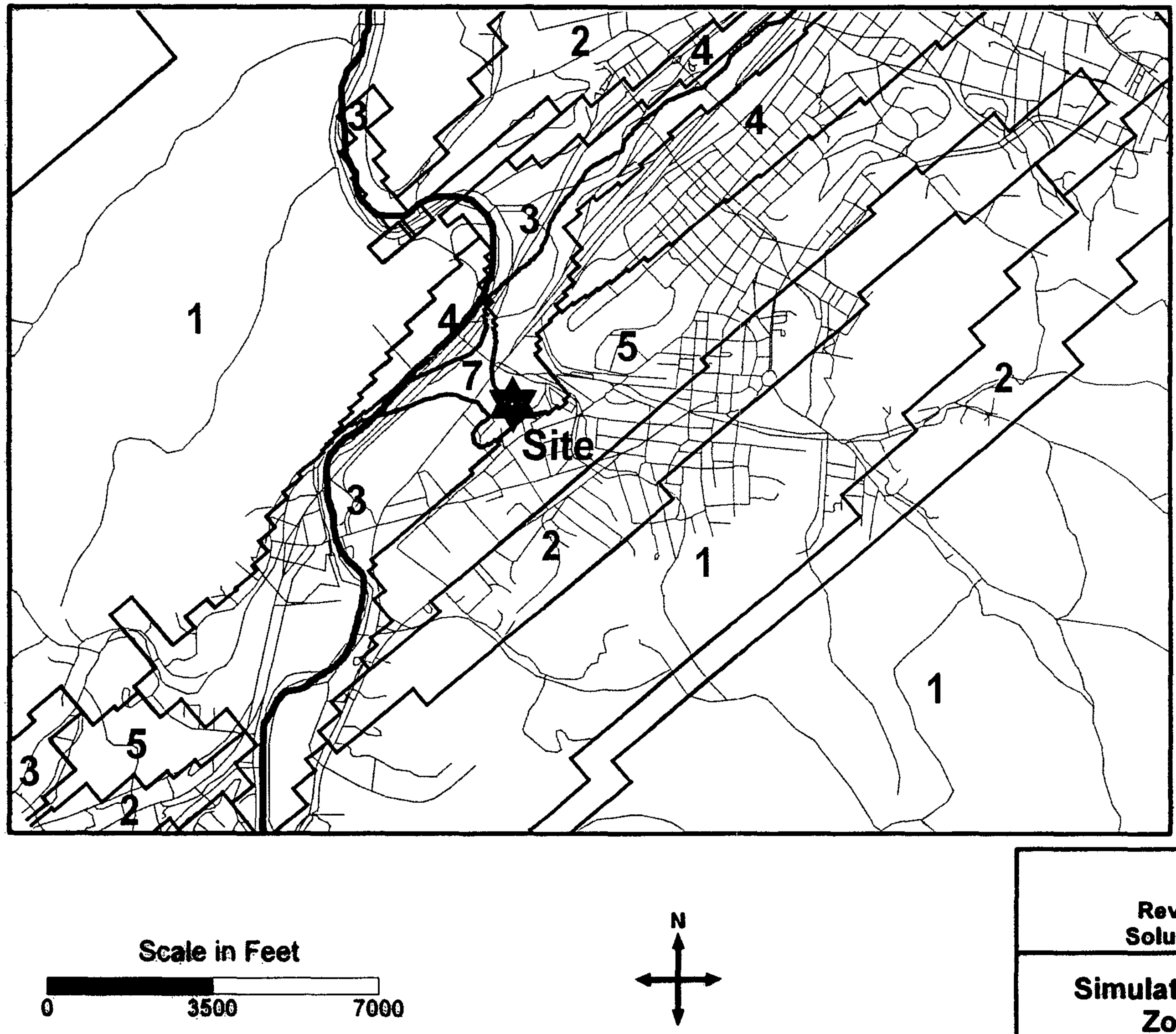
Uranium and Chlorinated Solvent Source Areas

ARCADIS

FIGURE
2-6

CITY: KNX DIV/GROUP: ENV DB: B.ALTON PIC: B.ILGNER PM: P.PRESTON TM: M. KLADIAS
Project TNNF5903.MODL.00004
G:\ENV\TN\NFS_Erwin\GIS\MapDocuments\2010\Source Areas.mxd - 1/25/2010 @ 2:18:26 PM

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Hydraulic Conductivity (K) Zones

Zone	K (feet/day)
1	0.04
2	4
3	6
4	8
5	15
6	14
7	40
8	10000
9	40

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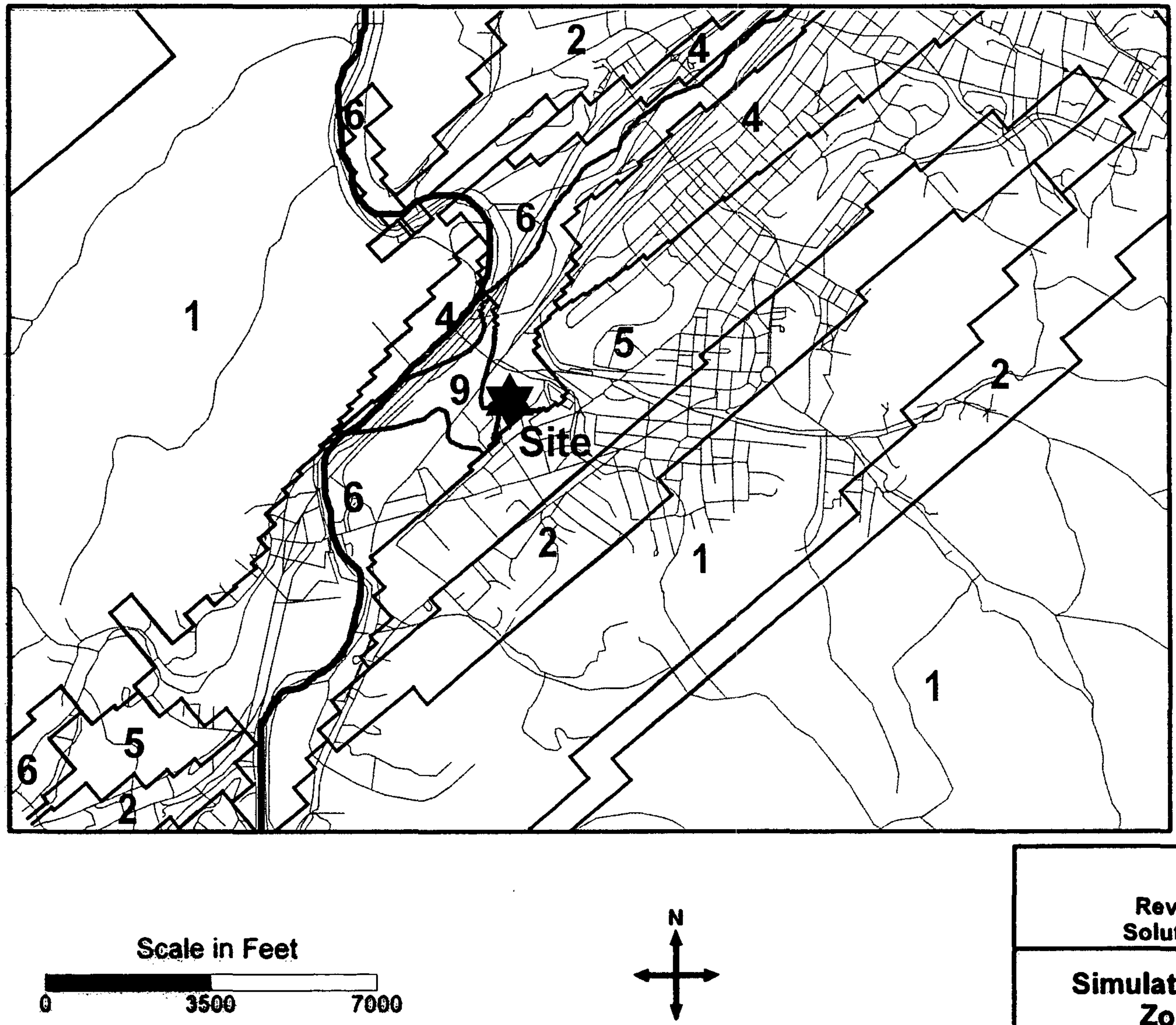
Simulated Hydraulic Conductivity Zonation: Model Layer 1

ARCADIS

FIGURE
3-1

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Hydraulic Conductivity (K) Zones

Zone	K (feet/day)
1	0.04
2	4
3	6
4	8
5	15
6	14
7	40
8	10000
9	40

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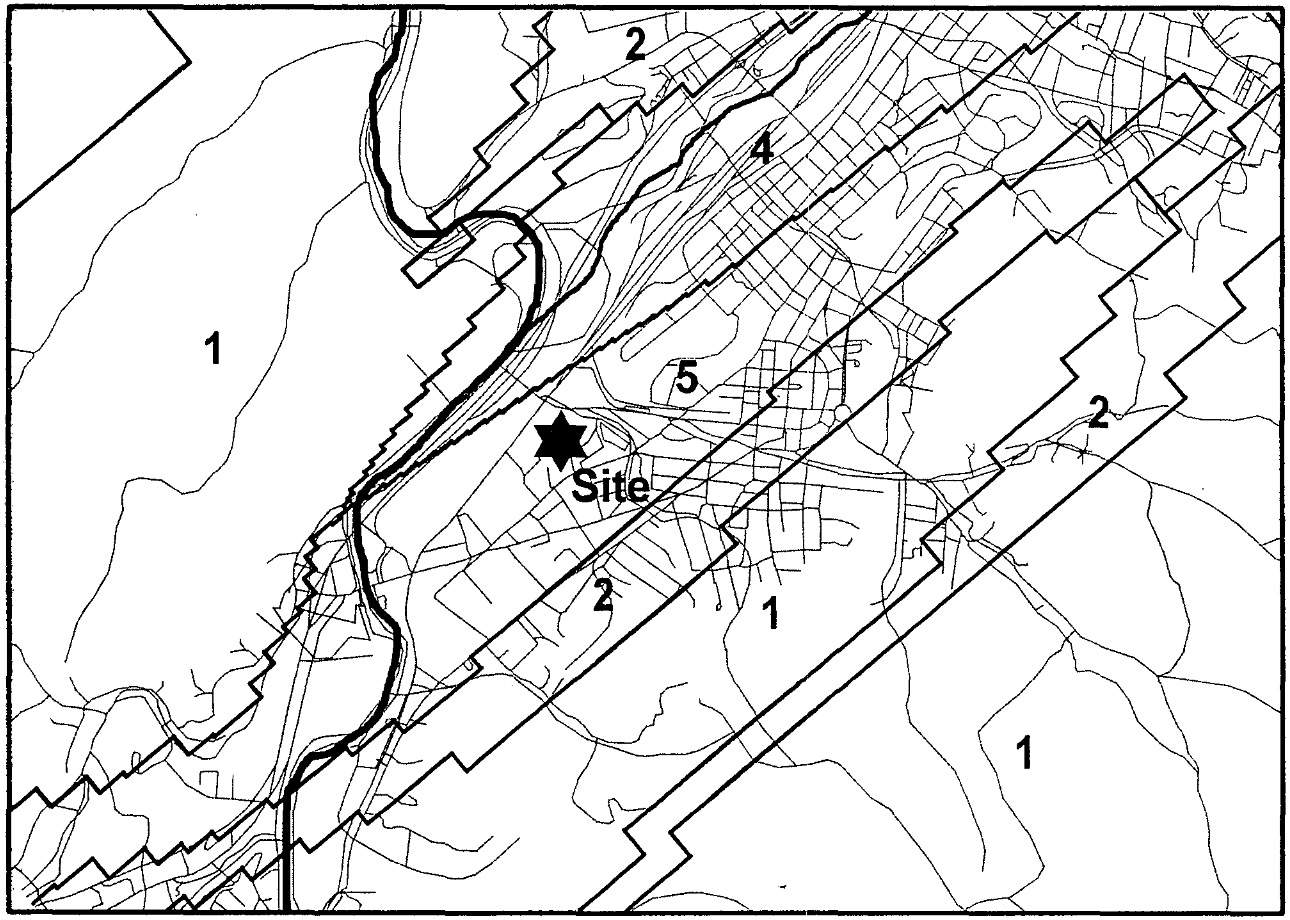
Simulated Hydraulic Conductivity Zonation: Model Layer 2

ARCADIS

FIGURE
3-2

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Hydraulic Conductivity (K) Zones

Zone	K (feet/day)
1	0.04
2	4
3	6
4	8
5	15
6	14
7	40
8	10000
9	40

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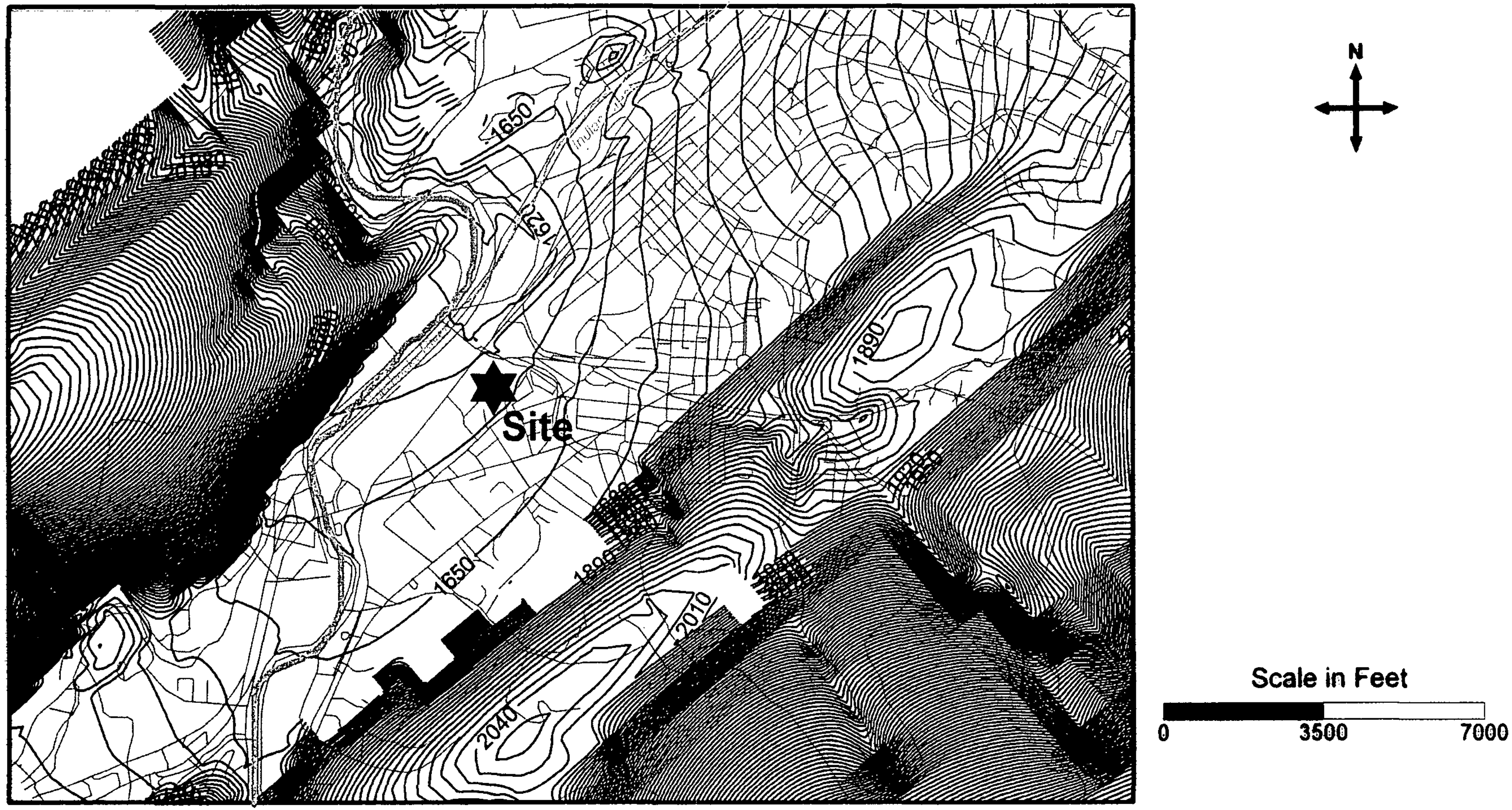
Simulated Hydraulic Conductivity Zonation: Model Layers 3, 4 and 5

ARCADIS

FIGURE
3-3

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



☐ Inactive Area

—1600— Simulated Hydraulic Head Contour (ft-amsl)

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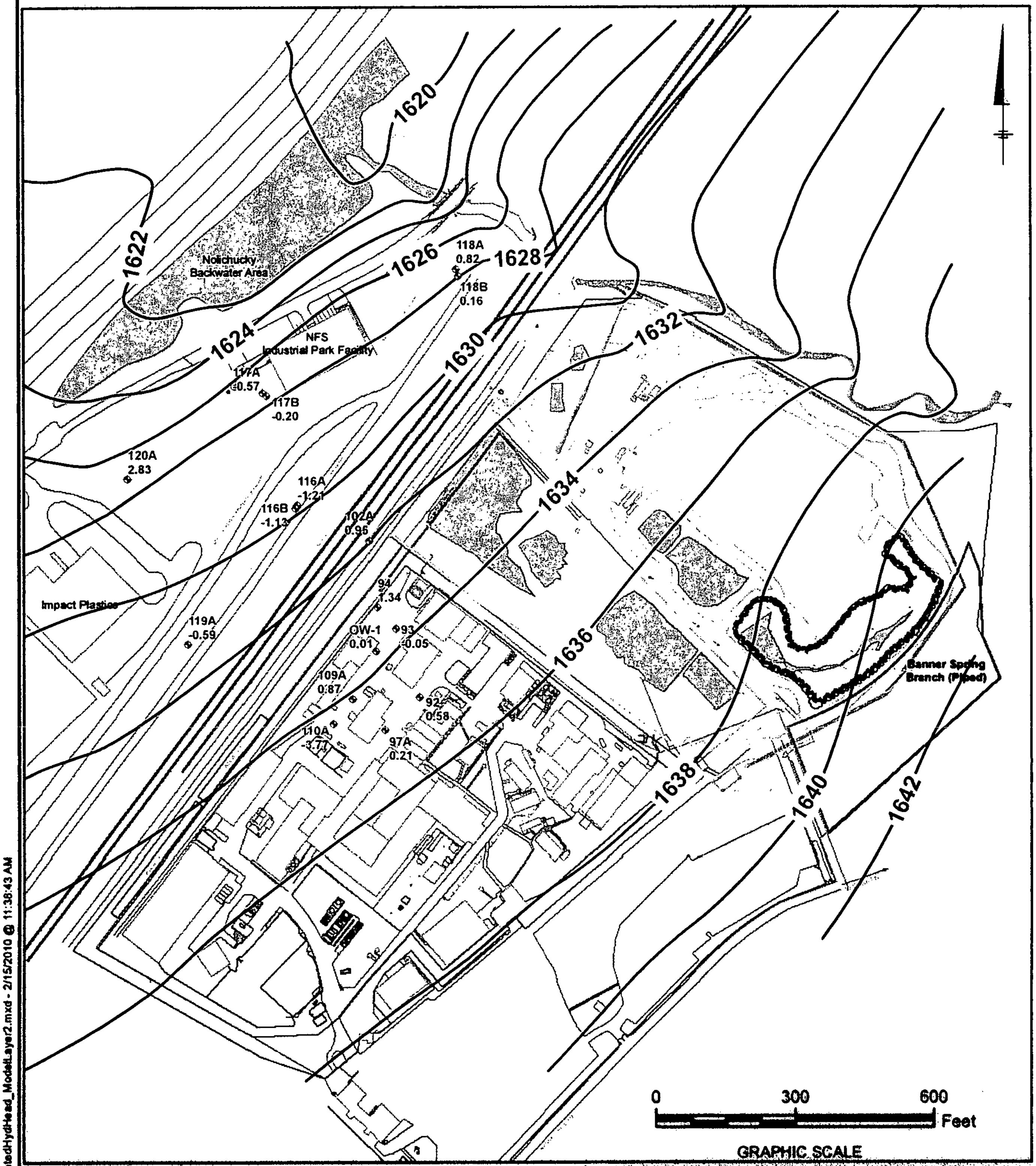
Simulated Regional Hydraulic Head Distribution in Model Layer 1

ARCADIS

FIGURE
3-4



Legend

- ⊗ Difference Between Observed and Simulated Water Levels (ft)
- —— Simulated Hydraulic Head Contour (ft-amsl)
- ▨ Water Bodies

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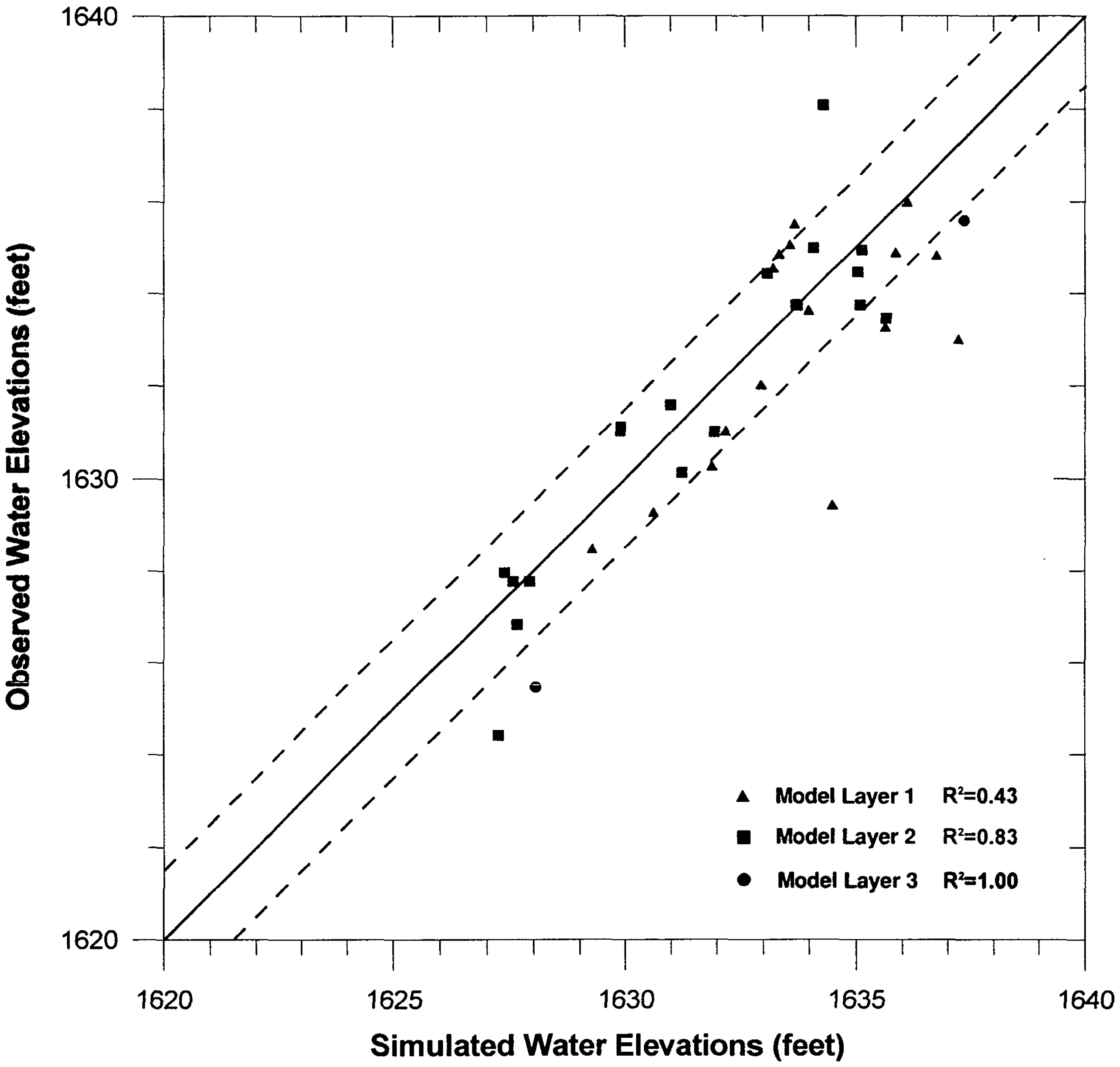
Simulated Hydraulic Head Distribution and Residuals: Model Layer 2

ARCADIS

FIGURE
3-5

CITY: DIV/GROUP: DB: LD: PIC: PM: TM: TR:
Project (Project #)
G:\GIS\TNNFS\GIS\MapDocuments\2010\SimulatedHydHead_ModelLayer2.mxd - 2/15/2010 @ 11:38:43 AM



——— Linear Correlation between Observed and Measured Data with R-squared equals 1

– – – · Upper and Lower Bounds for the 10% of the Range of Observed Changes in Water Levels

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Observed versus Simulated Water Levels for Calibrated Model

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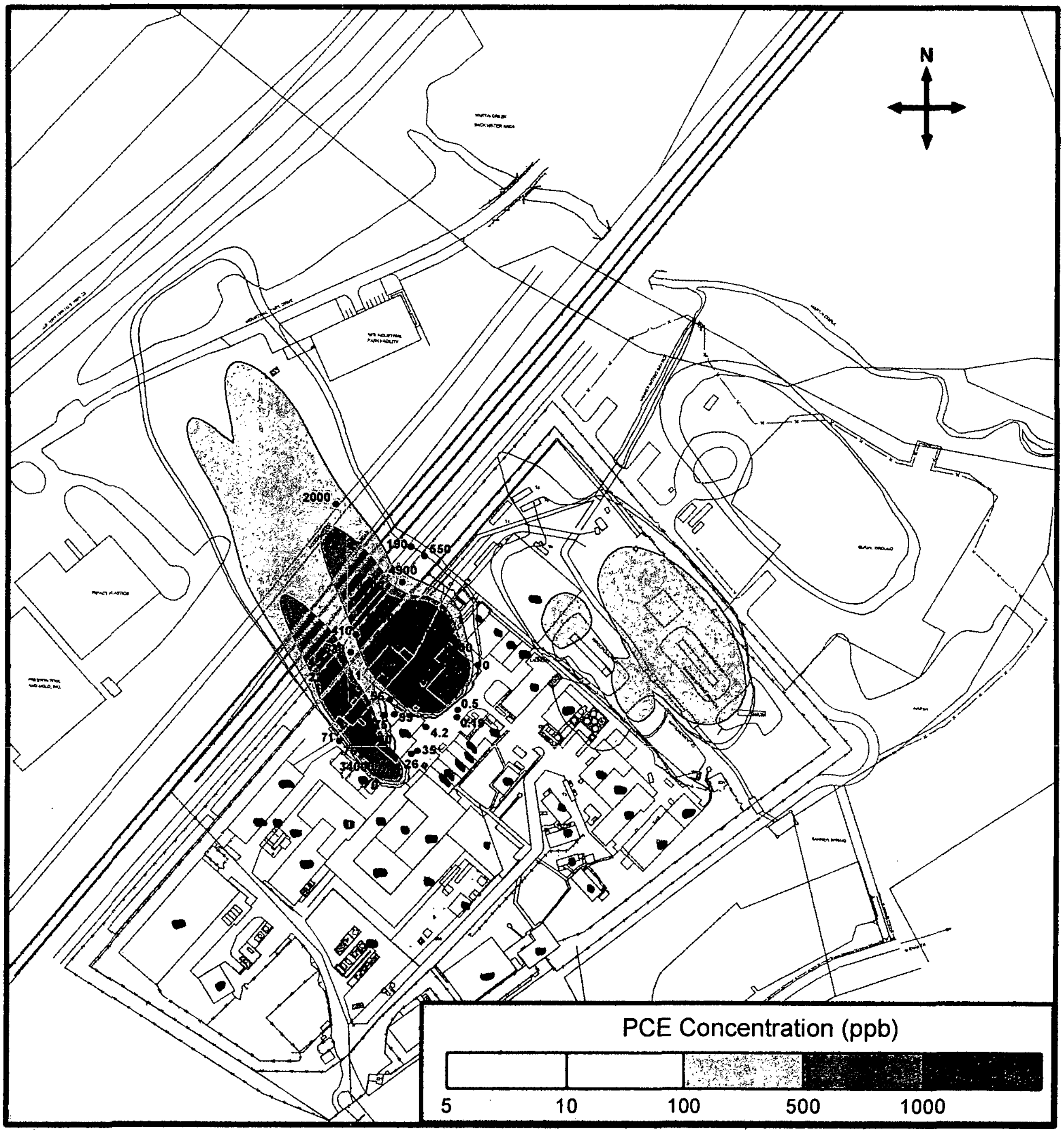
Figure
3-6

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



25.1 ● Observed PCE Concentrations in 2002 (ppb)

Scale in Feet

0 300 600

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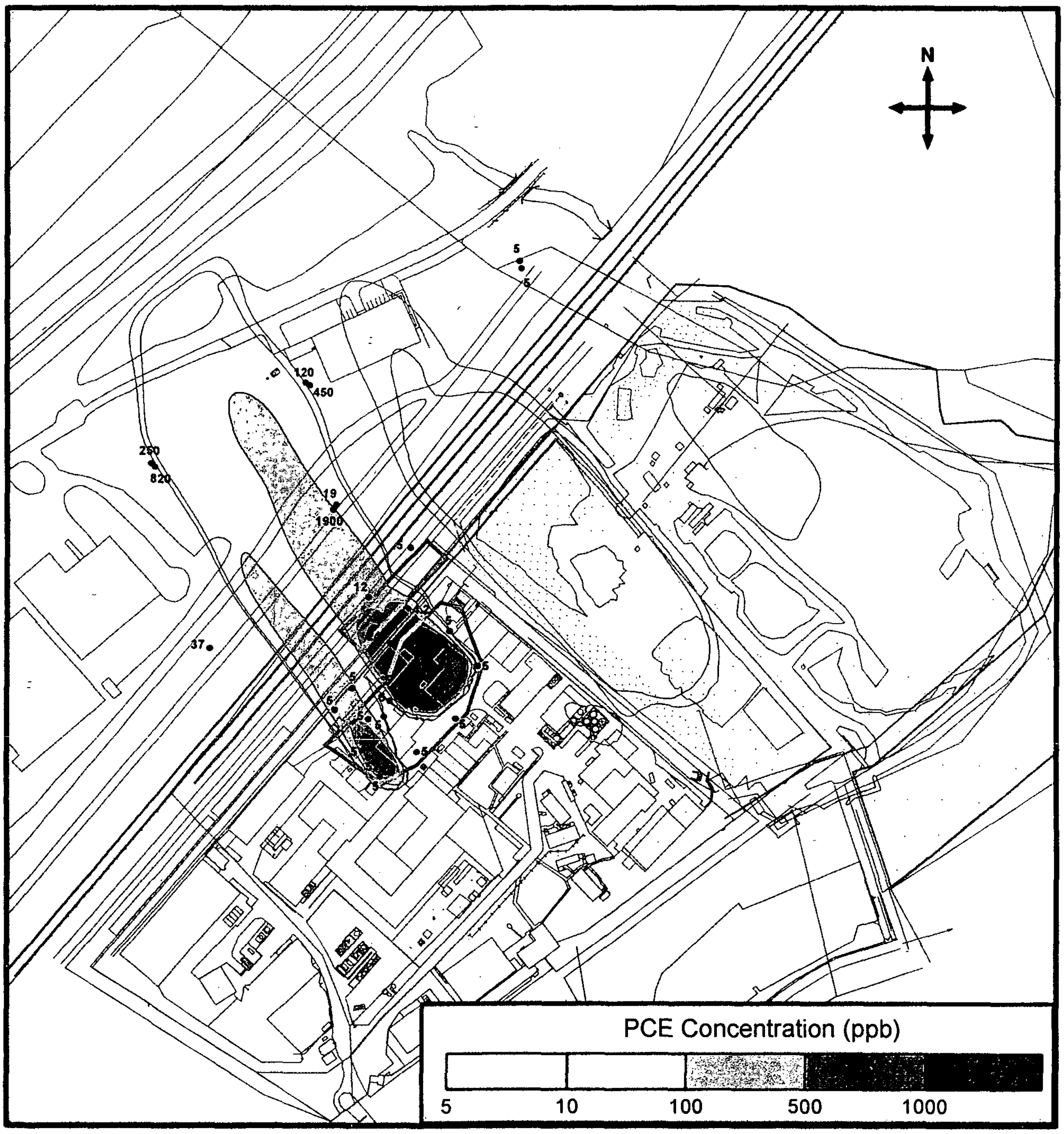
Simulated 2002 PCE Concentrations in Model Layer 2

ARCADIS

FIGURE
4-1

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



IRZ Degradation Zone between 2002 and 2009

25.1 ● Observed PCE Concentrations in 2009 (ppb)

Scale in Feet

0 300 600

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Revised Groundwater Flow and Solute-Transport Modeling Report

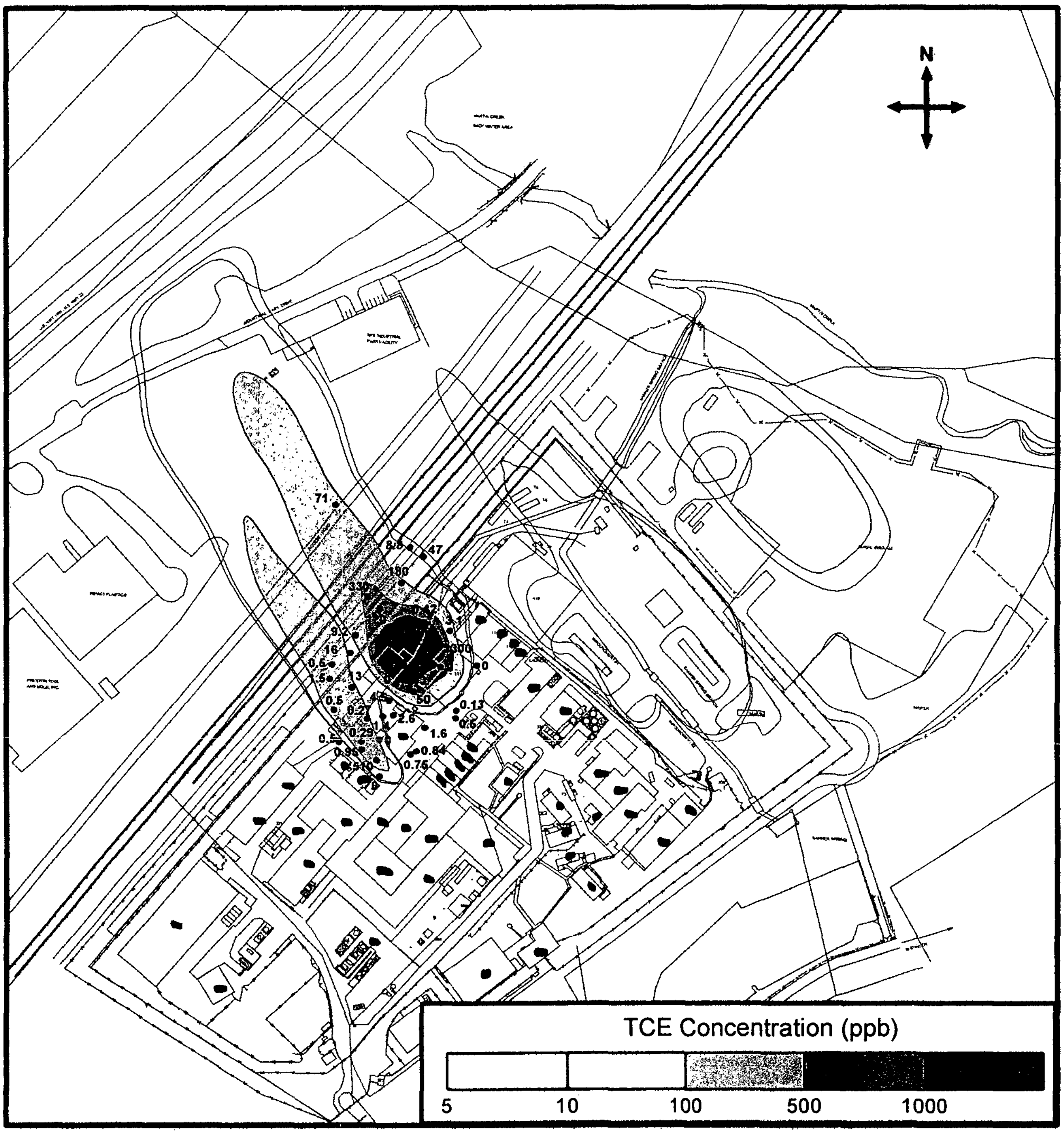
Simulated 2009 PCE Concentrations in Model Layer 2

ARCADIS

FIGURE

4-2

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS803.MODL.00004



25.1 ● Observed TCE Concentrations in 2002 (ppb)

Scale in Feet

0 300 600

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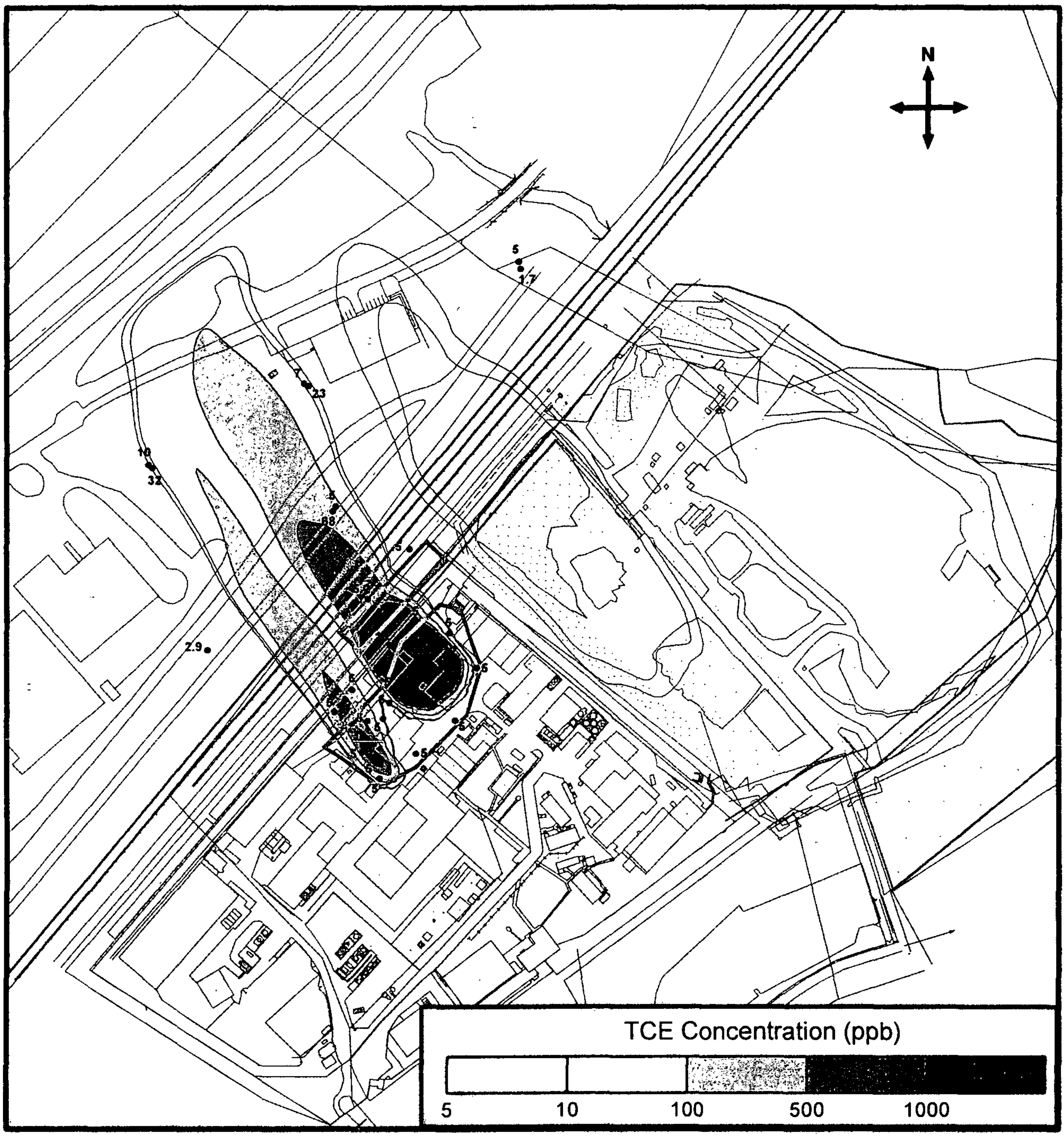
Revised Groundwater Flow and Solute-Transport Modeling Report

Simulated 2002 TCE Concentrations in Model Layer 2

ARCADIS

FIGURE
4-3

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



IRZ Degradation Zone between 2002 and 2009

25.1 ● Observed TCE Concentrations in 2009 (ppb)

Scale in Feet

0 300 600

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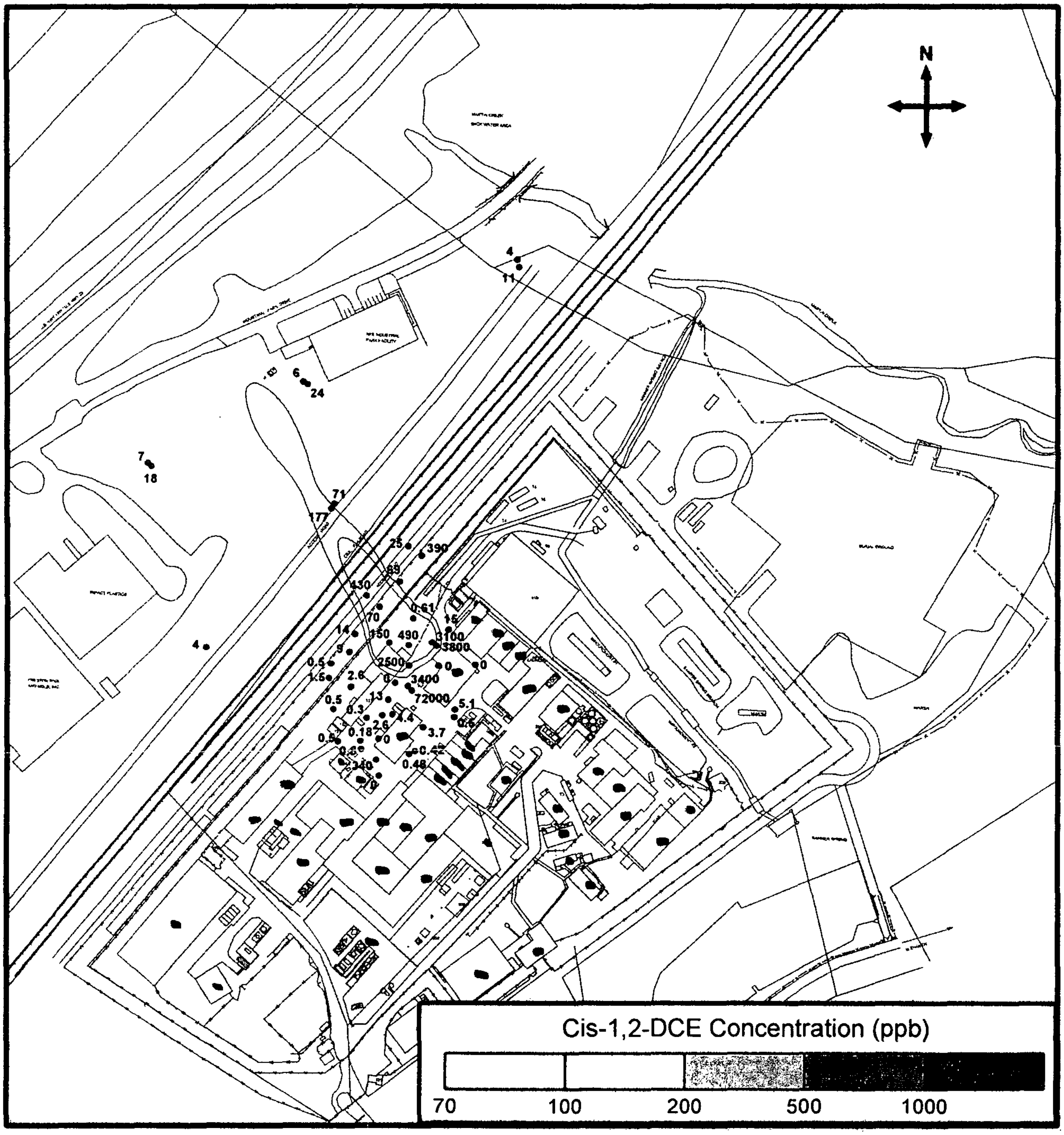
Revised Groundwater Flow and Solute-Transport Modeling Report

Simulated 2009 TCE Concentrations in Model Layer 2

ARCADIS

FIGURE
4-4

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.0004



25.1 ● Observed Cis-1,2-DCE Concentrations in 2002 (ppb)

Scale in Feet

0 300 600

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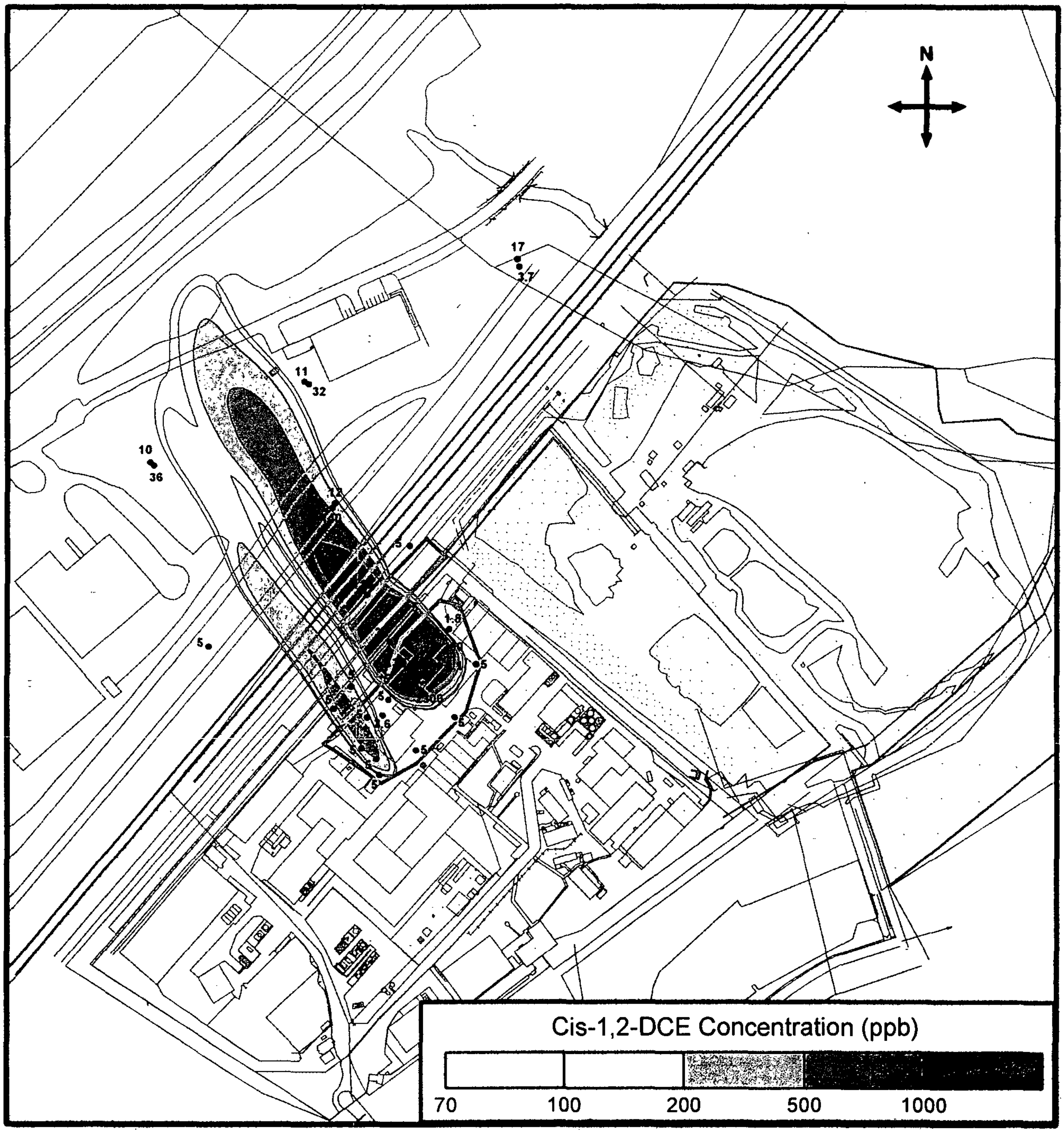
Revised Groundwater Flow and Solute-Transport Modeling Report

Simulated 2002 Cis-1,2-DCE Concentrations in Model Layer 2

ARCADIS

FIGURE
4-5

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



IRZ Degradation Zone between 2002 and 2009

25.1 ● Observed Cis-1,2-DCE Concentrations in 2009 (ppb)

Scale in Feet

0 300 600

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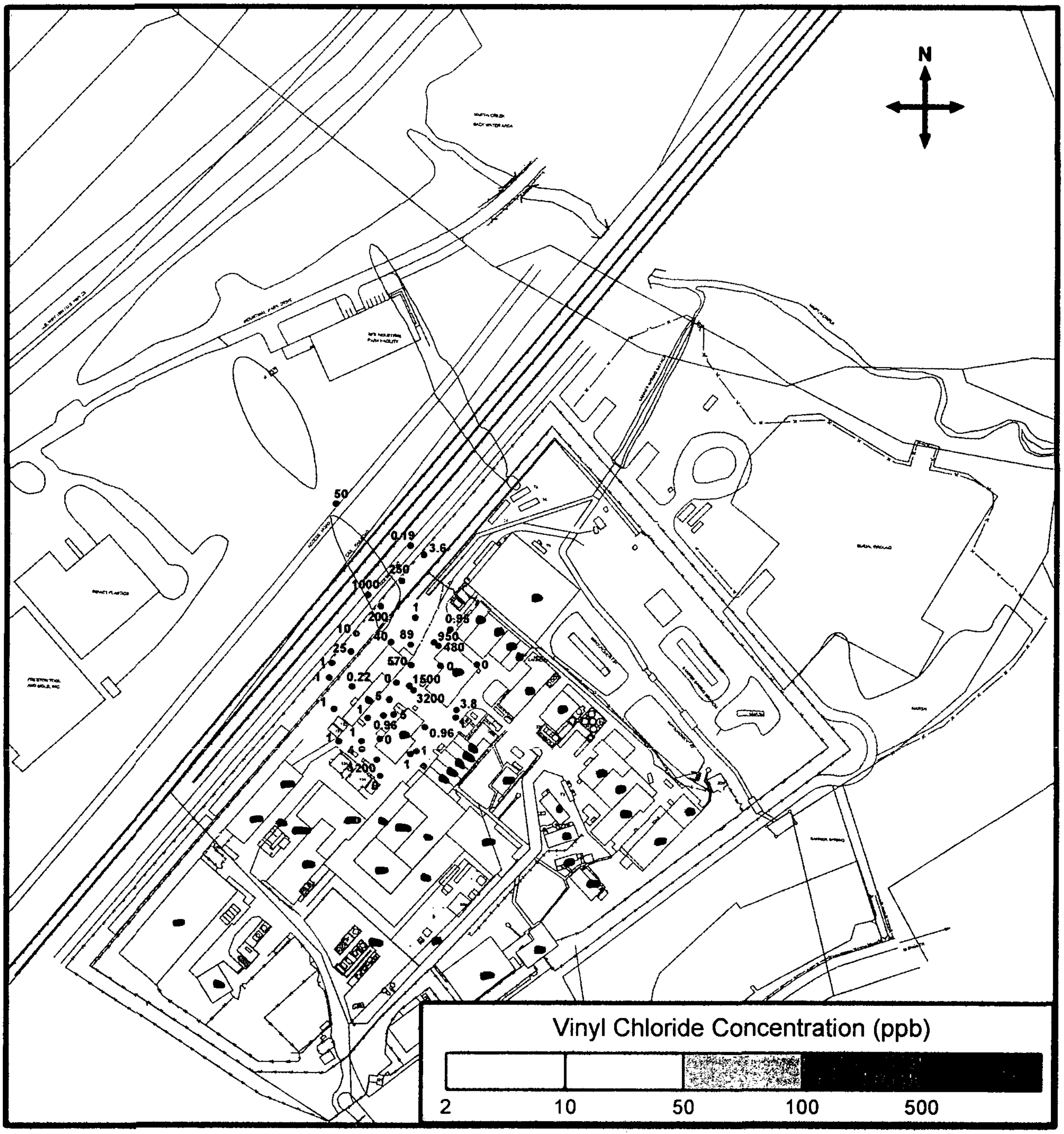
Revised Groundwater Flow and Solute-Transport Modeling Report

Simulated 2009 Cis-1,2-DCE Concentrations in Model Layer 2

ARCADIS

FIGURE
4-6

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



25.1 ● Observed Vinyl Chloride Concentrations in 2002 (ppb)

Scale in Feet

0 300 600

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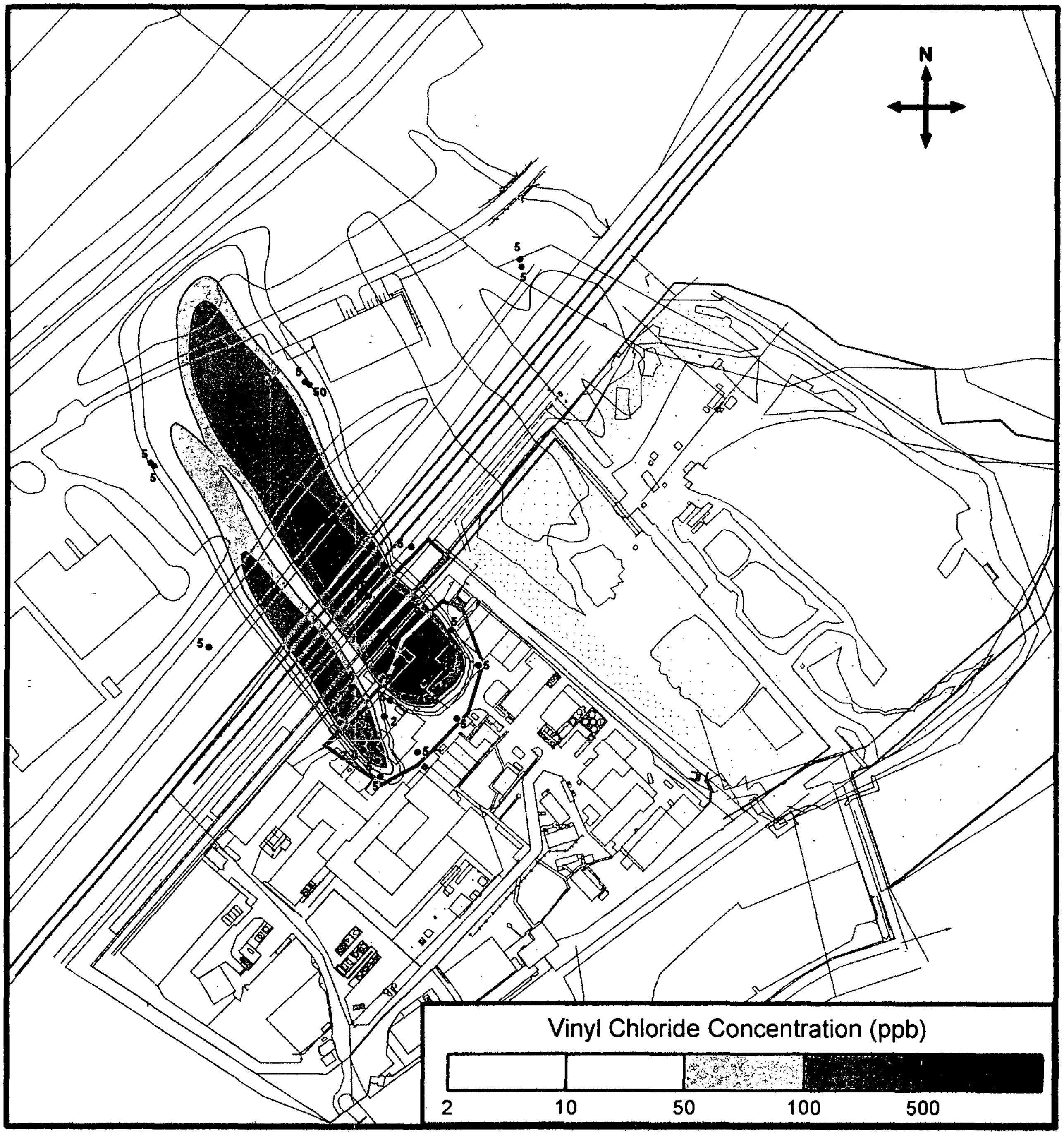
Revised Groundwater Flow and Solute-Transport Modeling Report

Simulated 2002 Vinyl Chloride Concentrations in Model Layer 2

ARCADIS

FIGURE
4-7

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



IRZ Degradation Zone between 2002 and 2009

25.1 ● Observed Vinyl Chloride Concentrations in 2009 (ppb)

Scale in Feet

0 300 600

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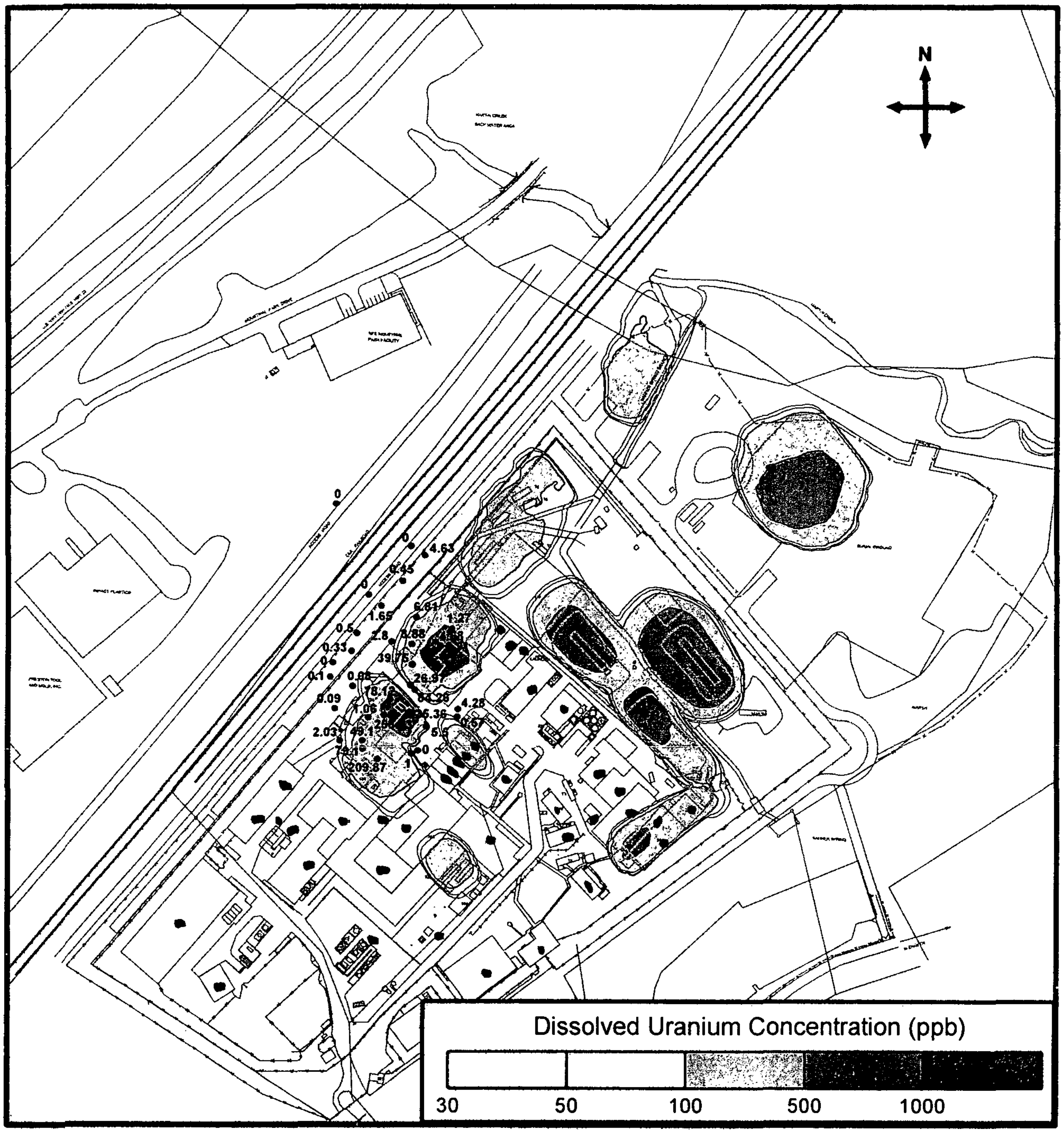
Simulated 2009 Vinyl Chloride Concentrations in Model Layer 2

ARCADIS

FIGURE
4-8

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



25.1 ● Observed Dissolved Uranium Concentrations in 2002 (ppb)

Scale in Feet

0 300 600

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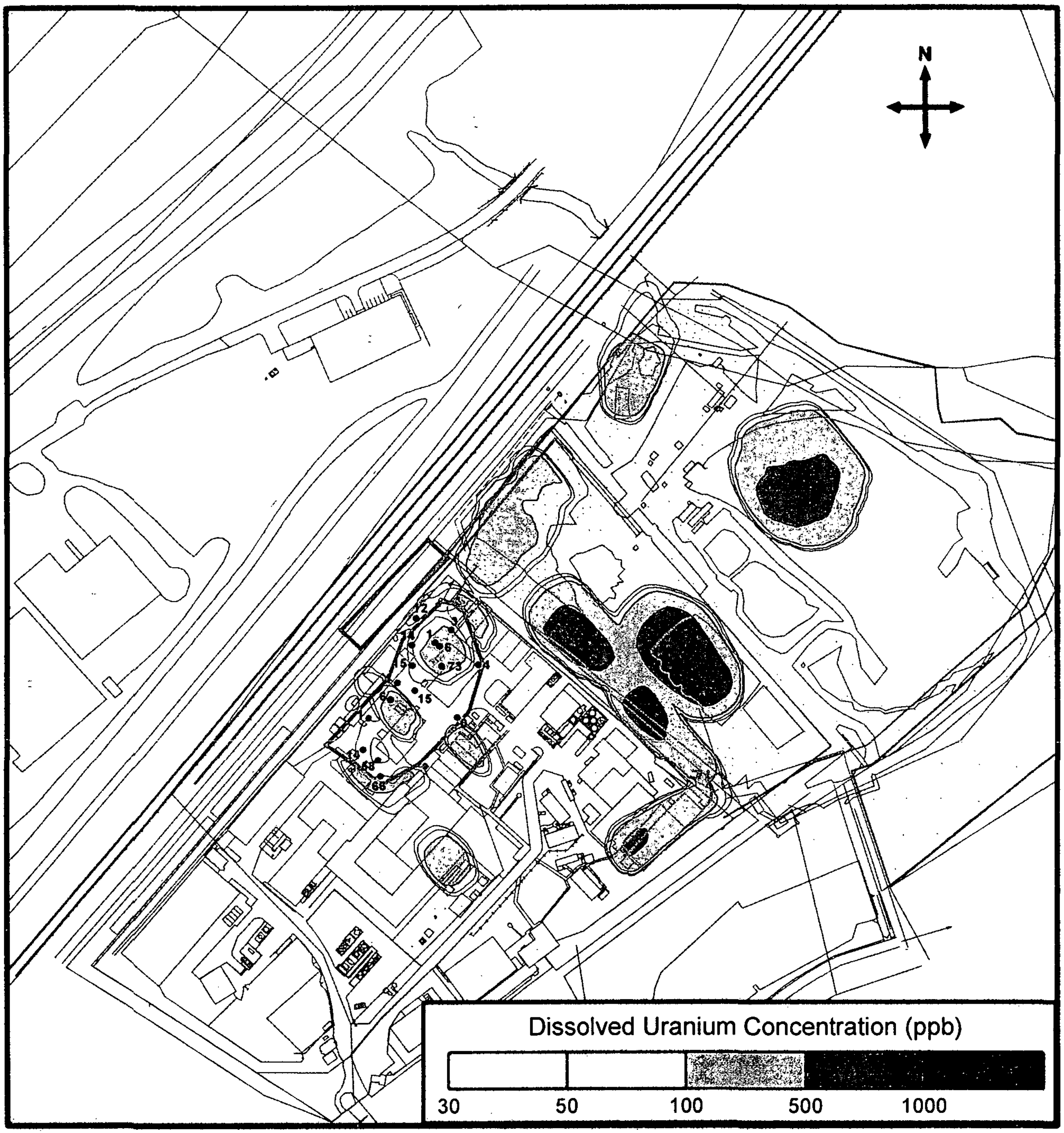
Revised Groundwater Flow and Solute-Transport Modeling Report

Simulated 2002 Dissolved Uranium Concentrations in Model Layer 2

ARCADIS

FIGURE
4-9

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.06004



IRZ Degradation Zone between 2002 and 2009

25.1 ● Observed Dissolved Uranium Concentrations in 2009 (ppb)

Scale in Feet

0 300 600

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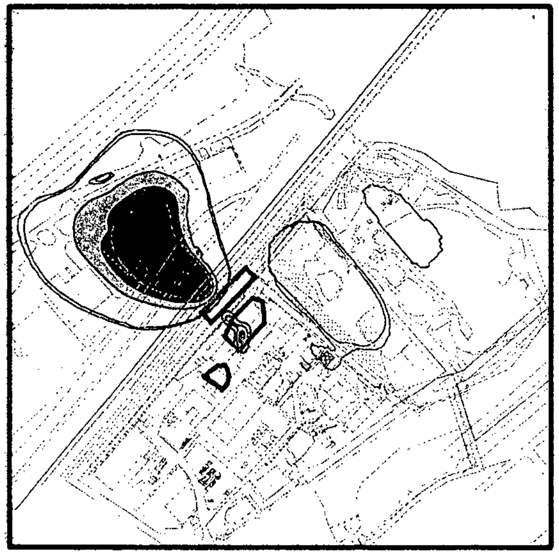
Simulated 2009 Dissolved Uranium Concentrations in Model Layer 2

ARCADIS

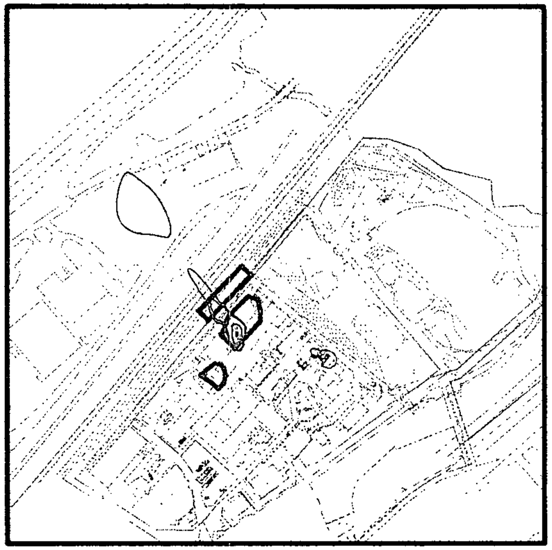
FIGURE
4-10

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004

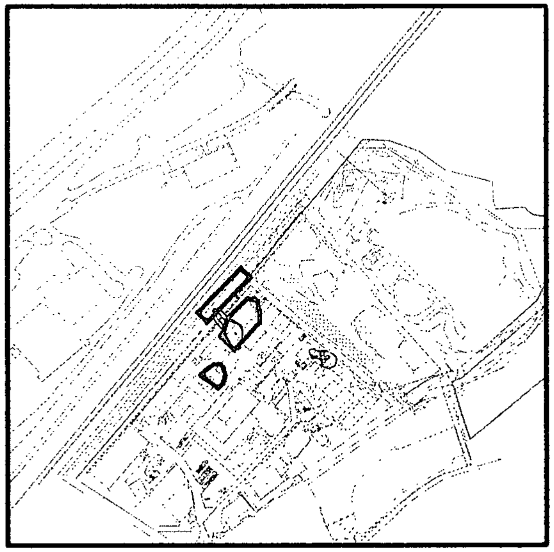
CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



PCE Concentration Distribution: 2009



PCE Concentration Distribution: 2019



PCE Concentration Distribution: 2059

N

Scale in Feet

0 750 1500

Current IRZ Degradation Zone

PCE Concentration (ppb)

5 10 100 500 1000

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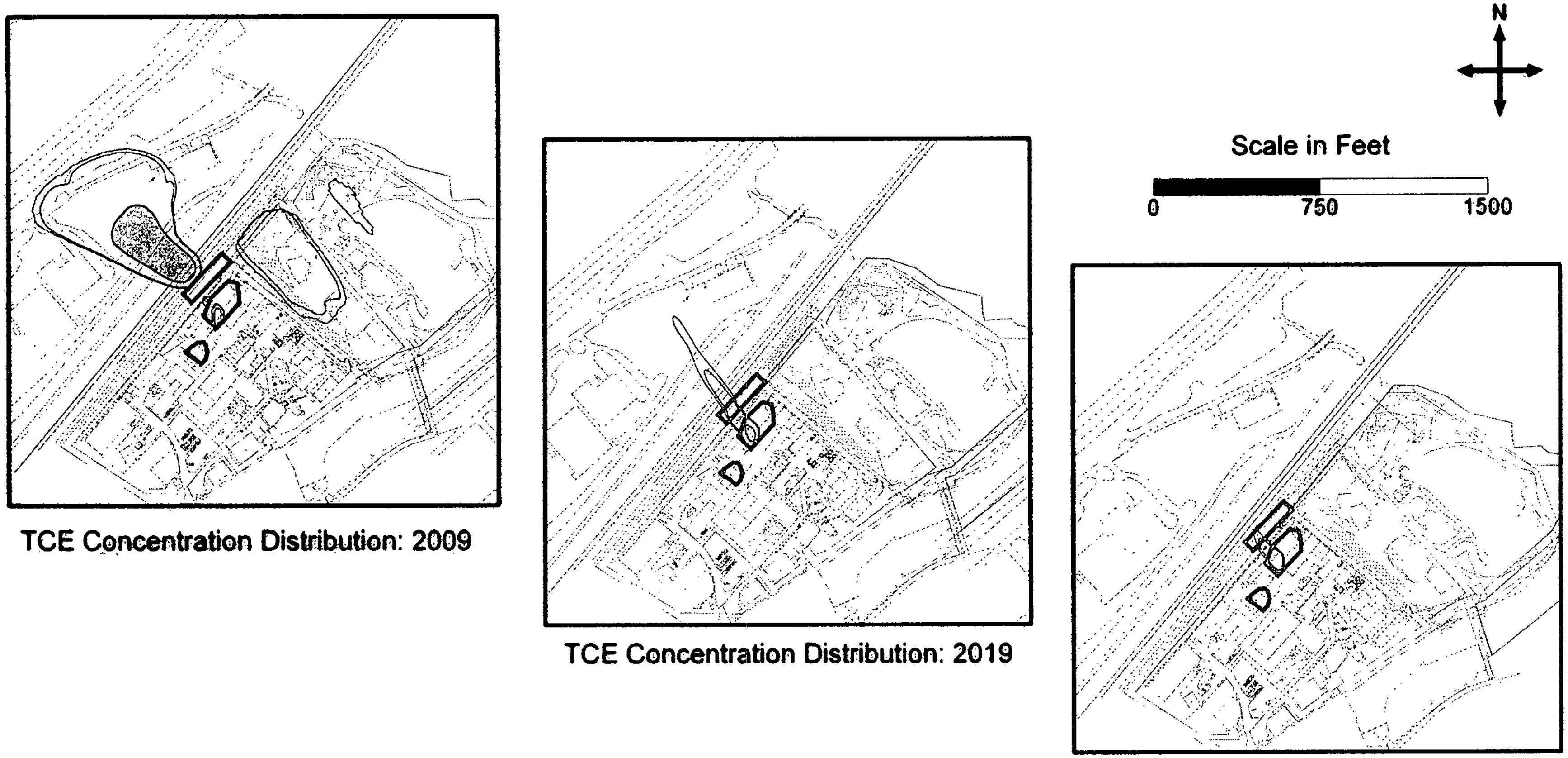
Current and Predicted PCE Concentrations for Simulated Transport in 2009, 2019, and 2059 With Continued Remediation (Model Layer 2)

ARCADIS

FIGURE
5-1

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



TCE Concentration Distribution: 2009

TCE Concentration Distribution: 2019

TCE Concentration Distribution: 2059

— Current IRZ Degradation Zone

TCE Concentration (ppb)

5	10	100	500	1000
□	□	▨	■	■

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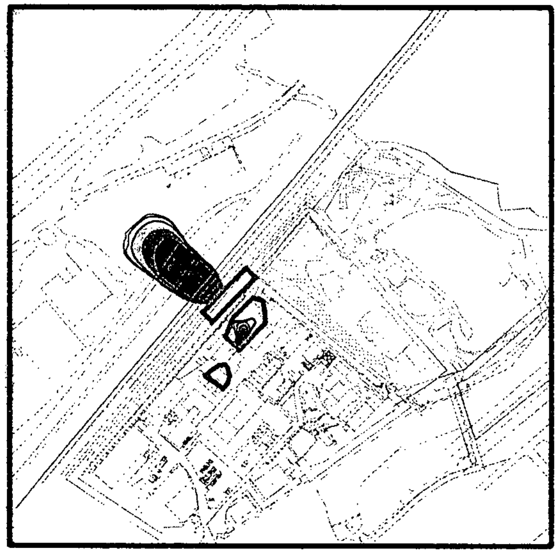
Solute-Transport Modeling Report

Current and Predicted TCE Concentrations for Simulated Transport in 2009, 2019, and 2059 With Continued Remediation (Model Layer 2)

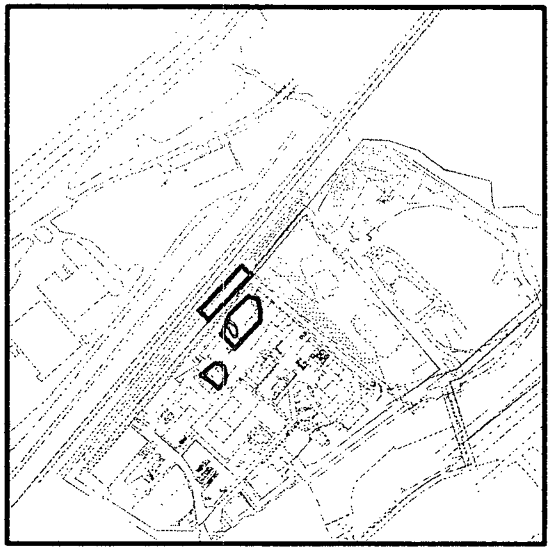
ARCADIS

FIGURE
5-2

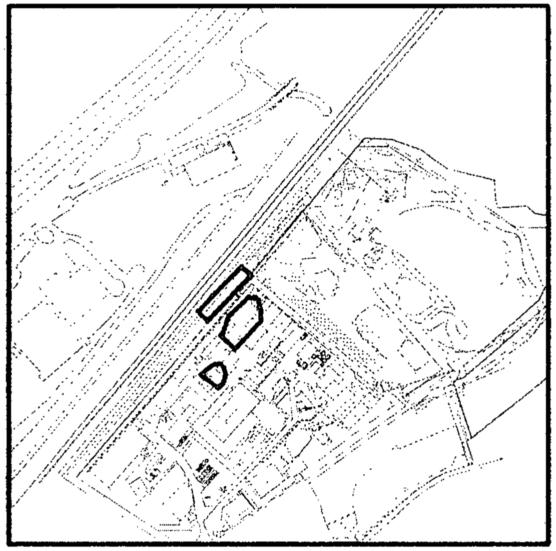
CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Cis-1,2-DCE Concentration Distribution: 2009



Cis-1,2-DCE Concentration Distribution: 2019



Cis-1,2-DCE Concentration Distribution: 2059

N

Scale in Feet

0 750 1500

——— Current IRZ Degradation Zone

Cis-1,2-DCE Concentration (ppb)

70 100 200 500 1000

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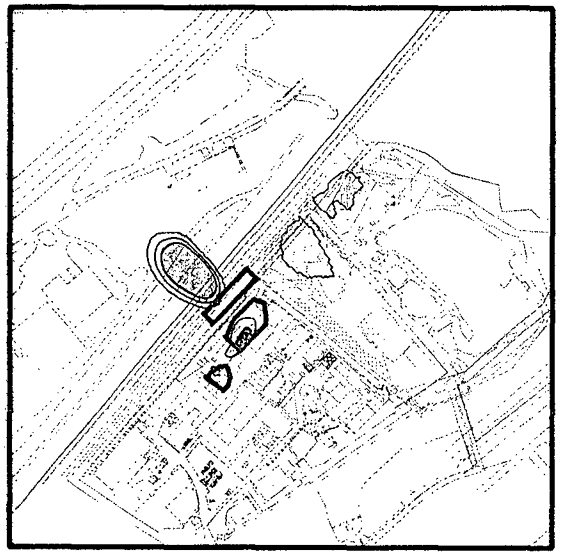
Revised Groundwater Flow and Solute-Transport Modeling Report

Current and Predicted Cis-1,2-DCE Concentrations for Simulated Transport in 2009, 2019, and 2059 With Continued Remediation (Model Layer 2)

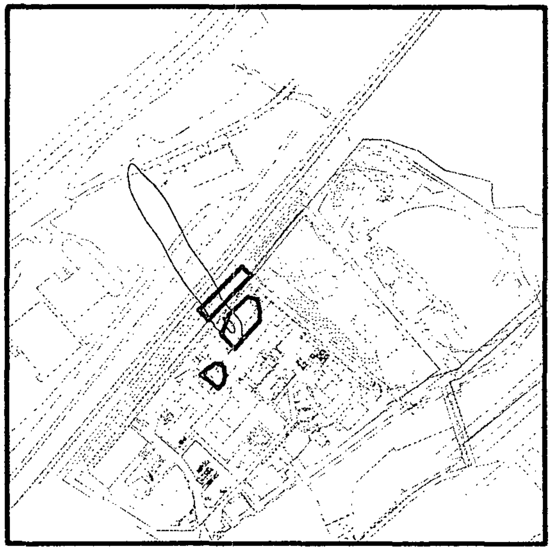
ARCADIS

FIGURE
5-3

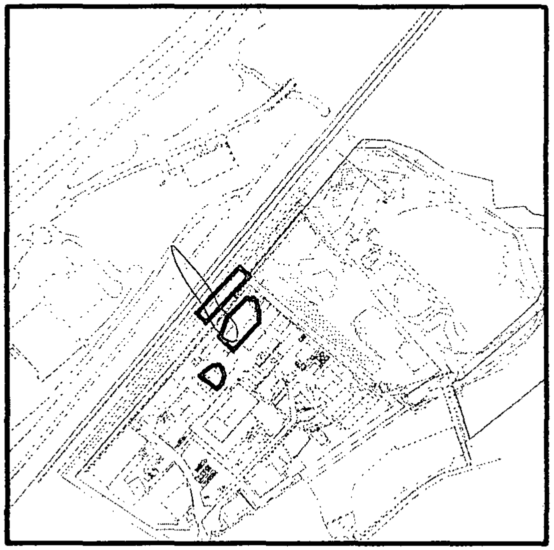
CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Vinyl Chloride Concentration
Distribution: 2009



Vinyl Chloride Concentration
Distribution: 2019



Vinyl Chloride Concentration
Distribution: 2059

N

Scale in Feet

0 750 1500

——— Current IRZ Degradation Zone

Vinyl Chloride Concentration (ppb)

2 50 100 500 1000

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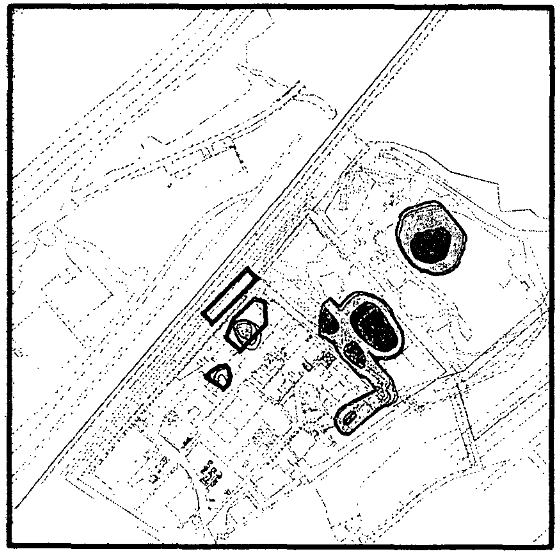
Current and Predicted Vinyl Chloride Concentrations for Simulated Transport in 2009, 2019, and 2059 With Continued Remediation (Model Layer 2)

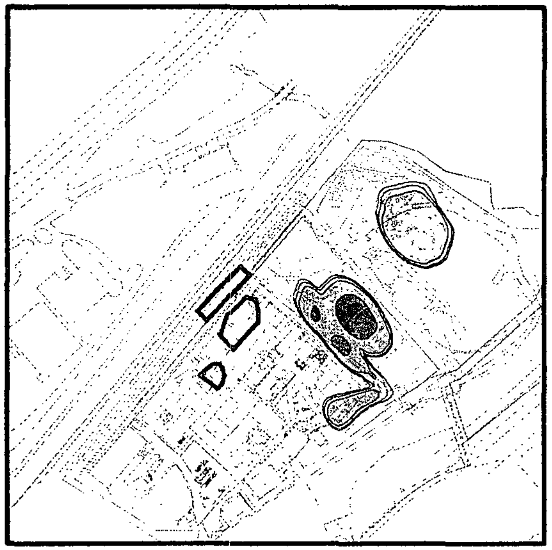
ARCADIS

FIGURE
5-4

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Dissolved Uranium Concentration
Distribution: 2009

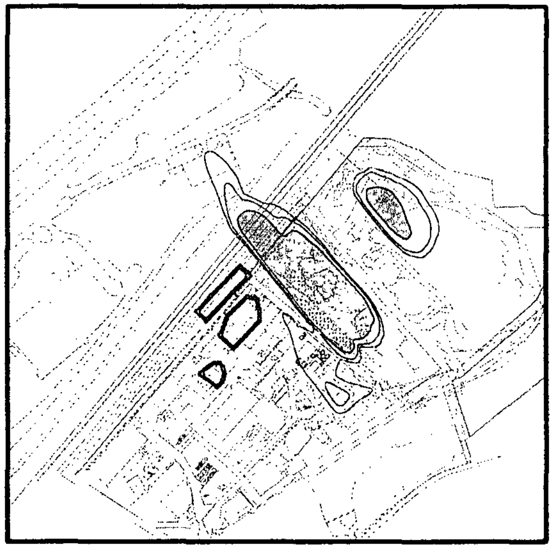


Dissolved Uranium Concentration
Distribution: 2109

N

Scale in Feet

0 750 1500



Dissolved Uranium Concentration
Distribution: 3009

—— Current IRZ Degradation Zone

Dissolved Uranium Concentration (ppb)

☐	☐	▨	■	■
30	50	100	500	1000

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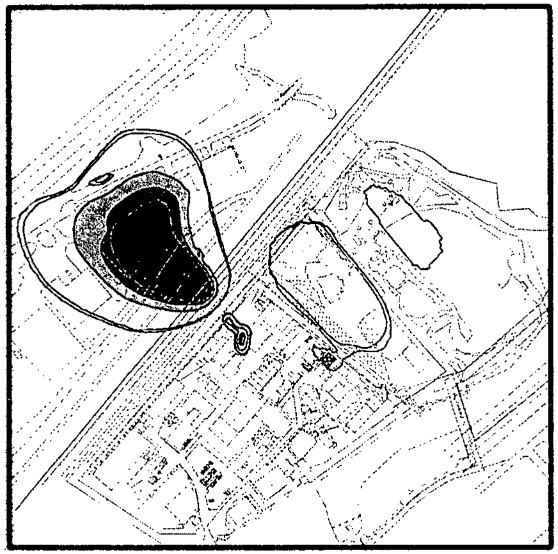
Revised Groundwater Flow and
Solute-Transport Modeling Report

Current and Predicted Dissolved Uranium Concentrations for Simulated Transport in 2009, 2109, and 3009 With Continued Remediation (Model Layer 2)

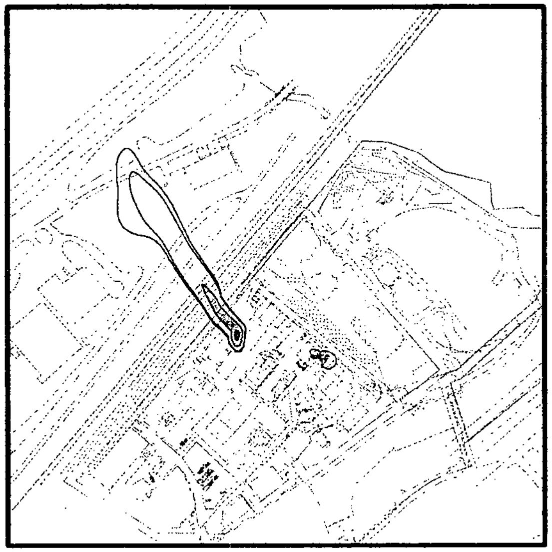
ARCADIS

FIGURE
5-5

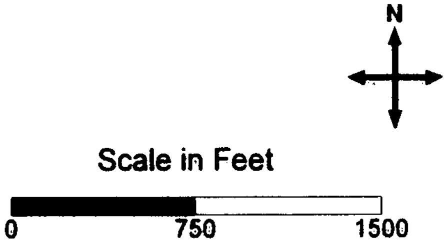
CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004

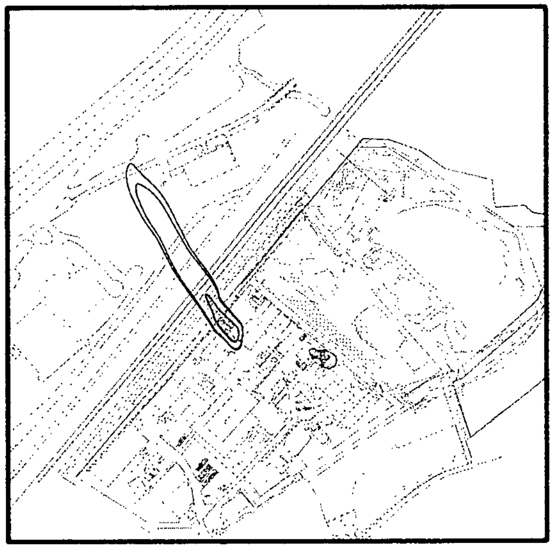


PCE Concentration Distribution: 2009



PCE Concentration Distribution: 2019





PCE Concentration Distribution: 2059

PCE Concentration (ppb)

5 10 100 500 1000

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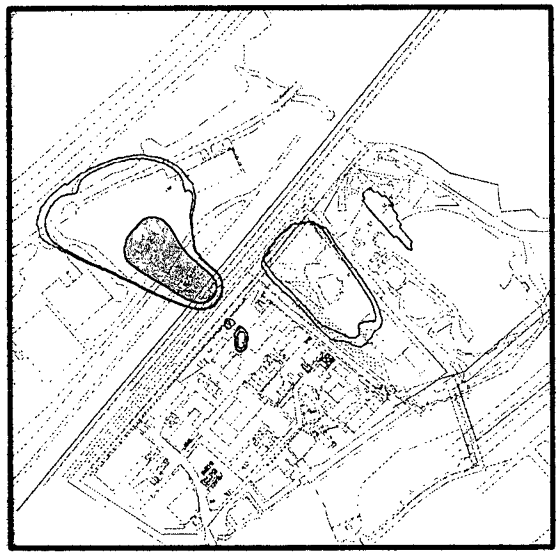
Revised Groundwater Flow and Solute-Transport Modeling Report

Current and Predicted PCE Concentrations for Simulated Transport in 2009, 2019, and 2059 Without Continued Remediation (Model Layer 2)

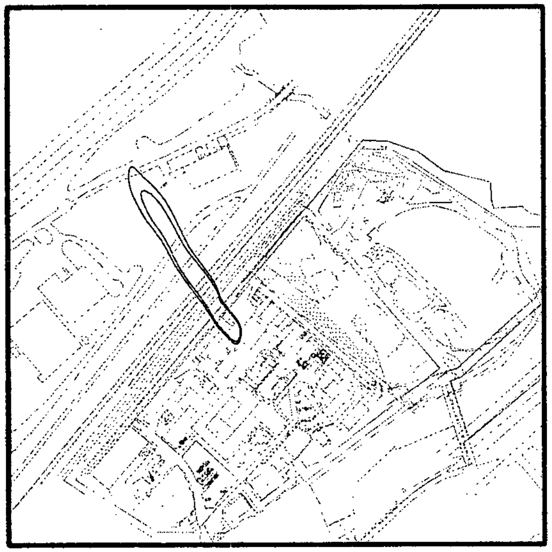
ARCADIS

FIGURE
5-6

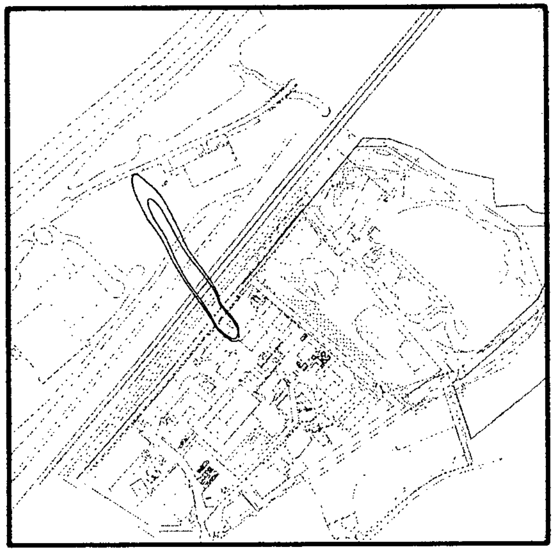
CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



TCE Concentration Distribution: 2009



TCE Concentration Distribution: 2019



TCE Concentration Distribution: 2059

N

Scale in Feet

0 750 1500

TCE Concentration (ppb)

5 10 100 500 1000

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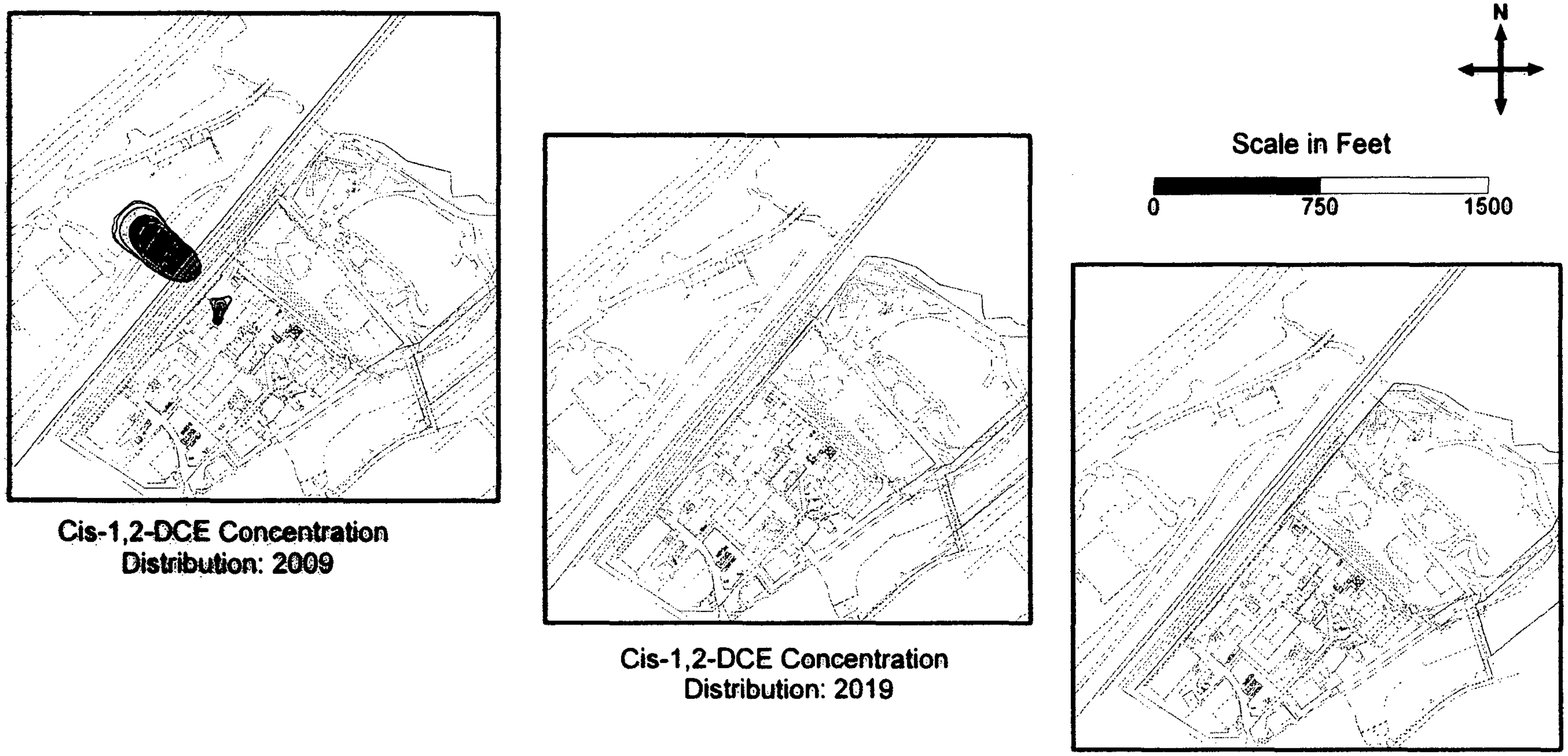
Current and Predicted TCE Concentrations for Simulated Transport in 2009, 2019, and 2059 Without Continued Remediation (Model Layer 2)

ARCADIS

FIGURE
5-7

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Cis-1,2-DCE Concentration
Distribution: 2009

Cis-1,2-DCE Concentration
Distribution: 2019

Cis-1,2-DCE Concentration
Distribution: 2059

Cis-1,2-DCE Concentration (ppb)

70	100	200	500	1000
☐	☐	▨	■	■

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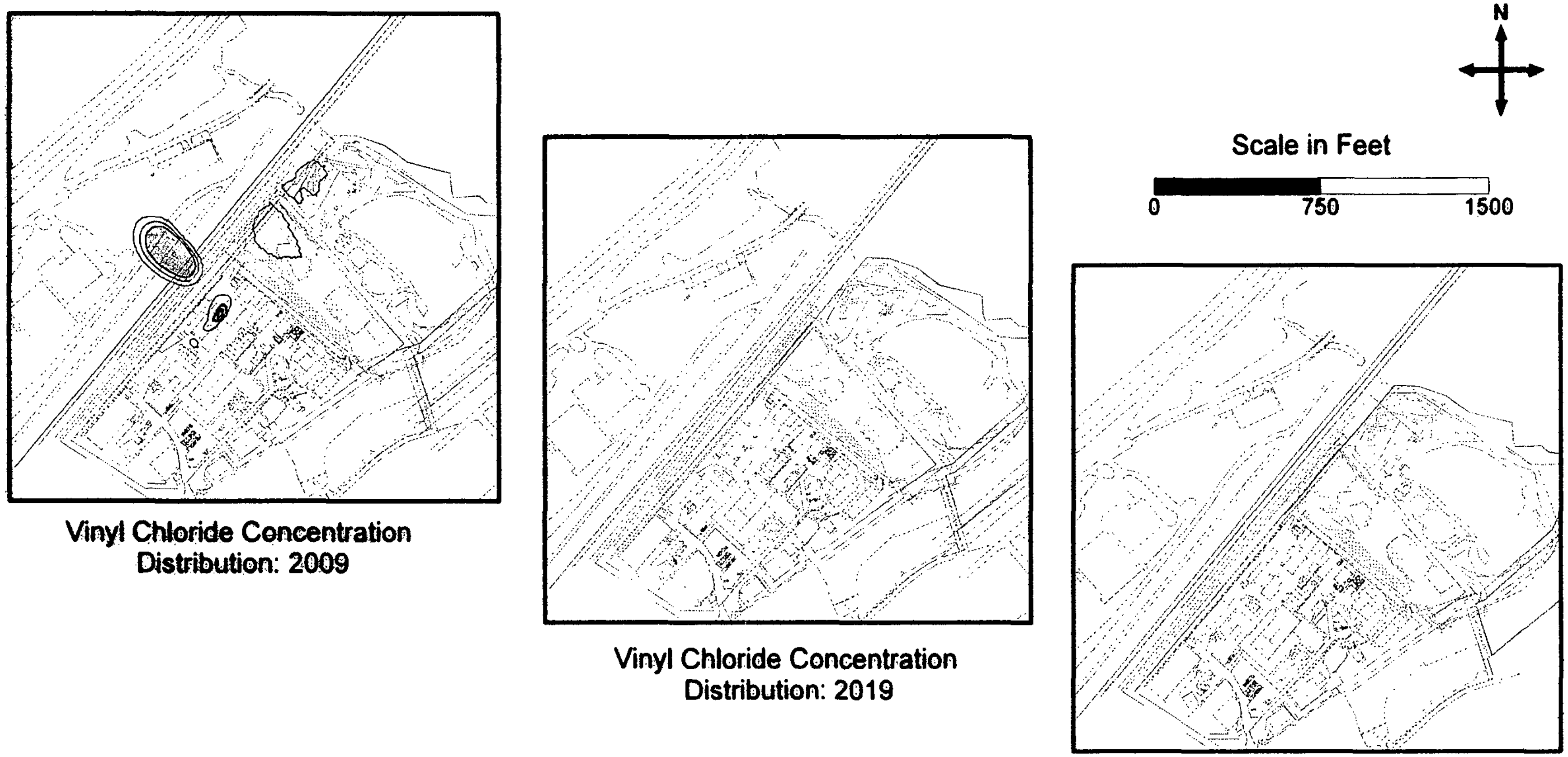
Current and Predicted Cis-1,2-DCE Concentrations for Simulated Transport in 2009, 2019, and 2059 Without Continued Remediation (Model Layer 2)

ARCADIS

FIGURE
5-8

CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Vinyl Chloride Concentration Distribution: 2009

Vinyl Chloride Concentration Distribution: 2019

Vinyl Chloride Concentration Distribution: 2059

Vinyl Chloride Concentration (ppb)

☐	☐	▨	■	■
2	50	100	500	1000

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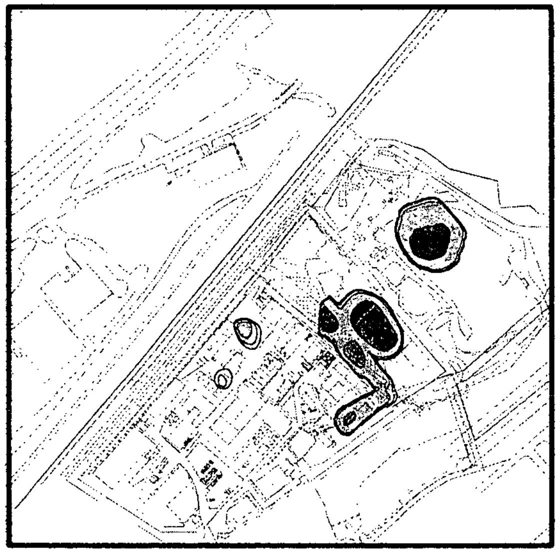
Revised Groundwater Flow and Solute-Transport Modeling Report

Current and Predicted Vinyl Chloride Concentrations for Simulated Transport in 2009, 2019, and 2059 Without Continued Remediation (Model Layer 2)

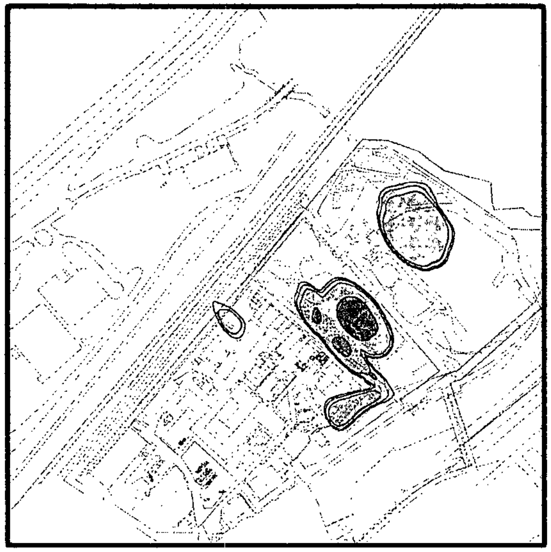
ARCADIS

FIGURE
5-9

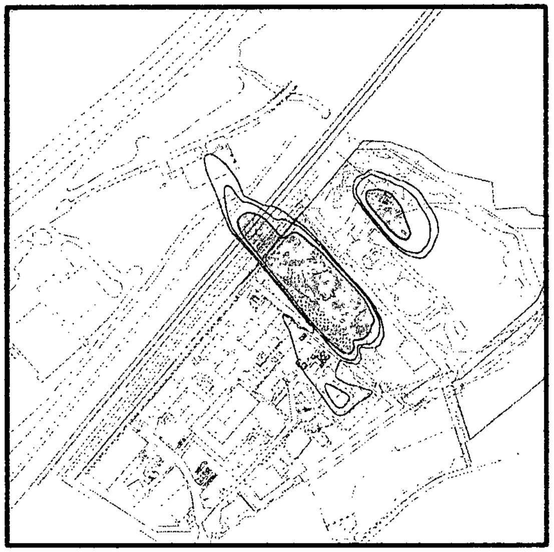
CITY: KNX DIV/GROUP: ENV DB: B.ALTOM PIC: B.ILGER PM: P.PRESTON TM: M.KLADIAS
Project: TNNFS903.MODL.00004



Dissolved Uranium Concentration
Distribution: 2009



Dissolved Uranium Concentration
Distribution: 2109



Dissolved Uranium Concentration
Distribution: 3009

N

Scale in Feet

0 750 1500

Dissolved Uranium Concentration (ppb)

□	□	▨	■	■
30	50	100	500	1000

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ERWIN, TENNESSEE
Revised Groundwater Flow and Solute-Transport Modeling Report

Current and Predicted Dissolved Uranium Concentrations for Simulated Transport in 2009, 2109, and 3009 Without Continued Remediation (Model Layer 2)

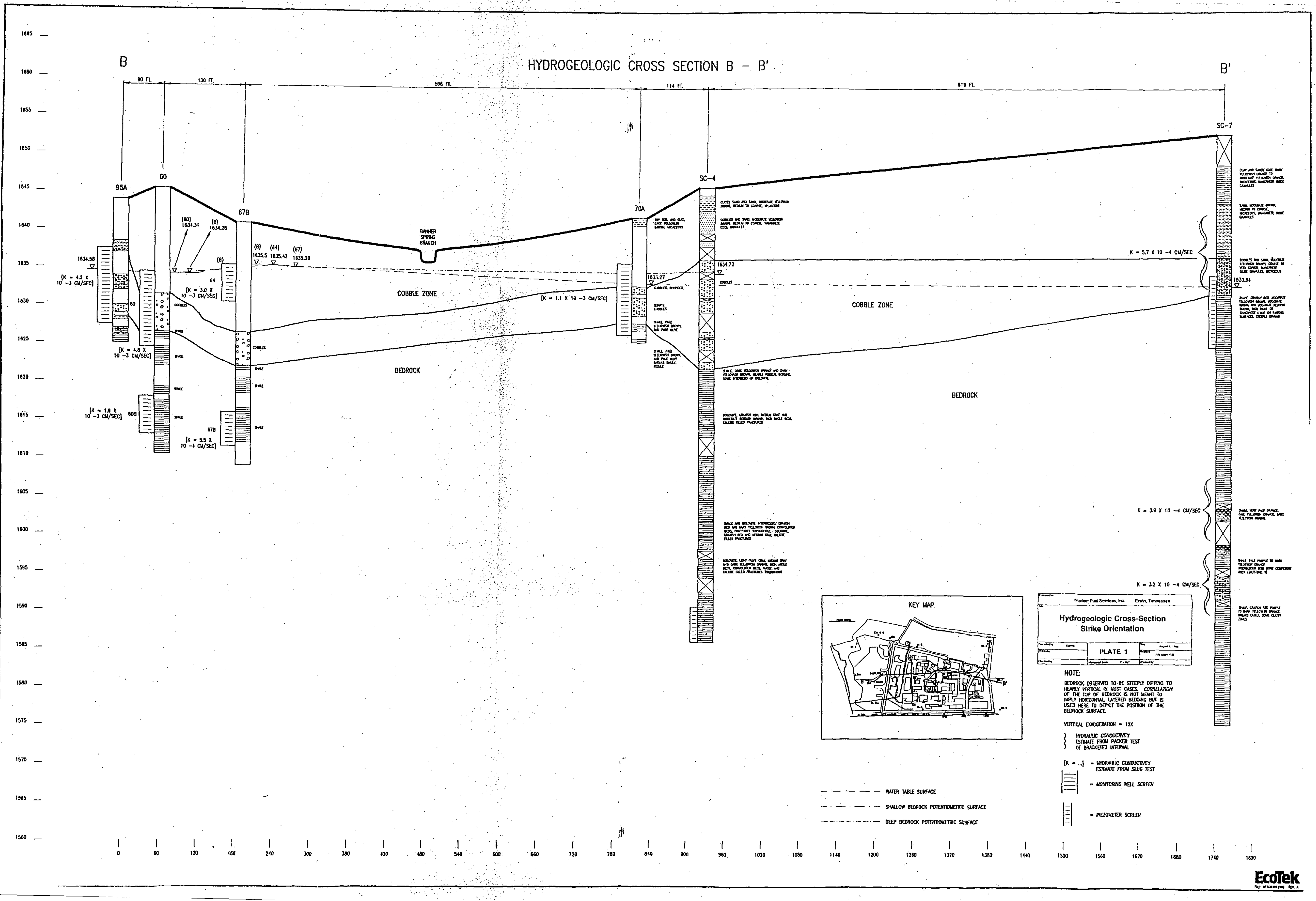
ARCADIS

FIGURE
5-10

RAI 9

Attachment 6

Final Project Report Maps



Nuclear Fuel Services, Inc. Erwin, Tennessee

Hydrogeologic Cross-Section
Strike Orientation

PLATE 1

Compiled by EcoTek
Date August 1, 1995
1AUG95 SB
Horizontal Scale 1" = 60'

NOTE:

BEDROCK OBSERVED TO BE STEEPLY DIPPING TO NEARLY VERTICAL IN MOST CASES. CORRELATION OF THE TOP OF BEDROCK IS NOT MEANT TO IMPLY HORIZONTAL, LAYERED BEDDING BUT IS USED HERE TO DEPICT THE POSITION OF THE BEDROCK SURFACE.

VERTICAL EXAGGERATION = 12X

} HYDRAULIC CONDUCTIVITY ESTIMATE FROM PACKER TEST OF BRACKETED INTERVAL

[K = ...] = HYDRAULIC CONDUCTIVITY ESTIMATE FROM SLUG TEST

= MONITORING WELL SCREEN

= PIEZOMETER SCREEN

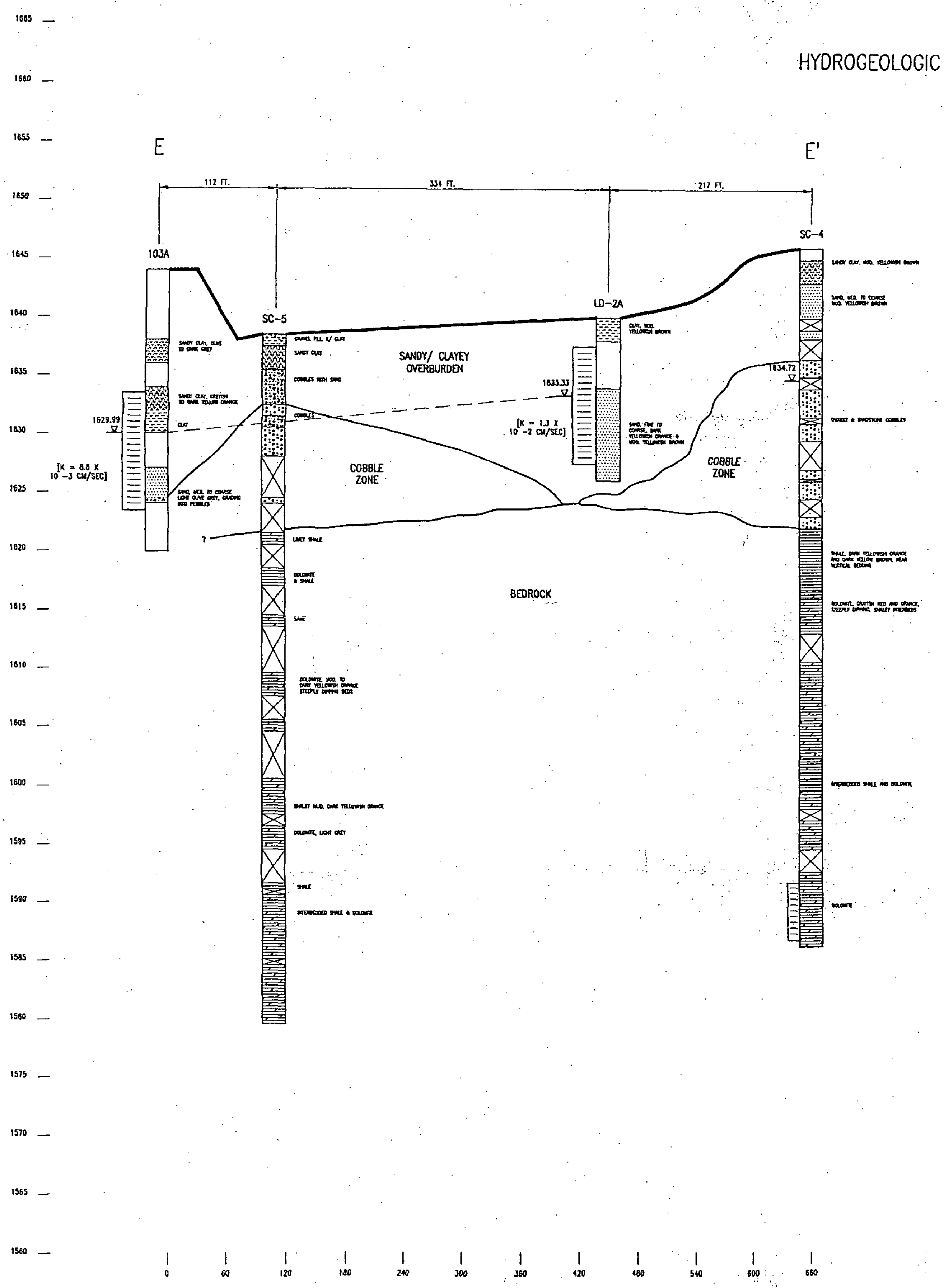
— — — — WATER TABLE SURFACE

— · — · — SHALLOW BEDROCK POTENTIOMETRIC SURFACE

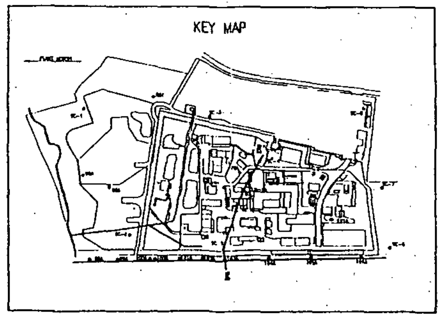
— · · — · · — DEEP BEDROCK POTENTIOMETRIC SURFACE

EcoTek

HYDROGEOLOGIC CROSS SECTION E – E'



KEY MAP



— — — — WATER TABLE SURFACE

— — · — · — SHALLOW BEDROCK POTENTIOMETRIC SURFACE

———— DEEP BEDROCK POTENTIOMETRIC SURFACE

Prepared for:
Nuclear Fuel Services, Inc. Erwin, Tennessee

Title
Hydrogeologic Cross-Section Dip Orientation

Certified by EcoTek	PLATE 2	Date August 1, 1995
Drawn by		1AUG95 SB
Checked by	Horizontal Scale 1" = 60'	Checked by

NOTE:

BEDROCK OBSERVED TO BE STEEPLY DIPPING TO NEARLY VERTICAL IN MOST CASES. CORRELATION OF THE TOP OF BEDROCK IS NOT MEANT TO IMPLY HORIZONTAL, LAYERED BEDDING BUT IS USED HERE TO DEPICT THE POSITION OF THE BEDROCK SURFACE.

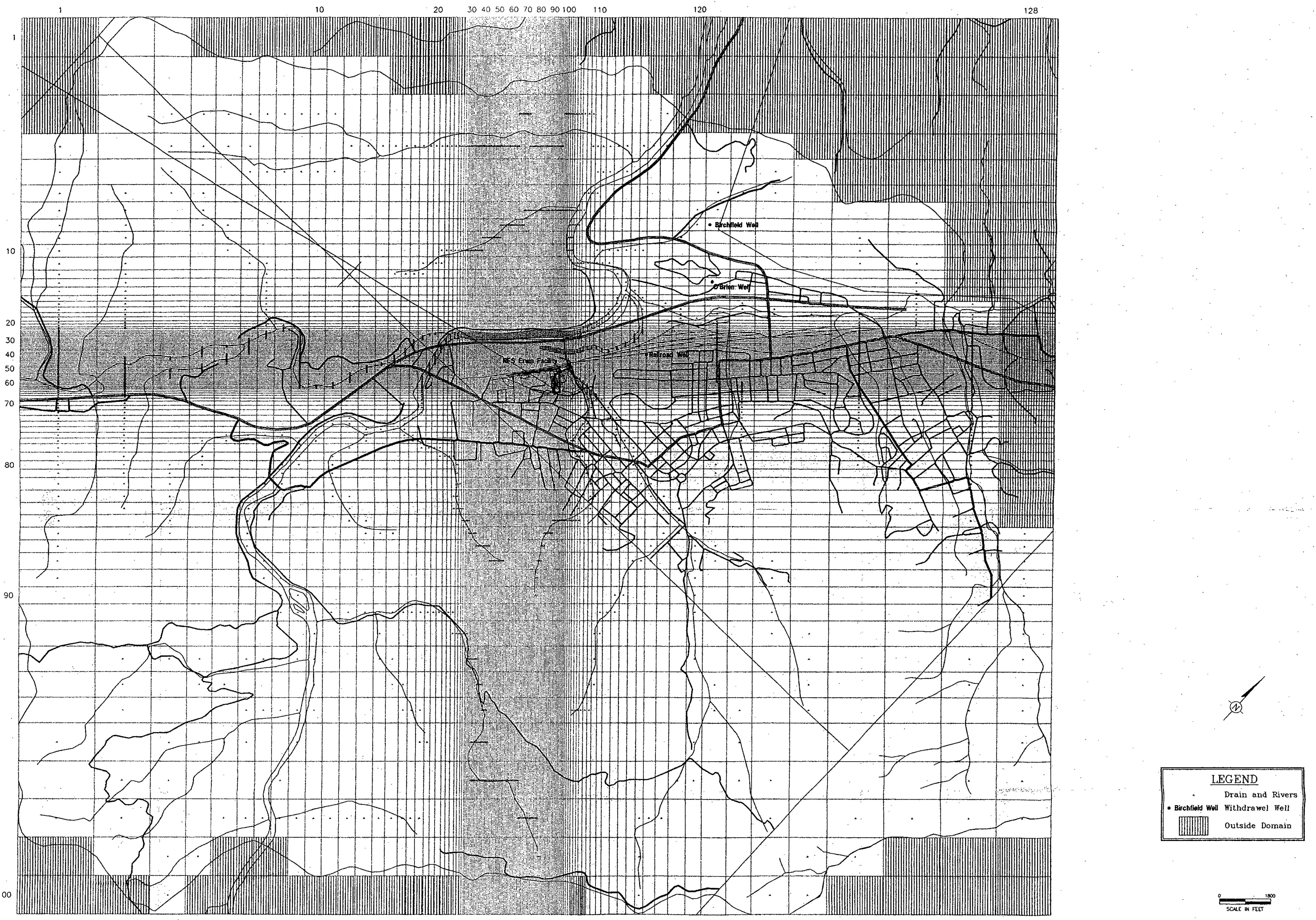
VERTICAL EXAGGERATION = 12X

} HYDRAULIC CONDUCTIVITY ESTIMATE FROM PACKER TEST OF BRACKETED INTERVAL

[K = ...] = HYDRAULIC CONDUCTIVITY ESTIMATE FROM SLUG TEST

☰ = MONITORING WELL SCREEN

☰ = PIEZOMETER SCREEN



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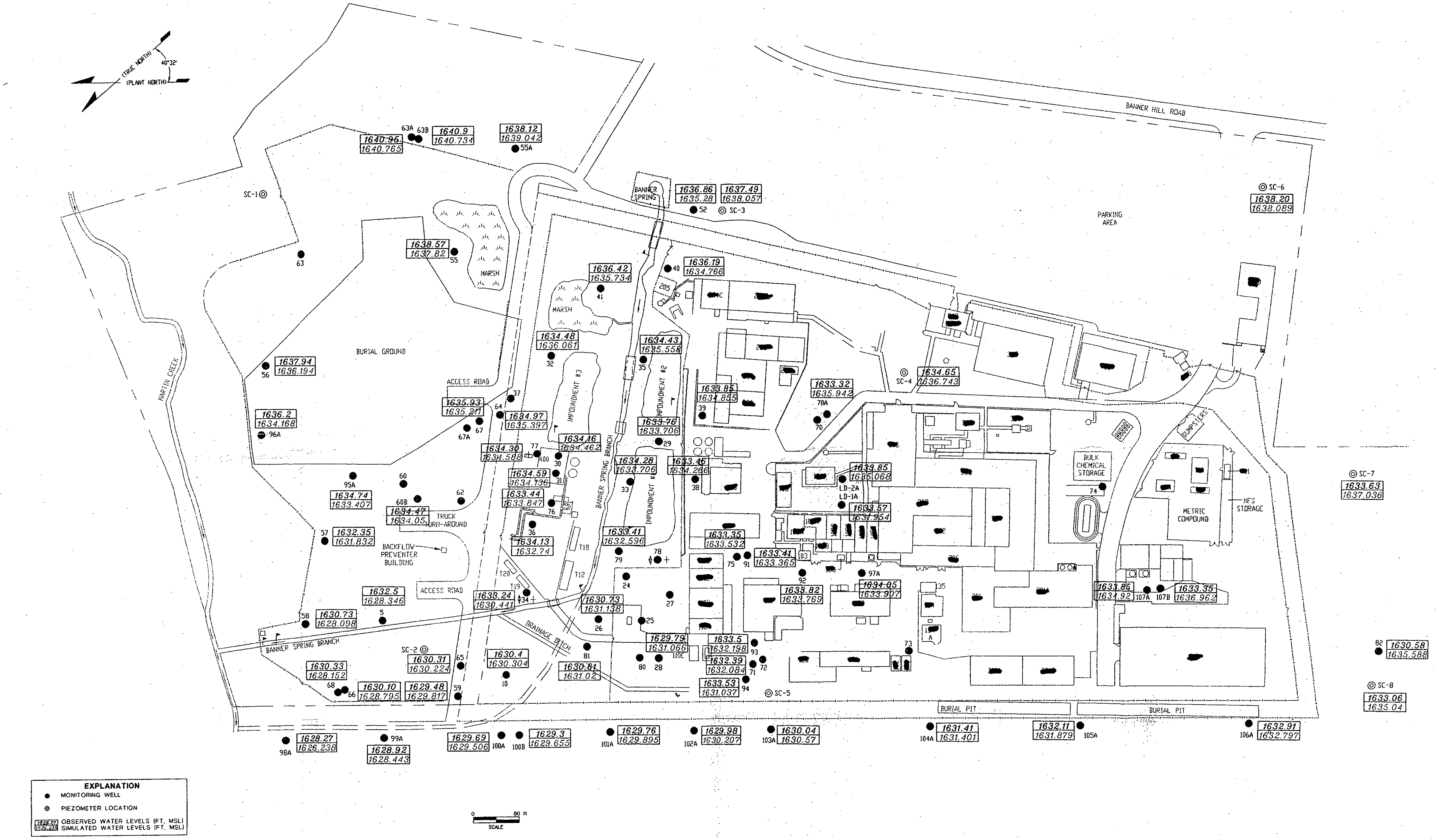
PROJECT NO.: TN0333.001
HARD FILE: MESH
DRAWING: D30144MB.DWG
PLOT SIZE: 1:1
DRAFTED BY: B. ALTOM
DATE: 03-31-96
CHECKED BY: T. KHAN
DATE: 10-18-95
APPROVED BY: B. ILGNER
DATE: 10-18-95

Finite-Difference Mesh and Boundary Conditions

Nuclear Fuel Services, Inc. Erwin, Tennessee

PLATE
3



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REV. NO.	DATE	DESCRIPTION	BY	APPR.

PROJECT NO.: TN0333.001
DRAWING: B30140.DWG
HARD FILE: PLATE
PLOT SIZE: 1"=80'
DRAFTED BY: B. ALTOM — DATE: 4-1-96
CHECKED BY: T. KHAN — DATE: 4-1-96
APPROVED BY: B. ILGNER — DATE: 4-1-96

Observed and Simulated Water Levels for the Calibrated Groundwater Flow Model

Nuclear Fuel Services, Inc. Erwin, Tennessee

PLATE
4