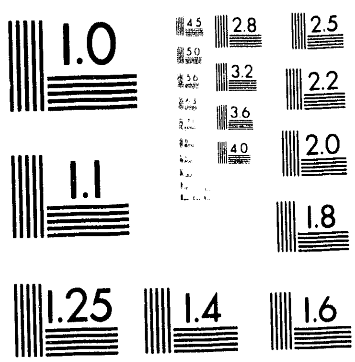
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WHC-SA-1908-FP

Prioritization and Accelerated Remediation of Groundwater Contamination in the 200 Areas of the Hanford Site, Washington

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Date Published
April 1993

To be presented at
1992 International Waste
Management Conference
San Juan, Puerto Rico
April 29-May 1, 1993

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Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse Hanford Company P.O. Box 1970 Richland, Washington 99352

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

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DISCLM-2.CHP (1-91)

PRIORITIZATION AND ACCELERATED REMEDIATION OF GROUNDWATER CONTAMINATION IN THE 200 AREAS OF THE HANFORD SITE, WASHINGTON

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INTRODUCTION

The Hanford Site, operated by the U.S. Department of Energy (DOE), occupies about 1,450 km^2 (560 mi^2) of the southeastern part of Washington State north of the confluence of the Yakima and Columbia Rivers (Figure 1). The Hanford Site is organized into numerically designated operational areas including the 100, 200, 300, 400, 600, and 1100 Areas (Figure 1). The 200 Areas, located near the center of the Hanford Site, encompasses the 200 West, East and North Areas and cover an area of over 40 km^2.

The Hanford Site, established in 1943, was originally designed, built, and operated to produce plutonium for nuclear weapons using production reactors and chemical reprocessing plants. Operations in the 200 Areas were mainly related to separation of special nuclear materials from spent nuclear fuel and contain related chemical and fuel processing and waste management facilities. Large quantities of chemical and radioactive waste associated with these processes were often disposed to the environment via infiltration structures such as cribs, ponds, ditches. This has resulted in over 25 chemical and radionuclide groundwater plumes, some of which have reached the Columbia River.

PURPOSE, SCOPE AND OBJECTIVES

An Aggregate Area Management Study program was implemented under the Hanford Federal Facility Agreement and Consent Order to assess source and groundwater contamination and develop a prioritized approach for managing groundwater remediation in the 200 Areas. The study process was similar in nature to the initial scoping level phase of the RI/FS CERCLA process. This included a comprehensive evaluation of existing waste disposal and environmental monitoring data and the conduct of limited field investigations (DOE-RL 1992, 1993). This paper will summarize the results of groundwater portion of AAMS program focusing on high priority contaminant plume distributions and the groundwater plume prioritization process.

The objectives of the study were to identify groundwater contaminants of concern, develop a conceptual model, refine groundwater contaminant plume maps, and develop a strategy to expedite the remediation of high priority contaminants through the implementation of interim actions.

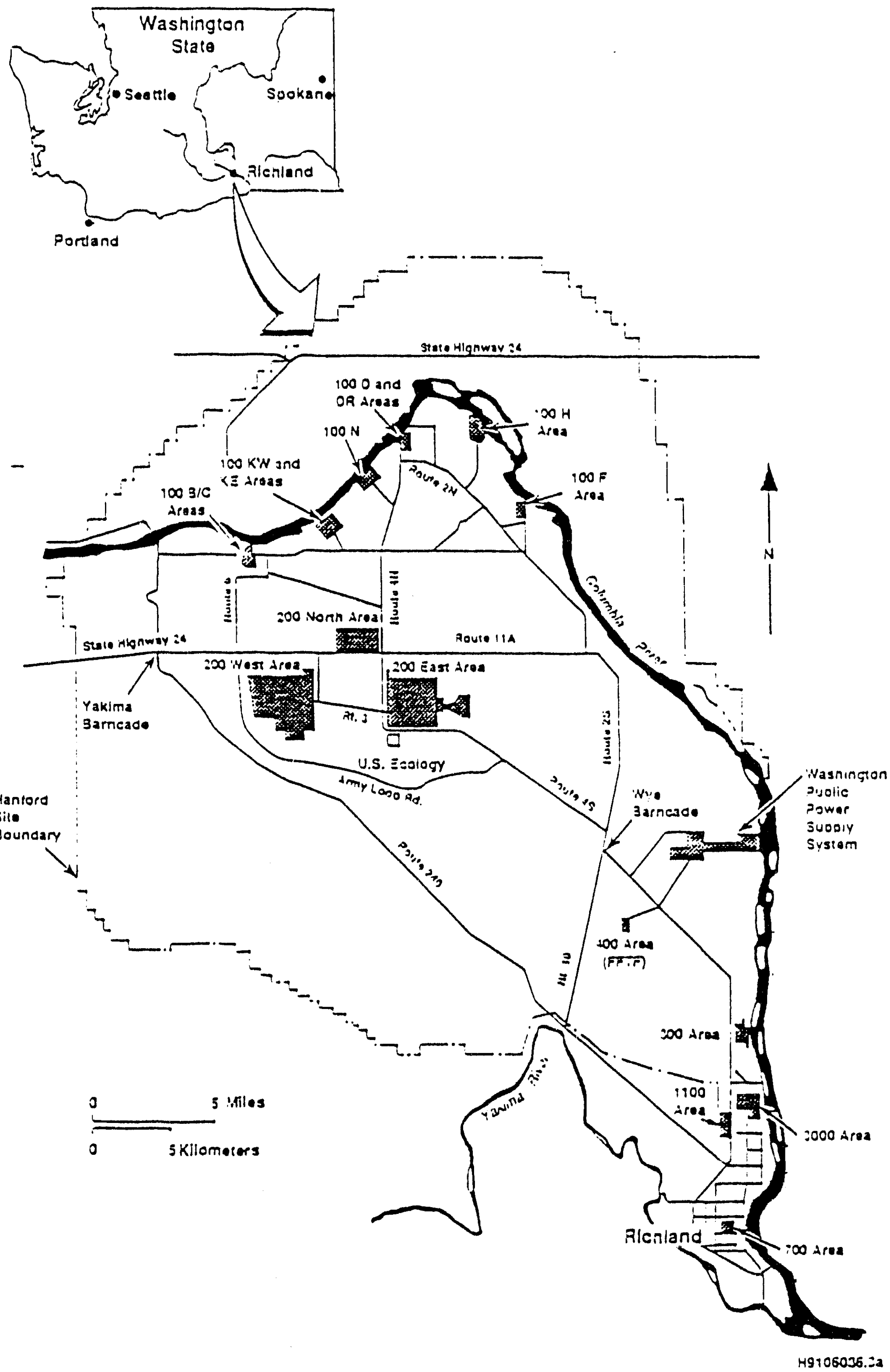


Figure 1. Location of the 200 West and East Areas of the Hanford Site.

APPROACH

Groundwater beneath the 200 Areas was divided into two aggregate areas, the boundary of which was based on the extent of known groundwater plumes originating from the 200 West and 200 East Areas. The first and primary task of the AAMS investigation process involved the search, compilation and evaluation of existing data. Information collected included facility and process descriptions and histories, waste disposal record, sampling of effluents and effected media, site conditions, environmental monitoring data. Collectively this information was used to identify contaminants of concern and to develop a conceptual model which established the relationships between waste sources, pathways, and receptors.

Field characterization activities implemented under the program included a groundwater monitoring and borehole geophysical logging program. Ground water chemistry data was collected from 125 wells to identify contaminants of concern and refine groundwater plume maps. Geophysical logging was performed in approximately 80 boreholes mainly associated with liquid disposal sites to develop concentration profiles of gamma-emitting radionuclides in the vadose zone to assess impacts to groundwater.

To effectively allocate remediation resources, groundwater plumes were prioritized via a process that evaluated the relative human health risk of a plume and/or its exceedance of concentration criteria associated with Applicable or Relevant and Appropriate Requirements (ARARs). Relative risks were estimated using the MEPAS computer software system, while ARAR exceedances were assessed relative to Safe Drinking Water Act Maximum Contaminant Levels (MCLs) or, for radionuclides where MCLs are not promulgated, 4% of the Derived Concentration Guides obtained from the DOE Order 5400.5.

An interim action program was then developed for the highest priority plumes. Depending on the levels of contamination, adequacy of data, and feasibility of remedial technology, interim actions were recommended including expedited response actions, interim remedial measures and limited field investigations.

SITE GEOLOGY AND HYDROLOGY

The Hanford Site is situated within the Pasco Basin of south-central Washington. The principal geologic units within the basin include Miocene basalts of the Columbia River basalt Group and overlying Miocene to Pleistocene unconsolidated to partially consolidated sediments. Sediments overlying the basalt bedrock are to approximately 230 m (750 ft) thick and are comprised of, from bottom to top, the Ringold Formation, Plio-Pleistocene unit, early "Palouse" soil and Hanford formation. Relatively thin surficial deposits of eolian sand, loess, alluvium, and colluvium overlie the Hnaford formation.

The Ringold Formation, consisting of fluvial gravels and sands, paleosol, and lucustrine muds, is up to 185 m (607 ft) thick south of the 200 West Area and pinches out north of the 200 East Area against Gable mountain. The Plio-Pleistocene unit and early "Palouse" soil are relatively thin strata consisting of calcium carbonate-cemented silts to gravels, and silts and fine sands, respectively. The Plio-Pleistocene unit creates local areas of perching water. The Hanford fromation consists of gravel, sand and silt fluvial deposits up to 65 m (210 feet thick).

The hydrology of the Pasco basin and Hanford site is characterized by a multi-aquifer system. The basalt aquifers are typically confined occuring in sedimentary interbeds except in the 200 East Area where the interbeds are exposed as an erosional window. The uppermost aquifer is generally unconfined and is contained laregly within the Ringold Formation and Hanford formation. Hydraulic conductivity, generally varies from 1.8×10^{-3} to 0.7 m/s (500 to 20,300 ft/day) for the Hanford Formation and from 3×10^{-7} to 2×10^{-3} m/s (0.1 to 600 ft/day) for the Ringold Formation gravels. The saturated thickness of the unconfined acquifer ranges from 67 m (220 ft) in the 200 West Area to near zero north of the 200 East Area. Because the majority of contaminants are found in the uppermost portion of the unconfined aquifer which ultimately discharges to the Columbia River, this portion of the aquifer is generally the most characterized unit and contains numerous wells.

Hanford liquid disposal practices artificially recharge the unconfined aquifer beneath the 200 Areas. Zimmerman et al. (1986) estimated that 6.33×10^{11} L (1.7 and 10^{11} gal) of liquid waste were discharged to the soil column in the 200 Areas between 1943 and 1980. This has resulted in local groundwater mounding beneath the 200 Areas (Figure 2).

CONTAMINANT DISTRIBUTION

A total of more than 300,000 groundwater sampling events were evaluated for the period of January 1988 through April 1992. Groundwater contaminant data were compiled, analyzed and plotted to develop a series of contaminant plume maps for contaminants exceeding regulatory limits. Over 25 groundwater contaminants were shown to exceed regulatory limits including both radionuclides and chemicals. Contaminants that were found to consistently exceed limits and/or were relatively extensive include carbon tetrachloride, chloroform, trichloroethylene, technetium-99, uranium, nitrate, arsenic, chromium, fluoride, tritium, plutonium-239/240 and iodine-129 in the 200 West Area, and arsenic, chromium, cyanide, nitrate, tritium, cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137 and plutonium-239/240 in the 200 East Area. Nitrate and tritium are the most extensive contaminants and have reached the Columbia River over 16 km (10 mi) east of the 200 Areas.

The plume maps were also used in the development of a conceptual model for groundwater in the 200 Areas, and were assessed in relation to known historical releases to the vadose zone from liquid waste disposal sites.

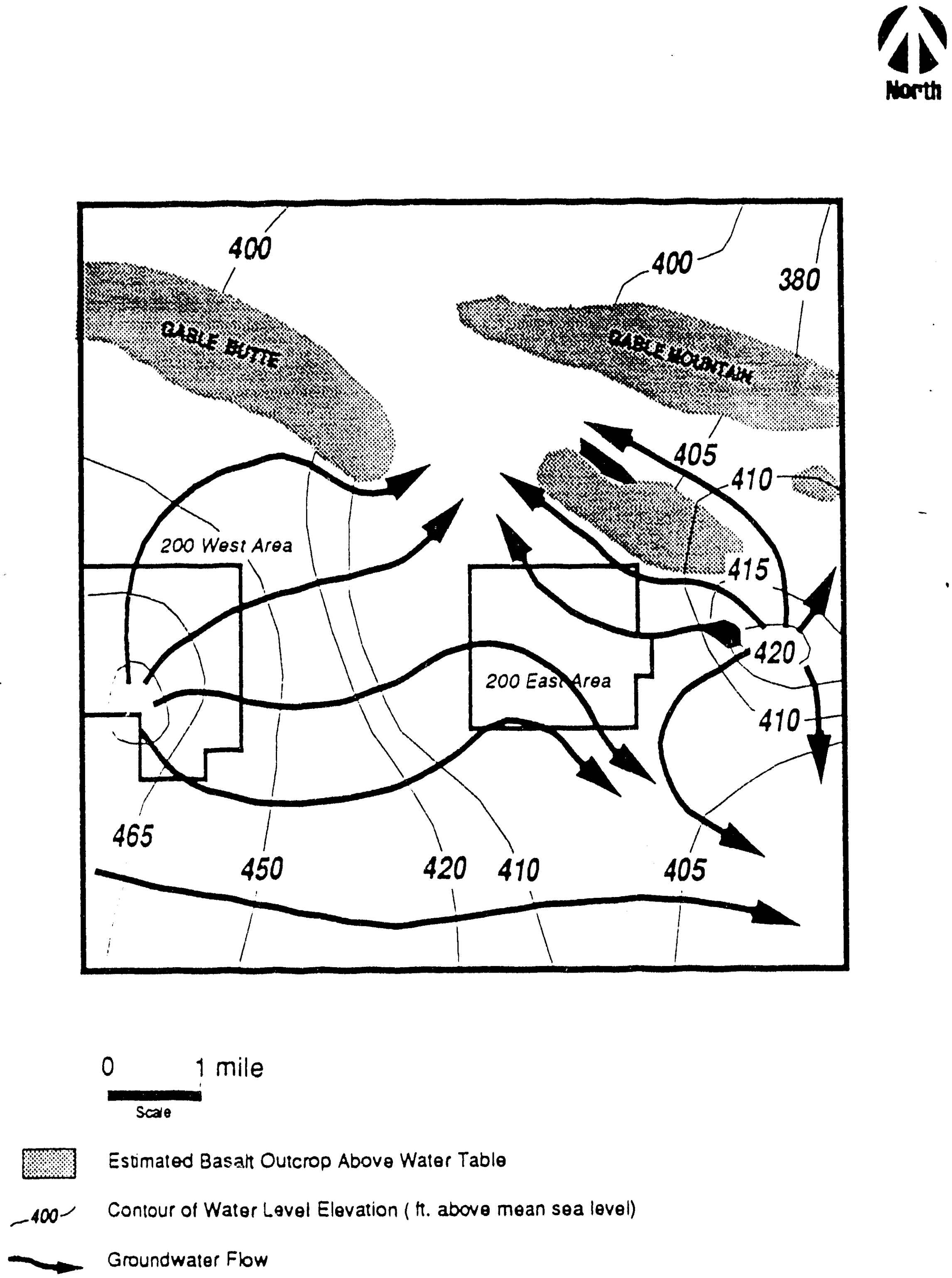


Figure 2. Water Table and Groundwater Flow in 200 West and East Areas.

Factors considered in the source assessment included the quantity of liquid released, depth to groundwater, contaminant inventory of the waste stream, gross gamma-ray activity from borehole logging, and historical groundwater flow patterns.

CONTAMINANT PRIORITIZATION AND REMEDIATION STRATEGY

To more effectively allocate remediation resources at the Site, groundwater plumes were prioritized based on risk and/or its exceedance of concentration criteria associated with Applicable or Relevant and Appropriate Requirements (ARARs). Relative risks were estimated using the Multimedia Environmental Pollutant Assessment System (MEPAS) computer software system (Droppo et al., 1989), while ARAR exceedances were assessed relative to Safe Drinking Water Act Maximum Contaminant Levels (MCLs) or, for radionuclides where MCLs are not promulgated, 4% of the Derived Concentration Guides obtained from the DOE Order 5400.5.

All Contaminants were recommended for remediation under four possible paths developed under based on the *Hanford Site Past-Practice Strategy* (DOE/RL 1992a) which which favors accelerated interim actions for high priority plumes. The four paths consisted of two interim actions (expedited response actions and interim response measures), limited field investigations (LFIs) for contaminants that may pose a risk but data are currently insufficient to justify and select an interim action, and final remedy selection (FRS) path for low priority contaminants which do not appear to warrant priority remedial action.

Based on exceedance of concentration criteria, adequacy of data, site conditions, and the feasibility of selecting and implementing a remedial action, five multi-contaminant interim actions have been proposed. These five interim action plume represented by 14 different contaminants (Figures 3 and 4) include the following:

- a technetium-99, uranium (-234, -235, and -238) and nitrate plume in the southeast portion of 200 West Area originating from liquids wastes disposed to cribs
- a volatile organic plume consisting of chloroform, trichlorethylene and carbon tetrachloride with nitrate in the northern portion of the 200 West Area associated with crib disposal sites.
- a cyanide, technetium-99, nitrate and cobalt-60 plume in the northern portion of the 200 East Area, originating from a group of cribs
- a small plume of uranium in west-central 200 East Area associted with a single crib
- a plutonium-239, 240 and cesium-137 and strontium-90 plume in west-central 200 East Area associated with an injection well.

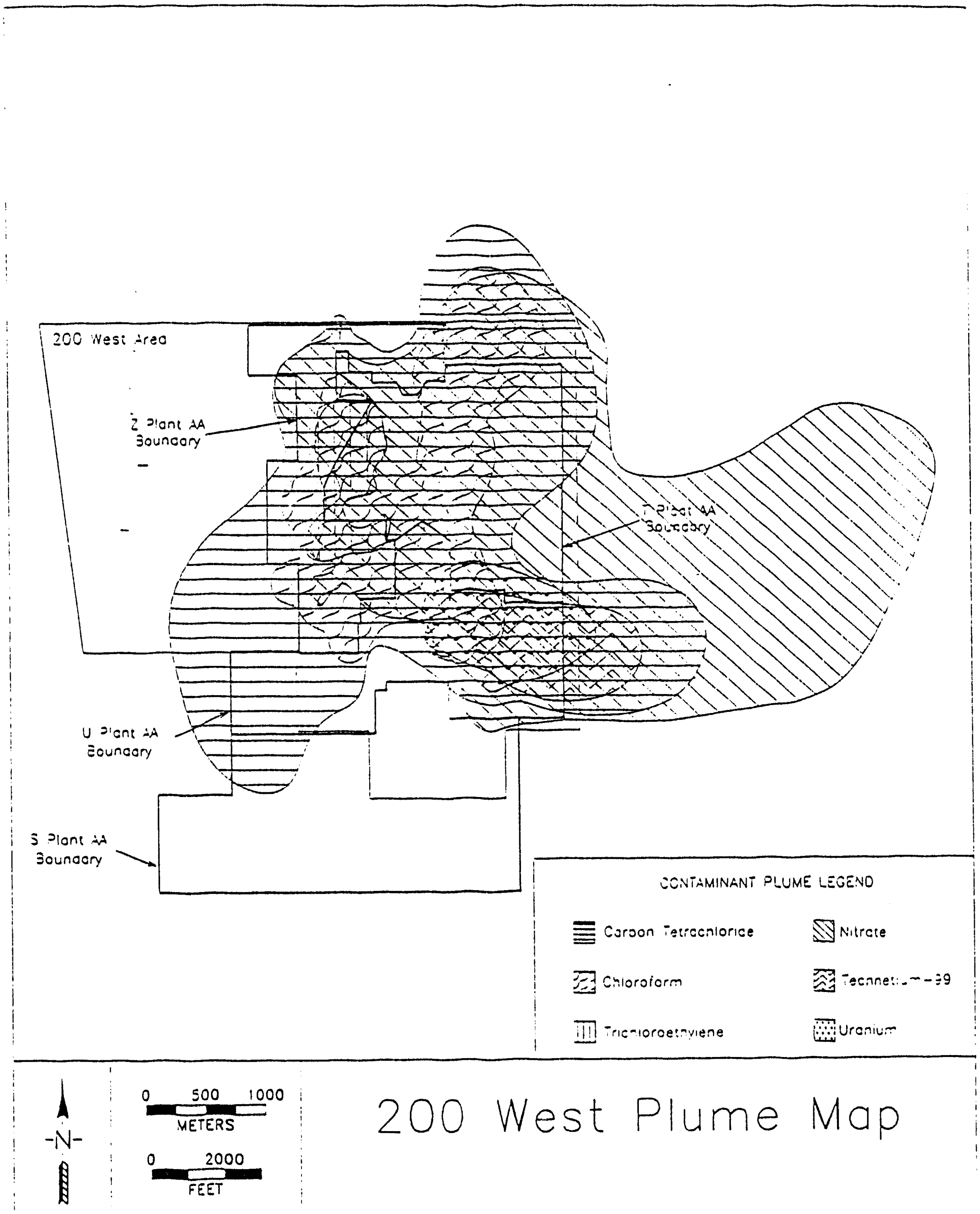
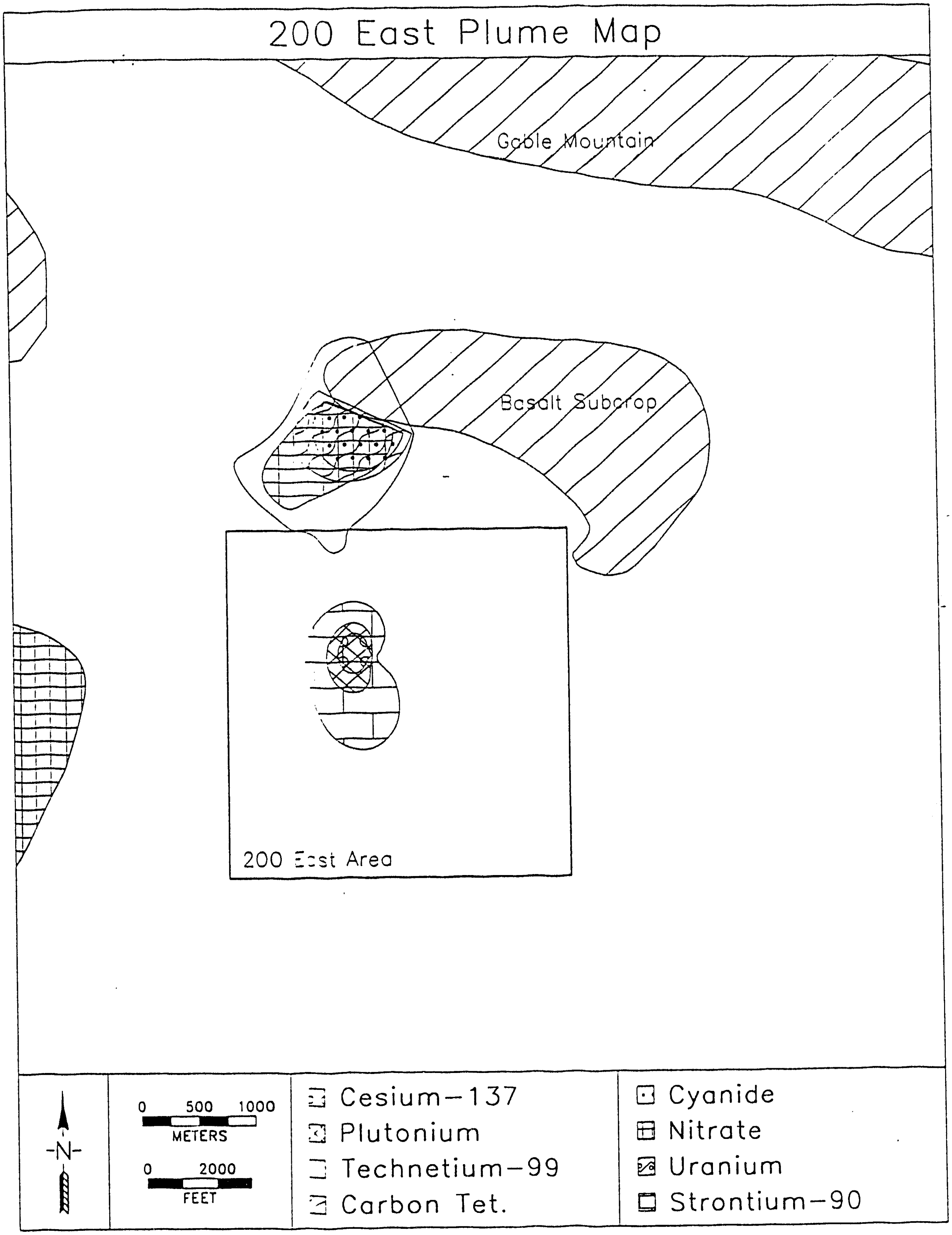


Figure 3. High priority groundwater contaminant plumes in the 200 West Area.


200 East Plume Map
Gable Mountain
Basalt Subcrop
200 East Area
N
0 500 1000
METERS
0 2000
FEET
Cesium-137
Plutonium
Technetium-99
Carbon Tet.
Cyanide
Nitrate
Uranium
Strontium-90

To support the above interim action recommendations based on health risk, the MEPAS code was used to calculate semiquantitative indices of contaminant relative risk. These relative risk indicies (RRIs) integrate the various contaminant characteristics (toxicity, mobility, persistence, quantity, etc.) into a single value. Using a geographic information system, unit RRI values for individual contaminants were combined with the 200 Area groundwater contaminant concentration database to produce total RRI values. Values were generated for groundwater monitoring well points, interpolated and plotted for both groundwater aggregate areas and separately for carcinogenic and non-carcinogenic contaminants.

Figures 5 and 6 present an example of the carcinogenic RRI contours for the unconfined aquifer for the 200 West Area. These plots which illustrate the cumulative risk effects of contaminants, assure that the portions of the 200 Areas with the highest relative risk, were in fact, proposed for priority remedial action. The plots show elevated RRI levels in the vicinity of four multi-contaminant interim action plumes including the volatile organic, and uranium, technetium-99 and nitrate plumes in the 200 West Area), and the strontium-90, cesium-137 and plutonium-239, 240, and cyanide, technetium-99, nitrate and cobalt-60 plumes in the 200 East Area.

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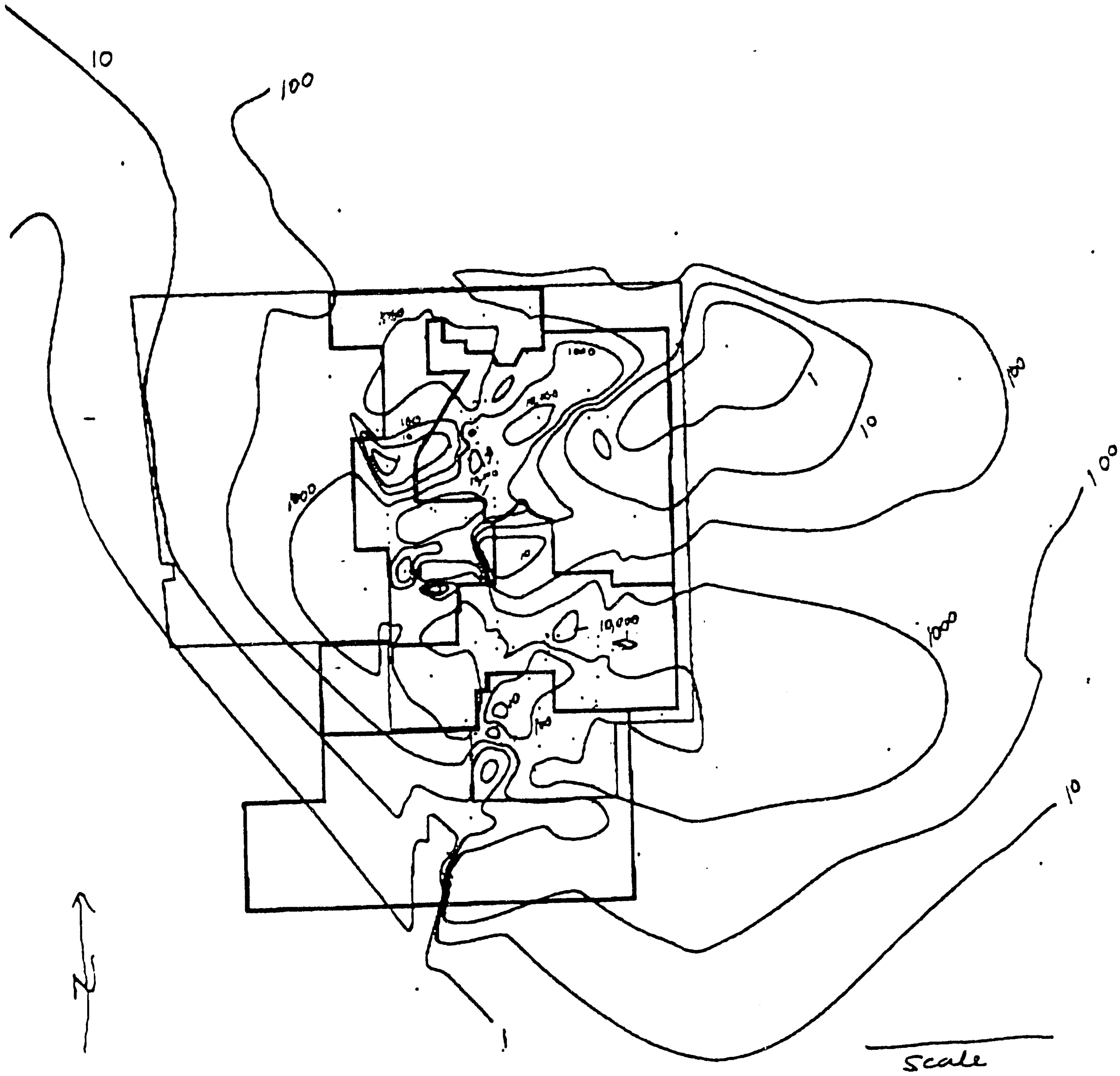

Figure 5. Total relative risk index (RRI) contours for carcinogenic detections in 200 West Area groundwater.

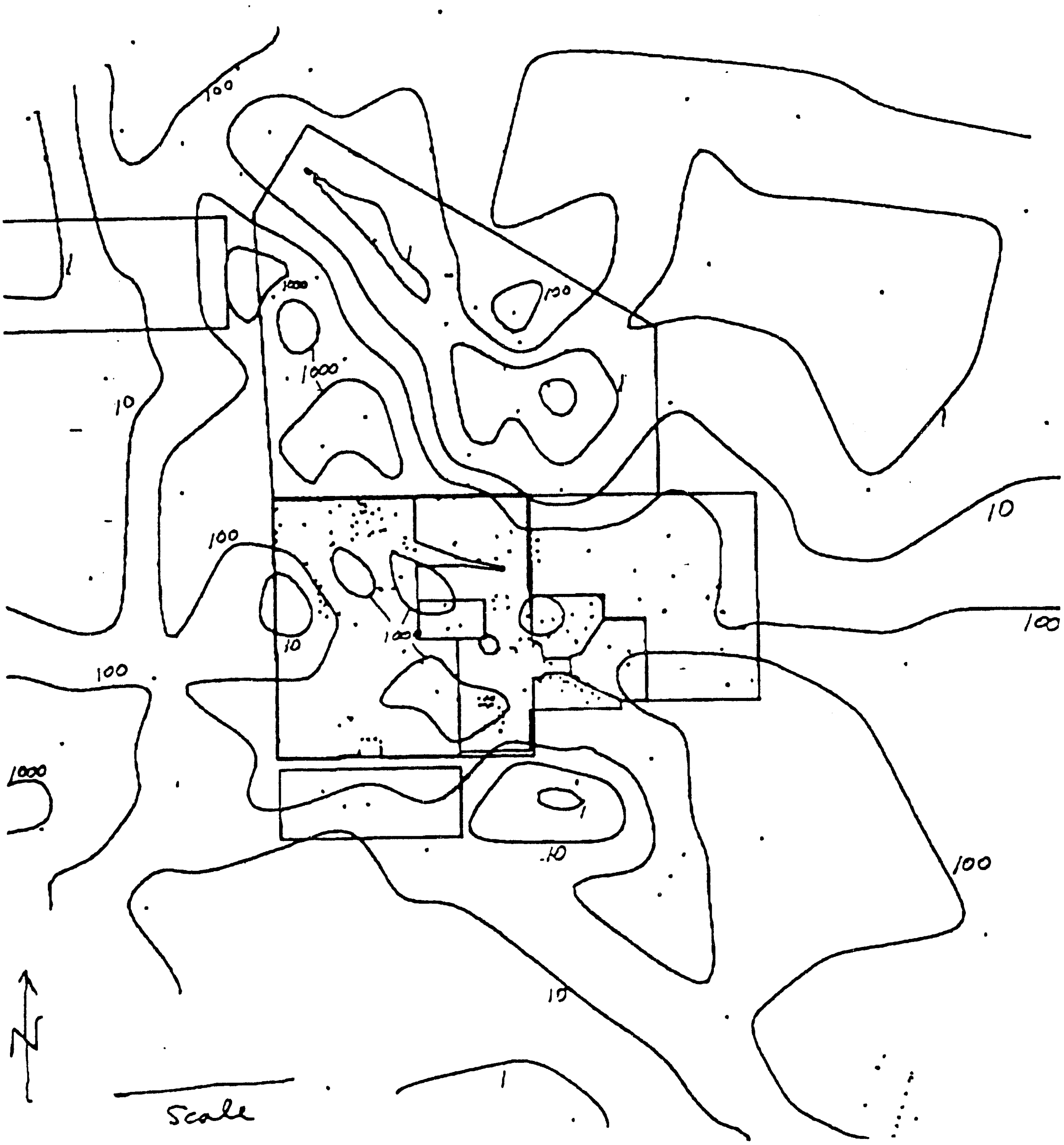

Figure 6. Total relative risk index (RRI) contours for carcinogenic detections in 200 East groundwater.

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