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# FIELD DEMONSTRATION OF RAPID TURNAROUND, MULTILEVEL GROUNDWATER SCREENING\*

Anthony R. Tingle  
Analysas, Inc.\*\*  
Oak Ridge, Tennessee

Lorie Baker  
Automated Sciences Group\*\*\*  
Oak Ridge, Tennessee

Delmar D. Long  
Hazardous Waste Remedial Actions Program  
Martin Marietta Energy Systems, Inc.,  
Oak Ridge, Tennessee

Mike Miracle  
Advanced Sciences, Inc.\*\*\*\*  
Oak Ridge Tennessee

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## ABSTRACT

A combined technology approach to rapidly characterizing source area and downgradient groundwater associated with a past fuel spill has been field tested. The purpose of this investigation was to determine the presence (or absence) and extent of fuel-related compounds or indications of their biodegradation in groundwater. The distance from the source area to be investigated was established by calculating the potential extent of a plume based only on groundwater flow velocities. To accomplish this objective, commercially available technologies were combined and used to rapidly assess the source area and downgradient groundwater associated with the fuel discharge.

The source of contamination that was investigated overlies glacial sand and gravel outwash deposits. Historical data suggest that from 1955 to 1970 as many as 1 to 6 million gal. of aviation gasoline (AVGAS) were discharged at the study area. Although the remedial investigation (RI) for this study area indicated fuel-related groundwater contamination at the source area, fuel-related contamination was not detected in downgradient monitoring wells. Rapid horizontal groundwater velocities and the 24-year time span from the last reported spill further suggest that a plume of contaminated groundwater could extend several thousand feet downgradient. The lack of contamination downgradient from the source suggests two possibilities: (1) monitoring wells installed during the RI did not

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intersect the plume or (2) fuel-related compounds had naturally degraded.

Drive-point technology (i.e., Geoprobe®) was used to advance 1-in. OD drive rods into the aquifer. Favorable soil conditions at the site allowed advancement of the drive rods to depths ranging from 72 to 120 ft. below ground surface. The small diameter of the drive rods minimized investigation-derived waste, and the drive-point technology generated no drill cuttings for disposal. The small-diameter drive rods, the lack of clayey material within the aquifer, and the lack of rotary motion during advancement minimized formation disturbance. Upon achieving the desired depth, a screen was extended from the 1-in. rods, and an inertial pump was used to sample groundwater. Groundwater sampling began at the bottom of the boring and continued at discrete 10-ft. intervals as the rods were pulled back to the water table. Eh, pH, specific conductivity, turbidity, temperature, and dissolved oxygen were measured during purging and recorded at each interval. In addition, an on-site field laboratory analyzed samples from each interval for fuel-related compounds [benzene, toluene, ethylbenzene, xylene, (BTEX)], total petroleum hydrocarbons (TPH), dissolved carbon dioxide (CO<sub>2</sub>), and bicarbonate. Rapid turnaround from the field laboratory allowed field interpretation of the data and influenced the placement of subsequent sampling locations. Concurrent with groundwater sampling, a global-positioning system was used to provide accurate locations for each sample point. After the screening phase of the project, permanent 1-in. stainless steel monitoring wells with prepacked stainless steel screens were installed, at selected locations, using drive-point technology. The overall approach resulted in the generation of real-time horizontal and vertical chemical data, determination of nature and extent of fuel-related contamination and biodegradation products, and accurate locations of sampling points. Permanent monitoring wells for future sampling were installed, and investigation-derived waste was minimized. The above approach resulted in a cost savings of approximately 50% over conventional investigation techniques.

#### PHYSICAL SETTING

The study area is one of 77 identified areas of concern on the Massachusetts Military Reservation (MMR) (Figure 1). MMR was added to the National Priorities List in 1991. MMR overlies an unconfined sand and gravel aquifer that has been designated as a sole-source aquifer by the U.S. Environmental Protection Agency. This aquifer is composed of poorly sorted sands and gravels of glacial origin. The water table lies approximately 50 ft. below ground surface at the study area, and groundwater flow is to the south.

Horizontal groundwater flow velocities at MMR range from 0.9 to 1.7 ft./day, and the hydraulic gradient across the study area is 0.002 ft./ft. (1). Characterization of eight other contaminant plumes at MMR indicates that groundwater descends within the aquifer at a rate of approximately 1 ft. of depth per 100 ft. of horizontal travel because of rainfall accretion. Upward vertical gradients are common near the kettle ponds and rivers that are abundant around MMR (2). Modeling at the study area indicates that groundwater particles descend into the aquifer then rise to discharge at a cranberry bog and the headwaters of the Quashnet River (3).

#### SITE BACKGROUND

Past practices at the study area may have released large quantities of AVGAS into the ground. The actual quantity of AVGAS released is not precisely known, but historical data indicate that during a 15-year period a maximum of 1 to 6 million gal. were potentially released at the study area. Records indicate that 24 years have elapsed since the last release (1). Groundwater flow velocities ranging from 0.9 to 1.7 ft./day (1) provide the potential for transport of fuel-related contamination several thousand feet downgradient.

Water table monitoring wells installed during the RI intersected contamination in groundwater at the source area but indicate little or no contamination downgradient. Background concentration of dissolved oxygen is approximately 11 ppm. Low dissolved oxygen concentrations (0 to 5 ppm) are associated with groundwater in and around the source area suggesting aerobic biodegradation is occurring at the study area (1). Lack of detection of contamination detected in downgradient groundwater during the RI was considered a data gap that precipitated the need for this investigation. Three of the possible reasons for this lack of downgradient contamination are:

1. The monitoring wells installed during early phases of the RI could have missed the contamination.
2. The actual amount of fuel released was much smaller than anticipated.
3. Biodegradation has consumed the AVGAS compounds.

First, monitoring wells installed during early stages of the RI were located based on the suspected path of a plume as determined by water table maps constructed at the time the RI was conducted (1991). Although current water table maps generated for this study area differ slightly from older maps, the general flow direction is similar. Studies of the groundwater flow beneath MMR indicate that groundwater flow vectors vary slightly over time (2, 3).

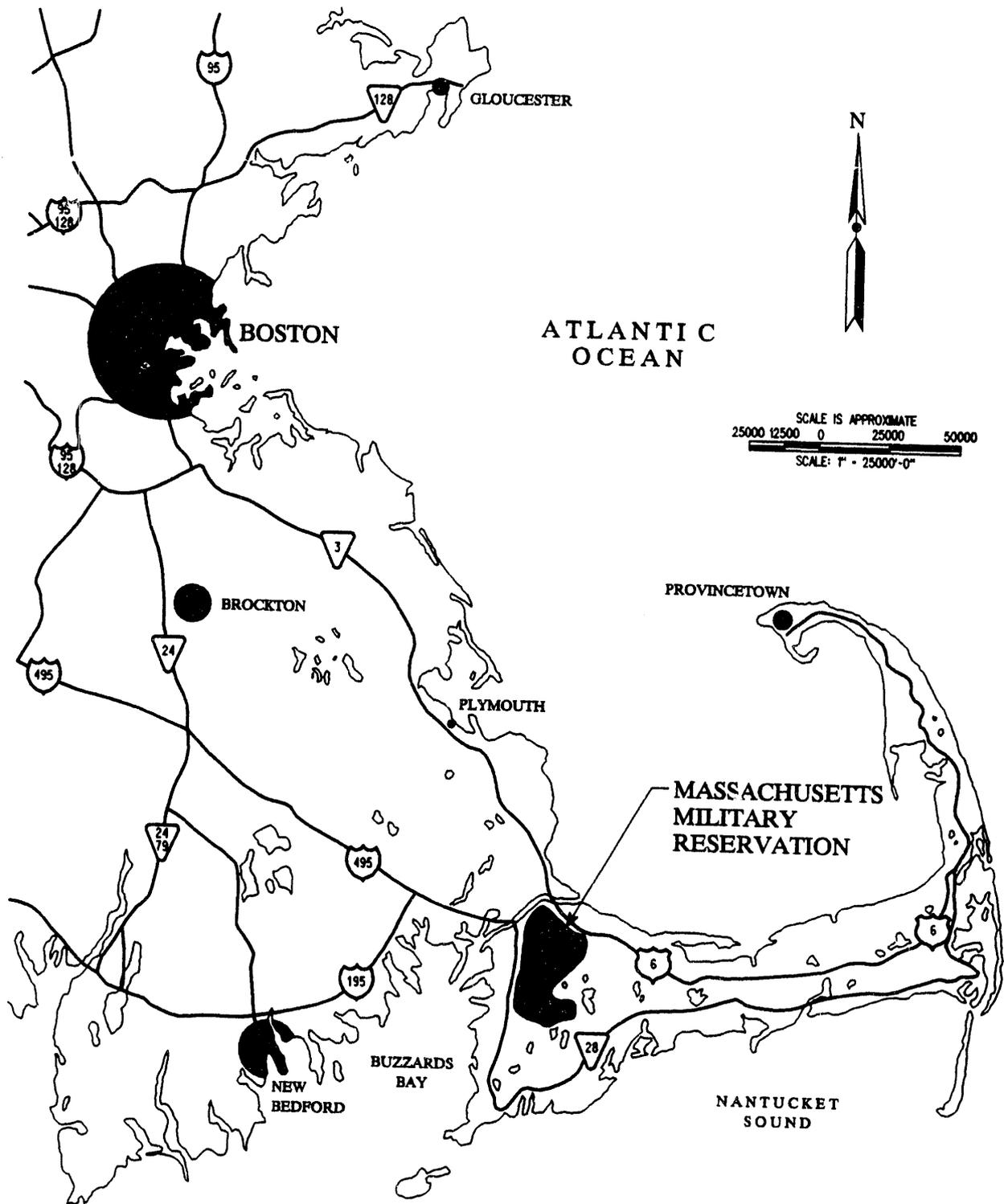


Figure 1 Location of the study area.

Second, records of AVGAS releases at the study area are not available, and estimates of the amount of AVGAS released varied widely. The records search performed for the study area (4, 5) as well as the RI report (1) provide estimates for AVGAS volumes ranging from 0 to 6 million gal. No additional information is available to verify the volume of fuel released.

Third, natural biodegradation of the AVGAS is considered a possible explanation for the lack of contaminants in wells downgradient of the study area. At a site bearing similar conditions to MMR, Cambereri et al. (6) note that active biodegradation of a fuel plume is suspected to be occurring. This site is within the same aquifer as MMR but is unrelated to the military base. Although biodegradation is suspected at the site described by Cambereri et al. a slug of undegraded benzene was detected 700 ft. beyond the downgradient extent of the recognized "plume." They suggest that the benzene contamination was unaffected by microbial degradation because of its travel through the zone of groundwater depleted in dissolved oxygen. Although biodegradation could explain the absence of contaminants in downgradient wells at the MMR study area, similarities between the two sites provide reason to investigate locations beyond the downgradient extent of known contamination at the source of the study area. Similarities between the site described by Cambereri et al. and MMR include chronic release history, contaminant type, aquifer characteristics, and low dissolved oxygen zones.

A field screening approach using screened hollow-stem auger drilling techniques to determine the presence or absence of AVGAS-related contaminants and evidence of their biodegradation would require a longer period of time, generate large quantities of purge water and drill cuttings, and increase cost. This investigation approach was planned to perform the work in less time, minimize investigation-derived waste, generate the data needed to make a decision on the nature and extent of a suspected plume, and decrease cost.

#### CHEMICAL BACKGROUND

Groundwater contamination by petroleum hydrocarbons is a common problem and has been studied by many workers (6, 7, 8, 9, 10, 11, among others). Studies suggest that natural attenuation of petroleum hydrocarbons occurs because of biodegradation (7, 8, 9, 11). Aerobic biodegradation of fuels in groundwater results in decreases in the concentrations of both contaminants and dissolved oxygen (6, 7, 8, 10). In addition, aerobic biodegradation of petroleum hydrocarbons results in the evolution of CO<sub>2</sub> (12) and possible increases in dissolved iron

concentration (2, 9). These factors were used to choose the parameters of interest for this investigation. The target analytes for this investigation are fuel-related hydrocarbons associated with AVGAS and indications of their biodegradation. To assess the groundwater, the following parameters were chosen for this study:

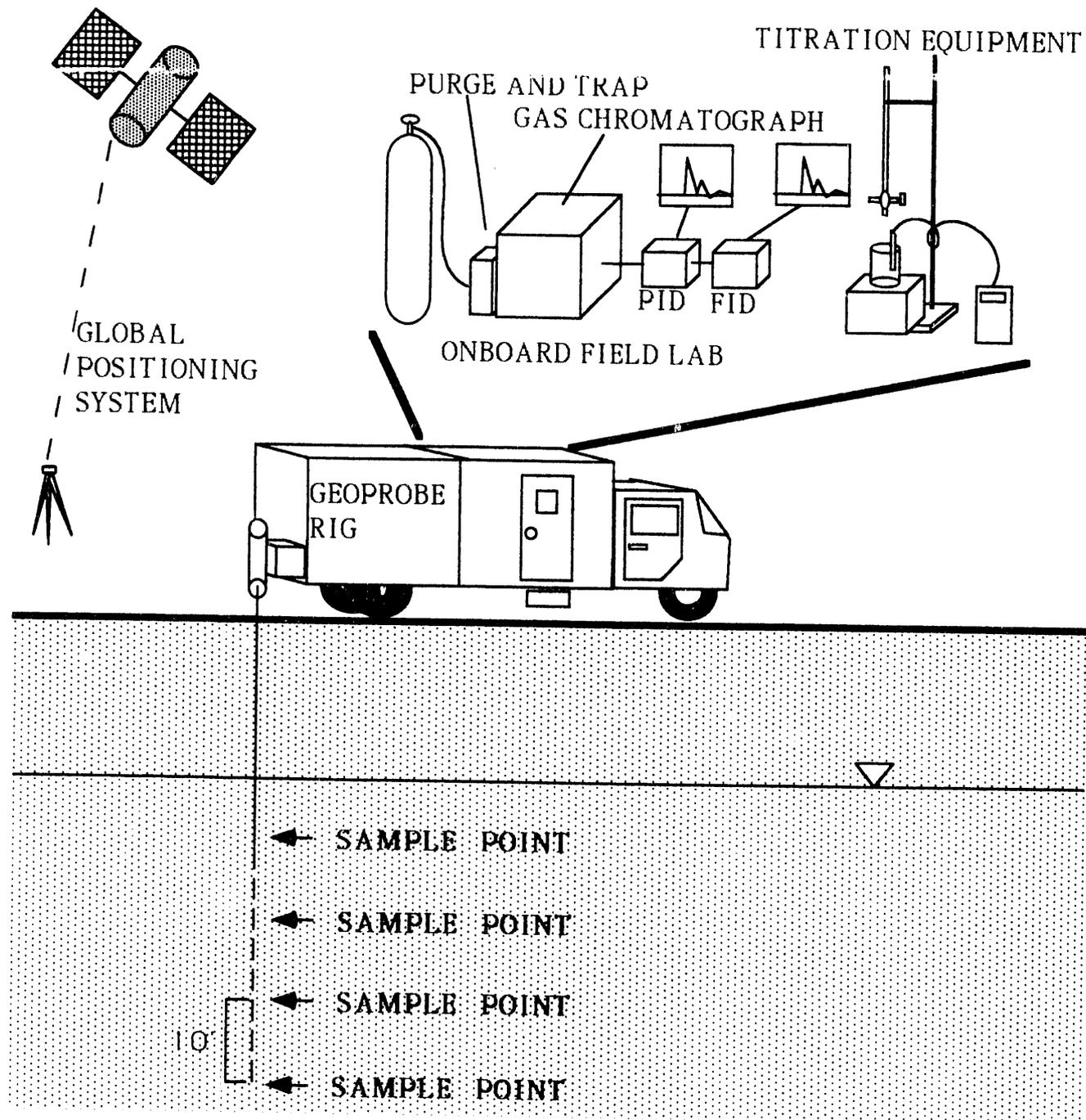
- BTEX by modified method 8020,
- TPH gasoline range (C<sub>4</sub> to C<sub>12</sub>) by modified method 8015,
- Dissolved oxygen by direct measurement in a closed cell, and
- CO<sub>2</sub> by titration

#### FIELDWORK

Three key elements to the investigation—a drive-point sampling device, mobile field laboratory, and global-positioning system—were used simultaneously (Figure 2). The goal of this combination was to generate real-time data on the presence and extent or absence of contaminants and to identify their horizontal and vertical location within the aquifer. These data would be used to support a final decision as to whether biodegradation has and/or continues to remediate the aquifer, and to prove or disprove the presence of a detached groundwater plume.

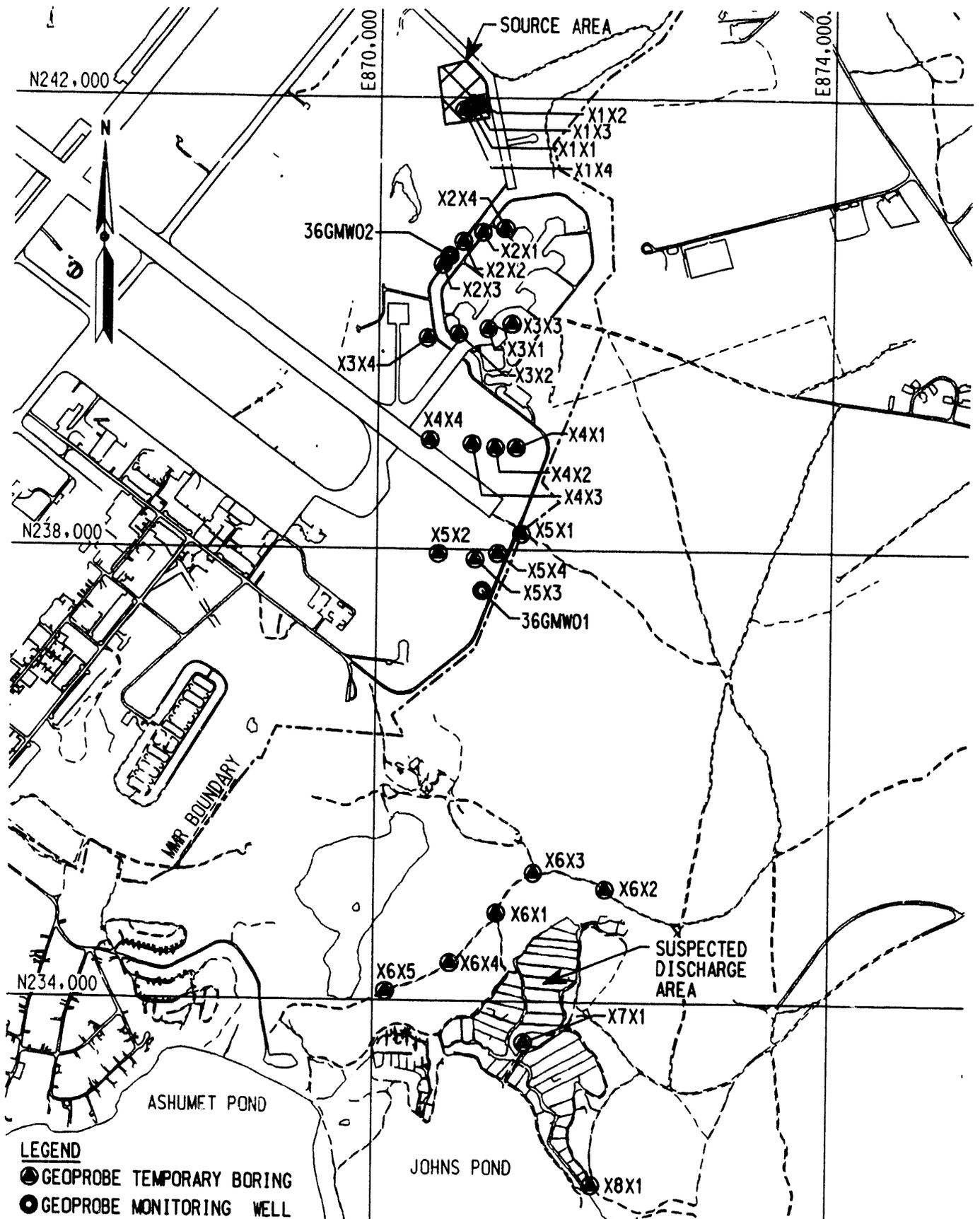
Sample locations were selected based on the regional groundwater flow as indicated by an unpublished water-level snapshot performed in March of 1993, the water table map generated by the Cape Cod Commission Water Resources Office (13), and the suspected path of the plume as indicated by modeling (6). Boring spacings were determined by the width of the contamination at the source as indicated in previous work at the study area (1) and knowledge of the characteristics of other fuel plumes at MMR. With the above information, "fences" consisting of four borings constructed in a line perpendicular to groundwater flow were installed beginning at the source area and continuing 4000 ft. downgradient (Figure 3). An additional fence of five borings was installed on the upgradient side of a bog located approximately 7,500 ft. downgradient of the study area. The bog is the suspected discharge area for contaminants entering the groundwater beneath the source area (based on particle tracking). Two additional borings were installed within the bog near the headwaters of the Quashnet River.

Groundwater samples were obtained from discrete vertical intervals in each boring using a Geoprobe® rig model 5400. Because of favorable soil conditions, the 1-in. carbon steel drive-point sampling rod was advanced to a depth of approximately 120 ft. below ground surface. At the total depth for each boring, the endpoint of the rods was dislodged and a retractable



▽ = WATER TABLE, PID = PHOTOIONIZATION DETECTOR, FID = FLAME IONIZATION DETECTOR

Figure 2 Conceptual integration of the drive-point sampling device, mobile field laboratory, and global positioning system.



**LEGEND**  
 ● GEOPROBE TEMPORARY BORING  
 ● GEOPROBE MONITORING WELL

Figure 3 Detailed site map including locations of the Geoprobe borings and permanent monitoring wells.

2-ft.-long screen was extended from the drive rods as they were pulled back. An inertial pump was used to purge the water in the rods and collect groundwater samples. Parameters measured while purging included pH, Eh, specific conductivity, temperature, dissolved oxygen, and turbidity. These parameters were measured by passing water directly from the pump line through a closed cell that housed a probe for each parameter. The purpose of the closed cell was to isolate the sample from oxygen in the atmosphere. After purging of the sample rods was complete, a groundwater sample was collected and carried to the field laboratory. After collection of the sample, the drive rods and screen were pulled upward 10 ft. and the process of purging and sampling began again. This continued until the shallowest sample from the water table was obtained and resulted in a vertical contaminant profile.

The field laboratory consisted of a gas chromatograph, titration equipment, and necessary chemical standards. The gas chromatograph included a purge and trap to ensure that detection limits below the Maximum Contaminant Levels were obtainable. Two detectors (a photoionization detector and a flame ionization detector) allowed for determination of both BTEX compounds and TPH for the gasoline range (C<sub>4</sub> to C<sub>12</sub>). Titration equipment and chemicals were used to determine CO<sub>2</sub> concentration. Analyses were performed constantly concurrent with driving and sampling, thus allowing for rapid generation and subsequent interpretation of the chemical data.

After a boring was completed, the drive-point rig was moved to another location, and the Global Positioning System was used to accurately determine the northing, easting, and elevation of each boring.

## RESULTS

A network of 30 temporary borings and 2 permanent monitoring wells ranging in depths from 50 to 120 ft. were installed in 27 days. The field laboratory analyzed 213 samples for BTEX and TPH and 190 samples for CO<sub>2</sub>. Data from the field laboratory indicate that although contamination was present beneath the source area, no significant contamination was detected downgradient of the source. Trace concentrations of fuel-related compounds were detected but were well below MCLs. Maximum concentrations of fuel-related compounds detected in the downgradient borings are: benzene 1.8 ppb, toluene 4.8 ppb, ethylbenzene 2.8 ppb, and total xylenes 1.8 ppb. In addition, downgradient of the source TPH concentrations did not exceed 100 ppb. Although low dissolved oxygen concentrations and high CO<sub>2</sub> concentrations were measured in the downgradient borings, no clear pattern is evident in the data set. This, combined with the low concentrations of BTEX and

TPH, suggests that no widespread contamination is present downgradient of the source area and that the presence of a detached plume is unlikely.

## CONCLUSION

A combination of commercially available technologies provided the ability to rapidly assess a large area of groundwater for the suspected presence of fuel-related compounds. A total of 27 days were spent in the field, and 30 temporary borings were installed. A total of 213 samples were analyzed in the field laboratory for BTEX and TPH, and 190 samples were analyzed for CO<sub>2</sub>. Two permanent stainless steel monitoring wells with a prepacked screen were installed using the drive-point device. Upon completion of the fieldwork, the field team had generated chemical and location data for the upper 50 to 70 ft. of the aquifer along the suspected path for a fuel plume originating at the source area, thus allowing the objectives of the study to be met. Data indicate that no significant contamination was present downgradient of the source area. After the fieldwork, a cost comparison between this and the conventional auger-rig approach indicates that the approach used in this study provided a reduction in cost of approximately 50%.

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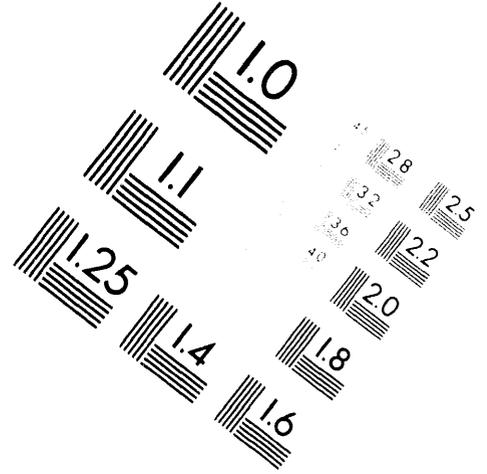
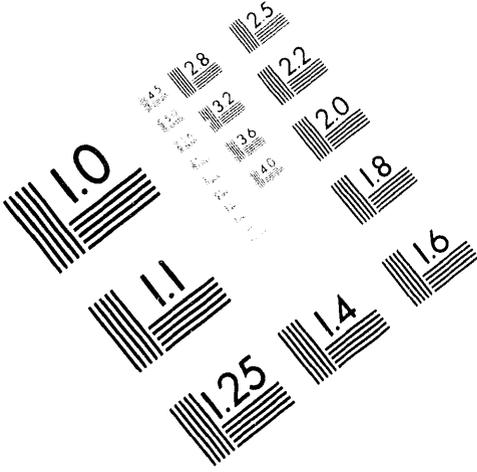
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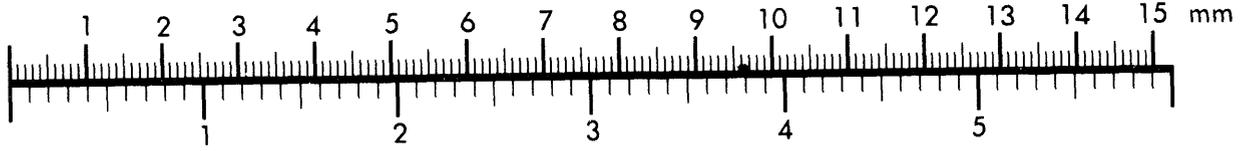
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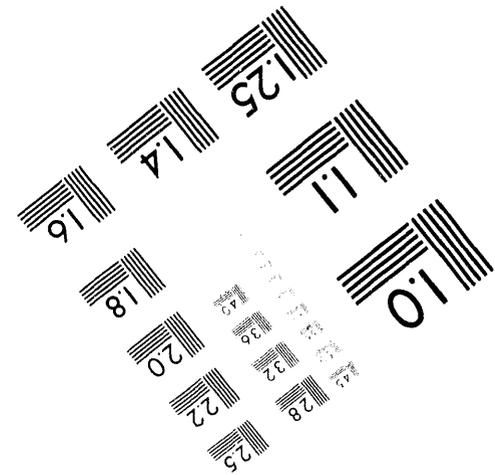
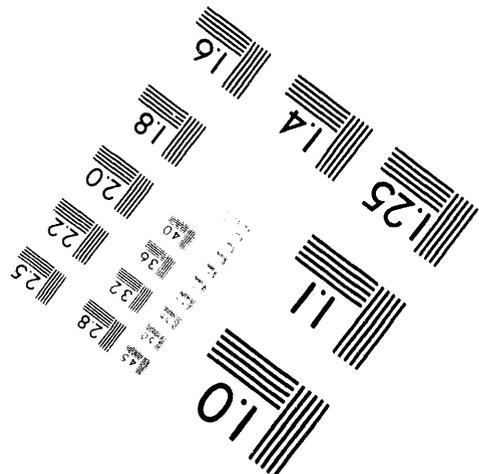
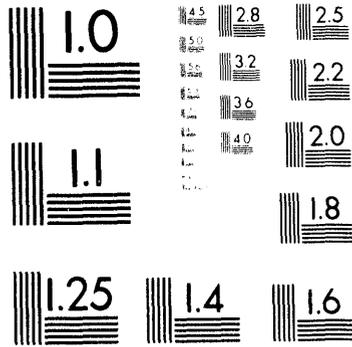
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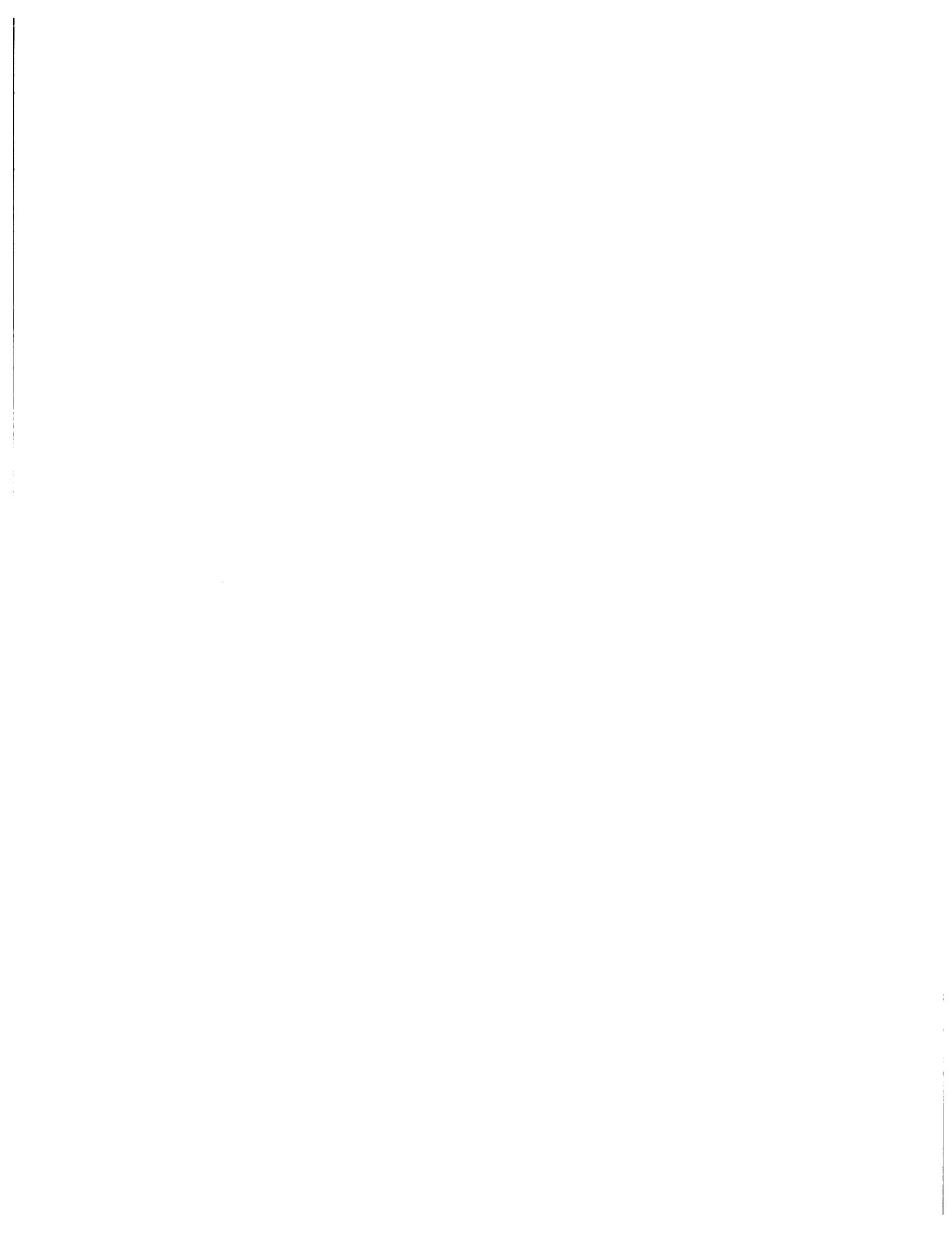
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