at least 20 feet of additional shale present below the Helper based on logs derived from bedrock wells at the facility (Kayenta, 2002).

1.4.3 Hydraulic Properties, Alluvium

Ten constant-rate-pumping tests have been performed at the KCP to determine the hydraulic conductivity and the storativity of the unconsolidated material. Five of the pumping tests were conducted in wells that fully penetrated the alluvial aquifer and produced vertically averaged hydraulic conductivity estimates between 1.1 ft/d (3.9×10^{-4} cm/s) and 3.0 ft/d (1.1×10^{-3} cm/s). The other five pumping tests were conducted in wells screened solely in the basal gravel and produced an estimated basal gravel hydraulic conductivity between 14 ft/d (4.9×10^{-3} cm/s) and 34 ft/d (1.2×10^{-2} cm/s). The green clay aquifer test also determined the vertical hydraulic conductivity of the green clay to be between 0.26 ft/d and 0.34 ft/d (DOE 1992). Storativity values from the tests ranged from 5.0×10^{-4} to 2.0×10^{-3}.

Laboratory testing on soil cores measured total porosity at 40% (DOE 1999). Effective porosity in the alluvium was not measured and accurate measurement is difficult. Collecting an unconsolidated core is often unsuccessful because the collection process disturbs the material and/or bypass occurs along the core sleeve. Tracer tests in the field take considerable time and/or the tracer is missed because actual flow directions are often not known. Additionally, an estimate of hydraulic conductivity is needed which varies spatially. Transport models at the KCP utilize an effective porosity of 10%. An effective porosity of 10% was also used to calculate horizontal groundwater velocities in the basal gravel.

1.4.4 Hydraulic Properties, Bedrock

Packer tests conducted on bedrock wells indicate that the bedrock has very low hydraulic conductivity. For example, packer tests conducted on the Pleasanton Shale showed no-flow conditions. Because packer tests can measure hydraulic conductivity's as low as 0.0001 ft/d (3.5×10^{-8} cm/s), it is safe to assume that the hydraulic conductivity of the Pleasanton shale is 0.00001 ft/d (3.5×10^{-9} cm/s) or lower. Based on packer tests of former bedrock wells 21, 22, and 23 the hydraulic conductivity of the Knobtown Sandstone ranges from 0.005 to 0.04 ft/d (1.8×10^{-6} to 1.4×10^{-5} cm/s) (Korte et al. 1985; Madril et al. 1986). Bail tests of wells 122, 123, and 124, analyzed using Hvorslev's method, produced similar measurements to Knobtown Sandstone hydraulic conductivities (2×10^{-5} to 4×10^{-5} cm/s) (DOE 1990a).

1.5 Subsurface Contaminant Nature and Migration

The primary groundwater contaminant at the KCP is trichloroethylene (TCE) and it's anaerobically produced degradation products 1, 2-dichloroethylene (1, 2-DCE) and vinyl chloride. Other compounds including 1,1-dichloroethane (1,1-DCA) and 1,1-dichloroethene (1,1-DCE) are found at the site but at significantly lower frequency and concentration when compared to the three primary compounds. Due to the low solubility of the chlorinated solvents they are considered immiscible in water.

PCBs have been detected in groundwater samples in wells located in areas of known PCB soil contamination. However, based on work performed in the 95th Terrace RFI, there is no evidence that PCBs, either colloidal or dissolved, are mobile at the KCP under natural flow conditions at concentrations above the site PCB groundwater clean-up standard (DOE, 1999). PCB detections in groundwater are related to PCB containing soil particles which are mobilized as a part of the sampling process.

1.5.1 Conceptual Site model

When groundwater contamination with chlorinated solvents was initially investigated the prevailing thought in the scientific community was that pump-and-treat would eventually eliminate all groundwater contamination through the physical removal of the contaminant from the aquifer (EPA, 1996). Subsequent work demonstrated that chlorinated solvents may form pools of pure phase product. These Dense Non Aqueous Phase Liquids (DNAPL) (in the case of solvents denser than water like TCE), could be sources of contamination for decades and possibly centuries (Wilson and Conrad 1984; Schwille 1988). More recent work has shown that the idealized pools mentioned above represent an oversimplification of DNAPL behavior for a site such as the KCP. The alluvium at the KCP is two to four orders of magnitude less-permeable than that envisioned in the idealized "pool" scenario.

Work by Korte et al., 1995 concluded that DNAPL at the KCP was believed to exist as ganglia in discontinuous phases. In a finer-grained system where the capillary entry pressure is significantly higher, a "pool" of DNAPL cannot form and the overall distribution will look more like that shown in Figure 1.6. Figure 1.6 presents a DNAPL distribution developed for a fine grained system in a laboratory (Wilson et al. 1989; Conrad et al. 1988; Conrad et al. 1992).
A field-scale conceptual drawing of such a distribution is shown in Fig. 1.7. The figure shows that "pools" are not formed and that DNAPL distribution is highly discontinuous. The figure suggests that, especially in heterogeneous flow systems, there are dead-end and even closed off pores where water or DNAPL can accumulate and be virtually impossible to displace. In a sense, the circumstances can be thought of as resulting in many "micro pools" of DNAPL interspersed with some water-filled pores as well. DNAPL ganglia will be dispersed throughout the source zone, and even though films of water surrounding the ganglia may contain saturated concentrations of the solvent, bulk samples, even from a very small area, will show significantly lower concentrations.

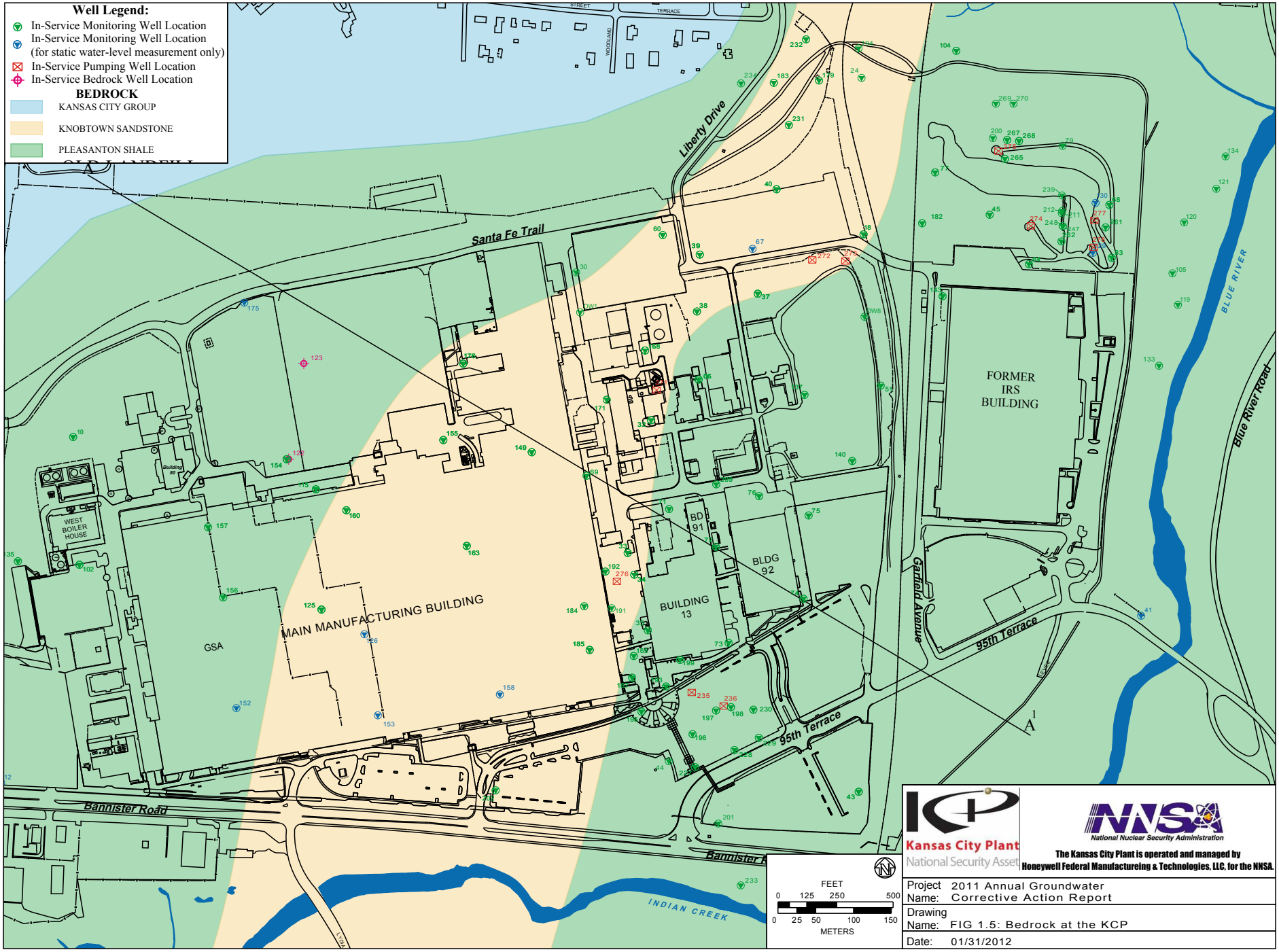
Interpretation of data from this study in conjunction with historical data was consistent with the hypothesis that DNAPL at the KCP is present as discontinuous ganglia throughout several feet of the soil at the base of the aquifer within the TCE Still Area and within the Main Manufacturing Building (MMB) near wells KC92-184 and KC94-192 (see Fig. 3.6). DNAPL was also visually noted in the area of the Old Ponds immediately north of the north lagoon as a part of the in-situ soil mixing project (GEOCON, 1996). It is also concluded, because of the likely presence of DNAPL and the tortuous flow path for groundwater at the KCP, that pump-and-treat is unlikely to significantly alter groundwater contaminant concentrations for an extensive period of time. However, as will be discussed later, pump and treat does effectively serve to prevent off-site migration of contamination over site cleanup standards.

1.5.2 Fit of the model to the KCP

DNAPL at the KCP is composed of TCE, with an aqueous solubility of 1,100 mg/l. One area of DNAPL is located in the area of the former plating building degreaser just east of MMB. Immediately down-gradient of a zone of residual DNAPL, one would expect the local groundwater concentration to be approximately 1,100 mg/l (well 192 exhibited TCE concentrations in this range prior to startup of adjacent pumping well 276). As one moves downgradient, TCE concentrations will be less due to hydrodynamic dispersion. Dispersion in the subsurface results in a lowering of concentrations along the axis of a plume in the downgradient direction. The maximum concentration of 1,100 mg/l can only be observed immediately adjacent to the DNAPL and will not be observed anywhere down-gradient of the source zone. This is the contaminant distribution noted in the area of the former vapor degreaser. Besides hydrodynamic dispersion, other factors including specific monitoring well placement and the amount of contaminant degradation over time (biotic or abiotic) work to produce lowered contaminant concentrations in wells downgradient of DNAPL source zones.

1.5.3 The Role of Natural Attenuation

Another factor influencing contaminant behavior at the KCP is that of natural attenuation. As will be shown in subsequent sections of this report, the presence of TCE, the primary contaminant in groundwater is limited in extent primarily to source areas. As one moves away from source areas, TCE concentrations drop dramatically especially in the BRGFS. While earlier studies did not conclude that natural attenuation was a robust phenomenon at the site (ORNL, 1998), significant degradation of TCE in the KCP subsurface environment is occurring and should be considered an ongoing contaminant reduction mechanism.


Well Legend:
In-Service Monitoring Well Location
In-Service Monitoring Well Location (for static water-level measurement only)
In-Service Pumping Well Location
In-Service Bedrock Well Location
BEDROCK
KANSAS CITY GROUP
KNOBTOWN SANDSTONE
PLEASANTON SHALE
Liberty Drive
Santa Fe Trail
FORMER IRS BUILDING
BLUE RIVER
Blue River Road
Garfield Avenue
95th Terrace
MAIN MANUFACTURING BUILDING
GSA
WEST BOILER HOUSE
BUILDING 13
BLDG 92
BD 91
Bannister Road
INDIAN CREEK
FEET
METERS
Kansas City Plant
National Security Asset
National Nuclear Security Administration
The Kansas City Plant is operated and managed by Honeywell Federal Manufactureing & Technologies, LLC, for the NNSA.
Project Name: 2011 Annual Groundwater Corrective Action Report
Drawing Name: FIG 1.5: Bedrock at the KCP
Date: 01/31/2012

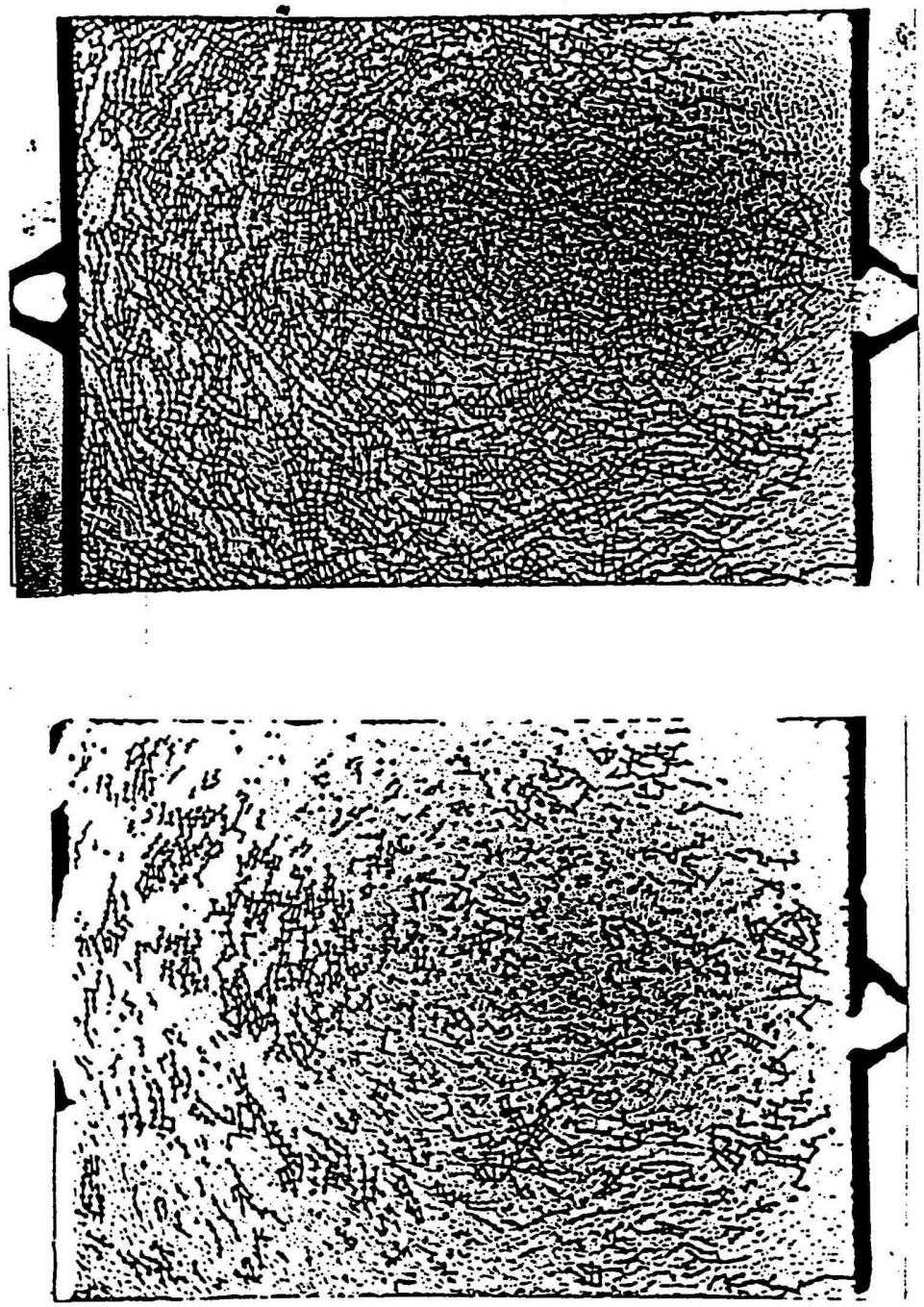
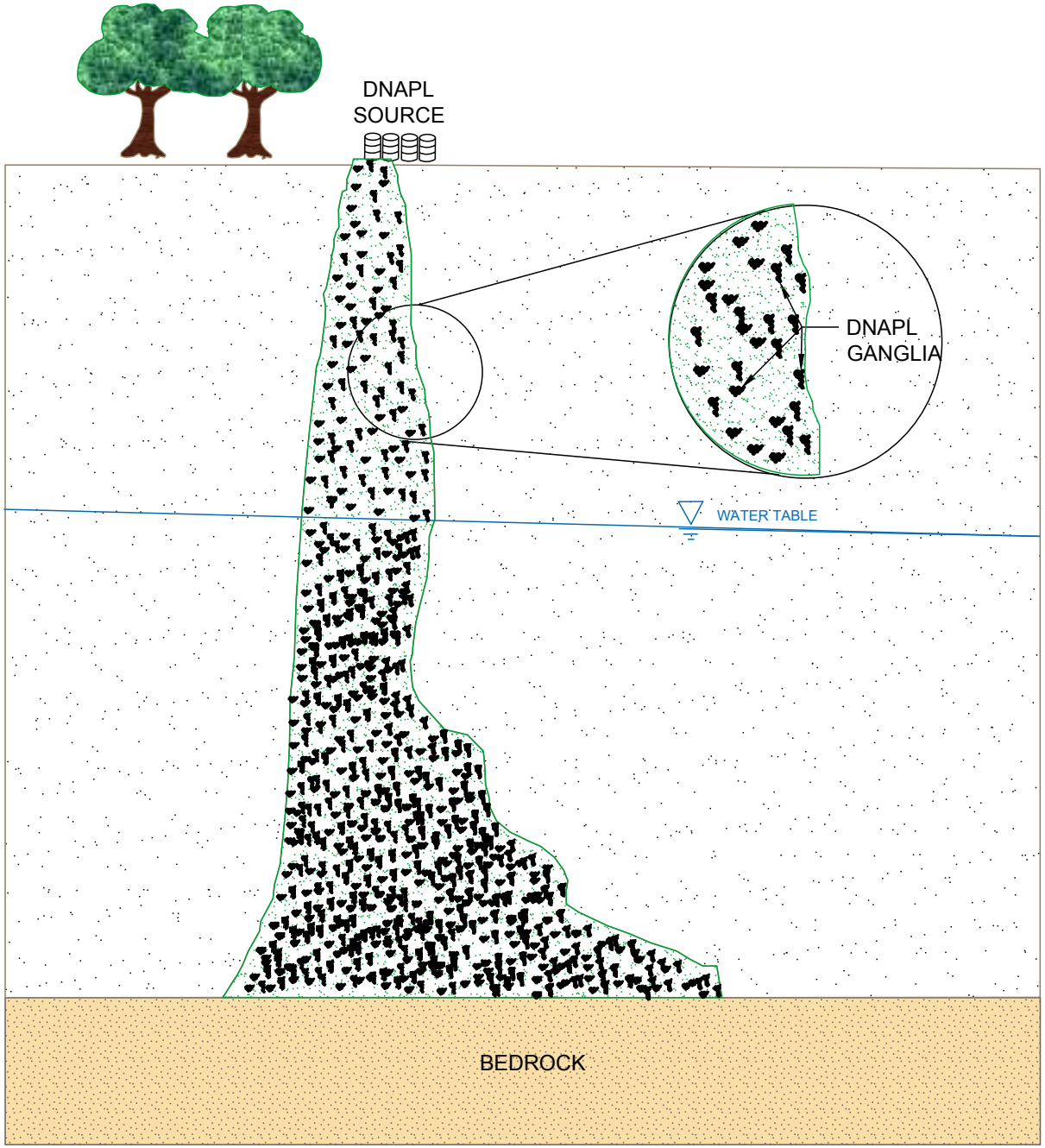


Fig1.6. DNAPL in residual saturation in relatively fine grained systems.
Source: Adapted from Wilson, J.L., S. H. Conrad, W. R. Mason, W. Peplinski and E. Hagen, Laboratory Investigation of Residual Liquid Organics from Spills, Leaks, and the Disposal of Hazardous Wastes in Groundwater, EPA/600/6-90/004, U. S. Environmental Protection Agency.



Kansas City Plant
National Security Asset

National Nuclear Security Administration

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Project Name: 2011 Annual Groundwater Corrective Action Report

Drawing Name: FIGURE 1.7 CONCEPTUAL DISTRIBUTION OF DNAPL IN A HOMOGENEOUS FINE-GRAINED SYSTEM

Date: 01/31/2012