# Time-Series Contaminant Interpolation using ArcGIS and Spatial Analyst

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Using ESRI ArcGIS 9.1 to develop a personal database, we have created several visualization tools to depict the spatial distribution of aviation gasoline contamination in groundwater at the spill site. The spilled aviation gasoline and associated aromatic contaminant plume covers approximately 50 acres within the commercial, residential, and recreational areas of the base, and effective monitoring the site during cleanup has become a high priority. One of the specific techniques developed is the ongoing interpolation and depiction of the spatial distribution of chemical concentrations in groundwater throughout the site. A graphic representation of the temporal changes in floating product and dissolved aromatic chemicals has been exported for a time-series presentation using PowerPoint® software. This time-series tracking information has proved useful in validating the conceptual site model, monitoring cleanup progress, and depicting site conditions to various stakeholders interested in monitoring cleanup progress at the site.

The interpolated models have been based on measurements from up to 180 extraction and monitoring wells, with data having been collected from many wells for nearly two decades. The apparent product thickness of the light-non aqueous phase liquid (LNAPL) plume is based on available historical data collected between 1985 and 2005, and the number of wells will reach approximately 200 by 2006. The personal database has been used to better understand temporal changes (from the discrete snapshots in time) in the apparent product thicknesses and associated concentrations of key fuel-related chemicals, such as benzene (which is the primary environmental risk driver at the site). A visual display of product thickness measurements, created in the form of interpolated product thickness maps, has been produced using the Spatial Analyst® software. The maps depict thickness using a color palette calibrated to site specific conditions. To create three dimensional views of the site, we incorporated the raster files showing chemical concentrations and product thickness using a triangular irregular network (TIN) grid created from site elevation data. The current database includes the x-, y-, and z-coordinates of each type of monitor well, the well diameter and total depth of solid and screened casing intervals, the depth to groundwater, and the depth to free product. The maps display chemical analysis data collected from the 180 wells, many of which are connected to three multiphase extraction systems though a system of subsurface extraction lines. Because of the size of the site (over fifty acres) and complexity of distribution in the subsurface, the visualization tools have been used to better show the chemical concentration changes over time.

## PAPER BODY

## BACKGROUND

Hickam Air Force Base (HAFB), located on the Island of Oahu, Hawaii, is one of the most active Air Force Bases in the Pacific. Residual contamination from historically released aviation gasoline (AVGAS) has impacted approximately 50 acres in the commercial, residential, recreational, and light industrial areas of the base as shown in Figure 1, Site Layout.

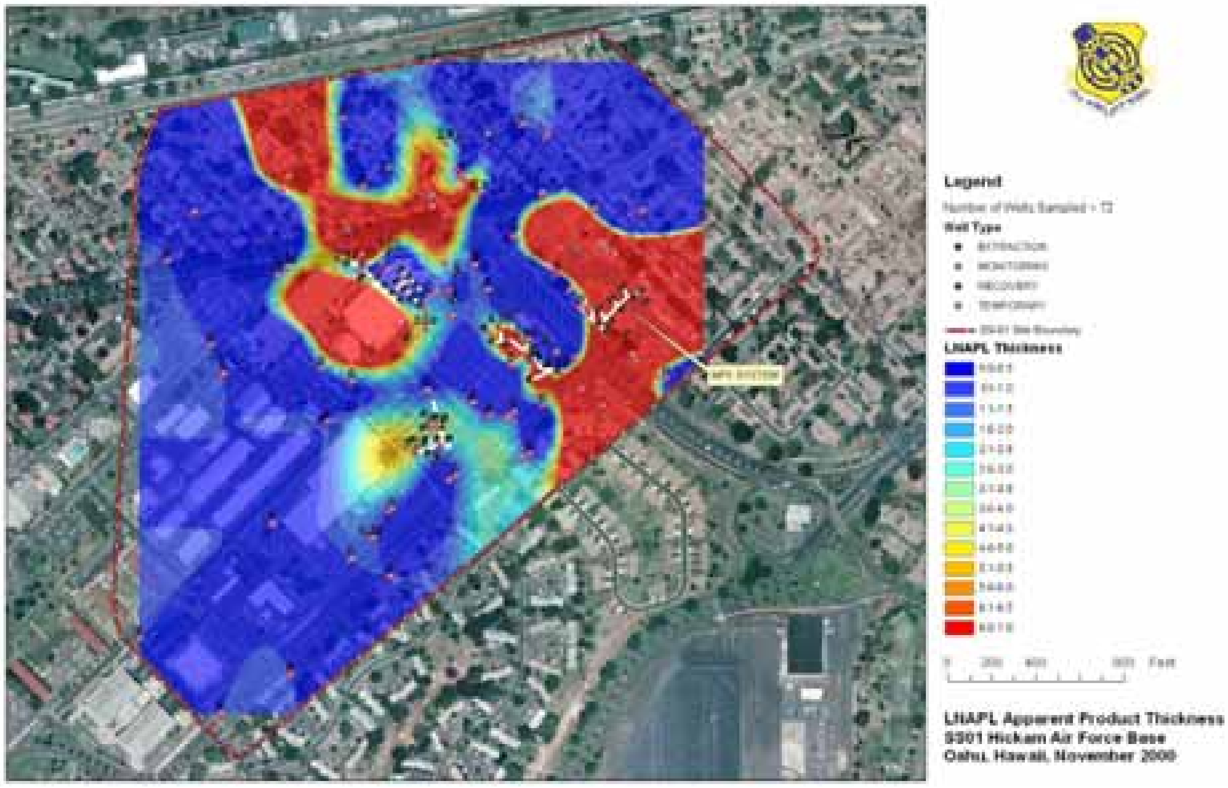


FIGURE 1 – LNAPL APPARENT PRODUCT THICKNESS

Figure 1 shows the interpolated apparent product thickness (in feet) of Light Non-Aqueous Phase Liquid (LNAPL). This interpolation was made using data collected in November of 2000, at the time of the decision to implement Bioslurping technology at the site. Bioslurping is an established cleanup remedy which was co-developed by the Air Force (Battelle 2001) and has proven effective as a cleanup remedy at many fuel contaminated sites. The cleanup at SS01 was implemented as a Removal Action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 within the Air Force Environmental Restoration Program.

Construction of three Bioslurpers, sometimes called multi-phase extraction (MPX) systems, began in 2001 (Weston Solutions 2001), and all are currently in operation at Spill Site 1. Over 100,000 of gallons of aviation gasoline have been removed from the subsurface to-date, and an estimated 200,000-300,000 gallons of fuel still remain at the site. The Bioslurpers use a 25 horse power (HP) liquid ring pump to extract subsurface fluids (from a network of underground extraction lines) through a vapor liquid separator, separating the gas phase from the liquid phases. An oil water separator recovers aviation gasoline from the groundwater, and the groundwater is subsequently processed through an air stripper, filter, and granular activated carbon treatment train, after which it is re-infiltrated back into the subsurface in a nearby infiltration gallery. A thermal oxidizer with supplemental propane is used to incinerate all extracted organic vapors. Recovered fuel is contained in 500 and 1,000-gallon aboveground storage tanks, which holds the recovered fuel for recycling. The Bioslurping process stimulates subsurface circulation and promotes the natural bio-degradation of hydrocarbons through mixing and oxygenation (hence the term Bioslurping).

An important aspect of the cleanup program is that there are many stakeholders involved in the process. Regulations require formal community involvement via a Restoration Advisory Board in addition to state regulatory oversight, involvement of on-base workers, a multitude of base tenants, and coordination with base command and program management. The multitude of stakeholders complicates reporting and decision making, and creates challenges with presentation of a large amount of technical data.

## DISCUSSION

Inherent to any large scale cleanup project are important monitoring activities that are needed to optimize cleanup effectiveness and determine cleanup endpoints. For these reasons, a site specific GIS database was developed to help track and depict key parameters at the site. The need to present the data with spatial analyst interpolations was not driven by the need for technical managers to make decisions, but rather, it was mostly to allow for a standardized reporting format for regular reporting to a large number of stakeholders.

The initial parameters that we identified for tracking were apparent product thickness (as measured in extraction wells), and the concentration of key compounds dissolved in groundwater at the monitoring well locations (e.g., benzene, toluene, ethylbenzene, and xylenes). Tracking these parameters over time is also necessary to demonstrate regulatory compliance.

The tracking for benzene was originally targeted because it has the lowest cleanup goal and was thought to be the key regulatory “driver” at the site. However, because there were relatively few data points for benzene gathered over time, this paper will focus on the presentation of apparent product thickness measurements gathered between 2000 and 2003.

The product thickness interpolations are shown below in Figures 2 through 8.

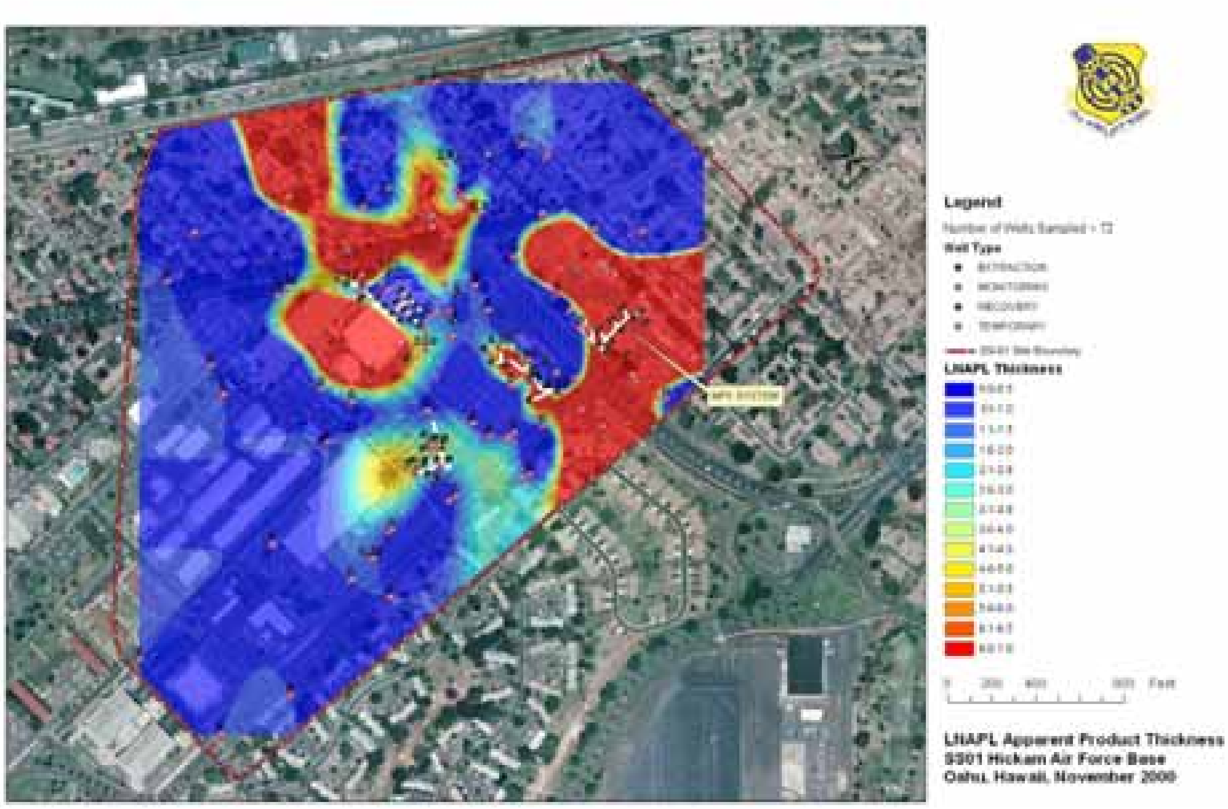


FIGURE 2 – Product Thickness November 2000

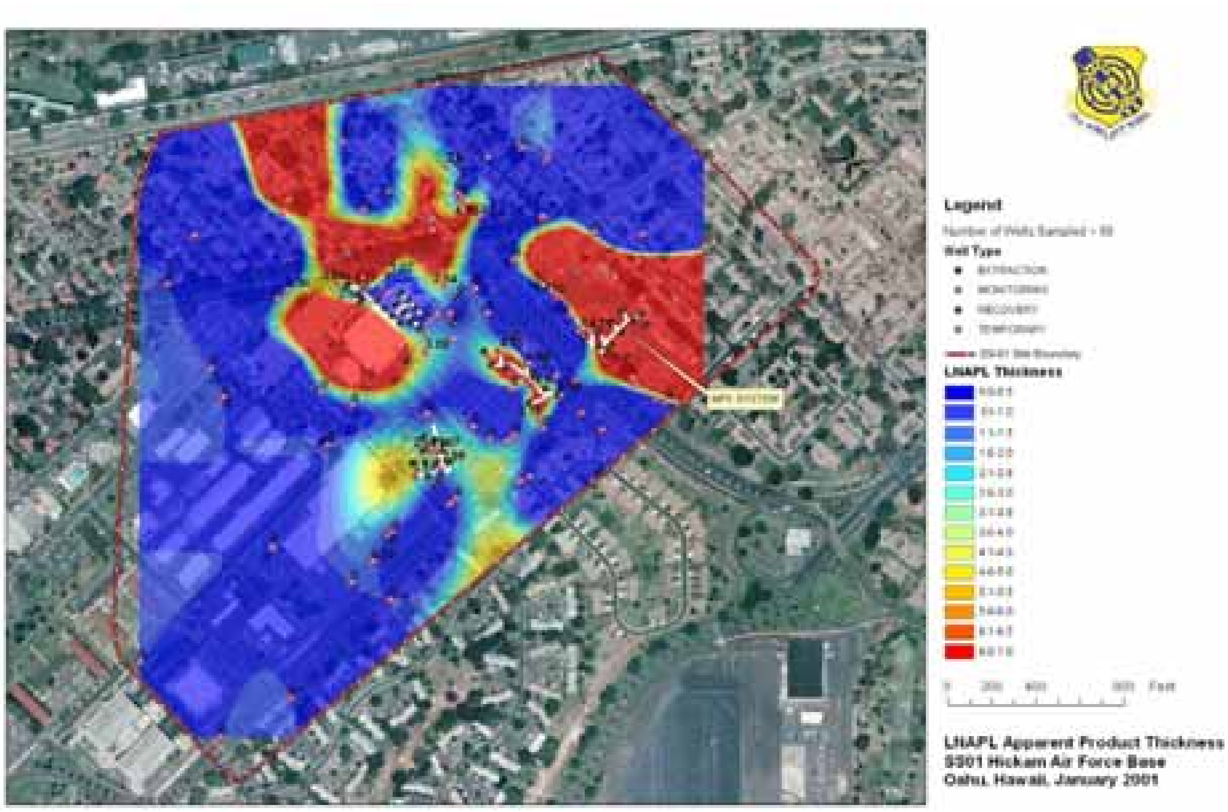


FIGURE 3 – Product Thickness January 2001

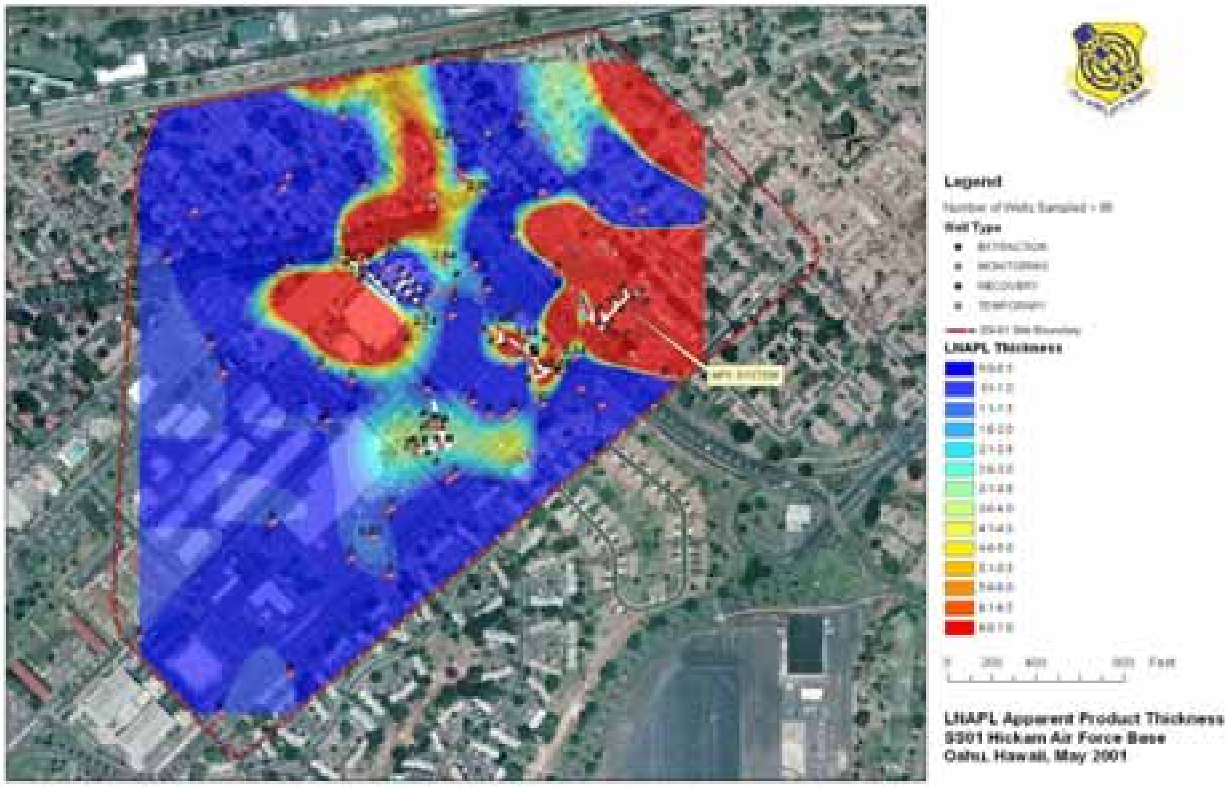


FIGURE 4 – Product Thickness May 2001

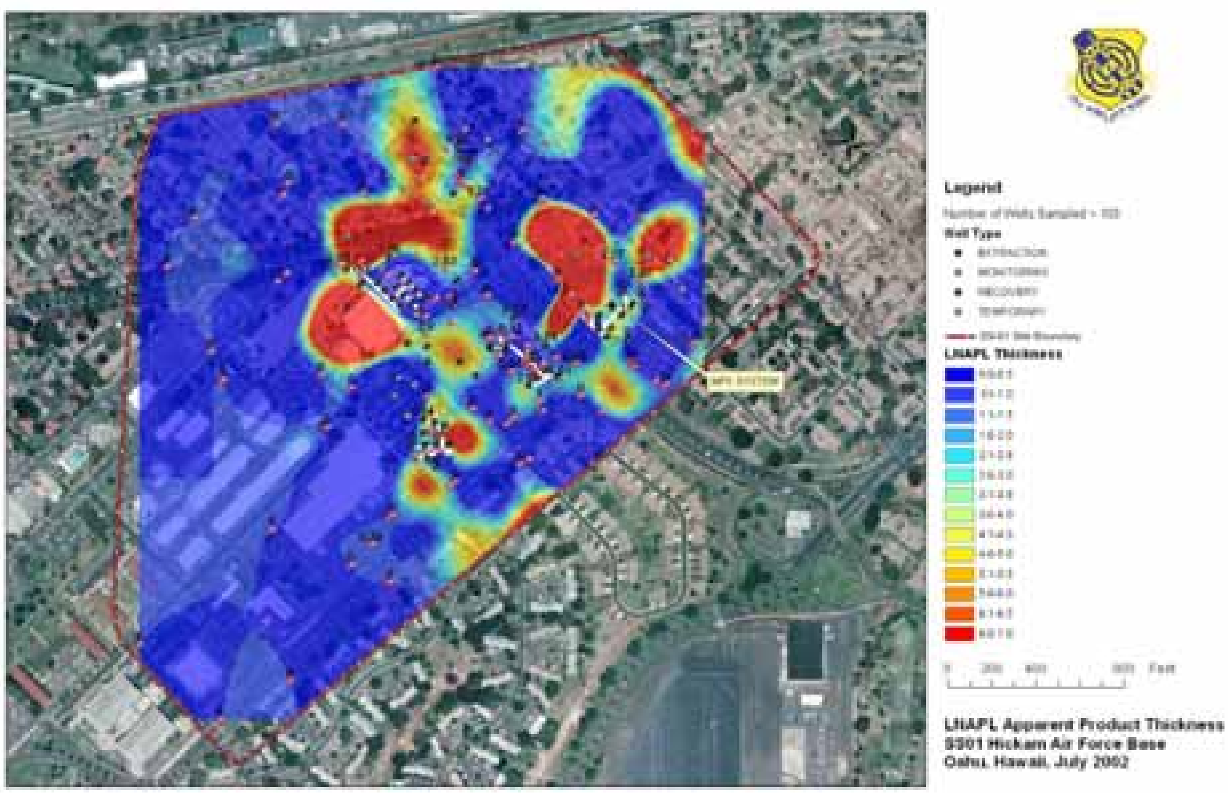


FIGURE 5 – Product Thickness July 2002

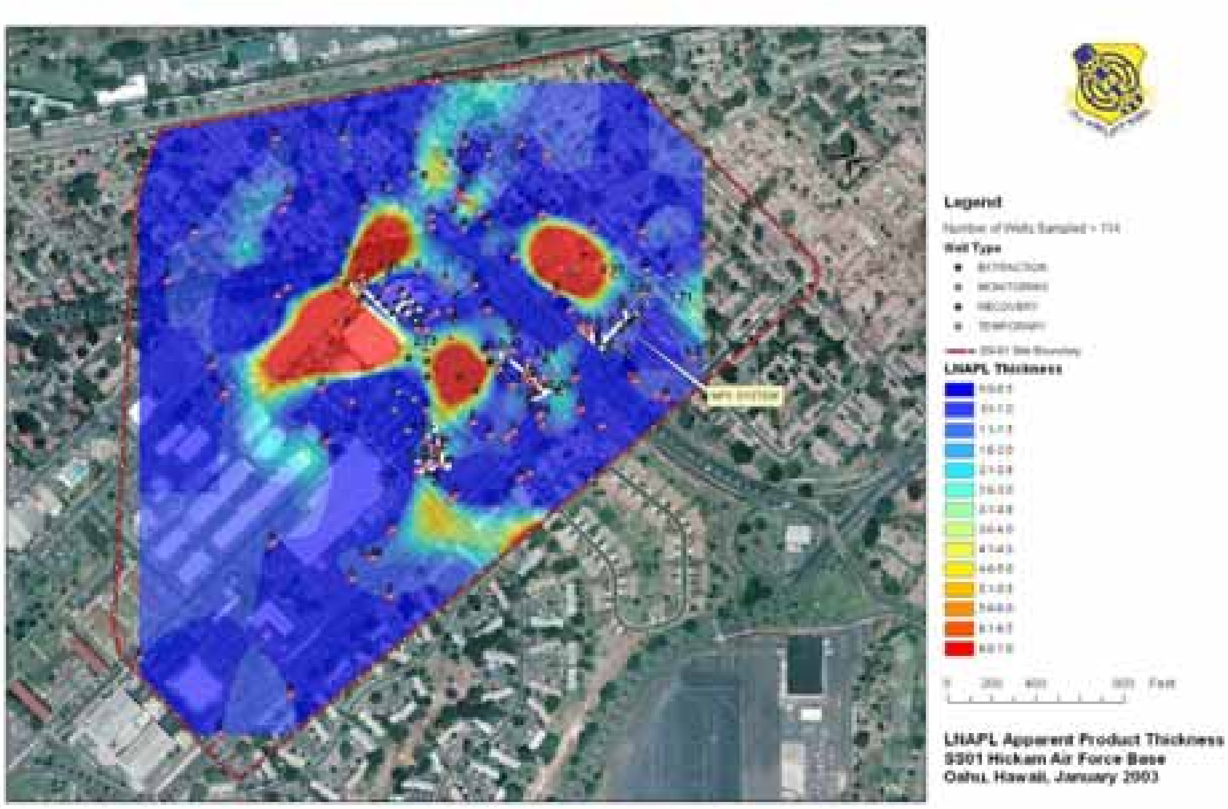


FIGURE 6 – Product Thickness January 2003

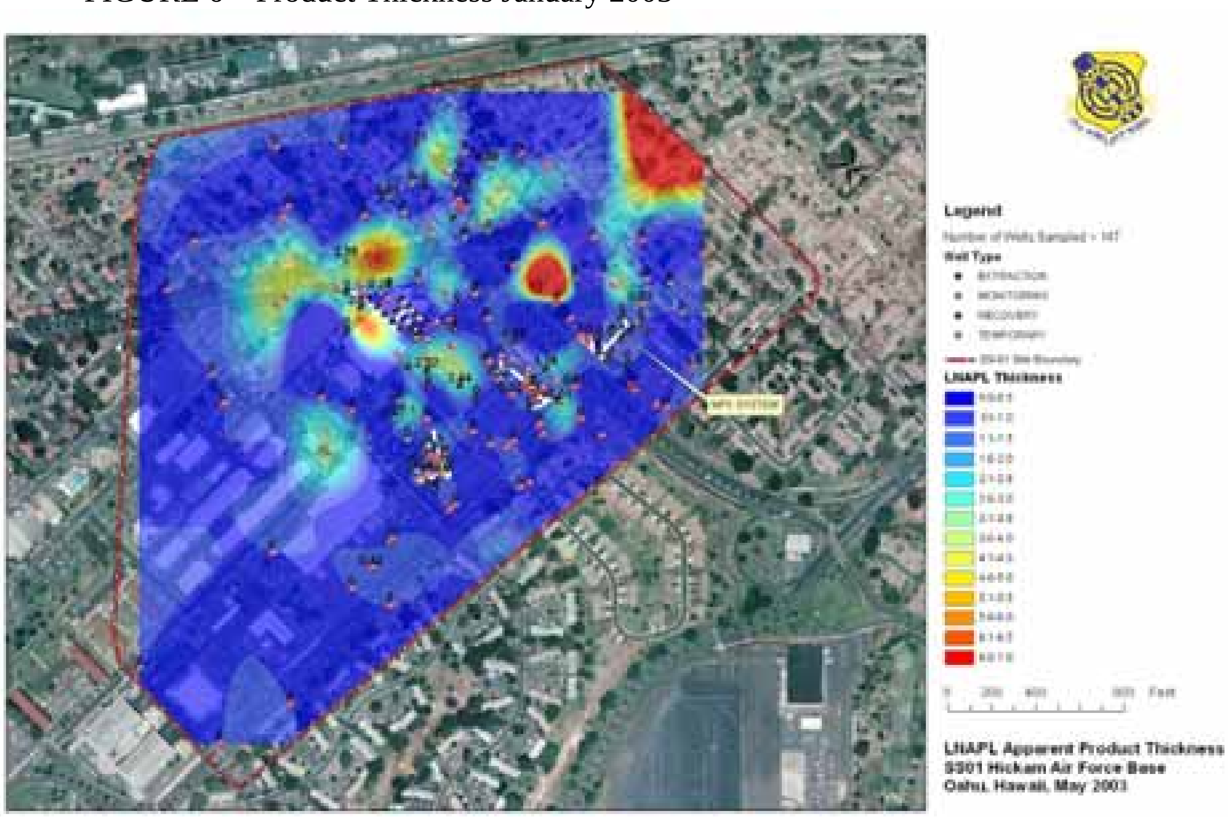


FIGURE 7 – Product Thickness May 2003

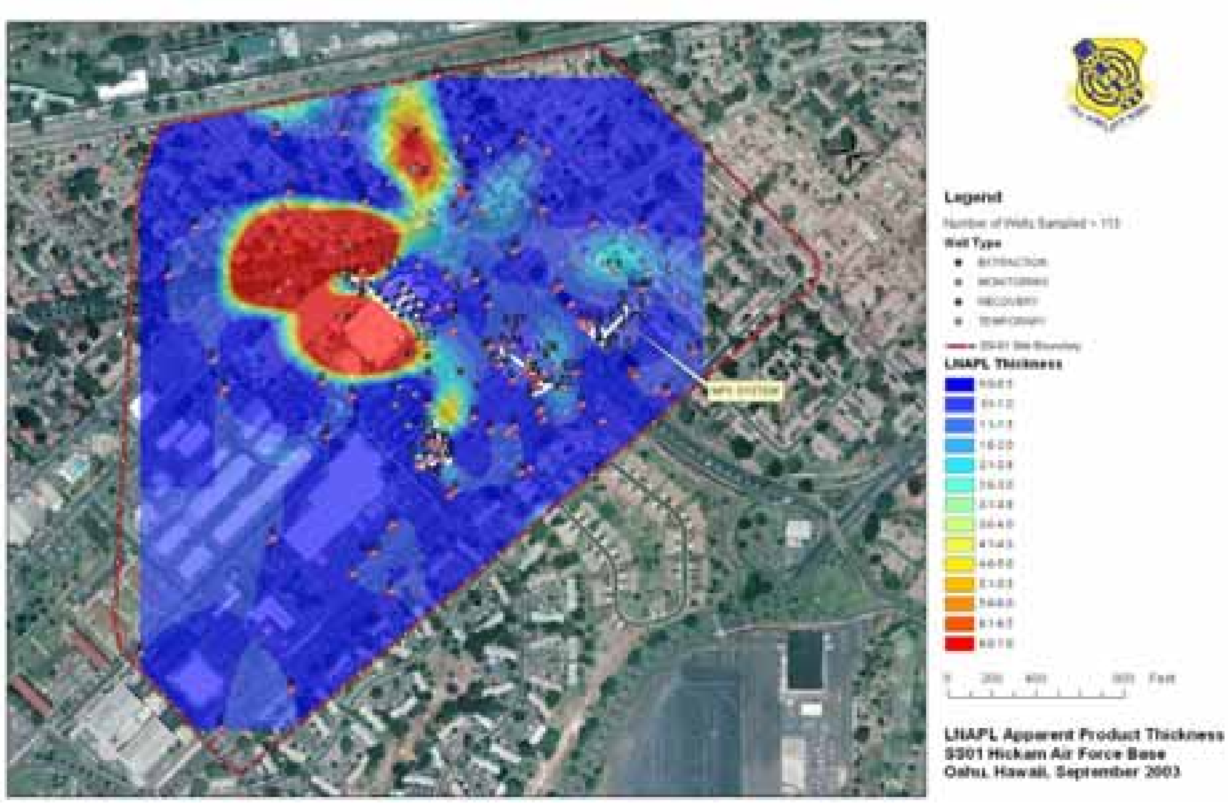


FIGURE 8 – Product Thickness September 2003

The seven images shown in Figures 2 through 8 depict the distribution of potentially recoverable free product and some measure of the relative decline in product thickness over time. The figures also show some areas where the presence of product appears to increases over time. This "product increase" artifact resulted from the installation of new monitoring wells and the "discovery" of new areas with floating product.

During discussions with stakeholders, it has been important to clarify the limitation of the interpolation methods. There were instances where stakeholders thought something was wrong because there was suddenly a new hot spot at the site. There was also an instance where a stakeholder thought it was suitable to construct a below grade swimming pool within the site just because it was not near the "red zone." The subsurface is highly heterogeneous, and there are known limitations to the accuracy of interpolations, especially those more distant from monitoring points, and this has had to be explained to certain stakeholders.

Overall, however, the ability to quickly provide interested parties with a "snapshot" of site conditions, and the general nature of the change in conditions over time has proved valuable.

## CONCLUSIONS

The ability to depict site conditions over time with the techniques described has help to effectively communicate and understanding of the site to the many stakeholders involved in the project. However, it should be noted that the use of the interpolated times-series depictions has not been an essential tool for the day to day operations of the Bioslurping systems.

For the purposes of presenting changes over time to the larger audience of stakeholders, it would seem appropriate to extrapolate the product thickness backward in time for these "new" product thickness "discoveries," since it is very likely that it has been since the original release several decades ago. This effort is currently underway.

The database is currently being updated to include data collected during the last two years. Future monitoring is being planned in a more regular fashion and at more regular intervals in an attempt to minimize variables under our control.

Efforts currently underway include depiction of soil gas concentrations throughout the site, in addition to updating floating product thicknesses and the concentration of dissolved aromatic chemicals of concern. Also under development are techniques to graphically represent the spatial degradation rates at the site using the ArcGIS model builder features now available with version 9. The objective is to use the model builder feature to manipulate raster files and produce chemical specific degradation rate maps for key compounds at the site.

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