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SELECTION OF A REMEDIAL ALTERNATIVE AT A SUPERFUND SITE IN AN ENVIRONMENTALLY SENSITIVE CONTEXT*

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Summary

The site is a former intermediate dye products research and production facility which operated from the late 1950's until 1981. It is located on a small island in the midst of a salt marsh, adjacent to the upper reach of a tidal creek. The remedial investigation identified a variety of synthetic organic chemicals, primarily aromatics and substituted aromatics, in the shallow groundwater and in a restricted area of soils. Treatment technologies selected for analysis during the feasibility study included off-site disposal, incineration, and low-temperature thermal aeration for soils and carbon adsorption for groundwater. As required by the National Contingency Plan, "no action" alternatives were included for both media. These technologies were combined to provide 12 remedial action alternatives, seven of which were selected for detailed analysis. The detailed analysis considered technical feasibility, legal and regulatory requirements, human health and environmental effects, and cost.

Introduction

The site which is the subject of this paper is located in the "low country" of South Carolina and is situated on a low-lying island surrounded by salt marsh. It is adjacent to a tidal creek near the creek's upper reach (Fig. 1). Surrounding land use is predominantly rural. The site contained a small intermediate-dye-products research and production facility which was constructed in the late 1950's and operated until 1978. The plant closed during 1982. The principal syntheses conducted at the plant were nitrations, catalytic hydrogenations (principally of aromatic nitrofunctions to the corresponding amines), oxida-

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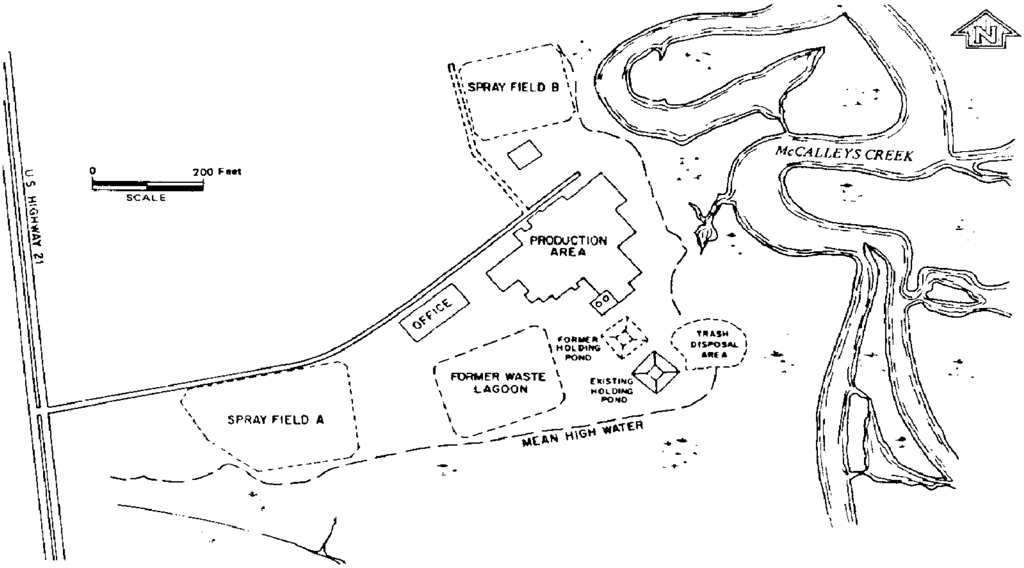

Fig. 1. Site facilities map.

tions, aminations, amidations, esterifications, condensations, low-pressure reactions (up to 200 psig), and sulfonations, almost always involving an aromatic substrate molecule. These reactions were used to produce a variety of dye intermediates.

Waste handling and treatment at the plant evolved as the plant grew. Initially, in the mid-1950's to mid-1960's, several small unlined holding ponds and a drainage ditch were used for waste management. By the early 1970's, the ditch and small ponds had been replaced by a single unlined holding pond and a waste lagoon (indicated in Fig. 1). However, these were soon replaced by two spray fields, also shown in Fig. 1, and in the mid-1970's the spray fields were supplemented by a concrete-lined holding pond. In the final phase of operation from the mid-1970's to 1982, wastes were handled by means of the lined holding pond, the two spray fields, and a system of solvent recovery and recycling.

Selecting a remedy for this site involved the conduct of a remedial investigation and a feasibility study. The remedial investigation characterized and quantified site-related chemicals in environmental media. It also evaluated the site-specific geology and hydrology and, following procedures in EPA guidance documents, assessed potential risks. The feasibility study also followed procedures in EPA guidance documents to set remedial action objectives, evaluate remedial alternatives, perform a detailed analysis of remedial alternatives, and select a preferred alternative.

Remedial investigation

Hydrogeology

Investigations of the geology and hydrogeology of the plant site revealed two principal lithologies beneath the plant (Fig. 2). In the upper 50 feet is a layer of sand of differing texture. Below the sand is the Ocala Limestone. These two subdivisions correspond to the aquifers at the site: There is a water table aquifer in the sand, which is not used as a potable water source, and there is an artesian aquifer in the limestone, which is the principal water source in the local area.

The hydrologic investigation of the site found the water table aquifer to be composed predominantly of sands, with no distinct confining unit separating the water table aquifer from the underlying artesian aquifer, however, the difference in hydraulic conductivity between the water table aquifer and the artesian aquifer results in partial confinement of the artesian aquifer by the water table aquifer. The vertical hydraulic gradient between the two aquifers was consistently positive (upward) during the remedial investigation field studies. This indicates that the site is in a zone of discharge for the artesian aquifer.

Horizontal hydraulic gradients within the water table aquifer were such that groundwater flows from the site toward the tidal creek under both high- and low-tide conditions. This was also true in another study that preceded the remedial investigation. Water levels in the tidal creek may occasionally reach

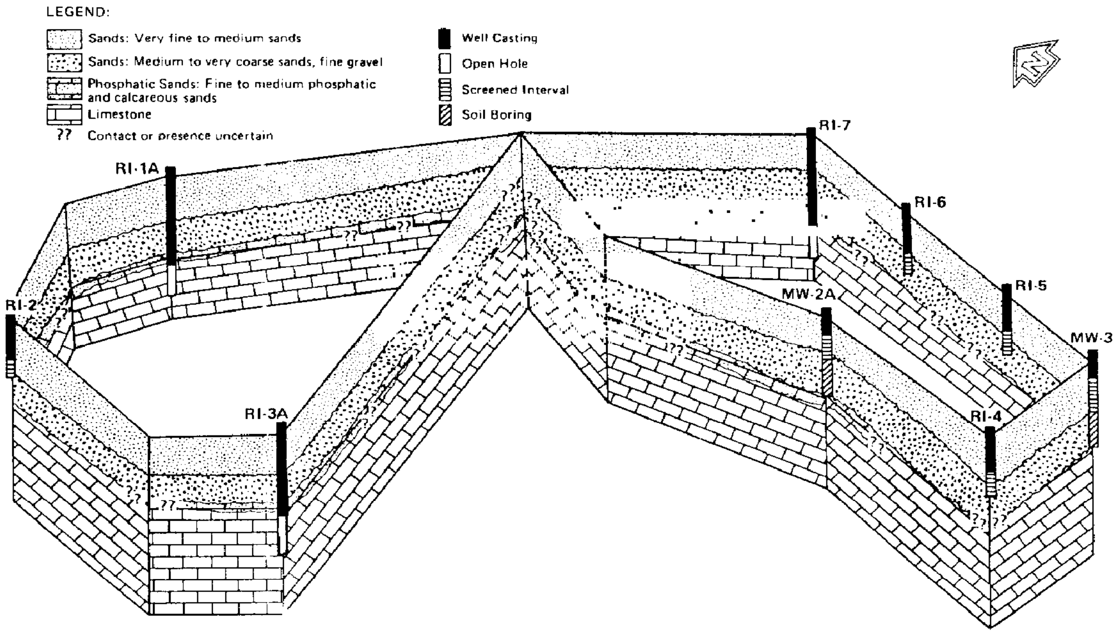

Fig. 2. Fence diagram of site with lithologic units and well locations.

levels high enough to cause a brief reversal of the water table gradient very near the creek, but such reversals are of extremely limited duration and extent.

The horizontal component of groundwater flow in the artesian aquifer near the site is to the northwest, as inferred from horizontal hydraulic gradients in the artesian aquifer.

Continuous water level data collected during the remedial investigation show a diurnal variation in both aquifers and in the tidal creek. The data indicate that the creek has a greater effect upon the water table aquifer and the zone closer to the creek, and that it has less effect on the artesian aquifer.

Biological resources

The site is located in the outer coastal plain forest province ecoregion, as described by Bailey [1]. This ecoregion contains several major plant communities, including the evergreen forest, maritime forest, pine forest, and salt marsh. The site is on a small upland island surrounded by salt marsh. The island is dominated by herbaceous grass fields with loblolly pines and scattered live oaks.

Salt marshes surround the site. These marshes are downgradient of the facility and are major receptors of surface runoff and shallow groundwater flow. These marshes support vegetation dominated by cordgrass, black needlerush, salt grass and glassworts. The marshes also support a very large assemblage of fauna, especially, fish and crustaceans. Economically important species include shrimp, oysters, crabs, and a variety of fish.

The salt marsh and tidal creek are also habitat for other species. Some of these other species may include, on a seasonal basis, species which are listed by the United States government or the government of South Carolina as rare, threatened, or endangered. Such species include one or more species of sea turtles and an Atlantic sturgeon.

Chemical assessment

The most mobile chemicals detected in groundwater (acetone, benzene, toluene, and total xylenes) were present on site in a restricted portion of the water table aquifer. It appears that the plume in the water table aquifer may have originated near the former holding pond (Fig. 1). However, contamination of the water table aquifer may be discontinuous as a result of several on-site sources. Simulations of the migration of benzene, toluene, and total xylenes indicate that under existing site and environmental conditions the apparent plume within the water table aquifer will be largely restricted to this site within the next 30 years.

No site-related constituents were detected in samples from the artesian aquifer. This lack of site-related compounds in the artesian aquifer is attributed to the positive vertical hydraulic gradient between the two aquifers and to the nearby point of discharge to surface water.

Site-related compounds were also detected in soil samples collected on site. Highest concentrations were in samples collected near the former holding pond. Other areas showed little or no evidence of site-related compounds.

Surface water samples collected from the tidal creek contained no detectable organic compounds. Sediment samples collected from the creek contained some trace concentrations of site-related constituents; however, these concentrations were considered insignificant in terms of environmental risk.

Potential effects of site-related compounds on organisms were assessed by analyzing oyster tissue samples collected from the tidal creek. These analyses detected no site-related chemicals. Oysters were selected for analysis because of their known tendency to accumulate organic chemicals and because of their sedentary life habit. Independent analyses of oyster samples collected from the creek by the U.S. Fish and Wildlife Service also found no site-related contaminants.

Risk assessment

Risk assessment performed during the remedial investigation determined that the site poses no immediate threat to human health or the environment. The risk assessment identified low potential risks associated with long-term discharge into the tidal creek of site-related chemicals in the water table aquifer. There is also low potential risk associated with erosion of soils from the former unlined holding pond; such risk would be associated with significant storm events such as hurricanes.

The risk assessment selected nine indicator chemicals for the site. These chemicals are acetone, benzene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, 2,4-dinitrotoluene, naphthalene, toluene, 1,2,4-trichlorobenzene, and xylenes.

Feasibility study

The feasibility study consisted of selection of remedial action objectives, preliminary screening of technologies, development of remedial action alternatives, detailed analysis of the remedial action alternatives, and selection of the preferred alternative. In selecting the preferred alternative, the environmental setting was a key consideration.

Remedial action objectives

Basic to selecting remedial action objectives is the requirement that the objectives protect human health and the environment, considering potential present and future exposure. Such health- and environmental-based objectives were developed from an integrated consideration of the inherent health and environmental effects of the indicator chemicals in the site-specific processes facilitating exposure of humans and the environment to these indicator chemicals. The remedial action objectives are design goals for the various remedial alternatives evaluated as part of the feasibility study.

In developing the remedial action objectives, we identified dominant human and environmental exposure pathways, noted established acceptable exposure levels for each indicator chemical, and calculated the maximum concentrations of the indicator chemicals, in both groundwater and soil at the source, which would keep concentrations of these chemicals below the acceptable levels at the point of exposure.

Since no human exposure pathways currently exist at the site (groundwater in the water table aquifer is brackish, not used), protection of aquatic life was the principal goal; therefore, quantitative applicable relevant and appropriate requirements (ARAR) were based upon ambient water quality criteria (AWQC) for protection of salt water aquatic life, or upon general aquatic toxicity information for indicator chemicals with no AWQCs. Remedial action objectives for groundwater were set at concentrations equal to the AWQC (Table 1); these were applied to the concentrations in the water table aquifer at the source. Remedial action objectives for soil were calculated as concentrations in soil which would not result in future exceedances of AWQC in groundwater at the source. Both sets of remedial action objectives follow a very conservative (protective) approach which ignores attenuative effects and dilution. The area to be considered for soil remediation is outlined in Fig. 3; approximately 2000 cubic yards will be remediated.

TABLE 1

Summary of various parameter values and soil remedial action objectives for the contaminants of concern

Contaminants of concern	Groundwater remedial action objectives (mg/kg)		Soil remedial action objectives (mg/kg)
Acetone	ALT[a],	1000	97.81
Benzene	AWQC,	0.700	2.43
1,2-Dichlorobenzene	AWQC,	1.97	33.43
1,4-Dichlorobenzene	AWQC,	1.97	38.06
2,4-Dinitrotoluene	AWQC,	0.37	3.62
Naphthalene	AWQC,	2.35	74.57
Toluene	AWQC,	5.00	34.47
1,2,4-Trichlorobenzene	AWQC,	0.129	4.23
Total xylenes	ALT[a],	2	67.59

[a]ALT is alternate criterion derived from literature review of toxicologic data for acetone and total xylenes.

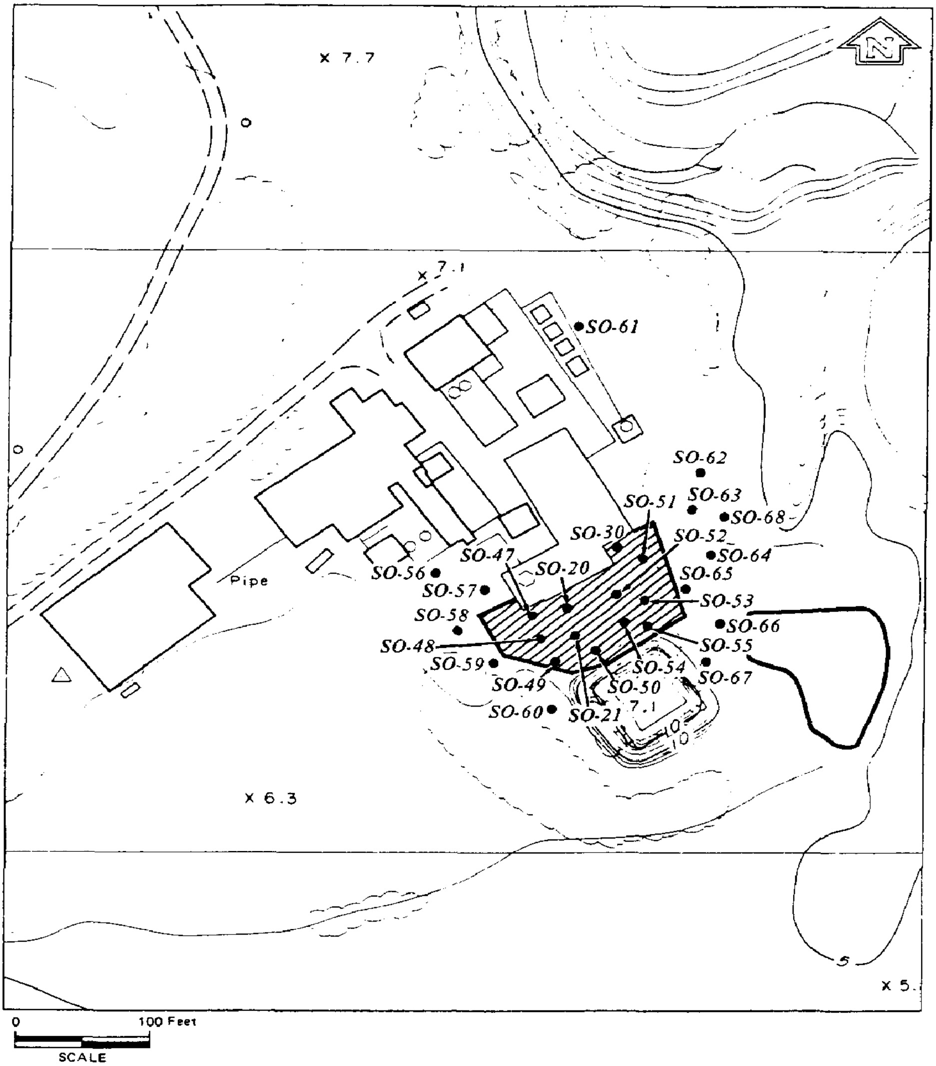

Fig. 3. Area to be considered for soil remediation.

Identification and screening of remedial action technologies

General response actions considered for groundwater remediation included containment technologies (capping, subsurface barriers, and access limitations), collection and control technologies (pumping and subsurface drains), and treatment technologies (biological treatment, chemical treatment, and physical treatment). Containment technologies were eliminated as impractical for this site. Of the collection and control techniques, extraction by well point system was best suited to this site's topography and hydrology. Biological treatment was not appropriate for the indicator chemicals. Other treatment technologies which were considered included ultraviolet ozonation which, although well suited to treatment of organics, was eliminated due to a higher cost than other treatment technologies; air stripping, which was well suited to the more volatile organics; and activated carbon, which was well suited to treatment of organics and is often used as a post treatment following air stripping.

General response actions considered for soils included containment, removal and disposal, *in situ* treatment, and direct treatment. Containment and *in situ* treatment were eliminated as impractical for this site. The most promising technologies for soils were excavation and off-site disposal, low-temperature thermal treatment, and incineration. Excavation and off-site disposal were retained for consideration primarily because this is a requirement of the Superfund Amendments and Reauthorization Act (SARA). Although SARA requires consideration of excavation and off-site disposal, current EPA policy prohibits land disposal of Superfund-generated wastes.

Detailed evaluation of remedial action alternatives

The prescreened remedial action technologies were incorporated into twelve remedial action alternatives and subjected to detailed analyses. The twelve alternatives were defined by combining the various remedial action technologies, and the "no action" alternative was included to address the requirements of SARA. The twelve alternatives are

1. No action (included as a baseline for comparison with other alternatives).
2. Excavation, removal and disposal of soil, no action for groundwater.
3. Low-temperature thermal treatment of soil, no action for groundwater.
4. On-site incineration of soil, no action for groundwater.
5. No action for soil, provisory treatment of groundwater, long-term monitoring.
6. Excavation, removal and disposal of soil, provisory treatment of groundwater, long-term monitoring.
7. Low-temperature thermal treatment of soil, provisory treatment of groundwater, long-term monitoring.
8. Incineration of soil, provisory treatment of groundwater, long-term monitoring.
9. No action for soil, groundwater treatment.
10. Excavation, removal, and disposal of soil, groundwater treatment.
11. Low-temperature thermal treatment of soil, groundwater treatment.
12. Incineration of soil, groundwater treatment.

The twelve remedial action alternatives were analyzed and evaluated for technical feasibility, environmental and public health considerations, legal and regulatory compliance, and cost.

Technical feasibility was evaluated on the basis of performance, reliability, implementability, and safety. Performance was assessed on the basis of effectiveness and useful life. Effectiveness in turn was evaluated on the capacity of the technology to meet the response objectives. Useful life is the time that effectiveness can be maintained. Reliability was assessed on the basis of demonstrated performance and operation and maintenance requirements. The potential for poor performance or failure of the system or its components was considered as well as the capacity of the system to accommodate variations between design criteria and field conditions. Operational complexity, monitoring requirements, and frequency of maintenance were also assessed. Implementability was defined as the ease of installation and the time required to implements the technology. The time required after installation for the technology to effectively meet remedial action objectives was also considered. Safety was evaluated in terms of potential risk to public health and the environment in the event of system failure and in terms of the safety of workers, public, and environment during initial system construction and subsequent operation.

Alternatives that met the technical feasibility criteria were further evaluated in terms of environmental and public health. Both short- and long-term potential risks were considered. For public health, these effects could include noise or air pollution, odor, use of natural resources, aesthetics, and interference with public services of local businesses. Environmental risks include acute or chronic toxic effects on plant or animal life, alteration of wildlife habitat, and threats to endangered species.

Legal and regulatory considerations included air, water and noise standards, land use and zoning, and federal, state and local laws.

Cost estimates were based upon anticipated installation costs, operation and maintenance costs, and net present worth over the expected life of the project.

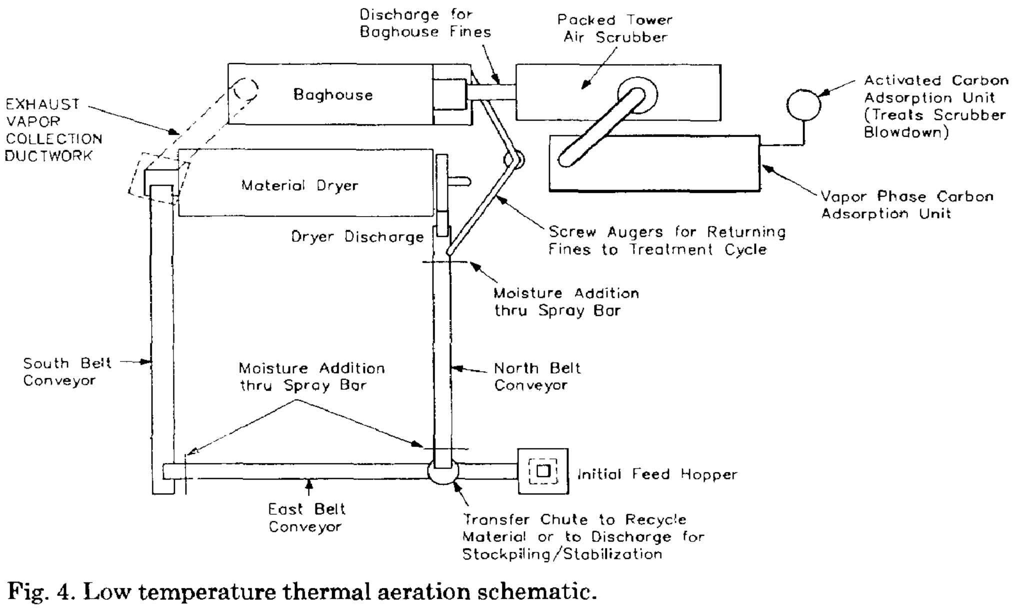

Fig. 4. Low temperature thermal aeration schematic.

Detailed analysis of the twelve remedial action alternatives eliminated the no action alternative and every alternative which included no action for any particular medium on the basis of inability to meet the remedial action objectives. Alternatives including provisory treatment of groundwater and long-term monitoring were eliminated due to the classification of groundwater within the site's classification review area as Class I Groundwaters according to the EPA's groundwater classification guidelines. This classification was based upon two findings. The first finding was that the groundwaters were vulnerable, and the second was that the classification review area (i.e. the area within a 2-mile

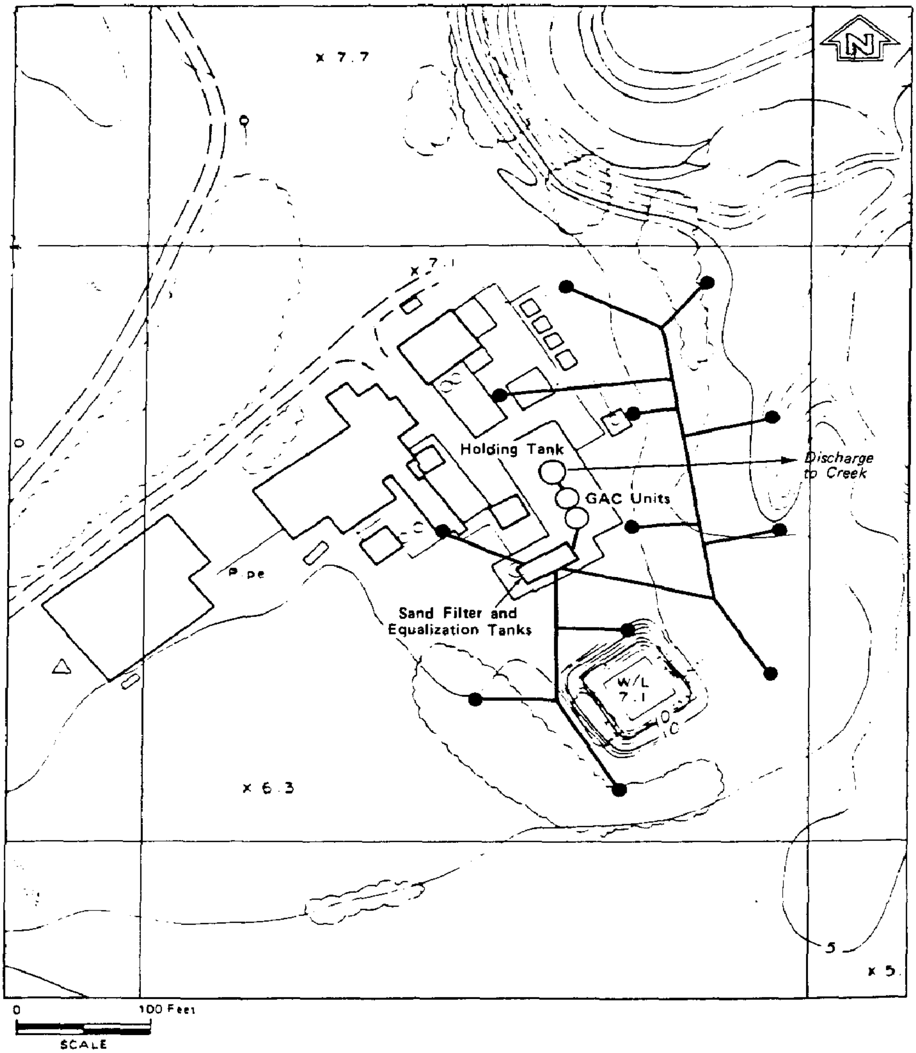

Fig. 5. Preliminary site layout for groundwater treatment.

radius of the site) provided habitat to threatened or endangered species. This classification need not be based upon a determination that a facility pose an actual threat to threatened or endangered species or even the presence of such species within the classification review area. The presence of habitat for such species within a two mile radius of a facility is sufficient. The area within two miles of the subject site contains habitat for threatened or endangered sea turtles. A Class I Groundwater classification, according to EPA guidelines, mandates selection of a groundwater treatment alternative.

The remaining alternatives involved groundwater treatment and either low-temperature thermal treatment of soil or incineration of soil. Incineration of soil proved more costly than low-temperature thermal treatment of soil. Therefore, the selected alternative was low-temperature thermal treatment of soils (Fig. 4), and groundwater treatment involving air stripping and carbon absorption (Fig. 5). All components in this remedial action alternative have a high technical feasibility already demonstrated in other full scale projects. The alternative is capable of meeting remedial action objectives for both soil and groundwater, and it meets SARA's preference for alternatives which involve treatment. It provided the lowest cost for treatment for both media. The groundwater extraction rate would be governed by consideration of the effects of treated water on salinity in the adjoining creek to eliminate potential impacts on the creek.

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Reference

1 R.G. Bailey, Description of the Ecoregions of the United States. U.S. Department of Agriculture, Forest Service, Washington, DC, 1980.