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GROUNDWATER CLEAN-UP: THE SAVANNAH RIVER SITE EXPERIENCE (U)

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Abstract

A full scale pump and treat groundwater remediation program which addresses a large plume of volatile organics has been ongoing at the Savannah River Site since 1985. The system has recovered over 100,000 kilograms of solvent and is containing the center of the plume. While overall protection is being achieved, reducing the concentration of contaminants to very low levels is problematic.

INTRODUCTION

Protection of the Earth's valuable resources is of great concern to the public in relation to safety and health. One of the resources receiving extensive attention is groundwater. Past waste disposal practices have impacted groundwater quality in many locations throughout the nation. In response, the Federal Government has passed legislation to protect and restore the environment. In many cases, application of this legislation has lead to strict clean-up standards. Savannah River Site (SRS) experiences suggest that meeting clean-up standards is a challenge in light of technical realities.

The purpose of this paper is to describe the corrective action program that is addressing a plume of volatile organics beneath the A/M Area of the SRS. The history and status of the program, costs, measures of performance, lessons learned, and challenges faced are presented.

HISTORY

SRS, which has been in operation since 1953, is a 780 square kilometer reservation that produces special isotopes for the national defense program (Figure 1). As a result of past waste disposal practices, groundwater at several locations within the Site has become contaminated with solvents, metals and radionuclides. In 1981, the groundwater located beneath the Site's fuel and target fabrication facility (M-Area, Figure 2) was found to be contaminated with volatile organic degreasing solvents, primarily trichloroethylene (TCE) and tetrachloroethylene (PCE). The sources of contamination were a settling basin and sewer line (now closed) (1) , a solvent storage area, and other release points located near the fabrication facility. In response, SRS voluntarily initiated a groundwater corrective action program, including an extensive groundwater monitoring system. Groundwater remediation in the A/M Area began in 1982 with the startup of an experimental air stripper. To date over three hundred monitoring wells have been installed to characterize the plume.

Full scale groundwater recovery with treatment by air stripping has been ongoing in the A/M Area since 1985. The remedial system comprises eleven recovery wells and an air stripper. Since the beginning of remediation over 114,000 kilograms of degreaser solvents have been removed from over 4,920,000,000 liters of groundwater. The system is effectively reducing the mass in the central plume region, and is serving to contain the contamination present there. SRS has realized through continuing evaluations that the current system will require augmentation to address other areas as discussed below.

Ongoing investigations have determined that a significant amount of solvent remains in the vadose zone. More recently, a separate phase of solvents was detected in a monitoring well located near the closed settling basin. Both occurrences continue to influence the amount of solvent in the aqueous phase. SRS has completed a program to more fully characterize the vadose zone beneath source areas. Contamination in the vadose zone has been and will be addressed by vacuum extraction. The presence of dense non-aqueous phase liquids (DNAPLs) is the focus of a current characterization effort. DNAPLs represent an even greater challenge in terms of characterization and remediation because they can be more difficult to locate.

SRS has completed some enhancements and plans to expand the corrective action program. The recovery rate of the current system was recently increased. In 1989, packing in the full scale air stripper was replaced, the system was tested (2) and flow from the recovery wells to the air stripper was increased from 1500 to 1900 liters per minute, a 25% increase. Additional recovery capacity has been installed; SRS has installed a recovery well and relocated a prototype air stripper to a source area near the northern Site boundary, outside the influence of the original recovery system.

In addition to relocating the prototype air stripper, SRS also plans to install additional groundwater recovery capacity near the northern Site boundary, and in a dilute plume region in the south of the A/M Area, and downgradient from the major sources of contamination. SRS has also initiated projects that will address contamination remaining in the vadose zone. A 1987 pilot system recovered over 450 kilograms from the vadose zone in a three week period. More recently experimental horizontal well systems, tested by the Savannah River Laboratory under the auspices of the Office of Technology Development, have recovered over 7200 kilograms from the subsurface through the use of vacuum extraction and in situ air stripping of the aquifer near a source area (the closed sewer line). Based on the success of these efforts, SRS plans to pursue the installation of additional systems that will address source sites.

The remediation program at SRS is providing knowledge and experience regarding how well clean-up programs work. SRS is conducting extensive risk assessments associated with contaminated sites. A better understanding of the limits of remediation, combined with the amount of risk posed by the impact, should eventually lead to improved decisions regarding clean-up goals.

PROGRAM COSTS

The original 11 recovery well and air stripping system cost $4,800,000 to design and construct. The system costs approximately $100,000 per year to operate and maintain. The system has performed very well with an operating utility of greater than 95%. The major maintenance concern is lightning strikes.

Other costs associated with the corrective action program are the expenses of groundwater monitoring, data interpretation and management, modelling, reporting, and continuing investigations and project development.

REMEDIATION REQUIREMENTS, GOALS

The A/M-Area Groundwater Corrective Action Program is permitted under the post closure requirements of the Resource Conservation and Recovery Act (RCRA). The facility became fully permitted in September 1987.

Exact conditions for the program are stated in the Site's hazardous waste permit (3), and in the associated permit application (4). Goals and standards are summarized below.

The initial goal of the program was to remediate the most contaminated groundwater by maximizing mass removal from the center of the plume. It has been the SRS position that the remediation would take place in stages. The corrective action program (4) calls for groundwater remediation to be continued until "...the groundwater concentration ... no longer poses a threat to human health and the environment..." However, concentration limits listed in the permit and permit application for the primary constituents of concern are very near analytical detection limits. Although concentrations of a few other constituents are above the limits described in the permit and associated application they do not exceed these limits in the influent stream to the air stripper. These other constituents are of limited extent, and are detected in only a few monitoring wells near the closed settling basin.

Although the program is largely driven by RCRA, SRS is also in the process of integrating the requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). It is expected that the eventual integration of CERCLA requirements into the groundwater program will encourage the use of risk and cost benefit analyses to determine the degree and need of future enhancements to the program.

MEASURES OF PERFORMANCE

RCRA requires that the effectiveness of the permitted corrective actions be reported. SRS supplies quarterly groundwater reports to South Carolina and the EPA. SRS and South Carolina have agreed upon methods to be used to demonstrate the effectiveness of the A/M Area Groundwater Corrective Action Program. Three methods used are: Zone of Capture Analysis, Mass Removal, and Changes in Inventory.

Zone of Capture

Zone of Capture is defined as the volume element of groundwater which will enter a pumping well during a given time period. A 30-year Zone of Capture Analysis for the original recovery well system showed that the most concentrated portion (about one-third of the total plume area) as currently outlined by a 5 part per billion isoconcentration contour will be recovered in 30 years (Figure 3). The most concentrated portion of the plume includes concentrations greater than 1,000 ppb. In addition, unaffected groundwater from upgradient of the northern plume boundary will enter the recovery wells within the 30-year period. The Zone of Capture Analysis indicated good vertical containment at the center of the plume as well.

The Zone of Capture Analysis also shows that more dilute regions of the plume are outside the influence of the recovery system. The original system was not designed to address these areas. However, SRS has initiated modifications to the corrective action program which will enhance the effectiveness of the program relative to lesser impacts. As stated previously a second remediation system has been installed. Other enhancements are forthcoming as described above.

Mass Removal

One measure of effectiveness is the amount of contamination removed by the corrective action system. A primary goal of the program has been to maximize contaminant recovery. The amount of mass removed is calculated by performing a mass balance across the air stripper. As stated above, over 114,000 kilograms of solvent have been removed since startup of the system. This value compares favorably with the original estimate of 225,000 kilograms of solvent in the groundwater. The original mass of contamination in the groundwater was calculated from isoconcentration contour maps. A method for calculating the inventory in the groundwater is described below.

Changes in Inventory

Inventory changes calculated from monitoring wells is yet another way to determine the effectiveness of the remediation system. In this method a concentration value from a monitoring well is applied to a discrete area. A mass of contamination within that area is calculated and added to values associated with other wells (and areas) from the same sampling period. Current values for the amount of mass can then be compared to those calculated from prior periods. Although the method is somewhat arbitrary, if applied in a consistent manner does provided useful results. As provided above the amount of solvent removed by the recovery system between 1985 and 1990 was greater than 100,000 kilograms, however, the net difference as shown by the inventory method for the same period was only about 42,000 kilograms.

An evaluation of the data suggested that the difference between the mass balance approach and the inventory approach could be explained by the influence of residual contamination in the vadose zone and the DNAPL beneath the closed basin. Both occurrences continue to act as sources of contamination to the groundwater. The difference between the two methods was part of the basis for the initiation of a vadose remediation program at SRS. As discussed above, a vadose zone characterization program has been completed at source areas and remediation systems for the vadose zone are being designed. In addition, a program to more fully assess the occurrence of DNAPLs is underway.

Other Tools

As a guide by which to compare performance SRS constructed a theoretical mass removal curve for a thirty year period (Figure 4). The curve is a simple exponential decay which assumed an original starting mass of about 225,000 kilograms and assumes that 99% of the mass will be removed in thirty years. (The theoretical curve is meant to be a guide and does not represent a clean-up goal.) The solvent mass remaining in the vadose zone, and the mass associated with the DNAPL is not accounted for in the original mass estimate. Also shown in Figure 4 is a plot of the actual amount of mass removed. Although the deviation is small, it can be seen that the two curves are separating. The inflection in the plotted data is related to the 25% increase in the recovery rate which took place in 1990. While there has been incremental benefit from increasing the flow, the actual mass removal curve will become asymptotic above the theoretical curve.

A simple plot of concentrations versus time is shown in Figure 5. A smooth curve Throughthe data points has been extrapolated to thirty years. The concentration values plotted represent the concentration of the influent to the air stripper at a given point in time. The initial concentration of contaminants in the influent was about 50,000 ppb. The concentration in the influent has decreased to about 10,000 - 15,000 ppb over the 6 years of operation.

Figures 4 and 5 illustrate that the easy part of the clean-up is the early part. The data presented indicates the natural limits of the current recovery system. However, neither curve should not be used as an indictment of the pump and treat method.

CONCLUSIONS

SRS has developed a groundwater program intended to detect, characterize and remediate groundwater impacts. When evaluated against original goals the pump and treat system has been successful; a large amount of mass has been removed, and significant progress has been made regarding plume containment. However, low concentrations are probably not achievable through a standard approach. Although new technologies offer hope, they must still overcome the difficulties presented by a complex hydrogeologic system. In addition, other issues such as vadose zone contamination and uncertainties associated with DNAPLs need to be addressed. It is imperative that the sources of contamination be addressed to prevent further degradation of the groundwater resource. However, the limits of any type of remediation must be faced such that reasonable clean-up targets are chosen.

DOE and WSRC are committed to restoration while assessing risk and continuing to search for less expensive methods. Risk based approaches to clean-up may lead to more logically deduced clean-up goals and standards. It is essential that the benefit of such efforts be assessed such that resources are applied wisely.

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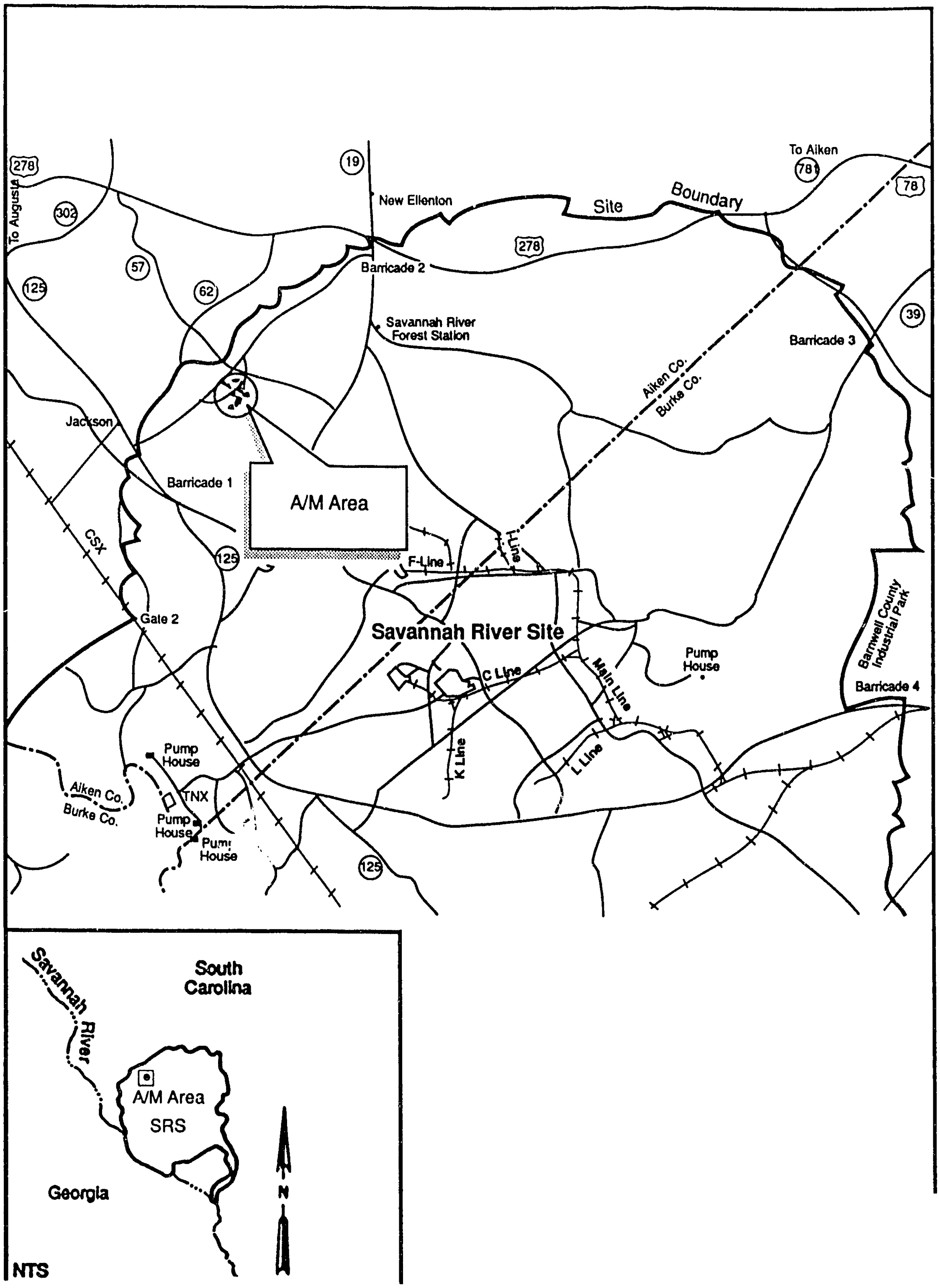

Figure 1. Savannah River Site Location Map.

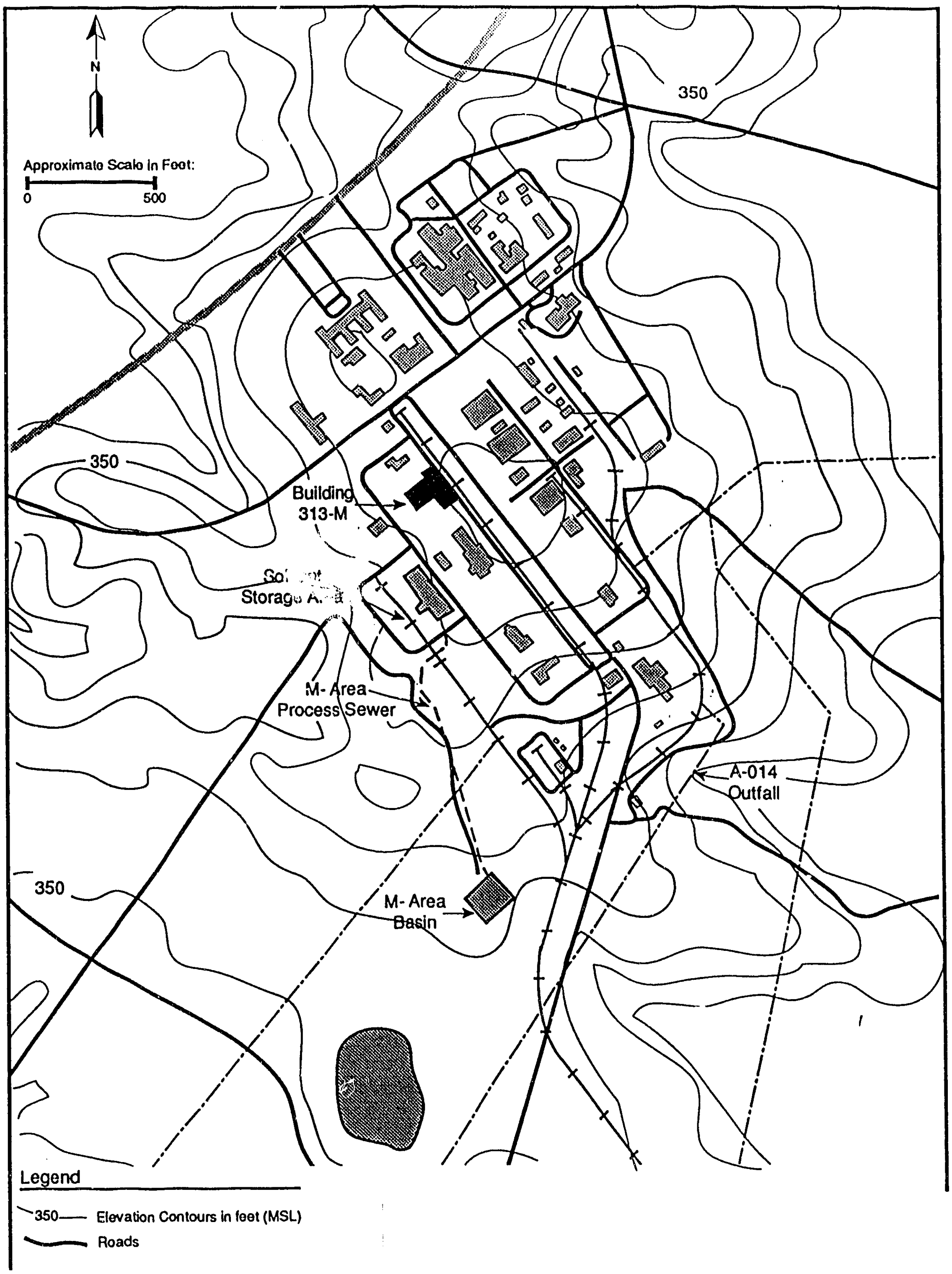

Figure 2. Map of the A and M Areas of the Savannah River Site indicating past solvent release locations.

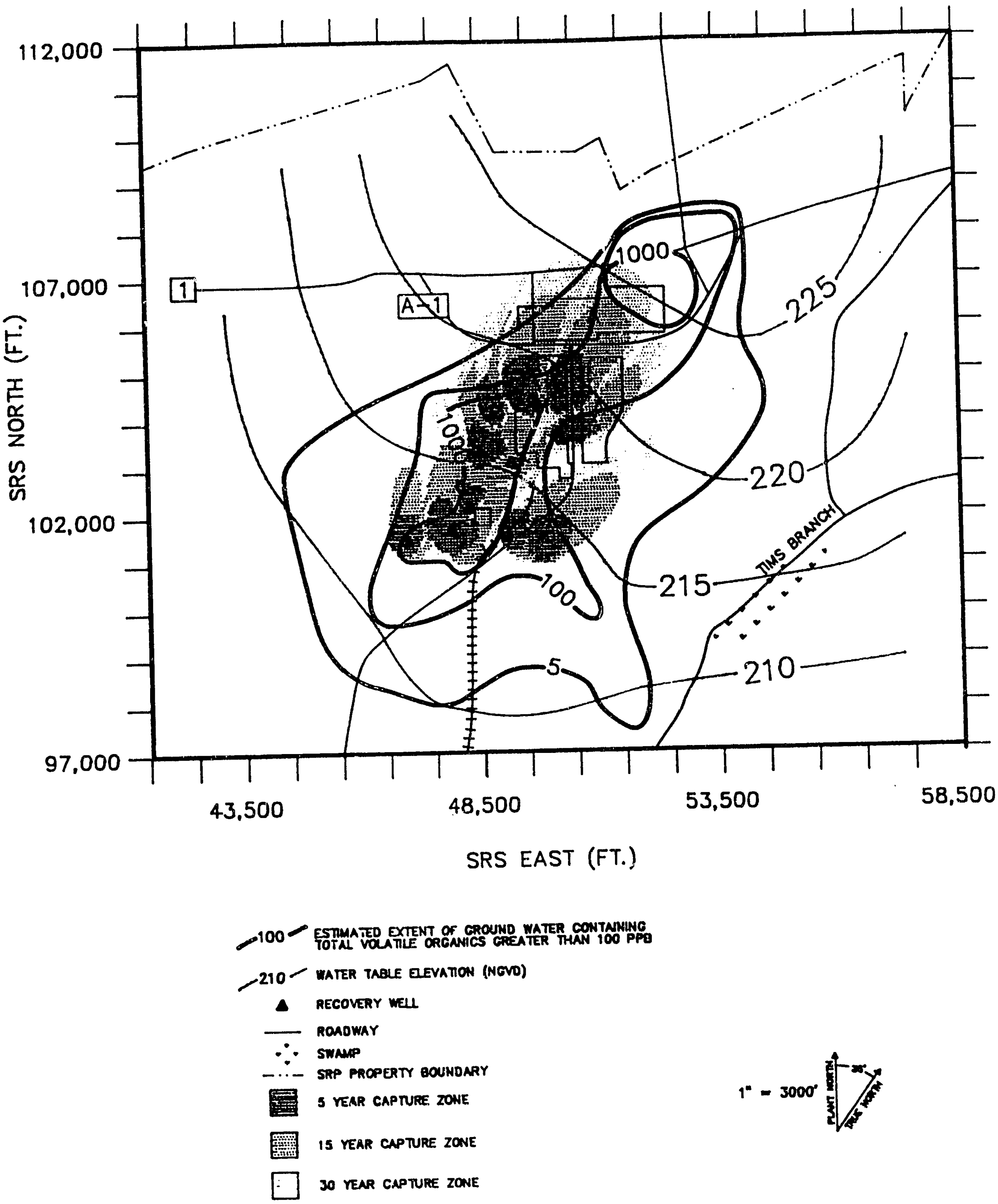

Figure 3. 30 year Zone of Capture Map (shaded) superimposed on isoconcentration contours (ppb) for one of three flow units.

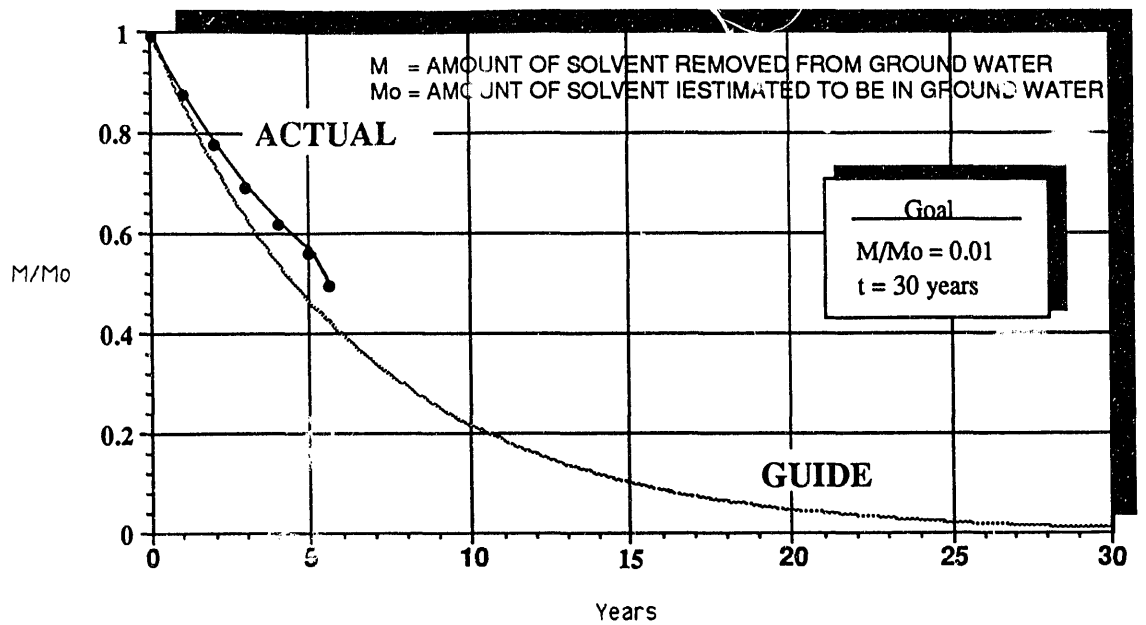

Figure 4. Actual Rate of Solvent Recovery (plotted data) compared to Theoretical 99% Mass Removal Guide.

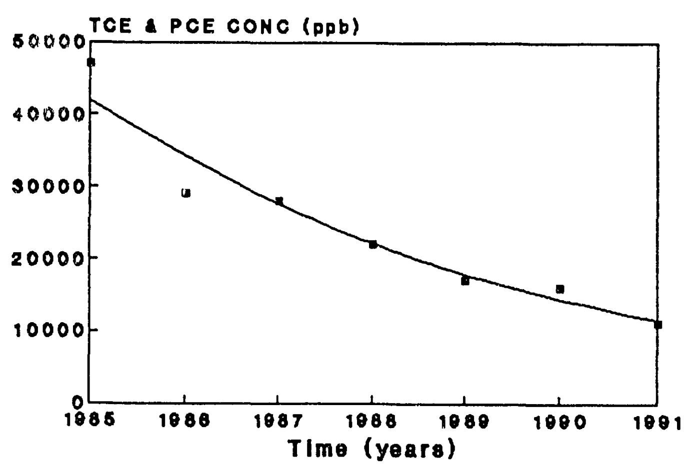

Figure 5. Concentration Trend Showing Decreasing Concentration of Solvents in the Air Stripper Influent.

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