

**Correct Implementation of the Argonne QuickSiteSM Process
for Preremedial Site Investigations**

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J.C. Burton and J.L. Walker

Environmental Research Division, Argonne National Laboratory, Argonne, Illinois

ABSTRACT: Expedited site characterization (ESC), developed by Argonne National Laboratory, is an interactive, integrated process emphasizing the use of existing data of sufficient quality, multiple complementary characterization methods, and on-site decision making to optimize environmental site investigations. The Argonne ESC is the basis for the provisional ESC standard guide of the ASTM (American Society for Testing and Materials). QuickSiteSM is the implementation package developed by Argonne to facilitate ESC of sites contaminated with hazardous wastes. At various sites, Argonne has successfully implemented QuickSiteSM and demonstrated the technical superiority of the ESC process over traditional methodologies guided by statistics and random-sampling approaches. A key feature in the success of QuickSiteSM investigations is achieving an understanding the subsurface geologic and hydrogeologic controls and processes at a site before extensive sampling efforts begin. The QuickSiteSM investigation at the Tustin Marine Corps Air Station (MCAS) in California will be used to illustrate the importance of understanding these potential controls in minimizing sampling activities and correctly predicting potential contaminant migration patterns for risk assessment.

INTRODUCTION

Argonne has developed a package of implementation tools to facilitate ESC of sites contaminated with hazardous wastes. The expertise (intellectual property, methods, software, etc.) gained by Argonne during the development and practice of ESC since 1989 (Burton et al. 1993; Burton 1994) has been consolidated into the QuickSiteSM package being commercialized by Argonne. ("SM" signifies a service mark.) The commercialization will permit organizations and companies with environmental problems, as well as those within the environmental industry, to gain access to Argonne's intellectual property without the time and expense of developing equivalent expertise and implementation tools. The ESC methodology is an interactive, integrated process emphasizing the use of existing data of sufficient quality, multiple complementary characterization methods, and on-site decision making to optimize site investigations. Throughout this paper, the terms "QuickSiteSM" and "Argonne ESC" are used interchangeably.

On March 7, 1996, President Clinton signed into law the National Technology Transfer and Advancement Act of 1995 (PL 104-113). Section 12 of this Act requires federal agencies to adopt and use, to the extent practicable, technical standards developed by voluntary, private-sector, industry-led, consensus-standard bodies and to work closely with those organizations to ensure that the standards are consistent with agency needs. If they do not use such standards, federal agencies must report their reasons to the Office of Management and Budget. As a result, the U.S. Department of Energy funded the development of a provisional ASTM standard for ESC (ASTM 1997), with the Argonne ESC as the basis.

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The QuickSiteSM process ensures cost minimization and rapid closure for site characterizations, leading to correct remedial action decisions. For sites of the U.S. Departments of Agriculture (USDA), Interior (DOI), Energy (DOE), and Defense (DOD), Argonne has successfully demonstrated the technical superiority of the QuickSiteSM process over traditional methodologies guided by statistics and random-sampling approaches. At former facilities of the USDA, QuickSiteSM reduced site characterization costs by 80-90% and time by 70-80%, compared to traditional methods (Burton 1994). DOE estimated that QuickSiteSM saved \$4 million and four years in a remedial site investigation at the Pantex Plant in Texas (Ferguson 1995).

Argonne's ESC is a flexible process that is neither site nor contaminant dependent. ESC can be tailored to fit the unique characteristics distinguishing one site from the next, in contrast to the traditional approach of making all sites conform to the same rigid, inflexible investigation regimen. QuickSiteSM has been applied successfully to remedial site investigations of landfills with multiple contaminants in the southwestern United States for the DOI, former grain storage facilities in the Midwest for the USDA, a weapons production facility in Texas for DOE, and closing and active military bases in several locations for DOD. The process can be applied both at sites that have seen little investigation and at sites subjected to many previous site characterizations without closure. In the latter case (e.g., at many DOE and DOD sites), QuickSiteSM offers a rapid solution, frequently with little additional field work.

QUICKSITESM FUNDAMENTALS

The QuickSiteSM approach to ESC emphasizes good scientific investigation principles and expert judgment. Key requirements are as follows: (1) The technical team leader has broad expertise in geosciences, and the multidisciplinary, geoscience-based team has strong field experience. (2) The team leader and team remain constant throughout the work and participate in all phases of the program, including all field activities. (3) The process uses multiple, complementary technical methodologies and emphasizes nonintrusive and minimally intrusive investigation methods. (4) High-quality data are required throughout the program for accurate decision making; screening techniques of lower quality are not used. (5) A dynamic work plan allows adjustments to the program in response to on-site data analysis and decision making.

In addition to these requirements, the QuickSiteSM approach requires an understanding of subsurface controls and processes prior to extensive contaminant sampling. The ultimate goal of the QuickSiteSM process is correct remedial-action decision making (that is, whether remediation is required and, if so, what types). To reach this kind of decision, an understanding of all subsurface controls on contaminant distribution and migration is required. The QuickSiteSM methodology differs from traditional site characterization investigations in requiring subsurface heterogeneity and control to be addressed as the first step in a characterization. This concept is addressed in detail in the ASTM standard and Argonne publications (Burton et al. 1993, 1995; Burton 1994; Burton and Meyer 1997 [in press]). Efforts by others to improve site investigations by combining dynamic work plans (an element defined by Argonne as part of its ESC) with adaptive sampling and field analytics (e.g., Robbat and Johnson 1996; Robbat 1997) fall short of the ESC defined by the ASTM standard. Such investigations make brief reference to geologic controls and then proceed to "brute-force" an answer on contaminant distribution via extensive sampling and low-cost analytics.

This approach is the antithesis of ESC; in the final analysis, the data generated are of little use in predicting long-term contaminant behavior for risk assessment, because contaminant migration is not understood.

The QuickSiteSM investigative program is divided into three phases: Phase I — Geologic and Hydrogeologic Controls, Phase II — Contaminant Distribution, and Phase III — Predictive Modeling of Contaminant Fate and Risk Assessment.

The importance of understanding subsurface heterogeneity prior to extensive contaminant sampling is illustrated by the QuickSiteSM investigation conducted by Argonne for the Naval Facilities Engineering Command, Southwest Division (here referred to as "the Navy"), at the Tustin MCAS.

QUICKSITESM AT THE TUSTIN MCAS

In 1993, the Navy requested Argonne to adapt and transfer the Argonne ESC program to accelerate remedial investigations at the Tustin MCAS in California, a helicopter training station scheduled for closure.

Site Setting and Investigative History

The Tustin MCAS is located in the central portion of Orange County, California, 25 miles southeast of central Los Angeles (Figure 1). The climate is Mediterranean, with hot, dry summers and cool winters. Average annual precipitation is 12.8 in., most of which falls between November and April. Average annual evaporation is about 60 in. The station lies at the northeastern edge of a broad coastal plain at an elevation ranging from +80 ft MSL (mean sea level) at the north corner to +45 ft MSL at the southern corner. When the property was first developed, marshy areas were backfilled and regraded. An extensive surface and subsurface drainage structure that was installed is still in use today. Three main storm drainage channels surround the station. These are the Santa Anna-Santa Fe channel along the northern boundary, the Peters Canyon Channel along the eastern boundary, and the Blasranca Channel along the southern boundary.

Before 1942, the property was part of the Irvine Ranch and was used extensively for agriculture. The facility was commissioned in 1942 as a Navy lighter-than-air (LTA) base, and two large wooden hangars were constructed to house the LTA aircraft. Since 1951, the station has been used for helicopter operations; it is now a helicopter training facility. The entire station is 1,569 acres, of which 530 acres are used for agriculture. The remainder is divided into areas for the various activities related to helicopter training.

Environmental investigations and corrective actions started at the Tustin MCAS in the mid 1980s as part of the DOD Installation Restoration Program (IRP) and in response to various federal, state, and local regulatory requirements. Sixteen suspected major contaminant source areas were investigated in preliminary assessments, and more detailed site investigations were conducted at

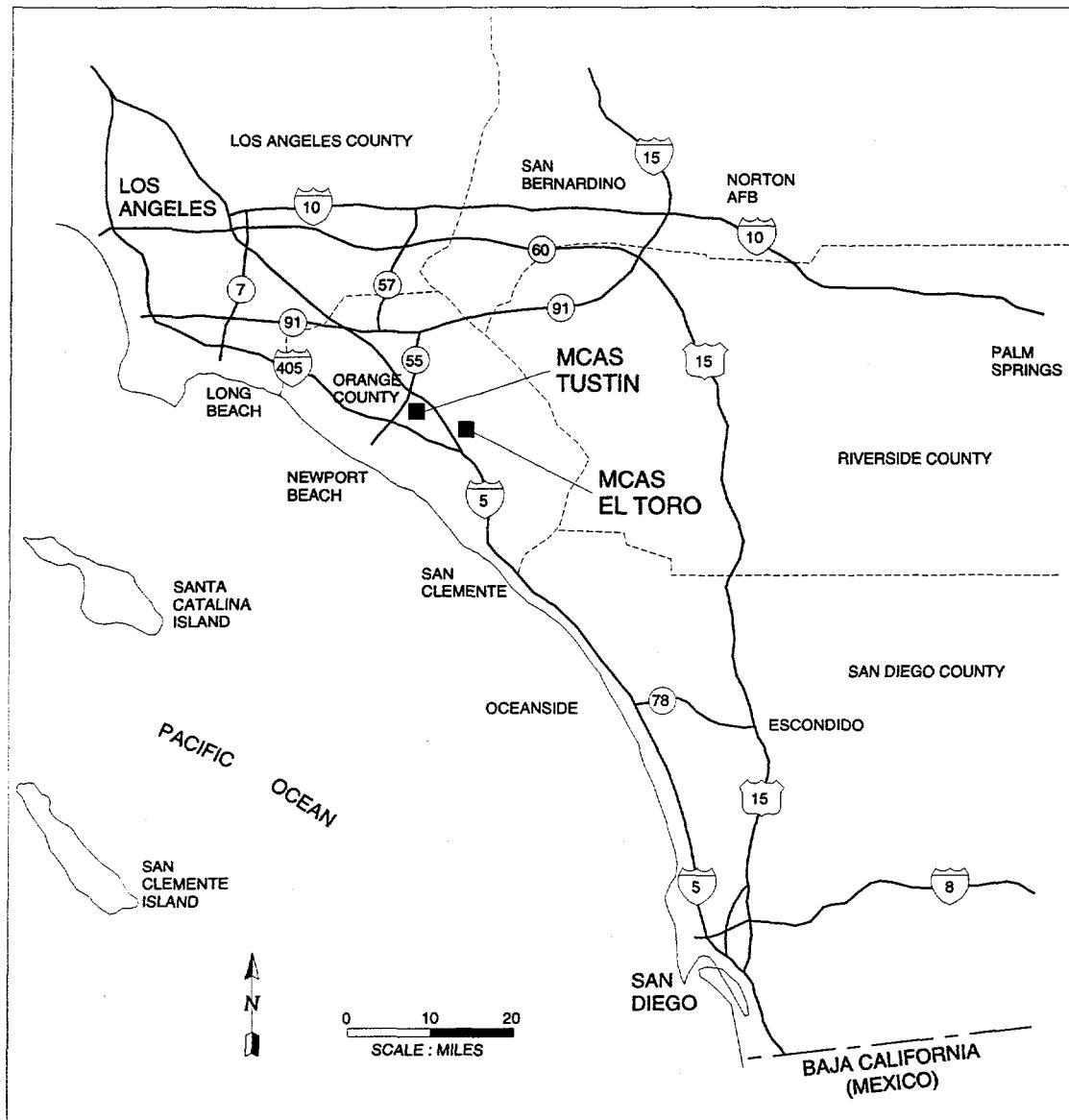


FIGURE 1 Location of the Marine Corps Air Station at Tustin, California

12 sites. All of these investigations addressed the individual sites in isolation, with no effort to integrate the findings into a sitewide model of any type. Contamination was confirmed at 11 sites in both soil and groundwater. At 2 sites, corrective actions were initiated.

In spite of these investigations, the Navy was in no position to reach closure on decision making for these individual sites, because the data had been interpreted without consideration of the known geologic and hydrogeologic heterogeneity. Therefore, nothing could be deduced from previous investigations about the effect of the heterogeneity on the migration and mobility of contaminant species. After the Tustin MCAS was slated for closure under the Base Realignment and Closure Act, the Navy requested Argonne to implement its QuickSiteSM program at Tustin to assist in reaching more rapid and cost-effective closure for the base by guiding investigations on a correct pathway for remedial decision making.

Evaluation and Use of Existing Data

The first step in the ESC and QuickSiteSM methodologies is to evaluate existing data for a site and use those data to the maximum extent possible. The QuickSiteSM review process for previous environmental investigations at the Tustin MCAS indicated that monitoring wells had been placed for a statistical sampling approach at individual sites of potential historical contamination, scattered across the base. Installation of monitoring wells was apparently based on an assumption of subsurface homogeneity and an absence of subsurface control on water movement or contaminant migration, even though no investigation of subsurface geology or hydrogeology had been initiated. The apparent model guiding previous groundwater investigations (not explicitly defined in any report) was of a continuous perched aquifer to about 50 ft depth below ground surface, underlain first by 100-150 ft of dry material and then by the major drinking water aquifer at depths exceeding 150 ft (Figure 2). The investigations based on this apparent model produced a confusing picture of the directions of water flow and potential contaminant movement. In nearly all previous reports, groundwater flow was reported to be radial from an individual location at the base, with presumed contaminant movement radially (Figure 3). Although Argonne judged the analytical data to be of good quality, they were of little use in interpreting the subsurface regime at the Tustin MCAS because of a complete lack of knowledge of aquifers and hydrogeologic controls.

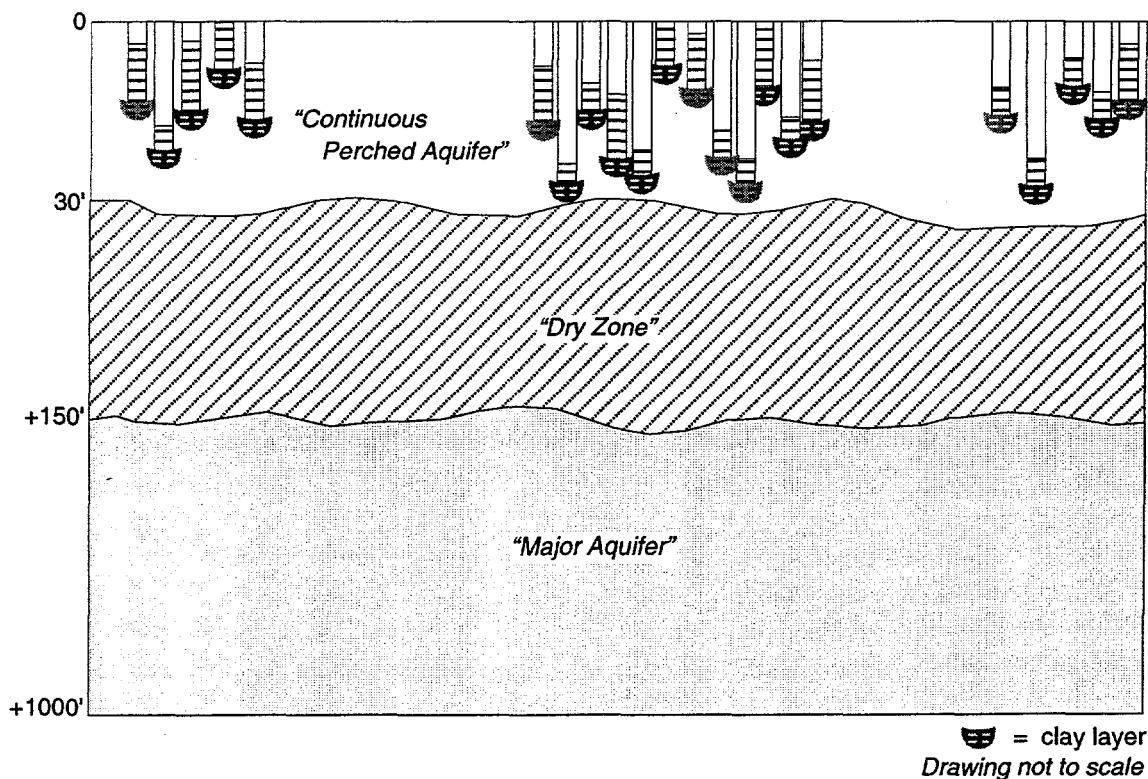


FIGURE 2 Apparent Model that Guided Previous Groundwater Investigations at the Tustin MCAS

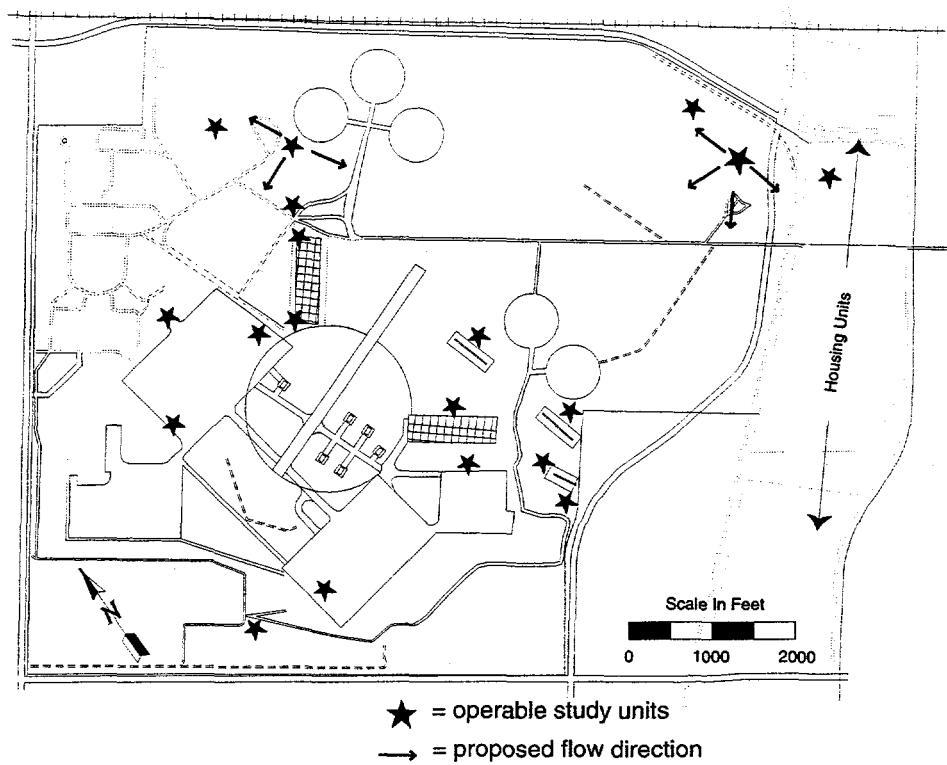


FIGURE 3 Predicted Groundwater Flow Patterns Generated by Previous Site Investigations at the Tustin MCAS

Argonne also reviewed published geologic logs and well data from various sources over a radius of about five miles from the Tustin MCAS in an effort to establish at least a regionally documented geologic/hydrogeologic framework to aid in interpreting existing data. The major significance of the local geology is the high degree of subsurface heterogeneity, both laterally and vertically, due to deposition in an active coastal setting. The waxing and waning of channel-like sand features indicated a high potential for multiple aquifers throughout the sequence, but there was no evidence of the dry zone postulated in the previous environmental investigations. Monitoring wells on the base were all less than 30 ft deep; therefore, no documentation existed below this depth to affirm or refute the hypotheses of prior contractors.

QuickSiteSM Phase I Hydrogeologic Investigation at Tustin

The primary objectives of the Argonne Phase I QuickSiteSM investigation were to determine the nature, number, and extent of the aquifer systems beneath the Tustin MCAS; to define the isolation or interconnection of these systems; and to establish a systematic sampling plan for further investigation of the base.

To meet these objectives, both intrusive and nonintrusive characterization technologies were used. The technologies selected included a drilling program using hollow-stem augers with continuous coring and HydroPunchTM groundwater sampling, cone penetrometer (CPT) pushes for calibrated

sensor measurements and groundwater sampling, surface and downhole geophysical surveys, groundwater geochemical analyses, and water level monitoring. The end product established the geologic and hydrogeologic framework and controls to support intelligent, efficient contaminant investigations.

Soil borings were drilled at strategic locations, and the cores were logged and examined in detail to establish the stratigraphic sequence, characterize lithologic variations, and identify groundwater zones. These cored holes were also used to calibrate the CPT sensors and downhole geophysical equipment for measurements of natural gamma activity and conductivity. Groundwater was sampled and analyzed for concentrations of major ions, inorganic metals, and various stable isotopes and for tritium-helium age dating. Well points were installed to augment the drilling data.

Short-term and long-term water level measurements and monitoring were carried out to assess the effects of pumping local irrigation and public water supply wells, changing barometric conditions, and local recharge. Limited pumping of well pairs was also conducted to test the local intercommunications between well pairs set at different depths, in what were interpreted as different aquifers.

Results of QuickSiteSM Phase I Geologic/Hydrogeologic Investigation

The data generated by the field techniques discussed above were integrated to delineate specific details of the geologic/hydrogeologic setting. Two aquifers were identified within the first 60 ft beneath the base, but no evidence was found for a dry zone beneath the second or deeper aquifer. A major objective of the investigation was to determine whether the aquifers are interconnected or separate, a characteristic that controls contaminant distribution and establishes potential migration patterns.

This paper uses one section line (Figure 4) from the QuickSiteSM Phase I investigation to illustrate the results of Argonne's investigations. This section incorporates borings SB17, SB04, SB08, and SB01. It extends horizontally about 9,600 ft and vertically from +50 ft MSL to -60 ft MSL. Figure 5 shows the geologic log and geologic interpretation for each drill location along this section line. The depositional facies shown on the cross section include fluvial floodplain sediments, fluvial channel sands and gravels, lake and lagoon deposits, and marine sediments. These types of sediments, however, change both laterally and vertically across the section. For example, the upper 20 ft of section in SB17 and SB04 is fluvial floodplain, but at SB08 shallow marine tidal channels alternate with the clay and silt of tidal flats. The lateral extent of these marine sediments in SB08 is limited, and they do not appear in SB04 and SB01. SB01 is also distinct in that the upper 20 ft comprise playa lake deposits. Numerous stacked channels extend through the deeper parts of the section, most notably in SB17 and SB08. These channels have a northeast-southwest depositional strike. A marine sequence occurring in SB04 and SB08 at an elevation of -35 ft MSL represents marine regression for the area. The marine regression is time transgressive, although the time range is not known.

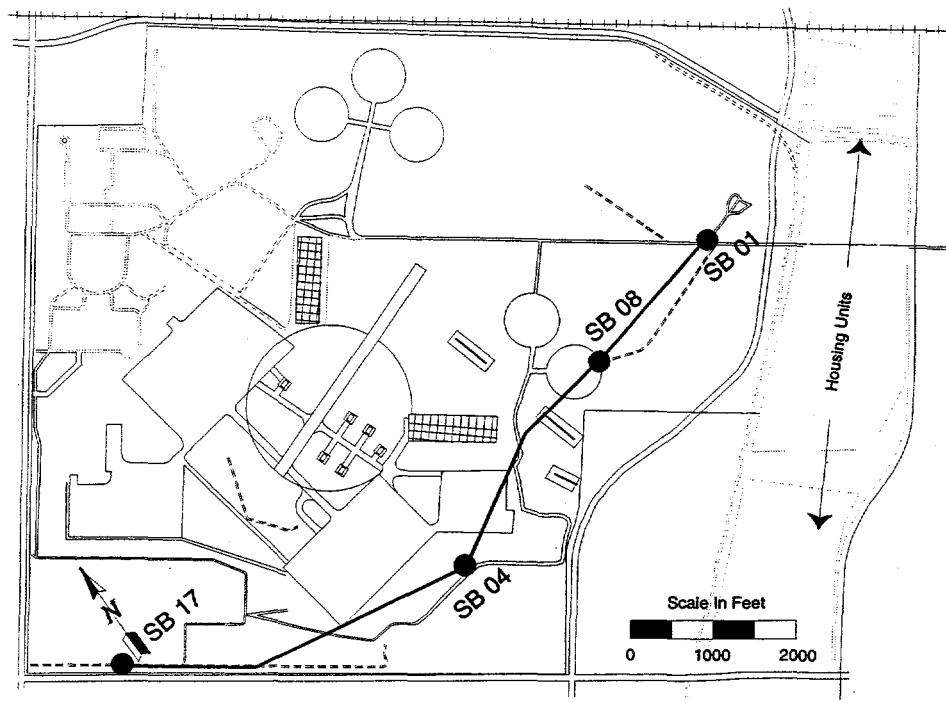


FIGURE 4 Locations of Soil Borings for Argonne's Investigation at the Tustin MCAS and of the Geologic Cross Section Discussed in the Text

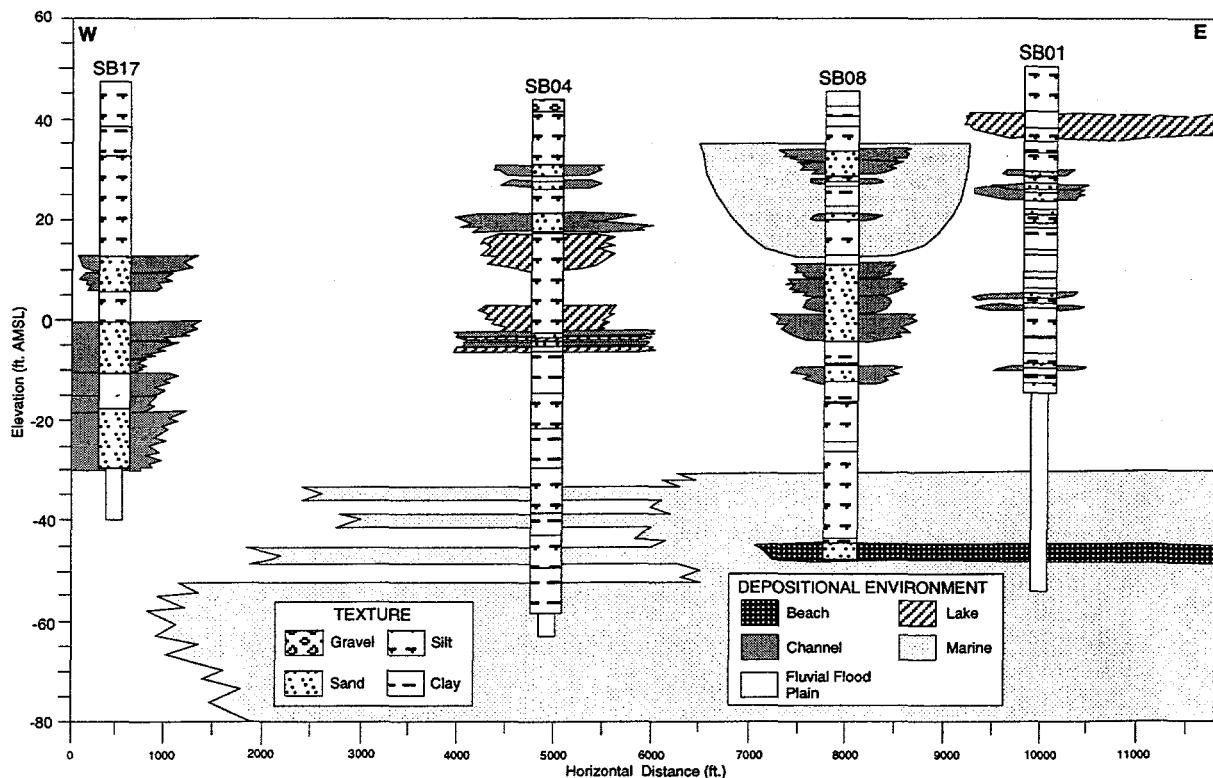


FIGURE 5 Geologic Data Generated by Argonne's Investigation at the Tustin MCAS, Illustrating Marked Lateral and Vertical Heterogeneity

The lateral extents of the various sandy, silty, and clayey units were not easily established from their geologic characteristics, and the hydrostratigraphic sequence could not be described on the basis of geology alone. Downhole geophysics and CPT sensor evaluation also did not help in the initial identification of individual groundwater zones.

In contrast, groundwater geochemistry and age dating were very successful in identifying the different aquifers. Groundwater samples collected by using the CPT or the HydroPunch™ sampler with the auger drill were analyzed for physical and chemical properties. Temperature, pH, and specific conductance were measured in the field immediately upon sample collection. Laboratory analyses were carried out for major and minor elements, major cations and anions, various stable isotopes, and tritium-helium age dating.

The groundwater samples exhibited a broad range of major ion compositions. Elevated concentrations of sulfate, calcium, chloride, and nitrate were found in the shallower groundwaters in association with the agricultural land use across the base and in the Tustin area in general. The profiles of the concentrations of sulfate and chloride are shown in Figure 6 along the geologic cross section. Significant differences exist in the relative and absolute concentrations. For example, in the uppermost groundwater, the sulfate concentration ranges from 840 to 21,000 ppm, whereas in the deeper groundwater, the sulfate concentration ranges from 120 to 690 ppm.

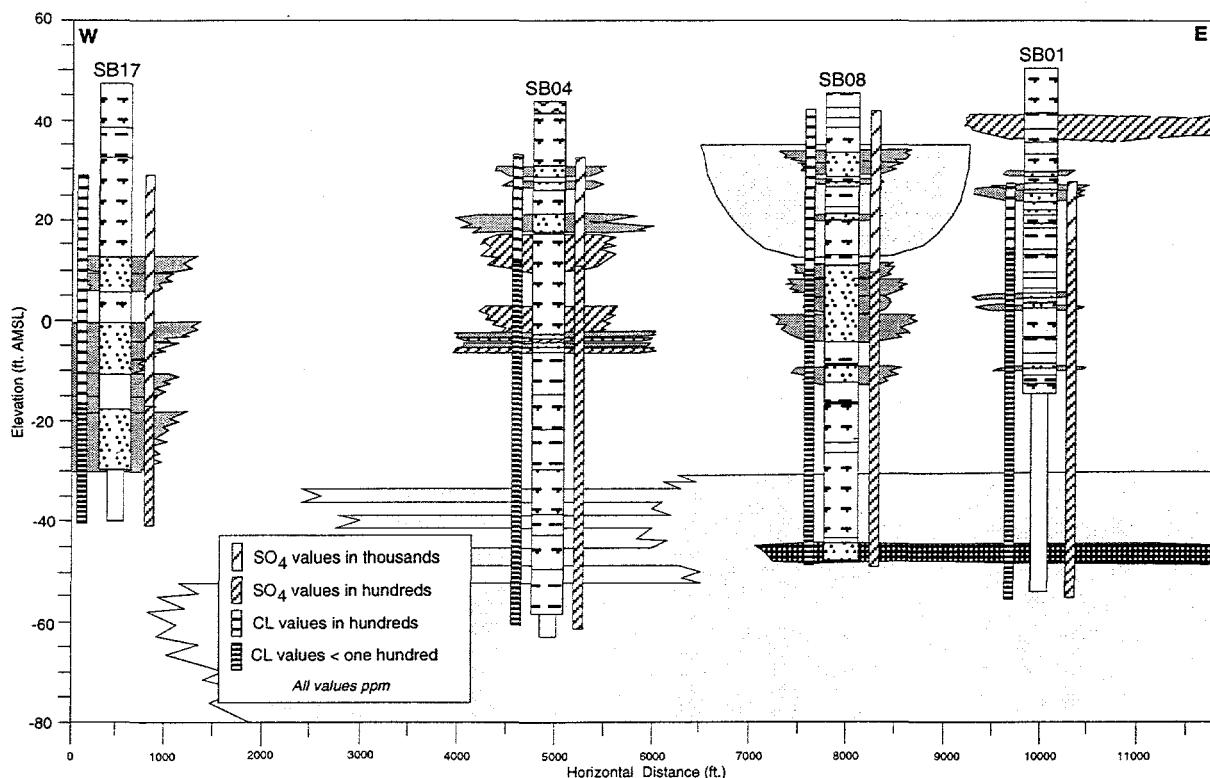


FIGURE 6 Major Element Geochemistry Results Generated by Argonne's Investigation at the Tustin MCAS, Indicating Two Different Groundwater Zones

On the basis of the combined relative and absolute concentrations, the groundwater samples for the base were divided into two groups distinguished by high concentrations in groundwater collected at 5-13 ft MSL and low concentrations in samples from depths below 5 ft MSL, except in SB17. These differences in chemical concentrations in the shallow and deeper groundwaters could indicate hydraulic separation between aquifers or two zones within a single aquifer. Table 1 summarizes the geochemical characteristics of the different groundwater zones.

To further discriminate the groundwaters, apparent ages were estimated by using tritium-helium isotope techniques. Table 2 summarizes the results of the age dating relative to the different aquifers. The results in the shallow groundwater gave ages of 8-36 years, in contrast to >60 years in the deeper groundwater. This age difference is consistent with the ionic chemistry, as shown in Figure 7, and it further confirms the inferred hydraulic separation of a shallow aquifer from a deeper aquifer. This demonstration that the aquifers are separate, coupled with data indicating contamination only in the shallow water, was a major breakthrough toward understanding the hydrogeology and establishing a Phase II QuickSiteSM program for contaminant sampling.

Downhole geophysical measurements showed that conductivity was related to the total dissolved salt concentration and, further, identified the shallow aquifer (Figure 8). As a result, calibrated CPT conductivity and other sensor measurements could be used to locate the shallow aquifer, supplementing the major element and isotope data and substantiating the presence and isolation of the two aquifers. Use of the CPT to identify the shallow aquifer provided a straightforward investigative approach for delineating aquifer boundaries for contaminant sampling in subsequent Phase II investigations.

Long-term water level monitoring of the two aquifers also confirmed their hydraulic separation. Figure 9 shows the potentiometric surface for the shallow aquifer, with its distinct flow to the south. This result contrasts with a flat elevation for the potentiometric surface of the lower aquifer (Argonne 1995).

To summarize, the Phase I QuickSiteSM investigation for the Tustin MCAS demonstrated that the subsurface is geologically complex, with two aquifers crossing the various geologic units and behaving independently of visually documented geologic changes. No geologic units could be readily used to delineate boundaries between the two aquifers. However, major element and isotope data for groundwater samples, as well as downhole geophysical measurements, indicated isolation of the two aquifer systems. Selected pump tests further confirmed this observation. Sampling of the aquifers indicated that contaminants were limited to the shallow aquifer. The flow direction of this shallow aquifer is to the south, contrary to the radial flow directions proposed in the previous environmental investigations. In addition, no dry zone is present beneath the base, as proposed in these previous investigations.

TABLE 1 Summary of Groundwater Elevations and Geochemical Characteristics for the Aquifers at the Tustin MCAS

| Aquifer | Lithologic Units | Aquifer Top | | | Aquifer Bottom | | | Geochemical Characteristics | | |
|---------|---|------------------------------|--------------------|------------------------------|--------------------|---|-----------------------|-----------------------------|--|--|
| | | Depth (ft BGS ^a) | Elevation (ft MSL) | Depth (ft BGS ^a) | Elevation (ft MSL) | Ionic Concentration (mg/L) | Age (yr) ^b | Water Levels (ft MSL) | | |
| Shallow | Alternating sand, clay, and silts; fluvial channel; and lake deposits with some marine deposits | 15-30 | 30-45 | 65 to 33 to 77 (west) | +3 to -20 (west) | High TDS: ^c SO ₄ ²⁻ (380-21,000) Cl ⁻ (71-12,000) NO ₃ ⁻ (0-360) Ca ²⁺ (190-730) | 8-36 | 37-60 | | |
| Deep | Alternating sand, clay, and silts; fluvial channel, beach, and marine deposits | >35 to >90 (west) | Below +13 to -20 | >110 | Below -60 | Low TDS: SO ₄ ²⁻ (81-620) Cl ⁻ (17-340) NO ₃ ⁻ (0-100) Ca ²⁺ (23-670) | >60 | 45-47 or 27 | | |

^a BGS, below ground surface.

^b Tritium-helium isotopic age.

^c TDS, total dissolved solids.

TABLE 2 Tritium/Helium Ratio and Estimated Age of Groundwater in Temporary Monitoring Wells SB40 through SB61 in March 1995^a

| Aquifer | Well | Total Helium (10 ⁻⁸ cm ³ /g) | Neon (10 ⁻⁸ cm ³ /g) | $\delta^3\text{He}$ (%) | Tritium (TU) ^b | Age (yr) ^c |
|---------|------|---|---|----------------------------|------------------------------|--------------------------|
| Shallow | SB40 | 9.10 | 26.62 | 4.5 | 5.6±0.3 | 25.0±0.8 |
| | SB41 | 5.50 | 20.01 | 11.4 | 3.8±0.4 | 23.3±0.8 |
| | SB43 | 6.13 | 21.59 | 27.0 | 9.4±0.4 | 17.2±0.4 |
| | SB46 | 5.89 | 21.58 | 43.0 | 5.2±0.3 | 27.5±0.9 |
| | SB47 | 6.43 | 21.45 | 14.9 | 11.9±4 | 13.6±4 |
| | SB50 | 5.69 | 20.72 | 5.8 | 3.3±0.7 | 19.9±2 |
| | SB52 | 4.75 | 19.90 | 17.3 | 8.6±0.4 | 8.2±0.3 |
| | SB55 | 8.46 | 19.95 | 67.2 | 13.8±0.7 | 28.0±1 |
| | SB57 | 5.25 | 21.49 | 4.8 | 0.3±0.3 | 36.0±16 |
| | SB61 | 5.86 | 19.98 | 15.0 | 12.4±0.5 | 12.1±0.4 |
| Deep | SB49 | 23.18 | 23.21 | 22.6 | 0.5±0.5 | >60.0 |
| | SB51 | 6.74 | 19.80 | 0.0 | 0.0±0.3 | >60.0 |
| | SB53 | 7.32 | 23.37 | 5.3 | 0.2±0.2 | >60.0 |
| | SB54 | 9.52 | 29.95 | 5.3 | 0.5±0.3 | 61.0±2 |
| | SB56 | 14.03 | 29.51 | 59.6 | 1.6±0.3 | 74.0±3 |
| | SB60 | 10.93 | 23.24 | 28.5 | 0.0±0.2 | >60.0 |

$$^a \delta^3\text{He} = \left[\frac{\left(^3\text{He}/^4\text{He} \right)_{\text{sample}}}{\left(^3\text{He}/^4\text{He} \right)_{\text{air}}} - 1 \right] \times 100.$$

^b TU, tritium units.

^c Tritium-helium isotopic age.

Sampling Program Delineated by QuickSiteSM Phase I Hydrogeologic Investigation

The results of the Phase I QuickSiteSM hydrogeologic investigation established the foundation and constraints for the Phase II investigation of contaminant distribution. The constraints were as follows:

- The Phase II investigation could be limited to the upper aquifer.
- The thickness and depth of the upper aquifer at different operable units could be established rapidly and cost effectively by using geochemistry (with CPT sampling) and CPT resistivity data. Monitoring wells were not needed.
- The shallow aquifer could be sampled for contaminants with the CPT.

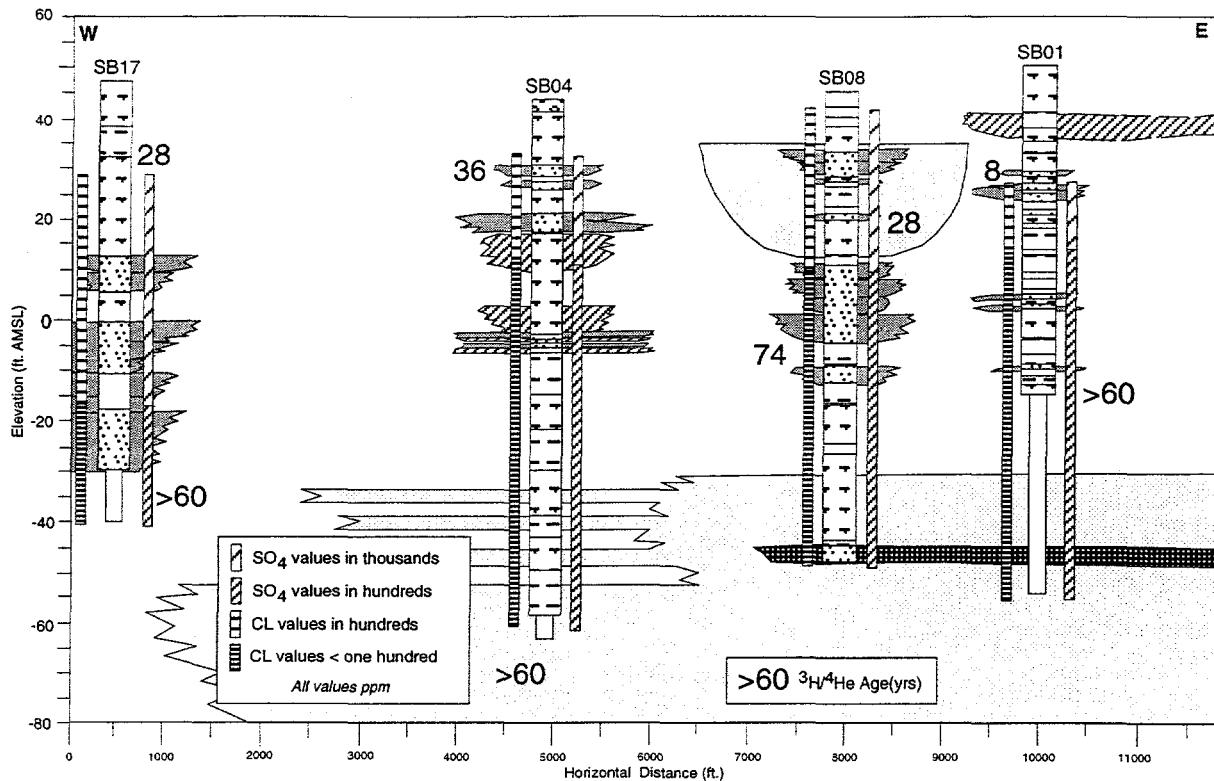


FIGURE 7 Tritium-Helium Age Dating Results Generated by Argonne's Investigation at the Tustin MCAS, Supporting the Concept of Multiple Aquifers

- Monitoring wells for the additional aquifer characterization required for modeling should be placed only in the upper aquifer at the different sampling units, because of the geologic heterogeneity beneath the base.
- The geometry of the contaminant plume must be used to guide the scale and extent of vadose zone sampling, because of the heterogeneity discussed above.

CONCLUSIONS

The Argonne ESC methodology is an interactive, integrated process emphasizing the use of existing data of sufficient quality, multiple complementary characterization methods, and on-site decision making to optimize environmental site investigations and lead to correct remedial action decisions. The Argonne ESC is the basis for the ASTM's provisional ESC standard guide. QuickSiteSM is the implementation package developed by Argonne to facilitate ESC of sites contaminated with hazardous wastes. Throughout this paper, the terms "QuickSiteSM," and "Argonne ESC" were used interchangeably because the two are identical in Argonne investigations.

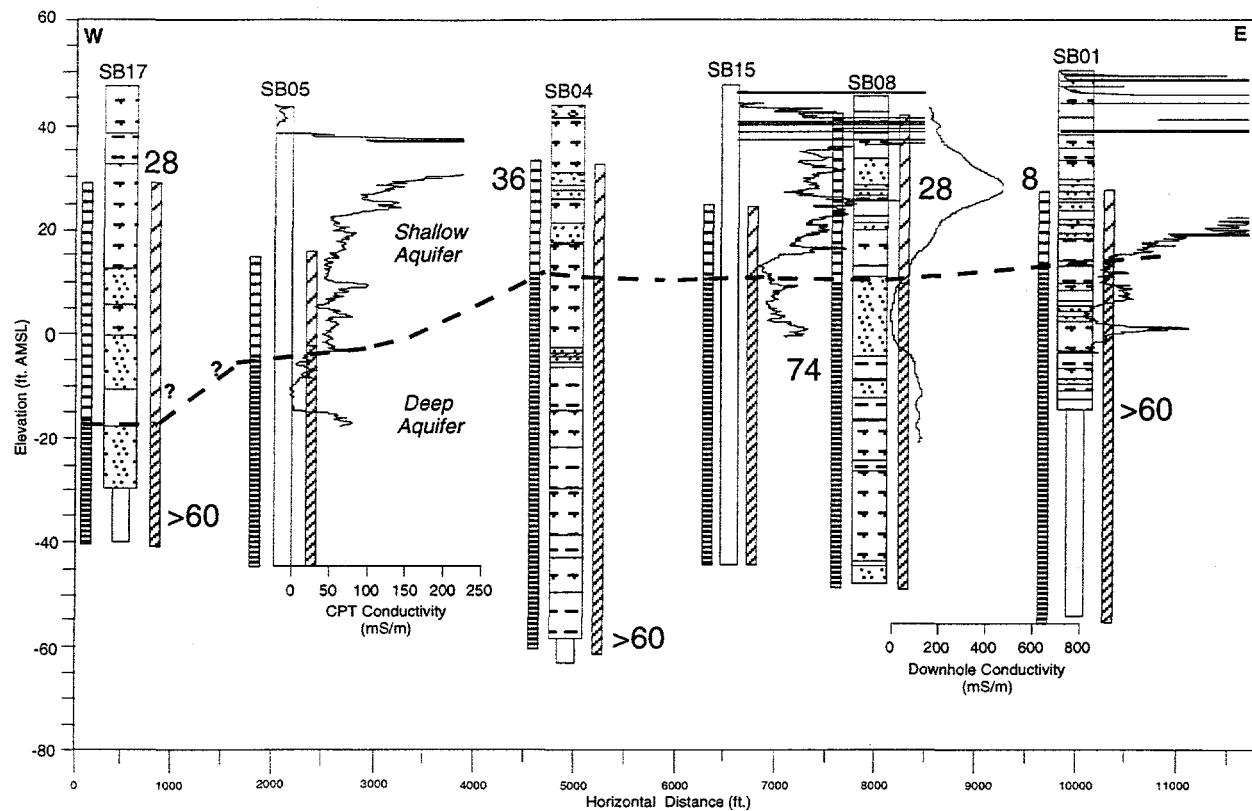


FIGURE 8 Geophysical, Geochemical, and Age Dating Results Generated by Argonne's Investigation at the Tustin MCAS, Indicating the Presence of at Least Two Aquifers with No Evidence of Mixing

At various sites, Argonne has successfully implemented QuickSiteSM and demonstrated the technical superiority of the ESC process over traditional methodologies guided by statistics and random-sampling approaches. A key feature to the success of QuickSiteSM investigations is understanding the subsurface geologic and hydrogeologic controls and processes prior to extensive contaminant sampling efforts at a site. The QuickSiteSM investigation at the Tustin MCAS in California illustrates the importance of understanding these subsurface controls in optimizing and minimizing contaminant sampling activities for generating data that will correctly predict potential contaminant migration patterns for risk assessment.

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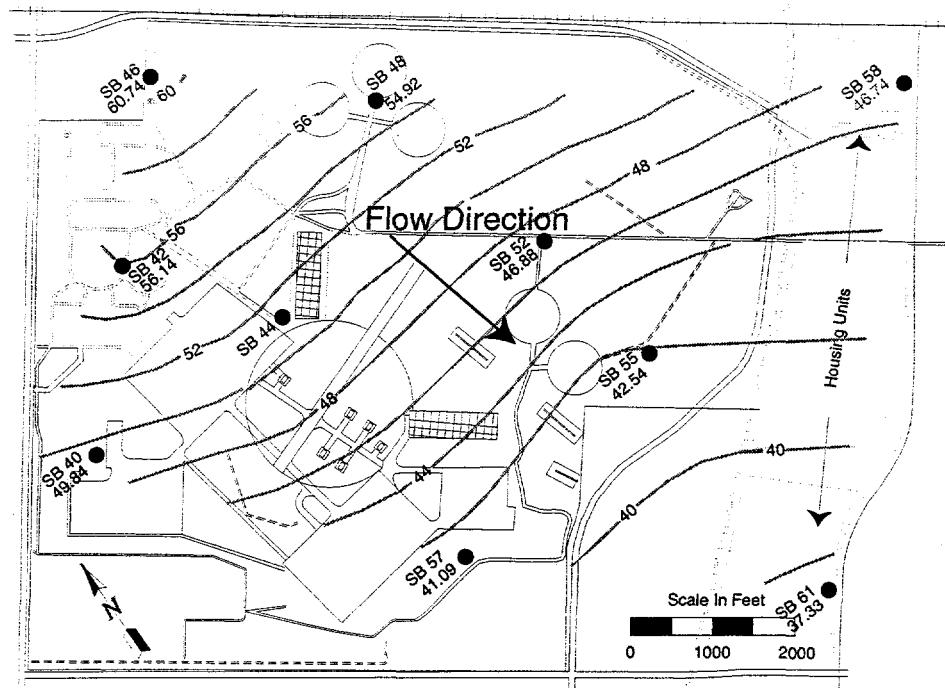


FIGURE 9 The Flow Direction of the Shallow Aquifer at the Tustin MCAS, the Aquifer Most Likely to Carry Contamination

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Jacqueline C. Burton, Ph.D.

Jacqueline C. Burton received a Ph.D. in geology from the University of Tennessee in 1978. She worked for Exxon for eight years in minerals research following completion of her Ph.D. During her employment with Exxon, Dr. Burton led numerous research programs emphasizing the integration of geology, geochemistry, and geophysics in understanding the origin and exploration strategy for uranium and epithermal gold deposits. Dr. Burton joined Argonne National Laboratory in 1986 to develop environmental programs emphasizing the integration and application of all geological disciplines to remedial characterization and design. She is the developer of the Expedited Site Characterization Program and QuickSiteSM methodology at Argonne National Laboratory and leader of the Applied Geosciences and Environmental Management Section, Environmental Research Division.

John L. Walker, Ph.D.

John L. Walker received his Ph.D. in 1964 in geology and geochemistry at Imperial College of Science and Technology, London. He has spent a large part of his career as a consultant to major mining companies, government agencies, and the United Nations. He has been in the forefront in the development and application of field geochemical techniques to advance geologic and hydrogeologic studies. During the past seven years at Argonne National Laboratory he has led a number of Expedited Site Characterization and QuickSiteSM investigations where he has applied his extensive geological knowledge to the integration and interpretation of geology, geochemistry, and geophysics.