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FINAL
PHASE III REMEDIAL
INVESTIGATION REPORT

BALLY ENGINEERED STRUCTURES SITE
BALLY, PENNSYLVANIA

AR301271

REMCOR

"REALISTIC SOLUTIONS FOR HAZARDOUS WASTE PROBLEMS"

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PHASE III REMEDIAL
INVESTIGATION REPORT

BALLY ENGINEERED STRUCTURES SITE
BALLY, PENNSYLVANIA

PREPARED FOR

ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

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REMCOR, INC.
PITTSBURGH, PENNSYLVANIA

AR301272

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REMCOR

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

This report is submitted by Remcor, Inc. (Remcor), on behalf of Allegheny International, Inc. (AI), to document the results of a remedial investigation (RI) conducted at the Bally Engineered Structures (BES) Site, Bally, Pennsylvania. This RI was performed in response to a Final Administrative Order by Consent (ACO) between the U.S. Environmental Protection Agency (EPA), Region III, and BES, dated January 28, 1987.

This investigation addresses the presence of chlorinated volatile organic compounds (VOCs) in the aquifer utilized by Bally as a municipal water supply. The occurrence of VOC contamination was first noted in 1982, leading to the precautionary removal of one of Bally's municipal production wells (Municipal Well No. 3) from the supply system. The objectives of the current RI were to examine suspected source areas, to delineate the extent of VOC contamination within the aquifer, to assess potential surface water contamination, and to assess resulting public health and environmental concerns, as well as to characterize the hydrogeologic conditions in adequate detail to permit development and evaluation of feasible remedial actions.

The RI included test boring and monitoring well installation, both within suspected source areas at the BES plant and in the surrounding aquifer. Subsurface soils, ground water, and surface water and sediment samples were collected for analysis by the NUS Corporation Laboratory Services Division (NUS LSD) for Target Compound List (TCL) VOCs and, in the case of the municipal supply wells, acid and base/neutral extractable (ABN) organics. Based on existing data regarding contamination within the aquifer, VOCs were defined as the principal contaminants of concern at this site.

Chapter 2.0 of this RI Report provides the relevant background data. Chapters 3.0 and 4.0 discuss the results of the subsurface investigation and surface water evaluation, respectively. Chapter 5.0 presents the evaluation of public health and environmental concerns, and Chapter 6.0 is a brief closing.

2.0 SITE BACKGROUND DATA

Based on the initial indication in 1982 that samples from Municipal Well No. 3 contained elevated levels of VOCs, use of this well for public water supply was terminated. This action forced Bally to revert to the use of Municipal Well No. 1 and a series of springs to the northwest of the Borough as their municipal water supply. This scheme had been operative from 1959 through 1979, prior to bringing Municipal Well No. 3 on line. In addition to the municipal wells, there are two active industrial wells and several residential wells within the aquifer downgradient of the BES plant.

Additional studies of the aquifer contamination problem were performed in 1983 by the Pennsylvania Department of Environmental Resources (PADER) and the EPA. Although unaware of any sources of the VOC contamination resulting from its activities, BES met with PADER in 1984 and retained Environmental Resources Management (ERM) in 1985 to perform aquifer characterization studies to determine the source of contamination of Municipal Well No. 3. The results of the ERM study, published in October 1986, indicated that the BES plant was a likely source of the VOC contamination noted in the aquifer in the plant vicinity.

Manufacturing activities at the BES plant began in the 1930s with the production of high-quality cabinets and cedar chests by the Bally Case and Cooler Company (BCC). Production facilities were briefly commissioned in the 1940s by the government to assist in the war effort. In the 1950s the main product line became continuous line, porcelain-coated meat display cases and porcelain panels for use in constructing building facades. In 1972 BCC was acquired by Sunbeam Corporation (Sunbeam), and

became a subsidiary of AI in 1982 with AI's acquisition of Sunbeam. In 1984 BCC was renamed Bally Engineered Structures, Inc., in response to an increased emphasis on the manufacture of insulated panels and product diversification. On June 23, 1987, the business was sold to Bally Aquisition Corporation, while Dagan, Inc., a subsidiary of AI, has retained the property.

Section 2.3.2 of the RI Report provides a complete summary of solvent use at the BES facility, based on all available records. These records indicate two primary candidate source areas where degreasing solvents were or are used at the plant.

A 2,000-gallon capacity degreasing tank was formerly located in what is now the BES carpentry shop. This tank was used from the late 1950s until approximately 1969 to degrease the shells of the meat display cases prior to the application of a urethane insulating material. The cases were dipped in the tank and staged in the vicinity of the tank to dry prior to applying the insulation. Trichloroethene (TCE) was the only solvent used in this tank.

The second area is a 600-gallon degreasing tank for cleaning small parts used to fabricate an interlocking mechanism for the insulated panels. This tank has been in continuous use since the early 1960s.

In addition, solvents have been used as flushing agents in cleaning molds and urethane foam injection nozzles in the plant foaming department since the mid-1960s.

The principal chlorinated VOCs found in the aquifer are 1,1,1-Trichloroethane (TCA), TCE, and 1,1-Dichloroethene (DCE). Spent degreasing solvents have been managed as a Resource Conservation and Recovery Act (RCRA) hazardous waste at BES since hazardous waste regulation began in 1980. Flushing agents used in the foaming department are recycled by a reprocessor and reused by BES. The major use of TCE was curtailed in

about 1969 with the cessation of production of the meat display cases. TCA (Eaken Saf-T-Sol 15®) was used in the small parts degreasing tank from 1980 until 1986, when it was replaced by a nonchlorinated solvent currently in use (Eaken Saf-T-Sol 31®. None of the principal chlorinated VOCs found in the aquifer have been used as flushing agents in the foaming department since 1986. The history of solvent use at the plant and the character of chlorinated VOCs present in the aquifer suggested at the outset of the RI that the aquifer contamination may have arisen as a result of an historic release.

Based on a review of archival aerial photographs, the EPA had also suggested four former lagoons active in the 1950s and currently lying underneath plant production and office areas as potential sources of the aquifer contamination. Both the lagoons and the areas of degreasing solvent use in the plant were examined in the RI in an effort to define whether source areas persist at the BES facility.

In response to comments received from the EPA after submittal of the RI Report, Remcor performed an additional source investigation within a parking area immediately adjacent to the northern perimeter of the BES plant. This investigation was conducted to determine whether an active source of VOC release to the aquifer was present within the unsaturated zone soils in this area. The investigation consisted of soil borings and collection of both soil and ground water samples for VOC analysis. This area was investigated because it lies hydraulically downgradient of the former lagoons and current and former degreasing areas, and hydraulically upgradient of contaminated shallow wells MW 86-4 and MW 86-3S.

3.0 SUBSURFACE INVESTIGATION

The primary focus of the RI was an investigation of potential source areas at the BES plant and hydrogeologic conditions within the aquifer. Initially, fourteen test borings were advanced, and soils were sampled and analyzed for TCL VOCs in the source delineation investigation.

Later, 17 more test borings were advanced and sampled in the additional source investigation. The hydrogeologic investigation included performance of 1 exploratory boring, installation of an additional 11 ground water monitoring wells, baseline monitoring, conduct of a 72-hour pumping test of Municipal Well No. 3, and ground water sampling. Section 3.1 provides a detailed description of field investigation methods. Section 3.2 discusses validation of the chemical-analytical data base. Section 3.3 discusses the results of the subsurface investigation in various subsections. Salient points have been summarized below.

Regional Geologic/Hydrogeologic Setting

The BES site lies within the Triassic Lowlands Physiographic Province, a former plateau-like region that has been modified by renewed erosion into gently rolling hills with less than 200 feet of overall relief. Triassic sediments, principally limestone fanglomerate with minor amounts of siltstone and shale, underlie the site area. These sediments extend to depths of thousands of feet. According to the geologic literature, the Reading Hills Physiographic Province lies immediately northwest of the Borough, with its eastern extent delineated by a major fault system, identified as the Triassic Border Fault. The Reading Hills Province consists of Cambrian and Precambrian Age basement rocks.

Site Geologic Investigation

The uppermost geologic units defined within the site area consist of plant fill and colluvial materials. The colluvial materials were found in all but the easternmost portions of the site area. These materials are clayey silts with a little gravel and are derived from weathering of the Precambrian and Cambrian rocks on the hillside to the west of the Borough. The greatest thickness of these materials was found to the northwest and along drainage courses.

A layer of residuum, weathered from the Triassic sediments, underlies the colluvial materials and overlies bedrock throughout the site area. The residuum is principally of silty clay to clayey silt composition with occasional fragments of limestone. The material grades into bedrock and, as such, retains much of the relict structure (e.g., jointing, bedding) of the parent material. The thickness of the residuum was found to be highly variable, ranging from 10 to 80 feet.

Bedrock encountered during the subsurface investigation was found to be exclusively of the Brunswick Formation. In the site area the bedrock was composed of limestone fanglomerate with interbedded siltstone and shale. It is significant to note that this finding differs from the published geologic literature which indicates that the western portion of the site should be underlain by quartzite rock characteristic of the Reading Hills Province. This finding is significant from a hydrogeologic perspective, in that the Triassic Border Fault separating the two units must be presumed to occur immediately west of Municipal Well No. 3. The frequency of discernible fractures in the fanglomerate was found to decrease with depth. In an exploratory corehole (E-1) in the vicinity of Municipal Well No. 3, an extensive fractured zone was found to occur to a depth of 140 feet, with more competent bedrock and more isolated fracture zones occurring below this depth.

Site Hydrogeology

From the hydrogeologic perspective, the site is characterized by a single, thick, unconfined (or locally semi-confined) aquifer that occurs within the limestone fanglomerate and overlying residuum. Transmission of ground water is principally controlled by secondary porosity caused by fractures, joints, and solutioning activity. The aquifer is presumed to extend vertically for several hundred feet with fractures decreasing with depth to a point at which open fractures no longer occur. The current RI did not determine the effective depth of the aquifer/extent of open fractures. In the vicinity of Municipal Well No. 3 the bedrock is severely fractured, possibly due to the proximity of this area to the

Triassic Border Fault. Well yields in this area were found to be several hundred gallons per minute (gpm).

Ground water flow direction was determined in the RI to be principally eastward. Ground water discharge to surface water may occur east of Route 100, but it was apparent from the subsurface investigation that this does not occur in the immediate site area. Surface water sampling results also do not suggest a connection between surface and ground water in the site area. The horizontal hydraulic gradient under normal conditions ranged from 0.0025 to 0.02. A low hydraulic gradient occurs in the vicinity of Municipal Well No. 3 and Chestnut Street due to extensive fracturing and weathering of the aquifer in this area.

Influence in water levels from the daily pumping of Municipal Well No. 1 was found during baseline monitoring to extend to a point approximately halfway between the well and the BES plant (i.e., a distance of about 1,200 feet). Industrial withdrawal from the aquifer at Bally Ribbon Mill and the Great American Knitting Mill are approximately 20 percent of that from the municipal well and do not appreciably alter ground water flow direction.

A 72-hour pumping test was performed at Municipal Well No. 3 to evaluate the response of the aquifer to pumping at this point. Based on historic data, it is possible to conclude that ground water extraction and treatment at this location may serve to mitigate further spread of contamination within the aquifer and capture such contamination to a significant degree.

The conduct and interpretation of the pumping test are discussed in Section 3.3 of the RI Report. The maximum cone of depression developed during the pumping test was elongated in the north/south direction, reflecting the anisotropic nature of the aquifer. After 72 hours of pumping, the capture zone of Municipal Well No. 3 had reached the BES plant area, but did not extend significantly beyond State Route 100 to

the east. Sluggish response to pumping in a few of the shallow monitoring wells indicated the presence of localized semi-confining conditions.

Estimates of transmissivity (T) and storativity (S) were generated from the pumping test and were found to range from 80,000 to 5,000 gallons per day per foot (gpd/ft) for T and between 10^{-1} to 10^{-3} for S. Interpretation of the data was complicated by aquifer anisotropy, partial penetration effects, and unavoidable pumping of Municipal Well No. 1 during the test. These factors, to an extent, limit the reliability of quantitative analysis from the test. The values generated, however, can still be used for future approximation of capture zones for different pumping schemes utilizing Municipal Well No. 3.

Source Delineation Investigation

In an initial effort to evaluate suspected sources of the aquifer contamination, borings were installed and subsurface soil samples were collected from four specific areas:

- Former degreasing area
- Present small-parts degreasing area
- Former northern lagoon area
- Former southern lagoon area.

Subsequently, the northern perimeter of the plant was investigated via a series of borings.

An HNu photoionization detector (PID) was used to screen soil samples in the field as a basis for selection of samples to be submitted for TCL VOC analysis. Field screening readings are summarized in Table 2 of the RI Report. Readings above background (zero parts per million) were found only from soils taken from the former northern lagoon area and from selected borings immediately north of the BES plant. Ten samples were submitted for laboratory analysis from the former degreasing area, two from the present degreasing area, five from each of the former lagoon areas, and 25 from the northern perimeter area. TCL VOCs were

detected in samples from the former degreasing area, where very low levels of TCE, TCA (i.e., less than 10 micrograms per kilogram [µg/kg]), and toluene (13 to 43 µg/kg) were found, and from one boring on the northern perimeter where TCA, TCE, and DCE were detected near the water table. Analytical data are summarized in RI Table 7.

The results of the source delineation investigation do not indicate conclusively that any of the suspected source areas are a principal source of the current extent of VOC ground water contamination. Nonetheless, the configuration of the contaminant plume supports the conclusion drawn from previous studies that the BES facility is a source of the contamination. The fact that specific source areas have not been found in the most likely areas suggests that the contamination may have arisen as a result of historic solvent management practices that permitted releases to the aquifer. These activities would most likely have occurred over a substantial period from the late 1950s until the early 1970s. These data suggest that there is no longer any active release of VOCs to the aquifer.

Nature and Extent of Ground Water Contamination

The presence of VOCs in ground water was determined by sampling 18 monitoring wells, 4 industrial wells, and 11 residential wells, in addition to the 2 municipal wells and analyzing the samples for TCL VOCs. VOCs were found in 19 of the 35 wells sampled. The municipal well samples were also analyzed for TCL ABN organics, with none detected.

The RI chemical-analytical data (RI Tables 8 and 9) show that a ground water plume of VOC contamination extends from the BES plant to the east and northeast. The plume consists predominantly of TCA, TCE, and DCE. It is apparent that the full-scale pumping of Municipal Well No. 3 from 1979 to 1982 has had the effect of drawing the VOCs deeper into the aquifer and to the north toward the well. Following cessation of pumping, the contaminant movement has become more controlled by the natural ground water flow direction to the east. Ground water and contaminant

migration has also been influenced by the pumping of Municipal Well No. 1. Past pumping of Municipal Well No. 3 and its subsequent shutdown may have actually exacerbated VOC levels currently found in Municipal Well No. 1 by drawing the contaminants into a portion of the aquifer where they could be captured by pumping at Municipal Well No. 1, which resumed after the shutdown of Well No. 3.

4.0 SURFACE WATER INVESTIGATION

Site Hydrologic Evaluation

The BES plant area and its immediate vicinity north of Barto Road are situated in a drainage basin of approximately 320 acres. Surface drainage is captured in two principal drainageways, both unnamed tributaries to the West Branch Perkiomen Creek. The more easterly of these receives approximately 80 percent of the drainage from the watershed and is a perennial stream. This stream originates in springs at the head of the drainage and flows past Municipal Well No. 3 and into an abandoned mill pond prior to discharging to the Bally storm sewer system and, ultimately, to the West Branch Perkiomen Creek. The second drainage is a minor feature, arising in a crop field northwest of the BES plant and primarily serving as an outlet for a tile drainage system in the fields.

The abandoned mill pond has been inactive for some time; the breast of the impoundment was breached by the current owner within the past five years to reduce liability associated with the impoundment. As a component of the RI a preliminary wetlands assessment was conducted. A Palustrine wetland has developed in this area and is readily defined by the perimeter of the former impoundment. Riparian wetland areas along the perennial stream form an extension of the Palustrine wetland to the northwest. On the basis of this preliminary assessment, it appears that these wetland areas do not represent critical habitat elements in the local area, nor are they likely to in the future because of the extensive residential and commercial development in their immediate vicinity. In addition, the U.S. Fish & Wildlife Service (USF&WS) has

determined that the site area is not of significant concern relative to the occurrence of special status species.

Extent of VOC Contamination in Surface Water and Sediments

Samples of surface water and sediment were collected initially at three locations during the RI, one within the perennial stream and two within the Palustrine wetland. Later, in response to EPA comments, two surface water and sediment samples were collected from the perennial stream to the east of Route 100. Analytical results are summarized in RI Table 10. The initial samples revealed only the presence of acetone and methylene chloride at levels consistent with laboratory-induced contamination. The most easterly of the later samples revealed low levels of VOCs consistent with the suggestion that ground water discharges to the stream in this area.

The hydrogeologic investigation determined that the wetland area north of the BES plant could not be receiving discharge from the contaminated aquifer. This fact is confirmed by the chemical-analytical results. It is possible, however, that ground water could be discharging to the perennial stream east of Route 100 where the VOCs were detected.

5.0 PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS

An assessment of public health and environmental concerns was performed in accordance with guidelines established by the EPA for performance of such evaluations at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites.

The following VOCs were selected as indicator compounds in the characterization of risk because of their presence in ground water and their potential chronic health effects (i.e., primarily their suspected carcinogenicity) at low levels:

- TCE
- TCA
- Tetrachloroethene (PCE)
- DCE
- 1,1-Dichloroethane (DCA)
- Methylene chloride.

The assessment considered noncarcinogenic and carcinogenic health effects and environmental toxicity for these compounds in defining risk to public health and the environment.

The only known current human exposure takes place through potable use of the contaminated municipal supply well (Municipal Well No. 1). The municipal system currently services approximately 1,200 residents of Bally. Remcor considered both ingestion and showering exposure pathways in defining cumulative risk.

In assessing risks associated with use of the municipal water supply, Remcor did not consider the effect of dilution of water drawn from the municipal well(s) by water from the springs. The relative contribution of each source is known to vary with seasonal conditions; significant pumping of the municipal well(s) is required only during the summer and fall months to supplement the springs. Existing data are not adequate, however, to permit a precise estimate of the contribution of each source to actual consumption. A cumulative carcinogenic risk estimated for use of the current municipal system, considering no dilution of well water with uncontaminated spring water, is 1.0×10^{-3}. In reality, this risk is significantly reduced by dilution of uncontaminated spring water occurring within the Municipal system. The amount of dilution is directly related to spring flow and, as such, will vary seasonally. The risk of noncarcinogenic health effects is deemed acceptable for the current municipal ground water supply system in accordance with EPA guidance on risk assessment.

Future plans for the municipal water supply system are to reduce reliance on Municipal Well No. 1 and to use Municipal Well No. 3 as the primary supply well. This well has been equipped with an air-stripping treatment unit. VOC concentrations to be achieved in the treated well water are those set forth in water supply and National Pollutant Discharge Elimination System (NPDES) permits issued by the PADER for

this treatment system. The extreme worst-case cumulative carcinogenic risk estimated for use of treated water from Municipal Well No. 3, again considering a worst-case scenario (no dilution of the well water with spring water), is 3.3×10^{-5}. Estimated noncarcinogenic risks were again found within acceptable limits.

Contaminated ground water is not discharging to surface water in the immediate site vicinity. There is evidence, however, that ground water discharge to surface water does occur east of Route 100. Surface water VOC concentrations found in one sample from this area were found to be below applicable criteria for the protection of aquatic biota. When using those concentrations to develop an estimated dose for dermal contact and accidental ingestion, the carcinogenic risk is estimated at 2.5×10^{-8}, well below the lower limit of the risk range considered acceptable for CERCLA sites by EPA policy (i.e., 10^{-4} to 10^{-7}).

1.0 INTRODUCTION

This report describes the Phase III Remedial Investigation (RI) for the Bally Engineered Structures (BES) site in Bally, Pennsylvania. This RI was conducted by Remcor, Inc. (Remcor) on behalf of Allegheny International, Inc. (AI) in response to a Final Administrative Order by Consent (ACO) dated January 28, 1987 (U.S. Environmental Protection Agency [EPA], January 1987). This ACO was issued under Section 106(c) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This report consists of two volumes; Volume I includes text Chapters 1.0 through 6.0, and Volume II includes Appendices A through I.

Figure 1 is a site location map. The area of investigation, hereafter referred to as the site, includes the BES plant and the surrounding aquifer used by the Borough of Bally (Bally) as a municipal water supply. The RI field activities were conducted in accordance with EPA-Approved Work Plans (Remcor, September 23, 1987, February 1989) and in accordance with the final responses to EPA Region III technical comments (Remcor, September 23, 1987). The Phase III study is based, in part, on the results of the Phase II work conducted by Environmental Resources Management, Inc. (ERM) in 1985. The EPA has accepted the ERM data, subject to qualifications contained in its letter to BES dated January 23, 1987 (EPA, January 23, 1987).

1.1 OVERVIEW OF THE REMEDIAL INVESTIGATION

1.1.1 Problem Statement

In 1982, the Bally Municipal Water Authority conducted a water quality check of the Bally water system. The presence of elevated concentrations of chlorinated volatile organic compounds (VOCs) in one of Bally's municipal wells (Well No. 3) focused attention on users of industrial solvents in the area. A survey conducted by the Pennsylvania Department of Environmental Resources (PADER) in 1983 (PADER, March 28, 1983)

indicated that the BES plant was a potential source of the VOC contamination. Although unaware of any sources of the VOC contamination resulting from its activities, BES met with PADER in 1984. Subsequently, BES retained ERM to evaluate existing data and to perform an initial RI (Phase I and Phase II studies) to evaluate potential sources of contamination to Bally Well No. 3.

ERM's report submitted in October 1986 (ERM, October 27, 1986) suggested that the BES plant was a primary source of the VOCs found in ground water north of the plant. The report concluded that the VOC contamination extends north and northeast of the plant, toward Bally Municipal Wells Nos. 3 and 1. Industrial ground water users are also located within Bally northeast of the BES plant. The only industrial users in the site area are the Bally Ribbon Company and the Great American Knitting Company. Figure 2 is a plan view of the Borough of Bally and the BES facilities. This figure also shows the location of the municipal wells and the above referenced industrial wells.

Bally Municipal Well No. 3 was removed from the municipal supply system on December 10, 1982 as a result of the presence of VOCs, most notably 1,1,1-trichloroethane (TCA) and trichloroethene (TCE), both commonly used industrial degreasers. The 1986 ERM report concluded that high-volume pumpage (approximately 300 gallons per minute [gpm]) of Well No. 3 from its start-up in 1979 through to December, 1982 served to draw VOCs from the BES plant toward the well, capturing contaminants that might otherwise have migrated into Bally Well No. 1 or other local wells. Although Bally continued to pump Well No. 3 to waste intermittently from 1982 until March 12, 1987, the increased levels of VOCs in other wells in the vicinity indicate that its role in mitigating contaminant dispersion was reduced. This continuing trend suggests the need for remedial action to counteract the further spread of contamination in the ground water system.

1.1.2 Focused RI Overview

1.1.2.1 Objectives

The objectives of the Phase III RI are as noted:

- To delineate the source of ground water contamination
- To determine the extent and distribution of ground water contamination by VOCs
- To assess the potential current and future risks to public health and the environment
- To characterize the hydrogeologic setting in sufficient detail to permit design of an effective ground water cleanup program, if required.

Based upon a preliminary evaluation of the Bally site, Remcor has identified the pumping and treating of ground water as the principal remedial action technology to be implemented. The RI was appropriately focused to obtain the data necessary to evaluate this action as well as to identify other potentially significant exposure pathways, as well as any other required remedial responses.

1.1.2.2 Scope

The scope of the Phase III RI activities was designed to achieve the above-stated objectives. Former waste lagoons, former and present small-parts degreasing areas, and an area north of the facilities at the BES plant were sampled to evaluate suspected historical sources of the VOCs. Current plant solvent use and spent solvent handling practices were evaluated to define the potential for a continuing release. The degreasing areas have been associated with various industrial solvents containing TCA, TCE, methylene chloride, and other hydrocarbons. Soil samples were collected to depths up to 22 feet in these areas and were analyzed for target compound list (TCL) VOCs.

The local hydrogeologic setting was characterized and the extent and distribution of ground water contamination were determined via the following activities:

- Exploratory core drilling and geophysical logging were performed to define subsurface lithologies and stratigraphy.
- Eleven new monitoring wells were drilled and installed. Subsequently, these and all existing monitoring wells, as well as residential, municipal, and industrial wells were sampled to determine contamination extent and distribution of VOCs. The municipal wells were also sampled for acid and base/neutral extractable (ABN) organics.
- A large-scale pumping test was performed to define hydrogeologic parameters and to aid in developing aquifer remediation alternatives.
- Surface water and sediment samples were collected at three points within the upland wetland north of the BES plant and at two points in the unnamed tributary to the east of Route 100, and analyzed for VOCs.
- Local municipal and industrial ground water usage patterns were determined by interviewing cognizant personnel to define possible effects on the ground water table and contaminant movement.

Concurrent with the performance of the BES RI, Remcor designed and installed wellhead treatment on Municipal Well No. 3. This treatment consists of a packed tower air stripper with induced draft capable of treating up to 300 gpm. This system will serve two purposes:

1) Permit Well No. 3 to again be used to supplement the municipal water supply
2) Serve as a ground water extraction and treatment point to control the spread of VOCs and to remove them from the aquifer.

The treatability work performed by Remcor during design and implementation of the wellhead treatment system has proven the effectiveness of this technology at the site. The focus of the Feasibility Study (FS)

phase of this project will be to determine whether additional engineering controls can enhance remediation of the aquifer or provide additional benefits to the public health or environment. The data base available to the FS consists of that obtained in the RI, including chemical-analytical and hydrogeological data obtained during the operation of the wellhead treatment system. The air-stripping treatment system was in place and operational during the large-scale pump test performed on Well No. 3 during the RI. Final testing of the treatment system began on February 6, 1989 with continuous pumping of Municipal Well No. 3 and discharge of treated effluent from the air stripping units to the adjacent stream. Bally intends to begin using the treated ground water in June 1989 as a supplement to the springs.

1.2 ORGANIZATION OF THE REPORT

The organization of this report generally follows the guidelines set forth by the EPA's "Draft Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA, August 1988). Text Chapters 1.0 through 6.0 are included in Volume I; Appendices A through I comprise Volume II.

Chapter 2.0, Site Background Information, discusses the site's general environmental setting including geologic, physiographic, hydrologic, and land use features. Additionally, the history of the aquifer contamination problem is discussed including a summary of data developed in earlier investigations, a survey of aquifer use in the Bally area, and the history of BES plant operations and solvent use.

Chapter 3.0, Subsurface Investigation, presents a detailed description of all Remcor source evaluation and hydrogeologic field investigation methods and results. The methods discussion includes, but is not limited to, drilling, well installation, soil and ground water sampling, and aquifer performance testing. The results discussion presents regional and site-specific findings on soils, geology, and hydrogeology, including chemical-analytical results.

Chapter 4.0, Surface Water Investigation, presents surface water and sediment sampling methods and chemical-analytical results as well as the preliminary wetlands characterization of an abandoned mill pond area adjacent to BES.

Chapter 5.0, Public Health and Environmental Concerns, presents health and environmental risks associated with the site. This section includes discussions of hazard identification, dose-response assessment, exposure assessment, and risk characterization. The exposure assessment and risk characterization are quantitative in nature and are performed for site conditions both prior to and following ground water extraction and treatment at Bally Municipal Well No. 3.

Chapter 6.0 is a brief closing section.

2.0 SITE BACKGROUND INFORMATION

The BES plant consists of an active manufacturing facility situated on a tract of approximately 19 acres in Bally, about 12 miles south of Allentown on Route 100 (Figure 1). BES has operated the facility since 1972 and is engaged in the construction of insulated structures and structural panels. BES' predecessor, Bally Case and Cooler Company (BCC), initiated manufacturing activities at the site in the 1930s and was the original owner of the facility.

2.1 GENERAL ENVIRONMENTAL SETTING

2.1.1 Hydrogeologic Setting

Bedrock occurring beneath the site is of the Triassic Age Brunswick Formation, which consists of red shales, siltstones, and, in the site area, limestone fanglomerates. The fanglomerates are composed of limestone breccia and limestone pebbles in a sandy, argillaceous matrix. Unconsolidated material overlying bedrock consists of residual red-brown clays and silts weathered from bedrock and a thin (0 to 10 feet thick) mantle of alluvial material.

Within the Brunswick Formation, the occurrence of ground water is primarily associated with fractures and joints. Solution activity within the limestone fanglomerate has created a higher porosity and permeability than in the adjacent shales and siltstones.

2.1.2 Physiographic Setting

The BES site is located near the contact of two physiographic provinces. The hills to the northwest of the site are composed of igneous and metamorphic units of Precambrian and Cambrian Age that occur within the New England physiographic province. The site lies within the Piedmont Upland physiographic province, which occupies the lowlands east of the Precambrian and Cambrian Age hills. Relief between the two provinces is approximately 500 feet.

There is little topographic relief at the BES plant and in its immediate vicinity. The entire plant grounds lie at approximately 465 (±10) feet mean sea level (ft-msl).

The drainage area encompassing the BES plant site originates near the northern Borough boundary. The watershed is bounded on the west by an unnamed tributary to the West Branch Perkiomen Creek. The watershed is bounded on the south by Barto Road, and on the east by Route 100 and residential development. A man-made upland wetland lies approximately 300 feet north of the BES plant, fed by a second unnamed tributary to the West Branch Perkiomen Creek. Surface runoff from the asphalt parking areas around the plant flows to a municipal storm sewer that includes an open ditch running for approximately 200 feet along the southeastern perimeter of the facility. This sewer ultimately outlets to a main sewer line servicing the main street (Route 100) of Bally. Parking and plant yard areas to the northwest of the plant buildings are gravel-surfaced and generate little runoff.

2.1.3 Adjacent Land Use

Bottomlands to the north and west of the BES site are predominantly dedicated to agriculture, with some orchard production on the upland areas. To the east and northeast, old field areas separate the plant area from Bally Well No. 3, a municipal recreation area, and residential development. A Mennonite church and cemetery lie along Barto Road and Route 100 immediately south of the plant.

2.2 HISTORY OF THE AQUIFER CONTAMINATION PROBLEM

2.2.1 Summary of Previous Data

Following its closure in December 1982, the PADER conducted an evaluation of potential sources of the VOC contamination noted in Bally Municipal Well No. 3. The results of the PADER survey were reported in an internal memorandum dated March 28, 1983 (PADER, March 28, 1983). This report suggested that the BES plant was a possible primary source

for the local ground water contamination. BES was advised of these findings by PADER via letter dated August 25, 1983.

On September 21, 1983, the NUS Corporation Field Investigation Team (NUS/FIT) conducted a Preliminary Assessment/Site Investigation (PA/SI) of the BES site. The PA/SI report was submitted in September 1985 (Zima, et al., September 20, 1985). In conjunction with the PA/SI, NUS/FIT collected soil samples from an unpaved area east of the BES plant office and sampled the BES plant well, both municipal wells, a well at the Washington Elementary School, a domestic well (Gehman), and three farm wells on the Longacre Dairy property. The well at the elementary school and the three farm wells are located to the south of the site area, now known to be hydraulically upgradient of the site.

The NUS/FIT results represent the only full TCL analyses of environmental samples from the BES site. The organic results were reported as highly qualified and inconclusive because of elevated levels of contaminants not associated with the site and contamination of field blanks. In particular, TCA, TCE, and 1,1-dichloroethene (DCE) were detected in blank samples "at sufficient levels to question the aforementioned sample results for these parameters" (Zima, et al., September 20, 1985). VOCs were reported to be less than 10 micrograms per liter (µg/ℓ) in the ground water samples from the elementary school and the Longacre Dairy wells. Because of blank contamination, the presence of a number of these compounds was questioned. The following concentrations of TCE and DCE were reported for the remaining wells (Sample No. 5 appears to have been collected from the BES plant well though the well is incorrectly located in the PA/SI report):

NUS/FIT Sample No.	Parameter Description	(µg/ℓ) TCE	DCE
5	BES Plant Well	415.18	6.28
6	Municipal Well No. 3	484.70	175.72
8	Mabel Gehman Well	238.17	3.28
12	Municipal Well No. 1	4.88	0.58

Three soil samples collected to the east of the BES office and a single surface soil sample collected from the perimeter of the BES drummed waste storage area revealed less than 10 micrograms per kilogram (µg/kg) VOCs.

BES was not aware of any sources of contamination resulting from its activities. Nonetheless, BES representatives met with PADER January 26, 1984 to evaluate possible methods to study the ground water problem (ERM, October 27, 1986). In September 1985, ERM was authorized by BES to conduct a Phase I Study (Data Review and Evaluation) and a Phase II remedial investigation to determine the source(s) of the VOC contamination found in Bally Municipal Well No. 3. The results of the ERM study were submitted in a report dated October 27, 1986. During the course of the ERM Phase II study, five on-site and two off-site monitoring wells were installed. Samples were collected from the 7 ERM wells, the BES plant well, and 13 off-site residential/municipal/industrial wells. These samples were analyzed for chlorinated VOCs. The results of these analyses indicated that the BES plant well, all downgradient monitoring wells, one residential well (Gehman), both municipal wells, and the Bally Ribbon and Great American Knitting wells contained varying levels of chlorinated VOCs.

The ERM report concluded that based on ground water flow and well sampling data, the BES property was a probable source of the chlorinated solvent contamination in the vicinity of the BES plant. Their study revealed a northeasterly ground water flow direction from the plant. Chlorinated VOCs were detected at the northeast corner of the BES property (Well No. 86-4) in ground water at a concentration of over

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7,000 µg/ℓ. The unused Gehman residential well, located over 1,000 feet northeast of the site, showed a total chlorinated VOC concentration of 304 µg/ℓ. The outlying industrial wells and Municipal Well No. 1 exhibited concentrations of total chlorinated VOCs ranging from only 39 to 61 µg/ℓ.

In addition, the ERM report documented the effects that pumping nearby Bally Municipal Well No. 3 had on the contaminant plume. The high volume pumping (300 gpm) of this well had drawn contamination towards the northwest, which resulted in a total chlorinated VOC concentration of 3,509 µg/ℓ at Municipal Well No. 3 at the time of sampling. The pumping of this well appeared, in part, to retard the downgradient migration of the contaminant plume. The sampling results from this study are included as Appendix A.

Soil borings were also completed during the ERM study at five locations within what was termed a "dirt area" located approximately 315 feet southwest of Bally Well No. 3. Samples from these soil borings were also analyzed for chlorinated VOCs. This area had been identified in 1966 Environmental Photographic Interpretation Center (EPIC) aerial photographs (EPIC, August 1987) as a potential disposal area (i.e., ground scar) and a likely source of contamination for Bally Municipal Well No. 3. The laboratory results for these soil samples showed no measurable levels of VOCs, however, and on this basis the "dirt area" was discounted as a possible source of the contamination at the municipal well.

In an effort to continue the role that Municipal Well No. 3 had apparently played in confining contaminant movement, Bally continued intermittent pumping of the well to waste from 1982 until March 12, 1987. Pumping was discontinued at that time because of the inability of the Borough to obtain necessary renewal of its surface water discharge permit from the PADER, Bureau of Water Quality (BWQ). The permit had initially been issued for an interim period of two years to permit Bally the time to develop a remedy for the ground water contamination problem.

2.2.2 Aquifer Users

2.2.2.1 Bally Municipal Wells

The Bally municipal wells (Well Nos. 1 and 3) represent the most significant potential receptors of site contamination. The location of each well is shown in Figure 4 with reference to the BES plant.

Currently, about 1,200 residents of the Borough are served by the Bally Municipal Water Authority. Both municipal wells were intended to supplement the supply from a 270,000-gallon, spring-fed reservoir. The reservoir is located approximately 3,000 feet northwest of the BES plant on a hillside overlooking Bally, and has not been adversely affected by the ground water contamination. This reservoir lies at approximately 640 ft-msl, about 160 feet above the elevation of the BES plant. The springs and reservoir are hydrogeologically isolated from the observed ground water contamination.

Bally Well No. 1 has been in continuous service since October 1951. Bally Well No. 3 was placed into service in November 1979 and was taken off-line in December 1982 as a result of the VOC contamination found in October of that year. Well No. 3 was originally intended as a backup to Well No. 1. During the period when Well No. 3 was on-line, each of the wells was pumped on a biweekly (alternating) basis, at a rate of 300 gpm for approximately five hours each day.

Specific data for each of the municipal wells, reproduced from Bally records, follows:

Municipal Well No. 3:

- Permit No. 0678502
- Drilled in 1977
- On-line in November 1979
- 300 gpm pump
- Safe yield is 0.324 million gallons per day (mgd)
- Gas chlorination treatment
- 303 feet deep
- 10-inch diameter

- 150 feet to pump
- 300-foot pumping head
- Static water level 35 feet below grade (following drilling).

Municipal Well No. 1:

- Permit No. 8207-A
- Drilled in 1951
- Depth to bedrock is 96 feet
- Safe yield is 0.4 mgd
- 300 gpm pump
- Hypochlorinator
- 272 feet deep
- 10-inch diameter
- Static water level 15 feet below grade.

Table 1 shows the Borough's daily metered water consumption over the period from 1983 to present, since Well No. 3 was taken off-line. During this period, pumpage from Municipal Well No. 1 has accounted for about 50 percent of the total production of the Bally Borough water supply system. Actual production of water typically exceeds metered consumption, making it difficult to accurately define the actual quantities of water from Municipal Well No. 1 that are dedicated to potable uses.

2.2.2.2 Residential Wells

Figure 4 shows the locations of residential and industrial wells identified during the RI, located within or just outside Bally. Private wells are located at the Longacre Dairy, Keh's Brothers Garage, and at 11 residences. The Leo Bauer residence was the only private well not sampled during the Phase III RI. The Longacre Dairy and the Nace residence are located hydraulically upgradient of the BES plant. Farm Products is no longer in business and is currently the Newman residence. The Stofflet, Gehman, and Bauman wells are not currently in use.

2.2.2.3 Industrial Wells

The 1983 PADER survey identified industrial wells at the Great American Knitting Company and Bally Ribbon Company. The Bally Ribbon well lies

immediately adjacent to Bally Municipal Well No. 1, and the Great American Knitting well lies approximately 1,400 feet to the south (Figure 4).

Substantial quantities of ground water are withdrawn from both of these wells. Metered consumption at each wellhead during September 1988 indicates that Bally Ribbon pumps between 8,000 and 12,000 gallons per day (gpd) and Great American Knitting pumps 5,000 to 15,000 gpd. Until the spring of 1988, Bally Ribbon had been pumping ground water on a continuous basis at the rate of approximately 40,000 gpd; approximately one quarter of this volume was used in their processes and the remainder was discharged to the municipal storm sewer.

2.3 HISTORY OF BES PLANT OPERATIONS

2.3.1 Overview

Initial manufacturing operations at the current BES plant began in the 1930s with the production of high-quality wooden cabinets and cedar chests. Cabinet production continued until the 1940s when the plant was commissioned by the government to assist in the war effort.

In the 1950s, BCC turned to the manufacture of continuous-line, insulated meat display cases. The outer shell of these display cases was provided with a porcelain finish, and BCC also became a major supplier of porcelain panels for use as building facades.

The insulation used in the meat display cases during the 1950s was conventional fiberglass batting. In the late 1950s, BCC began experimenting with the use of urethane foam insulation to replace the batting. Actual use of urethane foam in the production process did not begin until the early to mid-1960s. Manufacture of the meat display cases was discontinued about 1969, and the production capability of the plant was fully dedicated to the manufacture of insulated panels.

BCC remained privately held until 1972, when it was purchased by the Sunbeam Corporation. BCC became a subsidiary of AI with AI's acquisition of Sunbeam in 1982. BCC was renamed BES in 1984, in response to the increased emphasis on the manufacture of insulated panels and product diversification. On June 23, 1987, BES business was sold to Bally Acquisition Corporation, while Dagan, Inc., a subsidiary of AI, has retained the property.

2.3.2 History of Solvent Use

Hazardous chemicals have been used at the Bally plant in two general areas since the 1950s:

- Pickling acids were used to prepare the surface of the metal shells for the display cases to receive the porcelain coatings
- Degreasing solvents were used to clean metal surfaces to ensure a good bond with urethane foam insulation, as well as to degrease small metal parts used in interlocking the panels to form the insulated structures.

The EPA EPIC archival aerial photographs of the plant site show the presence of four lagoon areas at the site from 1955 through 1970 (EPIC, August 1986). The approximate locations of these former lagoons are shown in Figure 3, which also shows the plant buildings in plan view as they were from about 1950 to 1970.

In advance of the current RI, much of the discussion of potential sources of the VOC ground water contamination from the BES plant has focused on these four former lagoons. These lagoons were reportedly shallow (i.e., maximum depth not greater than one foot), diked structures which may have received some spent degreasing solvents.

The first series of two lagoons was apparently constructed prior to May 1955, based on a May 2, 1955 aerial photograph (EPIC, August 1986), and was backfilled prior to the mid-1960s as the plant buildings expanded to the southwest. At about this time, a series of two other lagoons was

apparently constructed further to the south (Figure 3). The latter two lagoons were eliminated with the construction of the present plant office in 1970. These lagoons may not have been used after the late 1960s because production of the porcelain-faced meat display cases had ceased.

Initial use of degreasing agents at the Bally plant was concurrent with the switch to urethane foam as the display case insulating material. A 2,000-gallon capacity tank was located at the former degreasing area in the northeastern portion of the plant (Figure 3). Prior to the application of the porcelain shells and the foam insulation, an overhead monorail crane was used to dip the entire case into the tank. Following dipping, the cases were set on the floor and permitted to dry before being returned to the production line. The only solvent used in the former degreasing area tank was TCE. Use of this degreasing tank was discontinued in approximately 1969, with the end of the case manufacturing operations.

A second degreasing area known as the "small parts degreasing area" (Figure 3) has been in use since the early 1960s for degreasing small parts used in interlocking the insulated panels. The tank at this location has a capacity of 600 gallons, but usually contains less than 400 gallons of solvent.

The following chronology is provided for use of degreasing solvents in the small parts degreasing tank (600-gallon tank):

August 1986 to present:	Eaken Saf-T-Sol 31®
April 23, 1980 to August 1986:	Eaken Saf-T-Sol 15®
Prior to April 23, 1980:	Eaken Saf-T-Sol 5®

There is no reference in the plant operating records to use of specific degreasing solvents at the small parts degreasing tank prior to 1980. In addition to the Saf-T-Sol 5®, Chlorothane may have been used during this period.

Solvents have also been used as flushing agents to clean molds and urethane foam injection nozzles between mold shots. This activity has been ongoing since the initial use of urethane foam in the production process in the mid-1960s. Flushing solvents historically used in cleaning the injection nozzles in the foaming department are as follows:

January 1987 to present:	Methylene chloride (Chemical Solvents, Inc. SP-713®)
July 1986 to January 1987:	Eaken Saf-T-Sol 12®
February 1986 to July 1986:	Chemical Solvents, Inc. SP-711®
July 1976 to February 1986:	Eaken Saf-T-Sol 12®
October 1973 to July 1976:	Chlorothane VG®
Prior to October 1973:	Trichloroethylene

The general compositions of all aforementioned trade name solvents are as follows:

Solvent	Active Agent/Constituents
SP-711®	Trichloroethylene
SP-713®	Methylene Chloride
Chlorothane VG®	1,1,1-Trichloroethane®
Saf-T-Sol 5®	Methylene Chloride Tetrachloroethylene
Saf-T-Sol 12®	Methylene Chloride Methanol Toluene
Saf-T-Sol 15®	1,1,1-Trichloroethane
Saf-T-Sol 31®	Hydrocarbons (no TCE/TCA)

All spent degreasing solvents are currently drummed and disposed off site through the services of a licensed contract hauler and a disposer. The flushing agent is drummed and sent to a reprocessor; about 60 percent of the spent flushing agent is returned to the Bally plant, while the remainder is disposed by the reprocessor.

3.0 SUBSURFACE INVESTIGATION

3.1 FIELD INVESTIGATION METHODS

Subsurface investigations included the construction and sampling of 1 exploratory corehole, 31 test borings, 11 monitoring wells, and 2 temporary piezometers in the site area. This drilling supplemented the seven monitoring wells previously installed by ERM in their Phase II study. Additionally, background water level data were obtained to determine the hydrodynamic conditions occurring within the aquifer, and a large-scale pumping test of Municipal Well No. 3 was conducted to develop aquifer parameters. The following sections describe the methodology employed in each of these tasks.

3.1.1 Test Boring Drilling and Sampling

The test boring investigation was conducted at the BES plant to determine the source or sources of VOCs believed to have been the result of historic solvent handling and disposal practices. Four areas were initially identified as potential sources including two former lagoon areas (each consisting of two lagoons) and two degreasing areas. All of these areas were investigated through a network of 14 test borings, which were performed in three separate mobilizations. The suspected source areas and test boring locations are shown in Figure 3.

In reviewing the draft RI Report, the EPA suggested that unsaturated zone soils along the northern portion of the BES plant may constitute a possible VOC source area. Subsequently, 17 borings (SS-16 through SS-32), including 2 temporary piezometers, were drilled and sampled in an additional source investigation. The locations of these borings are also shown in Figure 3.

During November 17 and 18, 1987, four borings (SS-1 through SS-4) were drilled in the former southern lagoon area, and one boring (SS-9) was drilled in the vicinity of the current small parts degreasing area. The borings were advanced using a geotechnical drill rig (Mobile B-53) using

hollow-stem augers or a tricone roller bit. Soil samples were collected on a continuous basis into undisturbed residual material and at the geologist's discretion, based on visual characterization of the soil and organic vapor readings, thereafter. Three-inch (inside diameter [ID]) hollow-stem augers and plug were advanced to the sampling depth. Samples were taken with a two-inch (outside diameter [OD]) split-spoon, driven with a 140-pound hammer falling freely through 30 inches, in accordance with the American Society for Testing and Materials (ASTM) Method D 1586-74. Each boring was logged by a Remcor geologist. Logs of the borings are provided in Appendix B. After completion, each boring was sealed to grade with a bentonite and cement grout.

Soil samples obtained for analytical purposes were collected with clean, decontaminated split-spoon samplers. Several split-spoons were utilized so that a clean sampler was always available. The spoons were decontaminated between each use with the aid of a high-pressure steam cleaner.

Upon opening each split-spoon, the sample was scanned with an HNu photoionization detector (PID) (to determine the presence of VOCs) and examined visually for any obvious staining or waste characteristics (Table 2). After scanning, the sample was logged using the Unified Soil Classification System (USCS). A portion of each sample was placed directly from the spoon into 250-milliliter (ml) volatile organic analysis (VOA) soil jars using a clean pair of gloves and a clean, decontaminated stainless steel putty knife. A clean eight-ounce wide-mouth sample jar was also filled halfway with a portion of the sample to permit headspace analysis to be performed in the field with the HNu.

All samples were considered candidate laboratory samples prior to the headspace analyses. These samples were placed in a cooler on ice to maintain a temperature of approximately four degrees celsius (°C) prior to shipment. The sample portions intended for headspace analysis were stored at room temperature for a period of several hours, and then a headspace reading of the jarred sample was obtained with the HNu.

Results from the headspace readings were used, together with visual observations, to define which samples would be sent for laboratory analyses (Table 2). Shipment of samples selected for laboratory analysis occurred within 24 hours of sample collection. All chain-of-custody procedures were strictly adhered to during all phases of sample acquisition, storage, preparation, and shipment.

Borings SS-5 through SS-8 (Figure 3) were completed between November 29 and 30, 1987, through the concrete floor of the current BES foaming shop (i.e., the location of the injection molding equipment used to create the insulated panels). The confined area precluded the use of any standard test boring equipment. A concrete coring machine was used to penetrate the concrete slab. A hand-held power auger was used to advance the hole, and a bucket auger was used to obtain the samples. All borings were sealed with a mixture of cement and drill cuttings. Boring depth ranged from 2.8 to 8.0 feet. Boring logs are presented in Appendix B.

The sample acquisition and selection procedure was similar to that used for the test borings in the southern lagoon area, except that the samples were obtained with a clean, decontaminated bucket auger. Each bucket auger was decontaminated prior to use using a five-step process:

- Wash with distilled water and nonphosphate detergent
- Rinse with distilled water
- Rinse with hexane
- Rinse with distilled water
- Air dry.

Borings SS-10 through SS-14 were drilled from January 4 through 6, 1988, inside the BES carpentry shop in the former degreasing area. These borings were drilled with a skid-mounted geotechnical rig. Sampling and drilling procedures were the same as those used for borings SS-1 through SS-4.

Borings SS-16 through SS-32 were completed during the period of March 7

through 14, 1989. Like borings SS-1 through SS-4, the borings were advanced by a small geotechnical drill rig using hollow-stem augers. The only significant drilling procedural change was in the collection of split-spoon samples; a 300-pound weight was utilized in lieu of the 140-pound weight to enhance sample recovery. Two of the borings installed during this supplemental investigation (SS-17 and SS-22) were fitted with 2-inch polyvinyl chloride (PVC) standpipes to permit ground water sampling at these locations. Each boring was logged by a Remcor geologist; the prepared boring logs are presented in Appendix B-1.

Soil sample collection was similar to that of earlier portions of the investigation. Each sample was collected via a 2-inch (OD) decontaminated split-spoon sampler. Upon opening of the split-spoon, the sample was scanned with an HNu photoionization detector (PID) to detect VOCs. Samples were collected into two jars as follows:

- A 125-mℓ amber glass jar filled to capacity with minimal air space (selected samples based on preliminary scan results)
- A 250-mℓ amber glass jar filled one-third to one-half capacity (each sample as practical).

The 125-mℓ jars were labeled and prepared for shipment to the analytical laboratory. The samples contained in the 250-mℓ jars were placed in a warmed area to allow the soil gases to reach equilibrium in the jar headspace. After one hour the HNu PID was used to scan the headspace gases from the sample. This procedure was used to aid in the selection of samples requiring laboratory analysis. Table 2 shows the results of these headspace analyses.

3.1.2 Exploratory Drilling/Geophysical Well Logging

Exploratory drilling was conducted at boring location E-1 to determine lithologic conditions within the study area (Figure 3). McKay and Gould Drilling (McKay and Gould) of Darlington, Pennsylvania, performed the drilling from November 10 through 16, 1987, with a Mobile Model B-53

drill rig. At this location, hollow-stem augering (with split-spoon sampling) was conducted to a depth of 55 feet. The borehole was then advanced by NX coring to a depth of 198.50 feet.

Through the unconsolidated material, the boring was logged by the USCS method with particular attention given to determining the hydrogeologic characteristics of the residual material. Split-spoon samples were obtained at the rate of one sample per 5-foot interval to a depth of 30 feet, and thereafter at the geologist's discretion. Augering continued until bedrock refusal.

The bedrock core was carefully logged paying particular attention to fractured intervals and lithologic features. Rock quality designation (RQD) and percent recovery values were obtained for each core interval (Appendix B).

After drilling, the borehole was logged by borehole geophysical techniques consisting of the following logs: gamma, neutron, gamma-gamma (density), resistivity, spontaneous potential, fluid conductivity, temperature, and caliper. Appalachian Coal Surveys of Pittsburgh, Pennsylvania, conducted the geophysical borehole logging. In addition, existing ERM monitoring well 86-3D was also logged at this time. Geophysical logs for each of these borings are included in Appendix C.

After geophysical logging, borehole E-1 was tremie grouted, starting at the bottom of the boring and working upward to ground surface, with a grout mixture containing 3 percent bentonite and 97 percent cement, by weight.

3.1.3 Monitoring Well Installation

Eleven monitoring wells were installed during the hydrogeologic investigation. In addition, two previously undiscovered residential wells were identified in the general area of proposed monitoring well locations MW 87-6I and MW 87-9S (Remcor, September 23, 1987). Samples were

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obtained from these two wells, which eliminated the need for the originally proposed monitoring wells (i.e., MW 87-6I and MW 87-9S).

Proposed monitoring well location MW 87-6I (600 feet north of Municipal Well No. 3) was replaced with a ground water sample obtained from a well owned by Mr. and Mrs. Stofflet. The well is approximately 30 feet deep and is located north of the home (Figure 4). It is used for gardening purposes only and has a hand-operated pump. Proposed monitoring well location MW 87-9S (2,000 feet southeast of Municipal Well No. 3) was replaced with a ground water sample obtained from an inactive well owned by Mr. and Mrs. Bauman. This well was greater than 50 feet deep and is located on the north side of the home (Figure 4). Although the well is inactive, the electric suction pump still operates.

Of the 11 wells drilled, 3 were shallow wells (21 to 41 feet deep), 6 were intermediate wells (119 to 176 feet deep), and 2 were deep wells (203 and 210 feet deep). Well designations in this report commence with two digits indicating the year the well was drilled followed by a dash and the well location number (e.g., 87-10). The well designations are followed by a single letter suffix indicating:

- S - Shallow (21 to 41 feet deep)
- I - Intermediate (119 to 176 feet deep)
- D - Deep (203 to 210 feet deep).

The depth designations do not correlate exactly to the above for the ERM (86-series) monitoring wells.

All monitoring wells, except well 87-13S, were drilled by McKay and Gould using a Gardner Denver 15W air rotary rig. These wells were drilled between November 18, 1987, and December 17, 1987. Monitoring well (MW) 87-13S was drilled and installed by Empire Soils Investigation (ESI) of Edison, New Jersey. This well is located inside the BES Carpentry Shop (in the vicinity of the former degreasing area) and was installed between January 6 and 7, 1988, using a geotechnical skid rig.

A Remcor geologist supervised all monitoring well drilling and installation. Well locations are shown in Figure 4; drilling logs and as-built well construction diagrams are included as Appendix D. Monitoring well construction data are summarized in Table 3.

3.1.3.1 Shallow Wells

Shallow monitoring wells 87-7S, 87-11S, and 87-13S were all drilled and installed using different construction techniques. Monitoring well 87-7S was advanced to a depth of 41 feet using a 5-5/8-inch roller bit. To keep the hole open, 30 feet of 6-inch (ID) temporary steel casing was pounded into place with an air-activated casing hammer. Fifteen feet of 2-inch (ID), 0.010-inch slotted PVC screen was inserted into the hole attached to a 2-inch PVC riser via a threaded, flush-joint coupling. A coarse quartz sand pack was placed in the annulus around the well screen. A bentonite pellet seal, and a bentonite powder and cement grout (three percent bentonite) was used to fill the annulus of the well to grade. A 4-foot length of 6-inch protective steel casing with locking cap was cemented in place at the surface. Development consisted of 45 minutes of air surging and evacuation of the well bore. Potable water had to be added on several occasions to surge the well because the yield of the well was less than 1 gpm. Bailer purging of the well was performed on several occasions to reduce turbidity.

Monitoring well 87-11S was constructed as an open borehole well. A 7-5/8-inch hole was drilled to 20 feet (12 feet into bedrock). Approximately 20 feet of 6-inch (ID) steel casing was placed in the borehole and grouted to grade with a three percent bentonite and cement grout. The grout was permitted to cure for 24 hours. A 5-5/8-inch hole was then drilled to approximately 41 feet. After drilling, development procedures were conducted by air surging and evacuation with the drill rig compressor. Final yield was measured at approximately 20 gpm.

Monitoring well 87-13S was installed through hollow-stem augers to a depth of 21 feet. Ten feet of flush-joint two-inch stainless steel

screen (slot size 0.010 inch) threaded into two-inch flush-joint stainless steel riser was set to the base of the boring. A clean medium-grained sand pack was emplaced through the augers to fill the annulus around the well screen. The augers were slowly pulled up as the sand was added. The sand pack extended two feet above the screen. A two-foot bentonite pellet seal was emplaced on top of the sand pack followed by a cement/bentonite grout mixture to ground surface. Because of the well's location in an active portion of the plant (i.e., Carpentry Shop), a locking, flush-mount cover was installed over the well. Development was conducted by hand bailing several volumes of water from the well for a period of over one hour. This procedure greatly reduced turbidity from the well discharge.

During conduct of the supplemental investigation of March 1989, two of the test borings served as temporary piezometers. Borings SS-17 and SS-22 were fitted with 2-inch PVC screens and risers, which were removed upon completion of ground water sampling. Each boring was advanced approximately 8 feet into the upper portion of the aquifer. A 2-inch (ID) PVC 0.010-inch slot screen was placed into the saturated zone and had a sand pack placed around it. A 2-foot thick bentonite seal was placed on top of the sand pack, and the remaining annulus was permitted to stay open until the piezometer was removed. Boring SS-17 was located approximately 150 feet west of the monitoring well 4 cluster while SS-22 was approximately 150 feet west of the monitoring well 3 cluster. Each boring was developed by bailing with a dedicated, decontaminated, stainless steel bailer for over one hour prior to sampling.

3.1.3.2 Intermediate and Deep Wells

The intermediate and deep wells were drilled and constructed by air rotary methods. All intermediate and deep wells were constructed as open boreholes. Each boring was advanced by drilling a 12-inch diameter borehole into competent bedrock. An 8-inch temporary casing was then placed to the base of the 12-inch borehole to prevent caving of the unconsolidated material. The depth of the temporary casing ranged from

10 to over 60 feet within the wells.

After temporary casing emplacement, the well was advanced by a 7-5/8-inch roller bit to a previously determined interval (depending on the well's intended depth) for permanent 6-inch casing emplacement. Generally, the 6-inch casing extended to a depth of between 60 and 70 feet for the intermediate wells; MW 87-9I was the single exception with 103 feet of 6-inch casing. At the two deep well locations (MW 87-10D and MW 87-12D), the casing extended to 150 and 163 feet below ground surface, respectively.

The six-inch casing was inserted to the base of the borehole and retracted approximately one foot. The casing was then grouted in place by pumping a cement/bentonite mixture under pressure through the inside annulus of the casing. A cement plug made of four-inch PVC pipe, cement, a stainless steel band, and a rubber shale packer was placed into the six-inch casing at the surface. A pressure grouting fitting was then threaded to the top of the casing so that grout could be pumped, under pressure, into the casing. A measured volume of grout (three to five percent bentonite and cement) was then pumped into the six-inch casing forcing the cement plug to the bottom of the casing. The purpose of the plug was to prevent the dilution of the grout by mixing with ground water within the casing. The plug was forced out the bottom of the casing, allowing grout to pass and move into the annulus. Generally, one and a half times the calculated volume of the annulus was pumped down the casing, then a volume of water just less than the volume inside the casing was added under pressure to displace the grout still in the casing. Once this was completed, the casing was dropped to the bottom to prevent grout from flowing into the casing. In all cases, the grout was allowed to cure for 12 to 24 hours prior to further drilling.

After the grout had sufficient time to set, the well was advanced to its final depth with a 5-5/8-inch diameter roller bit. The cement plug and any grout remaining in the casing were drilled out as the hole was

completed to depth.

All wells were developed by air surging and evacuation using the drill rig compressor. Because of the relatively high yields, extensive development for most of the intermediate and deep wells was not required. In all cases, they were evacuated until the return water was clear.

3.1.4 Ground Water Sample Collection

Well sampling was principally conducted the week of January 4 through 9, 1988. Because of frozen pipes and unavailable owners, sampling of three domestic wells had to be deferred until January 21 and 22, 1988. Sampling of piezometers SS-17 and SS-22 was conducted on March 8, 1989.

3.1.4.1 Domestic, Municipal, and Industrial Wells

During the current RI, samples were collected from 11 domestic wells, 2 municipal wells, and 4 industrial wells. The locations of these wells are shown in Figure 4. All well samples were analyzed for TCL VOCs. The municipal well samples were also analyzed for TCL ABN organic compounds.

Purging and sampling of domestic wells was accomplished by running the faucet prior to any holding tank or treatment unit, where possible. No samples were collected subsequent to any treatment. In a few instances, it was not possible to obtain a sample prior to a holding tank; in these cases, adequate purging was completed to empty the holding tank, as well as to evacuate the well. Two wells were hand-operated wells with no storage or treatment; these wells were purged by hand. In all cases, wells were purged of at least three well volumes, and sample bottles were filled directly from the faucet or tap.

Bally Municipal Well Nos. 1 and 3 (Figure 4) were each purged at approximately 300 gpm for approximately one hour prior to sampling. Samples were collected directly into laboratory-cleaned containers at a point on the wellhead prior to any treatment or storage.

Industrial well samples were collected at Bally Ribbon, Great American Knitting, Longacre Dairy, and from the BES plant well (Figure 4). All of these wells, except the BES well, are in active use. The sample at Bally Ribbon was collected after little purging because at that time, ground water withdrawal was continuous. At Great American Knitting, the sample had to be collected at a point just prior to their treatment unit and storage tank but several hundred feet from the well. This well water traveled this distance through copper piping. Because this well had been operating prior to the time of sample collection, purging was performed only for a time deemed sufficient to evacuate the copper piping of any stagnant water. The Longacre Dairy well had also been operating prior to the time of sample collection. Purging and sampling were performed at a tap located prior to the holding tank.

3.1.4.2 Monitoring Wells/Temporary Piezometers

All monitoring wells were sampled, including those installed previously by ERM and those installed in the current Phase III RI. All of these samples were analyzed for TCL VOCs. Except for MW 87-7S, purging of these wells was accomplished with a flexible discharge (i.e., garden) hose and a submersible pump powered by a portable generator. MW 87-7S was purged with the stainless steel sampling bailer. All wells were purged of between three and five well volumes prior to sampling. Sampling was performed with dedicated, precleaned, stainless steel bailers lowered on dedicated polyethylene rope. Sampling was performed immediately after removing all purging apparatus from each well, except at well MW 87-7S, where the well was slow to recover and required sampling a few hours after purging. The first bail of water from each well was discarded to rinse the bailer with the sample medium prior to filling the sample bottles.

Temporary piezometers SS-17 and SS-22 were sampled in a manner similar to those mentioned above. The piezometers were each bailed within a few hours of sampling. The piezometers were subsequently sampled with an additional dedicated Teflon bailer. As with the above-mentioned

sampling, the first bail of water drawn was discarded to rinse the bailer with the sample medium prior to filling the bottles.

3.1.5 Water Level Measurements

Water levels were taken on all monitoring wells and the plant well frequently during the RI. Table 4 summarizes the water levels taken during the course of the investigation. Measurements were made using an electronic water level meter with 0.05 foot graduated markings. An engineer's rule with 0.01 foot graduations was placed against the tape of the electronic water level meter to obtain measurement accuracy to the nearest 0.01 foot.

3.1.6 Aquifer Performance Testing/Baseline Ground Water Survey

Prior to the initiation of the pumping test at Municipal Well No. 3, baseline ground water conditions in the Borough of Bally were monitored to determine dynamic influences occurring within the aquifer. To accomplish this task, Leopold-Stevens continuous recorders were installed on MW 87-7I, MW 87-10D, and the Bally plant well approximately one month prior to the start of the test. Approximately ten days prior to the test, three additional recorders were installed on MW 86-5D, MW 86-3D, and MW 87-12D. These instruments recorded the change in water level over time which revealed such influences as pumping from municipal and industrial sources as well as showing the effects of recharge to the aquifer. Graphs from the baseline data survey are included as Appendix E.

The pumping test of Municipal Well No. 3 was conducted at a rate of 243 gpm for 72 hours. Recovery of water levels within the aquifer was also measured for a period of 24 hours after pumping stopped.

During the pumping test, the six continuous recorders were used to measure water level changes on the same wells that they had monitored during the baseline survey, except that the recorder on the BES plant well was moved to MW 87-4I. Hand measurements were also made to supple-

ment the recorder data with electronic water level meters on all remaining monitoring wells and the BES plant well. Because of the large distance between well locations, several tapes were used to obtain the hand measurements. Each tape was calibrated to a standard reference tape to negate minor measurement differences between them. Measurements were taken repeatedly at the start of the test (at least once per minute for the nearest observation wells) and then taken at longer intervals as the test progressed. Measurements of the water level in the pumping wells were made at the rate of several per minute during the start of the test, decreasing in frequency as the test progressed.

Measurements of water level recovery were also recorded after pumping of Municipal Well No. 3 was terminated. Measurements during recovery were made repeatedly during the early stages, and less frequently as recovery progressed.

Measurements of well discharge were also made each time the water level of the pumping well was recorded. Well discharge was measured with an in-line Rockwell flow meter. Calibration of the flow meter was conducted during pumping by measuring well discharge over time in 55-gallon drums. The well discharge rate was held constant at an actual flow of 243 gpm. Adjustments to maintain a constant discharge were made with a gate valve that regulated flow from the well.

The well discharge was routed into a storm sewer approximately 500 feet from the pumping well, which eventually discharges into a small stream east of well cluster MW 87-10. All discharge water underwent treatment through the newly installed air stripper at the Municipal Well No. 3 pumphouse. This test also served as part of a system shakedown of the air stripper operation.

3.1.7 Equipment Decontamination

All sampling equipment that contacted the sample was cleaned prior to the start of the sampling activities; each piece of sampling equipment

was dedicated (used at one location only). The precleaning procedure used to clean bailers was as follows:

- Wash with soap and water and use a sponge and/or brush to remove visible contamination where necessary
- Rinse with potable water
- Rinse with solvent (hexane)
- Rinse with deionized water
- Air dry and wrap in aluminum foil until time of use.

Minimal decontamination of sampling instruments was conducted in the field.

Equipment used to purge monitoring wells, including the submersible pump and the flexible discharge hose, was rinsed thoroughly with potable or deionized water, or both, between wells. The polyethylene rope used to lower the pump and bailers into each well was discarded after each well and replaced with new rope before the next well.

In all cases, the test boring rig and air rotary rig were decontaminated with a high-pressure steam cleaner before beginning work and between sample locations. The water used was collected in a plastic-covered cribbed area, and subsequently drummed. This water is presently stored at BES. Between each boring, the augers and other downhole equipment were steam cleaned or washed with soap and water, hexane, and rinsed with distilled water. Before each sample was taken, the split-spoons and sampling knives were steam cleaned or washed with soap and water, hexane, and rinsed with distilled water. All cuttings and trash generated by the test boring operations were drummed and are currently stored at BES pending final disposition.

3.1.8 Quality Assurance and Recordkeeping

All RI subsurface investigation activities were conducted in accordance with the quality assurance and quality control (QA/QC) procedures

detailed in the Field Sampling and Analysis Plan (FSAP) and Quality Assurance Project Plan (QAPP) developed by Remcor as part of the Work Plan Scope of Work (Remcor, September 23, 1987). The fundamental approach taken by Remcor to assure quality work was to follow the methods described in the Approved Work Plan for sample collection, decontamination, sample handling, and field instrument calibration.

Systems audits were undertaken by Remcor to assess adherence to the approved procedures and to identify and correct any deviation where necessary. These audits were undertaken during two different phases of the subsurface investigation:

- During boring installation and soil sampling
- During ground water, surface water, and sediment sampling.

Systems audit reports for each of these episodes are included in Appendix F.

QC for analytical data was ensured by the collection of QA/QC samples. These samples provide the means by which the analytical data can be evaluated to ensure that they meet the Data Quality Objectives (DQOs) established in the Work Plan, including objectives for precision, accuracy, and completeness. QA/QC samples utilized for this purpose included the following:

- Field blanks
- Trip blanks
- Field replicates
- Laboratory replicates
- Laboratory matrix spikes.

Assessment of the laboratory results for matrix spikes and reagent blanks also serves as a performance audit of the laboratory, the NUS Laboratory Services Division (NUS), Pittsburgh, Pennsylvania. All laboratory QC procedures and performance were in conformance with those specified in the EPA Contract Laboratory Program (CLP) Statement of Work for Organics (EPA, July 1987).

All field activities were documented in waterproof field notebooks each day that field activities took place. Information recorded in the field notebooks included work performed, problems encountered, sample locations, sample descriptions, sampling times, field measurements, site visitors, and all other pertinent information. Information from the field notebooks was summarized in a dedicated, bound, site logbook. Other field documentation maintained included sample chain-of-custody forms, visitor log sheets, instrument calibration forms, sample labels and custody seals, and overnight carrier air bills. Aside from the sample labels and seals, these materials are retained in Remcor files in Pittsburgh.

3.2 VALIDATION OF THE CHEMICAL-ANALYTICAL DATA BASE-GROUND WATER RESULTS

Data validation was performed under subcontract to Remcor by Support Systems of Fort Collins, Colorado. Validation was performed in accordance with "Laboratory Data Validation - Functional Guidelines for Evaluating Organics Analyses" (EPA, April 1985). As such, the data were assessed with respect to completeness, holding times, mass calibrations, initial and continuing calibrations, matrix spike recoveries, surrogate recoveries, and blank results. The validation process resulted in the rejection or qualification of some data involving the compounds methylene chloride, acetone, and toluene. The data presented in text tables (Tables 7 through 10) are the end-product of the validation. The validation actions recommended and the supporting rationale are provided in validation letters supplied by Support Systems, which are also presented in Appendix F. It should be noted that the data collected at EPA's request in March 1989 (additional source investigation) are also included in these tables. These data were not validated by CLP procedures.

3.3 RESULTS OF THE SUBSURFACE INVESTIGATION

3.3.1 Regional Geologic/Hydrogeologic Setting

3.3.1.1 Physiography and Topography

Bally is located adjacent to the northeast/southwest-trending boundary between the Piedmont Physiographic Province and the Blue Ridge Physiographic Province. The majority of Bally and all of the BES plant area lie within the Triassic Lowlands of the Piedmont Province. This former plateau-like region has been modified by renewed erosion into gently rolling hills with vertical relief rarely exceeding 200 feet. In the vicinity of Bally, elevations within the Triassic Lowlands range from 400 to 550 ft-msl.

The northwest corner of Bally and areas beyond lie within the Reading Hills (a subdivision of the Blue Ridge Province and the Pennsylvania equivalent to the Jersey Reading Hills). These highlands are also known as the Reading Prong, an extension of the New England Province. The Reading Hills consist of several parallel, dissected ridges separated by flat valleys. Locally, peaks average about 1,000 ft-msl with valley floors at 500 ft-msl or less. The local physiography has been largely controlled by the underlying geology (Figure 1).

3.3.1.2 Regional Geology

Figure 5 is provided as a geologic map of the site area and its vicinity.

Triassic Basin

The Triassic Lowlands are a series of large basins filled with a thick sequence of sedimentary rocks. These basins developed as a result of tensional forces during the early Mesozoic Era. From the mid- to late-Triassic, extensive faulting broke up the Paleozoic sedimentary rocks and the Precambrian crystalline basement rocks of the area, forming an extensive rift valley system. The result was a series of parallel

blocky mountains (horsts) and long flat-floored basins (grabens). As the basins formed, they were filled with sediments carried down from the adjacent highlands. Simultaneously, molten rock from great depths migrated up the fracture zones and intruded into and onto the consolidating sediments. Today, a single belt of Triassic rocks extending from North Carolina to Canada remains as the only exposed portion of this wide rift system. A long fault (the Border Fault), which runs through the western edge of Bally, marks the northwestern boundary of the rift valley system.

The sediments that filled the basin in the New Jersey-Pennsylvania area consolidated into a thick sequence of sedimentary rocks known collectively as the Newark Group. Generally, these stratified rocks dip gradually to the northwest; however, dips and strikes may vary due to either local faulting or nearby intrusives. Although there are several rock types and facies within the Newark Group, only a few are present in the Bally vicinity.

The most widespread formation within the basin is the Brunswick Formation. This unit is typically composed of reddish-brown shales, mudstones, or siltstones consisting of feldspar, illite, chlorite, quartz, and calcite (Van Houten, 1960, p. 669). At the base of the formation (exposed at the southeastern edge of the basin), a few green and brown shales or red to dark gray argillites are found interbedded within the reddish-brown shales. Additionally, the dark gray to black, thickly bedded argillites of the Lockatong Formation are also interbedded within the Brunswick, especially at the southeastern edge of the basin. The maximum thickness of the Brunswick Formation (about 16,000 feet) is believed to be along the Border Fault not far from Bally (Bascom and Stose, 1938, p. 76).

The most predominant Newark Group rock type in the vicinity of Bally is the fanglomerate. Although the fanglomerate is mapped as two lobes north and south of the Borough, drilling for this RI has encountered the

fanglomerates with a little interbedded shale throughout the area of investigation.

The fanglomerate was deposited during the formation of the basins. Steep slopes formed along the normal fault borders (the Border Fault), and powerful streams carried debris down into the valley. As the stream gradient reduced upon reaching the flat floor of the valley (i.e., the site area), alluvial fans of coarse material were deposited along the margin. These deposits of rounded and angular clasts (pebbles, gravels, and cobbles) have been consolidated and cemented into rock. Their name, fanglomerates, refers both to the conglomeratic texture as well as the depositional environment in which they formed. Although fanglomerates composed chiefly of quartzite are common along the northeastern border of the basin, the clasts in the site area are composed primarily of yellow-gray and gray limestone and dolomite. The pebbles, gravels, and cobbles are cemented with calcite in a reddish-brown matrix of sand, silt, and clay. Intraclasts of reddish-brown shale, siltstone, and mudstone are common. The fanglomerates are extensively interbedded and grade laterally with increasing distance from the Border Fault toward the southwest into the Brunswick shales, siltstones, and mudstones.

Reading Hills

The Reading Hills to the northwest of Bally are underlain by ancient (Precambrian and Cambrian period) basement rocks. The complex origin and structure of the sedimentary and igneous rocks in this area have been obscured by repeated metamorphism; however, four distinct rock units can be differentiated in the Bally area.

The most abundant and prominent rock types are Precambrian gneisses. Two separate units exist, although they are very intricately interfingered. The Byram gneiss is a light gray granitic gneiss composed of a medium- to coarse-grained quartz and potassium feldspar with minor amounts of hornblende, pyroxene, and mica. Although this material is metamorphic, an igneous granite origin is suspected. The second gneiss,

the Pochuck, is a dark green to grayish black, conspicuously foliated, medium- to coarse-grained hornblende gneiss, with pyroxene, biotite, and oligoclase feldspar present. This metamorphic rock was probably formed by the alteration of sediments. Due to the gneisses' high resistance to weathering, they tend to form the foundations of most ridges and knobs northwest of the site.

Published geologic mapping in the immediate Bally vicinity is inconsistent with the findings of the RI. The Hardystone Formation is shown immediately below and northwest of the Borough when, in fact, drilling for this RI has determined this area to be underlain by Triassic sediments. However, the Hardystone is believed to lie immediately northwest of Bally. This light gray, fine- to medium-grained quartzite and feldspathic sandstone is quite massive, but thin beds of conglomerate do occur throughout. Greenman (1955) indicates a total thickness of 100 to 300 feet for the quartzite in the vicinity of Durham, Pennsylvania. Stratigraphically, the Cambrian Age Hardystone Formation lies unconformably above the gneisses and is transitional into the overlying Leithsville Formation.

The Leithsville Formation is a light blue to gray crystalline dolomite. This carbonate rock has massive bedding, oolites, chert, and some thin shale interbeds. It often underlies valley floors since it weathers relatively rapidly to a light gray and yellowish-brown residuum. The Leithsville is shown by available geologic mapping as two lenses, one north and the other south of Bally, in direct contact with the Triassic Basin border.

3.3.1.3 Regional Hydrogeology

The hydraulic properties of the Brunswick Formation, including the fanglomerate, and to a lesser degree the Highland rock units control the occurrence and movement of ground water in the site vicinity.

Triassic Basin

Within the Brunswick shales, siltstones, and mudstones, primary porosity is extremely low due to the fine-grained sediments comprising the rock. Although a small amount of moisture may pass between minerals along bedding planes, there is essentially no porosity perpendicular to bedding in an unfractured specimen. Nearly all flow in these fine-grained sedimentary rocks occurs through secondary porosity (fractures, joints, and along cleavage). S. Longwill and C. Woods in "Ground Water Resources of the Brunswick Formation in Montgomery and Berks Counties, Pennsylvania (1965)," attribute the majority of ground water flow to vertical jointing. Longwill goes further to describe three sets of vertical joints in the Brunswick, a small set striking N30°E, and two less well-developed sets striking N45°W and N75°E. Because the frequency and size of the jointing is quite variable from bed to bed, the permeability will vary significantly through a vertical section. Because bedding within the Brunswick is a series of overlapping, discontinuous lenses, it is not practicable to trace water-bearing zones over long distances. Additionally, secondary mineralization of calcite and quartz is commonly found to be cementing these fractures and joints, reducing the secondary porosity and further complicating ground water flows.

A survey by Greenman (1955) of 52 wells (residential, municipal, and industrial) completed in the Brunswick Formation had a range of yields from 2 to 260 gpm with an average of 40 gpm. This is similar to Longwill's (1965) findings in a similar, but much larger, survey of 199 wells in the Brunswick. Yields ranged from less than 5 to over 400 gpm, with an average similar to that of Greenman's study. Longwill also provided an elementary interpretation of six pumping tests performed in the Brunswick Formation. Transmissivities from observation wells ranged from 100 to 180,000 gallons per day per foot (gpd/ft), with a median value of 6,000 to 9,000 gpd/ft. Storage coefficients ranged from 0.000033 to 0.00029. Some additional transmissivities obtained from pumping wells ranged from 150 to 4,000 gpd/ft, with a median value of 600 gpd/ft.

Several of Longwill's observations are significant. In the well survey, there was a dramatic increase in the overall yield for wells completed over a depth of 200 feet. Also, yields increased only slightly for wells completed much beyond 200 feet, and not at all for wells deeper than 550 feet. Longwill acknowledged that many explanations totally unrelated to the hydraulic properties of the Brunswick could explain these trends; however, the results did point to two possibilities. First, hydraulic conductivities in the upper 200 feet of the Brunswick tend to be low; and, secondly, beyond 550 feet there does not appear to be significant jointing. During the pumping tests, Longwill also noticed a tendency for increased drawdowns along strike, and drawdowns in most observation wells fell below those levels predicted for confined aquifers. Ten years earlier, Greenman wrote of the same aquifer characteristics and provided some explanations (p. 34):

> The Brunswick lithofacies contains water under both water table and semiartesian conditions in the weathered zone of the formation, which may extend to depths of 600 feet or more. A water table aquifer of low permeability, comprising the highly weathered zone of the formation, occurs at a depth of about 250 feet; and one or more rather permeable artesian aquifers, consisting of beds of partially altered rock rarely more than 20 feet thick, occur to depths of 600 feet. In both types of aquifers the saturated voids are believed to be vertical joint fractures enlarged by solution. The water table aquifer contains many more fractures than the semi-artesian aquifers, but the near-surface rocks have been so thoroughly decomposed that many of the cracks are filled with clay residuum from the weathering of the shale (Greenman, 1955).

With regard to the water quality, Greenman (1955) notes that the Brunswick provides moderately hard to hard water "... of satisfactory quality for most uses without treatment." No available literature was located on the hydraulic or water quality properties of the limestone fanglomerates.

Reading Hills

The Reading Hills, as previously mentioned, are composed of several rock

types; however, with the exception of the Leithsville Dolomite, their hydraulic properties are very similar. The gneisses and the Hardystone quartzite are nearly impervious to water in unfractured (massive) form. Essentially all ground water in these crystalline rocks is found within faults, fractures, joints, or in the thin overburden (often perched on the bedrock surface). Occasionally, weathering products at the bedrock surface reduce the hydraulic conductivities enough to produce a semiconfining condition. According to Greenman (1955), a group of 47 wells drilled in the gneiss and quartzite had yields from 1 to 200 gpm with an average of 40 gpm. Greenman also asserts that Precambrian-aged crystalline rocks yield high-quality ground water, which is low in dissolved solids, hardness, and offensive mineral matter (except iron which may exceed 0.3 part per million [ppm]).

The Leithsville Formation, being a dense crystalline carbonate rock, does not have any significant primary porosity; however, the extensive secondary porosity within the weathering zone is typical of most carbonates. Fractures, jointing, and bedding planes provide the initial permeability for water to move through the rock. Over a comparatively short geologic time span, a carbonate formation can be honeycombed wherever acidic ground water is flowing. Once solution activity has opened secondary openings, large amounts of ground water can move rapidly over long distances through the formation.

No specific information on the water-bearing capacity of the Leithsville Formation in the vicinity of Bally was available, and ground water availability and source are difficult to predict. Yields for a typical carbonate area may vary tremendously, with maximum rates over 1,000 gpm. Carbonate rocks generally yield water high in dissolved solids, with high hardness due to bicarbonates of calcium and magnesium.

3.3.1.4 Summary

In summary, the following items are considered most pertinent to this investigation:

- The Border Fault located along the northwest edge of the Borough separates the site area within the Triassic lowlands to the southeast from the Reading Hills to the northwest. The Triassic lowlands are underlain by sedimentary rocks and appear as gently rolling hills where vertical relief rarely exceeds 200 feet. The Reading Hills are underlain by crystalline metamorphic rocks. Local elevations in the Reading Hills reach 500 ft-msl.

- The site is underlain by Triassic sediments of the Brunswick Formation. Specifically, limestone fanglomerate with some interbedded siltstone and shales were found throughout the area of investigation. This formation continues beyond the depth of this investigation.

3.3.2 Site Geology

The Borough of Bally is underlain by Triassic Age Sediments (of the Brunswick Formation) consisting of limestone fanglomerate, siltstone, and shale. Overlying the Brunswick Formation is a variable layer of clayey silt residuum weathered from the parent bedrock material. In the southwestern portion of Bally, a thin, variable layer of colluvium occurs. This material was eroded and transported from the Reading Hills Province to the west. Construction fill also unconformably overlies the unconsolidated material in portions of the plant area.

Figure 6 gives a plan view of two cross section locations. Figures 7 and 8 are cross sections through the study area depicting subsurface conditions.

3.3.2.1 Unconsolidated Materials

According to the U.S. Department of Agriculture Soil Conservation Service (USDA SCS) for Berks County (Ackerman, 1970), three soil series are found on the BES property: The Athol Silt Loam, the Glenville Silt Loam, and the Atkins Silt Loam. Soil borings both on and off site encountered material similar to those described by the SCS. Logs for all soil borings are presented in Appendices B and B-1.

The following is a description of all unconsolidated material

encountered during the RI.

BES Plant Fill

In the general plant vicinity, natural soil conditions have been partially disturbed by the addition of fill materials and the removal and reworking of the original soil horizons. In the former southern lagoon area (borings SS-1 through SS-4), fill materials were found extending to a depth of approximately 2 feet, except at SS-4 where 3.5 feet of fill was encountered. The composition of this fill is a soft to stiff, brown, clayey silt and dark gray, silty gravel. This material appears to be reworked soils and gravels which apparently replaced the shallow impoundment sediments and base during building construction in this area. No evidence of the lagoon bottoms was encountered in any of the borings.

In the former northern lagoon area, which is currently three to four feet higher than the former southern lagoon area, only a thin layer of subbase fill material less than one foot thick was encountered above the natural unconsolidated material. No evidence of the former lagoons was found when drilling in this area.

In the former and present degreasing areas, a variable layer of fill, three to eight feet thick, was encountered. At SS-9 (present degreasing area), four feet of brown to gray silty gravel was encountered. In the former degreasing area, the thickness of the fill ranged from three to eight feet with the material consisting primarily of silty rock fill containing slag and coal fragments. Cobbles and small boulders in this area made drilling very difficult.

Off of the BES property, fill was encountered at only one location (MW 87-7) where 8.5 feet of sandy silt and slag fill was encountered during monitoring well drilling. This location was within a parking area for the Bally Fire Company.

Colluvium

Along the western portions of Bally, a relatively thin layer of colluvium was encountered during test boring and monitoring well drilling. This colluvium was composed of weathered debris from the Precambrian and Cambrian rocks of the Reading Hills Province. This material consisted of a stiff, brown, clayey silt with a little gravel composed of gneiss, quartz, and other metamorphic debris consistent with the subsoil descriptions described for the Atkins and Glenville series. This material apparently has been carried downslope from the adjacent Reading Hills Province by surface runoff and downslope creep.

Generally, the colluvium extended to a depth of between five to ten feet below ground surface. Based on test boring and monitoring well drilling, the colluvium is present in all but the eastern portions of the Borough away from the Reading Hills Province, as evidenced by its absence at well locations MW 87-8 and MW 87-9. The colluvium appears to be thickest in the northwest portion of Bally and along drainage courses.

Residuum

Occurring beneath the colluvial material is a stiff, reddish-brown, clayey silt to silty clay with traces of shale fragments that increase in number with increasing depth. This material is a residuum derived from the weathering of the interbedded limestone fanglomerate and shale bedrock below. This residuum has a variable thickness ranging from less than 10 feet to nearly 100 feet in some areas. The contact between the base of the residuum and competent bedrock below is gradational, in some cases extending over tens of feet. The extent of this weathered residuum may be related to the fracturing and the composition of the bedrock. Fractures and joints in the fanglomerate and shales allow acidic near-surface water to dissolve and decay the carbonates in the bedrock, leaving behind clays and silts with weathered shale fragments. Generally, the total depth of this bedrock residuum increases to the north/northeast. At locations MW 86-2, MW 87-12D, MW 86-5D, and

MW 87-7I, a considerable thickness (50 feet or deeper) of unconsolidated residual material occurs above competent bedrock. Those holes drilled in the southern portion of Bally had total depths of unconsolidated residuum of less than 22 feet.

In areas where the overlying colluvium is absent, the shallow soils formed are characteristic of the Athol Silt Loam, which is derived from the underlying residuum.

3.3.2.2 Bedrock

Bedrock encountered during the RI and subsequent studies consisted exclusively of the Brunswick Formation which, in the Bally area, is composed of limestone fanglomerate with interbedded siltstone, and shale. Published regional geologic mapping (Figure 5) is inconsistent with this finding and indicates the western portion of Bally to be underlain by quartzite rock characteristic of the Reading Hills Province. Based on the results of the RI, the contact between the Precambrian rocks and the Triassic sediments occurs further west than the published data indicate. This is the contact between the Piedmont and Blue Ridge physiographic provinces, along the western edge of the Borough. Presumably, the Border Fault that separates these two provinces occurs in this vicinity.

To determine lithologic characteristics, one exploratory boring (E-1, Figure 4) was cored within the area of investigation. Rock coring of the exploratory boring provided a representative cross section of the upper portion of the formation within the study area. At this location, the unconsolidated bedrock residuum extends to a depth of 55.5 feet. From this depth very broken and highly weathered siltstone and interbedded limestone fanglomerate extend to 135 feet. The siltstone occurs in two intervals: from 60 to 72 feet and from 85 to 115 feet. The highly fractured and weathered condition of this bedrock interval is illustrated by the low percentage rock quality designation (%RQD) observed. The %RQD for this interval ranged from 0 to 18 percent.

Bedding planes were nearly horizontal; however, openings occurred both as partings along bedding and as steep joints/fractures through bedding planes.

From 135 feet to 198.5 feet the bedrock was exclusively limestone fanglomerate which became increasingly competent with depth. %RQD values reached 89 percent near the bottom of the hole; zones of fractured and weathered fanglomerate were encountered at discrete intervals. These zones yield significant quantities of ground water.

Core in the lower portion of the exploratory corehole provided unweathered samples of the limestone fanglomerate, which illustrated the alluvial fan deposition of the sediments. These were composed primarily of blue grey to reddish-brown limestone clasts which in some cases reached cobble size. The large clasts were closely packed and rounded. The smaller clasts composed of limestone and quartz chips tended to be angular. The matrix was composed of angular interclasts of reddish-brown shale, siltstone, mudstone, and sand thoroughly cemented with calcite. Bedding was absent. This description represents the maximum development of the limestone fanglomerates at this location. The formation is gradationally interbedded with the entire compositional and textural range between the above described fanglomerate and the shales and siltstones characteristic of the Brunswick Formation.

In addition to the coring, borehole geophysical logging was also conducted on E-1 and a nearby existing monitoring well (MW 86-3D). Logs from both of these boreholes are included in Appendix C.

The borehole geophysical logging conducted on E-1 indicates a rather consistent lithology that is silty to shaley in nature. The siltstone intervals differentiated from the limestone fanglomerate on the core log between 60 to 72 feet and 85 to 115 feet are not apparent on the gamma and density logs, although the density log does indicate generally lower density in the siltstone intervals. The lack of differentiation between

the units is probably due to the silty matrix occurring in the fanglomerate and the gradational contacts occurring between them.

The geophysical logging confirms the fracture controlled nature of the formation apparent from rock coring. The neutron, density, and caliper logs indicate an extensive fractured and broken zone from the top of bedrock to a depth of 137 feet. This is reflected in the core log which indicates very broken rock and %RQD values ranging from 0 to 20 percent. The low counts occurring on the neutron log also suggest a greater water saturation in this interval than the underlying portion of the formation. Coring through the broken interval yielded a water return in excess of 100 gpm.

Beneath a depth of 137 feet, the limestone fanglomerate becomes more competent as evidenced by %RQD values ranging from 60 to 85 percent. This depth is characterized by discrete individual fracture zones. Coring in this interval identified significant fracture intervals from 137 to 140 feet, 163 to 165 feet, and at 170.5 feet. These intervals indicated water-bearing fractures on the neutron, resistivity, temperature, density, and caliper logs. In addition, the neutron, resistivity, and temperature logs suggest water-bearing fractures also at 150, 155, 173, 174, 187, and 191 feet. In particular, a large spike indicating low neutron counts is observed between 170 and 173 feet. Less resistivity is also observed in this interval with a peak of lower resistance occurring just below the neutron peak at 174 feet. These logs suggest significant ground water in-flow occurring at this depth.

Air rotary drilling of the bedrock monitoring wells throughout the site revealed a lithologic sequence similar to that of E-1, based on the logging of drill cuttings. The frequency of discernible fractures was also consistent with that of E-1 where the frequency of fractures decreased with depth. Because of the nature of the drilling operation, detailed information was not obtained on fracture density or general fracture orientation.

3.3.2.3 Structural Geology

Regionally, the Triassic sediments of the Bally area are contained within an extensive rift valley system which extends from North Carolina to Canada. The predominant dip within the valley is to the northwest. Locally, structural conditions are not well defined due to the following conditions:

- The lack of definitive bedrock outcrops within the site vicinity.
- The lack of bedding existing in the predominant area lithology (limestone fanglomerate).
- The uncertain structural effects caused by the Border Fault occurring along the western edge of the Borough.
- The high degree of fracturing and jointing occurring within the shallow subsurface.

According to a previous study (Conlin and Gray, 1975) in the area of the site, attitude measurements were taken on an outcrop of shale located on the West Branch Perkiomen Creek (approximately .3 miles southwest of the BES facilities) indicating a N15°W strike with a dip of 45°SW. A major joint set occurring at this location had a strike of N65°W and a dip of 85°NE. A minor joint set in this locale had a strike of N25°W and a dip of 75°NE. Published geologic mapping of the area (Longwill and Wood, 1965) indicates a strike of N55°W and a dip of 45°NE just north of Bally. Neither of these observations correspond with the nearly horizontal bedding observed in the shaley portion of the corehole E-1.

Based on available data, it appears that the attitude of the Brunswick Formation in this region of the Triassic Basin is highly variable due to the combined effects of faulting and igneous intrusions.

A previous study (ERM, 1986) included a map with hypothetical fracture traces. One of these lineaments follows the upper reach of the unnamed tributary northwest of Bally. Some evidence, discussed in the pumping test results (Section 3.3.3.4), was found for a fracture continuing

along this direction down the unnamed tributary through to MW 87-10I and MW 87-10D. This may be a splay fault associated with the Border Fault system.

3.3.2.4 Summary

The following items from this subsection are considered most pertinent to this investigation:

- The unconsolidated materials are composed chiefly of weathered bedrock residuum.
- The clayey silt residuum was found up to depths of 80 feet in the vicinity of Municipal Well No. 3. The residuum grades into competent rock below.
- Throughout the area of investigation, bedrock is composed of limestone fanglomerate with some interbedded siltstone and shale.
- A highly fractured and porous upper zone was found within the bedrock. Hard fanglomerate extended below to depths beyond the intended depth of this investigation.
- Because of limited outcrop, the horizontal and vertical extent and orientation of bedrock bedding, fractures, and jointing are not known.

3.3.3 Site Hydrogeology

One aquifer occurs within the area of investigation for hundreds of feet within the Triassic sediments. This aquifer is generally under water table conditions; however, localized semi-confined conditions do occur. The water table ranges from depths of less than 5 to 60 feet below ground surface principally due to topographic expression. Aquifer recharge occurs from infiltrating precipitation and from surface water infiltration in the western portion of the Borough. Ground water flow is eastward.

3.3.3.1 General Aquifer Characteristics

The near-surface unconsolidated materials (fill, soil, and colluvium) are generally above the ground water table; however, temporary perching

of ground water occurs after periods of rainfall. Minor perched water zones were encountered at the base of fill material in boring SS-9 and during reconstruction of the locking cover for MW 86-2. These areas appear to be discontinuous as evidenced by the fact that surrounding borings did not encounter perched conditions. Minor amounts of shallow perched water were also encountered in borings SS-26 and SS-27 in the supplemental investigation. This water may have been the result of a significant snow melt which occurred during the drilling of these borings.

The water table is located within the bedrock residuum over much of the site area. Near the top of the residuum unit nearly complete decomposition of parent material has occurred. Compact, reddish-brown, silty clay and clayey silt prevail with a trace of soft shale fragments. Soil creep and infiltrating water through the unsaturated zone have destroyed or filled in much of the relict structure of the parent material, making it compact. This condition reduces the permeability of the residuum, which reduces flow velocity through this material.

With increasing depth, the component of shale fragments increases and a few soft limestone fragments are present. At this intermediate depth the residuum also contains some of the relict structure of its parent material such as bedding and a few small joints and fractures, increasing the hydraulic conductivity.

At the base of the residuum the bedrock structure is well preserved although the material is parted along bedding planes and does not hold together well because most of the calcite cement has been dissolved. Shaley sections are not significantly altered, while limestone zones are porous and soft. Hydraulic conductivity is improved, and the specific yield has increased significantly because of the increase in effective porosity resulting from the solution of the carbonate clasts within the fanglomerate.

Wells screened only in the residuum (MW 86-2, MW 86-5S, MW 87-7S, and MW 87-13S) generally yielded less than two gpm. These poor yields can be partially attributed to the fact that the drilling process destroys relict structure and tends to smear the borehole walls thus lowering the potential yield of the well.

A much greater permeability is evident for the underlying limestone fanglomerate as observed during bedrock well drilling and development. All intermediate and deep monitoring wells were constructed as open boreholes in competent fanglomerate. Most of the estimated total well yields were in excess of 100 gpm while 3 wells yielded 250 gpm or more (Appendix D). However, 3 of the 8 intermediate and deep monitoring wells yielded approximately 12 gpm or less. This large discrepancy in total yields within the fanglomerate reflects the primary controlling element of ground water flow in this formation, i.e., fractures. The primary porosity of the fanglomerate is very low. Ground water flow and storage in this formation is occurring in the fractures and in the enhanced porosity of weathered portions of the fanglomerate.

Two zones of weathering are contributing to ground water storage and flow within the fanglomerate. The first zone occurs directly below the residuum deposit. This upper bedrock is heavily fractured and broken. Portions of the carbonate constituent have dissolved, leaving small voids and clay impurities. An illustration of this zone is found in exploratory borehole E-1. Highly porous and weathered fanglomerate grades into hard rock over a large interval from 55 to 137 feet. A second zone occurs beneath the first and is characterized by fractured intervals. Chemical weathering has increased the width of the fractures and the primary porosity along the walls of the fractures.

Variable fracture density was apparent in the upper 200 feet of the aquifer drilled during the RI. MW 87-10I (open at 60 to 120 feet) and MW 87-10D (open at 150 to 210 feet), which were drilled within 30 feet of each other yielded 250 gpm and 12 gpm, respectively, during

development. Conversely, deep well MW 87-12D yielded in excess of 150 gpm from within the deeper portion of the aquifer (165 to 210 feet). In addition, while drilling well 87-10D, a yield of approximately 50 gpm was estimated for the same interval to which 87-10I was completed, further illustrating the heterogeneity of the aquifer. These variations are likely the result of lithologic changes and the unknown structural effects of the Border Fault which occurs along the western edge of the Borough. This fault could be increasing fracture density of wells such as MW 87-12D occurring in the western portion of the site area.

There is not enough information to define a depth at which fractures and weathering are no longer significant with regard to ground water flow. This issue is beyond the scope of this investigation.

3.3.3.2 Baseline Water Level Survey

The baseline water level study was performed to determine the static/dynamic conditions occurring within the aquifer due to local industrial and municipal pumping. Throughout the course of this investigation, manual water level measurements were obtained from available wells on many occasions. It was apparent from these measurements that many wells had large daily water level fluctuations in response to the daily pumping cycle of Municipal Well No. 1. To better understand this and other pumping influences on the hydrogeologic system, continuous water level recorders were installed on selected wells to supplement the manual measurements.

Table 4 is a compilation of water levels obtained from all monitoring wells, the inactive BES plant well, and Municipal Well No. 3. Also, several selected water level rounds were included during the pumping test at Municipal Well No. 3. The actual elevations of the water levels have been calculated and reported as ft-msl.

An example of a continuous water level record is provided by MW 87-10D

over the 12-day period (September 22 to October 3, 1988) just prior to the pumping test (Figure 9). The daily saw-toothed oscillations of about 1/4 foot are the influences from the cycling of Municipal Well No. 1, located about 2,000 feet away. The number of hours Municipal Well No. 1 was pumping are listed at the bottom of the chart. Generally, this pump was activated around mid-morning and continued for about eight hours at a rate of about 300 gpm. The pump was not run on Sunday, September 24, 1988.

The daily response to Municipal Well No. 1 pumpage during this period at some other monitoring wells was as noted:

- MW 86-3D, less than 0.05 feet
- MW 86-5D, 1 foot
- MW 87-7I, 3 feet
- MW 87-10D, 1/4 foot
- MW 87-12D, 3/4 foot
- BES Plant Well, not discernible.

Generally, those wells closer to Municipal Well No. 1 responded with a greater water level drop. The BES plant well was beyond the limits of a detectable cone of depression developed during the eight-hour pumping cycles.

During the fall, the Municipal Well No. 1 runs for a longer period of time relative to the rest of the year. This is because spring flow to the reservoir is at its lowest during the fall months, providing only about one quarter of the daily consumption. However, after late winter the springs provide most of the daily demand, and the municipal well is only required to run for an hour or two each day, if at all.

The two large deflections of over one foot on September 27 and 28, 1988, are due to some of the preliminary testing of the air stripping tower at Municipal Well No. 3 located about 1,100 feet away. The well pump was run on several occasions during these two days for various lengths of time. The pumping rates ranged from 230 to 300 gpm.

Two periods of significant rainfall occurred during this recording period: Once during the evening hours on September 24, 1988, and another during the second half of the day on October 2, 1988. The rapid response of water levels to surface water recharge following these rainfall events was observed in MW 87-10D and all monitoring wells with water level recorders. This provides further indication that the ground water system is behaving as one hydrogeologic unit and that no hydraulically restrictive unit is impeding the infiltration of precipitation.

In addition to pumping influences from Municipal Wells Nos. 1 and 3, a slight influence from the Bally Ribbon Company well was observed on recorders located in wells MW 87-7I and MW 87-5D. Daily pumping amounts from September 1, 1988, to October 9, 1988, for the Bally Ribbon and the Great American Knitting wells, and Municipal Well No. 1 are summarized in Table 5. During this time of the year industrial well pumpage is less than one fifth (20,000 gpd) of the municipal pumpage (over 100,000 gpd). However, until the spring of 1988, Bally Ribbon operated their well pump continuously at about 30 gpm. Although the Mill's use was similar to the current usage (about 10,000 gpd), about 40,000 gpd were pumped from the well. The surplus water ran directly to the Bally storm water sewer system. This surplus water flow was measured on July 16, 1987 at 28 gpm.

Other continuous recorder traces for the baseline water level survey are appended (Appendix E).

In addition to the dynamic influences occurring within the aquifer, some general observations with respect to the survey include:

- A general seasonal trend is suggested if the water level fluctuations during the pumping test are disregarded. The highest ground water levels occur in early spring while the lowest levels occur in the fall. These are normal conditions for this part of Pennsylvania.

- The seasonal fluctuation is not large despite the drought conditions that occurred in early summer. Only about two feet of seasonal fluctuation occurred over the year.

- Water levels do not appear to be returning quite to last year's levels, perhaps due to the drought.

- All wells have approximately the same amplitude of fluctuation. This fact implies that all these wells are installed in the same aquifer.

- Water levels at each cluster well do not appear to have consistent or large elevation differences between shallow wells, intermediate depth wells and deep wells. This also suggests that all the wells in the cluster are within the same hydrogeologic unit.

3.3.3.3 Ground Water Flow Direction

Ground water contour maps were prepared from the ground water elevations in Table 4 to evaluate flow direction under nonpumping and pumping conditions within the aquifer. The intermediate and deep monitoring wells were considered together when generating these figures.

Figure 10 illustrates the ground water potentiometric surface within the fanglomerate just before the pumping test at Municipal Well No. 3 began (9:10 a.m., October 4, 1988). This surface represents static conditions without the effects of any significant pumping on the aquifer. Municipal Well No. 1 had not been pumped for almost 24 hours, and water levels had recovered completely.

Ground water flow direction is to the east, parallel to flow in the unnamed tributary. The hydraulic gradient increases significantly beyond State Route 100. Two reasons may account for this feature. First, lower hydraulic conductivities in the fanglomerate may exist to the east. This could be due to fewer fractures and shallower weathering and an increasing shale content. A possible reflection of this condition is that MW 87-8I and MW 87-9I had significantly lower yields than most of the other wells completed in the fanglomerate. Second, the fanglomerate appears to discharge to the unnamed tributary east of State

Route 100. This discharge is maintaining lower water levels along the creek, forcing a steeper hydraulic gradient.

The noticeably flat hydraulic gradient in the vicinity of S. Chestnut Street suggests that highly fractured and weathered fanglomerate in this area allows for the free stabilization of ground water.

Figure 11 is the corresponding static ground water contour plot for the shallow wells only (at the same time as Figure 10). The flow direction and gradient from the shallow wells is very similar to that of the intermediate and deep wells, as would be expected of an aquifer under water table conditions. Although significant rainfall occurred less than 48 hours before this round of water levels was collected, the vertical potentiometric head differential at most cluster well locations is less than 0.2 foot. Well clusters MW 87-4 and MW 86-5 had vertical head differentials of 0.78 feet and 0.69 feet downward, respectively. Cluster MW 87-4 is located close to a storm sewer that may be allowing a continuous recharge of water which would account for the water level discrepancy. Cluster MW 86-5 is located in an area of thick residuum which is impeding the infiltration of the recent rainwater.

Figure 12 is a potentiometric surface developed from the intermediate and deep wells at the end of an eight-hour pumping cycle from Municipal Well No. 1 on August 25, 1988. This represents the maximum influence to the aquifer by Municipal Well No. 1 during normal cycling. Although there are not many observation wells in the immediate vicinity of Municipal Well No. 1, an inferred cone of depression is shown. Municipal Well No. 1 pumpage affects water levels in many wells; however, it does not appear that flow directions are altered significantly southwest of Church Street.

3.3.3.4 Pumping Test Results

The following describes the results of the 72-hour pumping test conducted during October 1988. The results are divided into two

subheadings. "Aquifer Response" describes the development of the cone of depression and variations in horizontal and vertical head during the test. The "Estimation of Aquifer Parameters" provides transmissivity (T) and storativity (S) values for the aquifer.

Aquifer Response

Figure 13 is a copy of the continuous recorder trace at MW 86-5D illustrating water level fluctuations throughout the pumping test and the recovery period following the test.

At MW 86-5D, two spikes indicating water level drops of short duration occurred during the afternoon of October 3, 1988. These are the results of running Municipal Well No. 3 for a couple of preliminary tests to set the pumping rate in anticipation of the long-term test. Flattening of the water levels was achieved during the early hours of October 4, 1988, indicating full recovery and static conditions had been reached in the aquifer prior to initiating the pumping test.

At 9:10 a.m. on October 4, 1988, the pumping test was started. Rapid drawdown occurred in Municipal Well No. 3 and gradually leveled off as pumping continued. At 5:03 a.m. on October 5, 1988, Municipal Well No. 1 started pumping to refill the reservoir. Municipal Well No. 1 cycled on and off three times during the period from 5:03 a.m. October 5, 1988, through to 3:00 p.m. October 6, 1988. After the last pumping cycle of Municipal Well No. 1, the reservoir was filled to capacity and Municipal Well No. 1 was not required to pump again until 9:00 a.m. October 8, 1988.

The pumping test at Municipal Well No. 3 was stopped at 9:10 a.m. October 7, 1988 (72-hour total duration). Recovery of water levels after shutdown continued until Municipal Well No. 1 was pumped again to fill the reservoir on October 8, 1988 at 9:00 a.m. Although full recovery of water levels was not reached before this time, the trend is reasonably clear. Full recovery probably would not have occurred

because some dewatering of the aquifer took place as a result of the pumping test. No significant rainfall occurred after Sunday night (October 2, 1988) prior to beginning the pumping test.

Figures 14 through 17 are contoured potentiometric surfaces of the aquifer at selected times during and after the pumping test. At 20 hours into the pumping test (Figure 14), the cone of depression from Municipal Well No. 3 is clearly developed. Municipal Well No. 1 began to cycle on and off at this time and by 50 hours (Figure 15) the maximum interference from pumping at this well is illustrated. Figure 16 represents the maximum alteration of the background gradient by the pumping of Municipal Well No. 3 at 243 gpm after 72 hours. The capture zone (area in which flow direction has been altered so that ground water will eventually be captured by the pumping well) has extended downgradient to a point just beyond State Route 100. Although pumping at Municipal Well No. 1 has not occurred for 18 hours, water levels are still recovering in the vicinity of the municipal well.

Figure 17 illustrates the potentiometric surface after Municipal Well No. 3 has been shut down and the aquifer has been allowed to recover for 25 hours without any pumping influences from Municipal Well No. 1. If this figure is compared with that of static conditions prior to the pumping test (Figure 11), the effects of dewatering of the aquifer can be seen. Full recovery would probably not have been achieved until the next significant rainfall.

Figures 18 through 20 are drawdown contour maps illustrating just the cone of depression developed from Municipal Well No. 3 during the course of the pumping test. At 20 hours into the pumping test, Figure 18 approximates the anisotropic shape of the cone of depression. At 72 hours (Figure 19) the maximum cone of depression is illustrated. Pumping at Municipal Well No. 1 has distorted this cone of depression towards the northeast. Figure 20 depicts the residual drawdown after 25 hours of recovery. This figure illustrates that two areas did not

recover as quickly as the surrounding areas. First, the area around MW 86-5D and the BES plant well is recovering very slowly. This agrees with previous data that indicated that this area may have a lower hydraulic conductivity. Secondly, in the northeast quadrant from Municipal Well No. 3, recovery has been slow. This is due to the added effects of pumping at Municipal Well No. 1 during the test.

During the pumping test it became apparent that for those wells screened in the bedrock residuum, a sluggish response to water level changes in the fanglomerate below occurred. To varying degrees, three factors account for this discrepancy:

1) The relict structure which provides the residuum with much of its permeability is destroyed during the well drilling process. The silts and clays of the residuum are mixed, compacted, and smeared along the borehole walls by the bit. No amount of development in a 10- or 20-slot, 2-inch well screen can remove all of this material. The result is that monitoring wells installed in the residuum probably tend to respond to water level changes more slowly than the residuum material itself.

2) Because the hydrogeologic system is under water table conditions, the effects of gravity drainage occur when this system is pumped. Gravity drainage refers to the delayed yield effects from the physical dewatering of the upper portion of the aquifer as the water table drops.

3) The hydraulic conductivities of the residuum (both horizontal and vertical) are probably one to two orders of magnitude lower than that of the fanglomerate. This difference in permeability is not significant enough to be an aquiclude in which complete semi-confined conditions would exist; however, flow is partially restricted in the residuum as compared to the fanglomerate and localized slight semi-confining effects are probable.

The magnitude of the influence of each of these three factors on water level responses in the residuum wells is difficult to ascertain because they affect these wells similarly. Time/drawdown plots of some of the cluster wells illustrate the sluggish response of the wells in the residuum. Figure 21 is a time/drawdown plot of the water elevations of MW 87-7S and MW 87-7I (cluster well MW 87-7) during the pumping test. MW 87-7S is a shallow well (40 feet deep) screened within the upper

portion of the bedrock residuum, which is about 80 feet deep at this location. MW 87-7I is open from 102 to 132 feet, well within the fanglomerate aquifer below the base of the residuum. Several comparisons in the trends of these two drawdown curves indicate the slight hydraulic restriction separating these two wells and the similar effects of gravity drainage:

- Although water elevations of both wells are within 0.2 foot at the start of the pumping test, water elevations within the fanglomerate (MW 87-7I) dropped much more rapidly than in the residuum (MW 87-7S).
- From 2,200 to 3,200 minutes, large water elevation fluctuations occurred in the fanglomerate in response to Municipal Well No. 1 cycling. These fluctuations were not exhibited in the well screened in the residuum.
- After pumping, the fanglomerate recovered much more rapidly than the residuum.

Well cluster MW 86-5 also responded in a similar fashion as cluster well MW 86-7. MW 86-5S is screened from 34 to 65 feet, well within the residuum which extends to almost 100 feet. MW 86-5D is open in the fanglomerate aquifer (from 112 to 165 feet). Figure 22 is the time/drawdown plot of these two wells during the pumping test. Once again, the well screened in the residuum (MW 86-5S) responds sluggishly to rapid water elevation changes in the fanglomerate below. Note that water levels in MW 86-5S generally maintained and recovered to an elevation above that of MW 86-5D. This may be due to the continued infiltration of rainwater from the previous week recharging the shallow well. Also, the extensive pumping of Municipal Well No. 3 has dewatered the fanglomerate to some degree.

The remaining shallow well clusters (MW 86-3 and MW 86-4) do not have shallow wells screened in the residuum. At these locations the residuum is not very thick, and the water table is generally at or below its base. For example, Figure 23 is the time/drawdown plot for MW 86-3S and MW 86-3D. Clearly these two wells are within the same water-bearing unit. Their water levels respond similarly and are consistently at the

same elevation. MW 86-3S is screened from 15 to 44.5 feet, while the residuum only extends to a depth of about 21 feet at this location. Because of the shallow depth of the residuum and the fact that static water levels are close to the base of this unit, the hydrogeologic system behaves as an unconfined (water table) aquifer in the vicinity of these two wells.

Cluster well MW 86-4 is similar to MW 86-3 in that both wells are open to the fanglomerate aquifer and the residuum is shallow (only 12 feet deep). However, MW 86-4 (41 feet deep) responded sluggishly during the pumping test and maintained a water elevation one-half to one foot higher than MW 86-4I (open from 60 to 120 feet) (Figure 24). One possible explanation for this trend is that near-surface water may be infiltrating down into the fanglomerate in the immediate vicinity of this well. A storm sewer and catch basin are located below the parking lot surface nearby. A supply of rainwater may be temporarily perched in this old trench line and could be seeping into the fanglomerate causing water levels in this well to be maintained at a higher elevation. Vertical movement of water down through the well screen is also a possibility associated with this infiltration.

Estimation of Aquifer Parameters

Many potential complicating factors were identified and considered in evaluating the pumping test data; however, the effects that these interferences may have had on the drawdown and recovery data were not always quantifiable. The limited information available and the compounding effect that these factors produced make complex analytical interpretations tenuous. Some of the potential complicating factors identified for the pumping test evaluation included:

- Unavoidable pumping of Municipal Well No. 1

  During the middle of the pumping test, pumping from this well effectively masked the last portion of the drawdown curve in many of the observation wells. This pumping was necessary to supply the Borough with water during the test.

- The effective depth of the aquifer

  This depth is not known with certainty. In order to complete calculations for the evaluation of the pumping test, a depth of 300 feet was used.

- Partial penetration effects of the pumping well

  Municipal Well No. 3 is only open from 154 to 303 feet from the surface, but the aquifer extends from 30 feet to some unknown depth.

- Semi-confining effects from the lower permeable unconsolidated materials

- Anisotropic aquifer parameters

  Dipping bedding, fractures, and lithology can all contribute to anisotropic flow. The lithology is highly variable, and structure specifics are not known.

- Horizontal limits of the aquifer

  The effects of the suspected fault/contact with the Precambrian crystalline material to the northwest are not known, for example.

- Delayed yield effects from porous blocks of limestone in a fractured system

  These effects cause a similar deflection in drawdown curves as delayed yield effects from gravity drainage.

- Incompletely defined recharge or discharge areas

- Casing storage effects of the pumping well

  These effects were considered insignificant in the observation wells.

In addition to the lack of an upper continuous confining layer, water level observations during drilling and quick response in water levels following rainfall events indicate that the aquifer is generally under unconfined conditions. These conditions were assumed for estimation of aquifer hydraulic parameters.

Time drawdown and recovery curves from several observation wells were constructed to calculate values of T and S for the primary bedrock aquifer. Data collected during the pumping test of Municipal Well No. 3

indicate that the aquifer in the Brunswick Formation is undoubtedly anisotropic and has some directional hydraulic properties. These properties are caused by a secondary permeability (fractures and joints) or distinct structure zones within the formation (e.g., fault, predominant fracture/joint systems). For example, the water level in MW 87-4I dropped 0.56 foot within 21 hours of the start of the pumping test. A drop of 0.51 foot was noted in MW 86-3D within the same period. MW 86-3D is located closer (686 feet) to the pumping well than MW 87-4I (1,020 feet). Similar effects have been observed in MW 86-5D (303 feet) and MW 87-12D (396 feet); well drawdowns within 21 hours of pumping were 3.67 and 6.69 feet, respectively. Figures 18 through 20 illustrate the anisotropic development of the cone of depression during the test.

Because the aquifer behaves anisotropically, the hydraulic properties derived from the pumping test data by conventional methods are questionable. Several different methods have been applied to determine the T and S of the aquifer. An attempt was made to use the Jacob Straight-line Method to determine the hydraulic characteristics of the aquifer from time-drawdown curves. In this case, the value of "u" [W(u)] was several orders of magnitude larger than the required "0.05" needed to correctly apply the straight-line methods. Therefore, the Jacob Method was not appropriate for the calculation of T and S in this case.

An alternative technique, the Boulton Solution Method, was selected for analyzing the pumping test data. Boulton produced a type of curve for the time-drawdown relationship of an unconfined aquifer. The gravity drainage from the interstices above the depression cone is seen on several drawdown-time curves for observation wells. The family of Boulton-type curves was applied to determine the values of T and S for the bedrock aquifer. The solution process consisted of plotting drawdown (s) and time (t) for selected observation wells on double-logarithmic paper (Appendix G) to define T and S. Data from the pumping well were not considered.

In addition to the Boulton Solution Method, the Boulton-Streltsova Method for unsteady flow to a pumped well in an unconfined fissured aquifer was also applied to determine aquifer hydraulic parameters in the fractured bedrock of the Brunswick Formation beneath the site. For both equations, the Boulton Solution and the Boulton-Streltsova Method, it was assumed that pumped well fully penetrated the bedrock aquifer. A summary of the calculated values for T and S is presented in Table 6.

Time-drawdown analysis of the drawdown data from the observation wells was performed. The drawdown data were not corrected for dewatering due to small drawdown values in relation to the total saturated aquifer thickness. The saturated aquifer thickness was estimated to be approximately 300 feet because the formation below the depth of 350 feet from the ground surface appears to be minimally productive within the site area. The recovery data were also analyzed for selected observation wells.

The time-drawdown and time-recovery curves for observation well MW 87-12D indicate a recharge effect on drawdown data. The recharge effect probably pertains to the "leakage" from the upper unit of the aquifer, which consists of unconsolidated material. A deviation of drawdown on the flat portion of the curve corresponds to the period of pumping Municipal Well No. 1. The Boulton Solution and Boulton-Streltsova Methods were applied to calculate aquifer parameters. Both methods gave a fairly good approximation of the values of T and S (Table 6).

The time-drawdown curve for MW 86-5D exhibits similar behavior to that described in MW 87-12D. The time-drawdown plot was matched against Boulton's delayed yield curve and the Boulton-Streltsova curve. The resulting T and S were lower (13,929 gpd/ft and 3×10^{-2}) from the Boulton-Streltsova Method than the estimated T and S (19,891 gpd/ft and 2.5×10^{-1}) from Boulton's Solution. The influence of pumping Municipal Well No. 1 is clearly seen on the curve during the period between 1,200

and 3,500 minutes of pumping Municipal Well No. 3.

The time-drawdown and time-recovery curves for MW 87-10I and MW 87-10D were also analyzed using the Boulton and Boulton-Streltsova solutions. The calculated T values for MW 87-10I and MW 87-10D are 79,565 and 27,848 gpd/ft, respectively. A lower T in the deeper MW 87-10D may indicate lower permeability of fractured bedrock in the deeper unit of the aquifer. The recharge effect from the upper unit of the aquifer is better seen on the MW 87-10I curve than the MW 87-10D curve. The calculated values of S range from 3.6×10^{-3} to 7.7×10^{-2} in MW 87-10D and MW 87-10I, respectively. The conventional Boulton Method produced relatively high T values for MW 87-10I. Due to this fact, the Boulton-Streltsova Method was applied to calculate the T and S values. The Boulton-Streltsova Method is more applicable for MW 87-10I because early recorded data appear to be the result of the release of water from storage followed by a period of gravity drainage. The T values of 13,200 and 12,658 gpd/ft were derived for MW 87-10I and MW 87-10D, respectively. The average coefficient of storativity is 7.25×10^{-3}. This method was more reliable for aquifer characteristics determination than the Boulton Solution because of ground water flow in the fractured medium.

The family curves of the Boulton Solution and Boulton-Streltsova Method did not match the time-drawdown curve for MW 87-11I. The MW 87-11I curve indicates a delayed yield in the first 280 minutes and, thereafter, continues into a progressively steepening slope. This slope approximates 0.5 and indicates that linear flow may have occurred.

A similar behavior of time-drawdown curves was found for MW 86-3D and MW 87-4I. Both curves show a short-term delayed yield and a slope of 0.5 indicating linear flow or discharge boundaries. The applied Boulton-Streltsova Equation produces T values of 55,695 and 66,304 gpd/ft and S values, 1.2×10^{-2} and 4.7×10^{-3} for MW 86-3D and MW 87-4I, respectively. The linear flow method of Jenkins and Prentice

could not be applied because the location of the fracture system is not known.

As in MW 87-11I, the Boulton and Boulton-Streltsova family curves could not be applied to the time-drawdown curve of MW 87-7I. An attempt was made to use the Theis Method. This method produced an anomalously high value of T, which is not representative for MW 87-7I.

The drawdown data for shallow observation wells could not be matched reasonably to the conventional type curves. The shape of curves for shallow wells indicate a decrease in T and S with time. Calculations of T and S values are summarized in Appendix G.

Based on the pumping test data, it is obvious that anisotropic hydraulic behavior occurs within the Brunswick Formation in the site area. The formation exhibits directional hydraulic characteristics dependent on the structural orientation of the formation. Also, the fractured condition of the aquifer causes nonuniform distribution of the drawdown in the pumping and observation wells. It was generally observed that the greatest drawdown in the observation wells occurred in the wells aligned south of the pumping well possibly due to fracturing parallel to the creek. The validity of T values estimated by the standard methods may be questionable, particularly where fractures and joint zones are abundant.

The hydraulic parameters derived from this pumping test are adequate to estimate a cone of depression for different pumping rates and patterns from this well. However, accurate delineation of a capture zone will require additional field investigations.

The variable nature of flow conditions within the aquifer precludes the use of this data to evaluate the effectiveness of recovery wells at other locations in the aquifer. Long-term pumping tests would be required to gather the empirical data necessary to determine the

specific aquifer flow conditions for other well locations.

3.3.3.5 Summary

The following points from this subsection are considered most pertinent to this investigation:

- One aquifer, under water table conditions, occurs within the area of investigation; however, localized semi-confined conditions do occur.
- The water table ranges from 5 to 60 feet below ground surface, principally due to topographic expression.
- Aquifer recharge occurs from infiltrating precipitation and surface water.
- Discharge of ground water to the perennial stream may be occurring southeast of Route 100.
- Ground water flow direction is generally eastward.
- The residuum has retained much of the relict structure of the bedrock, enhancing its hydraulic conductivity.
- Ground water flow in the bedrock occurs within fractures and weathered zones as indicated by the highly variable yields of the monitoring wells.
- The capture zone from daily pumping of Municipal Well No. 1 appears to extend only halfway to the BES plant.
- Pumping of Municipal Well No. 3 for 72 hours developed an approximate capture zone that included the BES facilities but did not extend significantly beyond Route 100.
- Values of T and S generated from the pumping test range greatly due to the highly variable and anisotropic hydraulic properties of the aquifer. Additional pumping tests would be necessary to evaluate the performance of potential recovery wells at locations other than in the immediate vicinity of Municipal Well No. 3.

3.3.4 Source Delineation Investigation

Four areas within the BES complex were identified in the Approved Work Plan (Remcor, September 23, 1987) as potential sources of the ground water contamination occurring within Bally. These areas, as shown in

Figure 3, were chosen based in part on historical aerial photography (EPIC, August 1986) and from interviews with plant personnel pertaining to prior plant use. These areas consist of:

- The former degreasing area (in use from the early 1960s until about 1969)
- The present small parts degreasing area
- Two former lagoon areas (northern and southern), each containing two impoundments.

Following completion of the initial RI Field investigation and submittal of the draft RI Report, the EPA requested performance of an additional source investigation along the northern perimeter of the BES plant. Seventeen additional soil borings were drilled located on approximate 100-foot centers along transects approximately 100 feet apart along the north end of the BES plant. The goal of this additional study was to determine whether an active source of VOC release to the aquifer was located in this area.

All areas were investigated using the test boring and sampling methods described in Section 3.1.1. The chemical-analytical results for the samples collected in these areas are presented in Table 7. The history of each of these areas and the scope and findings of the current RI in relation to each of these areas are described below.

3.3.4.1 Former Southern Lagoon Areas

The southern lagoon area originally consisted of a system of two lagoons, each approximately 80 by 60 feet in plan. Reportedly, these lagoons were shallow (less than one foot) diked structures which may have spent received some spent degreasing solvents. These lagoons existed from the mid-1960s up to 1970, when the present plant office was constructed in this area.

Four borings were drilled through the former lagoons to total depths of between 12 and 15 feet, as shown in Figure 3. Drilling was conducted by

hollow-stem augering using a geotechnical drill rig; samples were obtained using a split-spoon sampler driven by a 140-pound weight as described in Section 3.1.1. Boring logs are included in Appendix B.

A layer of clean, predominantly brown to gray, clayey silt and silty gravel fill occurs in this area to depths of 2.0 to 3.25 feet. No evidence of the lagoons was observed during test boring drilling.

Beneath the fill lies a zone of brown clayey silt-containing angular and subrounded gravel-size rock fragments of quartz, limestone, and gneissic composition. The base of this material ranges from approximately 7.75 to 11.75 feet, based on the test boring data. Beneath the clayey silt with angular and subrounded gravel, a stiff, reddish-brown, clayey silt residuum occurs. All borings terminated in this material.

Headspace readings were taken from jarred samples with an HNu PID. No sample from this area registered a reading of 1 part per million by volume (ppmv) above background. No sample indicated any obvious staining or odor that would suggest contamination. Based on the test boring program, it appears that the remnants of the lagoons were removed prior to building construction and replaced with clean fill.

Five samples were submitted from this area for TCL VOC analysis. The five samples consisted of two samples taken from the base of the clayey silt with angular and subrounded gravel (SS-2-004, SS-3-005), two samples from the residual material beneath the clayey silt with gravel (SS-1-003, SS-4-005), and one sample that straddles the contact between the two materials (SS-1-002). The analytical results are summarized in Table 7. All samples analyzed revealed nondetectable levels of VOCs. Based on these analyses, it does not appear that the southern lagoon area was a source of the ground water contamination occurring in Bally.

3.3.4.2 Former Northern Lagoon Area

The northern lagoon area consisted of two smaller, semicircular lagoons

that occurred beneath what is now the foaming department of the BES facility, as shown in Figure 3. The lagoons were constructed prior to May 1955 and were in use until the mid-1960s when plant expansion encroached upon their location. Four borings (SS-5 through SS-8) were drilled in the vicinity of these lagoons to define the potential for VOC contamination to have resulted from this area. Inconsistencies in scale between EPA EPIC aerial photographs and BES plan maps prevented precise location of the borings in the lagoon areas.

Because of limited access in this portion of the plant (foaming department), the borings were drilled by hand after penetration through the floor with a concrete coring machine. A gasoline-powered portable power auger and a hand auger were used to advance each boring; samples were collected with clean, decontaminated bucket augers.

Boring depths ranged from 2.8 to 8.0 feet. A medium-stiff to stiff brown silt with some rounded quartzite and gneiss fragments occurred to a depth of approximately five feet. Beneath the silt and gravel layer lies the residual reddish-brown silt with shale fragments.

HNu PID headspace readings on jarred samples are given in Table 2. Readings ranged to 25 ppmv above background, with the highest occurring in borings SS-6 and SS-7. Five samples from borings SS-6 and SS-7 were submitted for TCL VOC analysis; the laboratory results indicated no VOCs above the required quantitation limits.

No samples were submitted from borings SS-5 and SS-8 because the presence of cobbles prevented penetration past the depth of 4.8 and 2.8 feet in these borings, respectively.

3.3.4.3 Former Degreasing Area

Initial use of degreasing solvents at the BES plant occurred in the late 1950s with the switch to urethane foam as the insulation material for meat display cases. Prior to application of the porcelain shells and

foam insulation, an overhead monorail crane was used to dip the entire case into a 2,000-gallon capacity tank of degreasing solvent. This degreasing operation took place in the northeastern portion of the plant, as shown in Figure 3. Following dipping, the cases were set on the floor and permitted to dry before being returned to the production line. This degreasing operation was discontinued in approximately 1969, when case manufacturing operations ceased. The solvent used in the former degreasing area was exclusively TCE.

The former degreasing area, based on prior site operations, appeared to be the most likely source of chlorinated solvent occurrence within the aquifer. Its proximity to the elevated concentrations occurring in MW 86-4 and MW 86-3S also suggested this area as a probable source.

Drilling was conducted by a portable skid rig using hollow-stem augers. Samples were obtained by the split-spoon method in accordance with Section 3.1.1. Five test borings (SS-10 through SS-14) were drilled to depths ranging from 12.0 to 21.5 feet. In one of the test borings (SS-12), a shallow well (MW 87-13S) was subsequently installed.

Four of the borings were drilled along the area where meat coolers were dipped into a degreasing tank to be cleaned and then removed and set to dry. BES plant personnel have indicated that, at the time of the degreasing operations, this area of the plant had a wooden floor, possibly providing a more ready pathway for solvent drippings to permeate the underlying ground.

Beneath the present day concrete floor, five to eight feet of silty rock fill was encountered, except at SS-14, where three feet of silty rock fill was encountered. Beneath the fill, all borings encountered the medium-stiff red-to-brown clayey silt residuum that contains shale fragments.

Headspace readings were obtained on the jarred samples (Table 2). The

majority of samples registered a response of less than 1 ppmv above background. The highest reading occurred at boring SS-12, from three to five feet where a reading of 2 ppmv above background was detected. Other detectable readings include a 1 ppmv reading above background at boring SS-11 (seven to nine feet), boring SS-13 (three to five feet and five to seven feet), and boring SS-14 (seven to nine feet).

Ten samples were submitted for TCL VOC analysis from these borings (Table 9). VOCs were detected in five samples. TCE was detected in one sample at a concentration of 8 µg/kg at a depth of 3 to 5 feet (SS-11-001) in boring SS-11. TCA was detected in three samples from boring SS-11 (SS-11-001, SS-11-002, SS-11-003) at depths of 3.8 to 5 feet, 7 to 9 feet, and 10 to 12 feet, respectively, at respective concentrations of 6, 13, and 10 µg/kg. Other VOCs detected were toluene at SS-11-001 (3.8 to 5 feet), SS-11-002 (7 to 9 feet), SS-12-002 (3 to 5 feet), and SS-12-003 (5 to 7 feet) at concentrations of 43, 6, 13, and 36 µg/kg, respectively.

Based on the analytical soil results, the former degreasing area may have contributed to the aquifer contamination; however, the low residual levels remaining in the soil suggest that this historic spillage may not be singly responsible for the VOC levels found in ground water immediately north of this area (i.e., MW 86-4 and MW 87-4I).

3.3.4.4 Current Degreasing Area

A second degreasing area known as the small parts degreasing area (Figure 3) has been in use since the early 1960s for degreasing small parts used in interlocking insulated pa..els. The tank at this location has a 600-gallon capacity but usually contains less than 400 gallons of solvent. The following chronology is provided for use of degreasing solvents in the small parts degreasing tank:

- August 1986 to present: Eaken Saf-T-Sol 31® (active agents - hydrocarbons other than TCE or TCA)

AR301364

• April 23, 1980 to August 1986:	Eaken Saf-T-Sol 15® (active agent - 1,1,1-TCA)
• Prior to April 23, 1988:	Eaken Saf-T-Sol® (active agents - methylene chloride, tetrachloroethene)

The small parts degreasing area was investigated by drilling a test boring (boring SS-9) east of the degreasing tank, just outside of the plant building (Figure 3). This location is suitable to detect spillage of solvents that would have occurred directly outside of the degreasing area or from leakage through the plant interior floor in the degreasing room into the subsurface.

At this location, boring SS-9 was drilled to a depth of 32 feet. Silty, angular, gravel fill was encountered to a depth of four feet, underlain by the residual brown clayey silt with shale fragments.

Samples from two intervals were submitted for TCL VOC analysis. A sample and duplicate from four to six feet (SS-9-001, SS-9-001A) and a sample from six to eight feet (SS-9-002) were submitted for laboratory analysis. Headspace readings from these samples indicated a 7 ppmv reading above background from the 4- to 6-foot level and a nondetectable reading at 6 to 8 feet. The laboratory analytical data are summarized in Table 7; no VOCs were detected in any of the samples. Based on these results, it does not appear that the small parts degreasing operation contributed to the present aquifer contamination occurring in Bally.

3.3.4.5 Area North of Plant

The potential for a contaminant source located immediately north of the plant was investigated in March 1989. Borings SS-16 through SS-32 were drilled to the depth of ground water, and continuous soil samples were collected and screened for the existence of VOC contamination. One proposed boring (SS-15) was omitted because of property access, and

because possible alternative locations for the boring would not have provided any data not attainable from other borings.

This area of the BES facility is hydraulically downgradient of the former lagoons, and both former degreasing areas, while upgradient of the monitoring well MW 86-3 and MW 86-4 clusters. This area is adjacent to the current machine shop which was formerly the assembly line portion of the plant. These facts warranted the area's investigation.

Offices have occupied the northeast corner of the plant building since the plant's start-up in the 1930s. The area immediately outside of the building is currently utilized for employee parking and has been covered with asphaltic pavement since the plant's early days.

Drilling, geologic, and hydrogeologic conditions encountered concur with findings of earlier portions of this RI. Ground water levels observed in temporary piezometers installed in borings SS-17 and SS-22 were comparable to those of wells MW 86-4 and MW 86-3S, respectively. Analytical results for ground water samples taken from these piezometers also concurred with results from the adjacent monitoring wells.

Soil samples were collected for headspace analysis from each recoverable split-spoon sample. Headspace results ranged from 0.0 to 42 ppmv above background in soils above the water table and to 1,000 ppmv below the water table. These results are included in Table 2.

Twenty-five soil samples, selected based on headspace results, were submitted to the Spotts, Stevens, and McCoy, Inc. (SS&M), Wyomissing, Pennsylvania, for target volatile analysis. Three samples were replicated for submittal to NUS. VOCs were not reported above detection limits in any sample analyzed by SS&M, and only one sample (RB-SS-19-02) submitted to NUS was found to contain any VOCs.

The SS&M analyses were approved by EPA as screening data, and, as such,

were reported with higher detection limits. One of the objectives of the screening analysis was to confirm any soil samples suspected of containing higher levels of VOCs on the basis of the HNu PID scans. Elevated headspace VOC levels were generally found only in proximity to the water table (e.g., RB-SS-19-02). The NUS analytical protocols employed a lower detection limit as an additional confirmation of the SS&M data. In the single sample where NUS detected VOCs (RB-SS-19-02), the level found was below the detection limit for the SS&M analysis. Therefore, NUS and SS&M results were not inconsistent. These laboratory data are summarized in Table 7. The results of the analyses indicate that no active subsurface source exists north of the BES plant.

3.3.4.6 Source Delineation Summary

The sample results from the investigation of the five potential source areas did not exhibit subsurface soil contamination by VOCs believed adequate to account for the elevated levels of chlorinated solvents occurring within ground water in the site vicinity. The solvents TCE and TCA were detected in only one area (the former degreasing area) at relatively low concentrations. Although chlorinated VOCs were detected in sample RB-SS-19-02, the source of VOCs in this sample is more likely to be the ground water than the soil. No other detection of VOCs occurred in unsaturated zone soils immediately north of the BES plant. All other areas did not evidence the presence of any chlorinated solvents.

Headspace readings from the samples collected from the former northern lagoon area were as high as 25 ppmv. Laboratory analysis of these samples did not reveal any VOCs. In the north area of the BES plant, one surface soil sample exhibited an elevated headspace reading of 42 ppmv, but deeper samples exhibited less than 1.0 ppmv. Other elevated headspace readings occurred in samples collected from near the water table in borings through the asphaltic pavement north of the plant. Samples from borings into the former southern lagoon area (which replaced the northern lagoon area as the plant expanded in the

mid-1960s) did not exhibit any VOC contamination. Based on a review of prior plant history, the southern lagoons would have received the same wastes as the northern lagoon area. If contamination had resulted from the lagoon operation, it would likely have occurred in both areas because of their similar use. Additionally, no subsurface soils encountered showed visual evidence of contamination.

Based on these conditions, it appears that none of the suspected source areas are currently contributing to the ground water contamination occurring within Bally. The chemical-analytical data suggest a historic release from the BES plant, rather than a continuing release, as the source of the ground water contamination. Such a release is likely to have occurred some time ago (possibly in the 1950s or 1960s). The ground water and soils data suggest that active release of VOCs to the aquifer is not occurring.

3.3.5 Nature and Extent of Ground Water Contamination

3.3.5.1 General Extent of Contamination

The ground water contamination investigation performed in the Phase III RI consisted of the sampling of 35 ground water wells that included the following:

- 18 monitoring wells
- 2 municipal wells
- 4 industrial wells (including the Bally plant well)
- 11 residential wells.

VOCs were detected in 19 of these wells:

- 13 monitoring wells
- 2 municipal wells
- 3 industrial wells
- 1 residential well.

In addition, VOCs were detected in two temporary piezometers installed in borings SS-17 and SS-22 in conjunction with the March 1989 additional source investigation. Table 8 shows the ground water chemical-

analytical results, whereas Table 9 shows the results for the residential wells. These results are discussed in this section relative to data from previous site investigations. More recent data from field testing of the air stripping treatment system at Municipal Well No. 3 are also discussed in the draft FS Report (Remcor, May 1989).

The most prevalent VOCs detected were TCA, TCE, and DCE. TCA occurred in 15 of 24 monitoring, municipal, or industrial wells; both TCE and DCE occurred in 13 of these wells. Other VOCs detected were 1,1-dichloroethane (DCA) (6 of 24 wells), tetrachloroethene (PCE) (1 of 24 wells), methylene chloride (5 of 24 wells), toluene (1 of 24 wells), and acetone (3 of 24 wells).

Shallow Ground Water Contamination

No VOCs were detected in wells upgradient of the Bally plant. Shallow VOC contamination appears to be concentrated in the area immediately downgradient of the plant, but within the BES property. MW 86-3S exhibited a total VOC (TVOC) concentration of 1,400 micrograms per liter (µg/ℓ), and MW 86-4 exhibited a TVOC concentration of 513 µg/ℓ. These concentrations are over an order of magnitude greater than the TVOC concentrations detected in the BES plant well and MW 87-13S within the former BES degreasing area. TVOC concentrations at borings SS-17 (2150µg/ℓ) and SS-22 (485µg/ℓ) are consistent with those found at MW86-4 and MW86-3S, respectively (Table 8). Shallow wells MW 86-5S and MW 87-7S, located further downgradient (i.e., northeast), did not demonstrate VOC contamination (acetone and methylene chloride detected in MW 87-7S are suspected to be the result of laboratory contamination). MW 87-11S, located approximately 600 feet southeast of the BES plant, exhibited a TVOC concentration of 10 µg/ℓ. Figure 25 presents TVOC isoconcentration contours for all shallow wells, excluding piezometers SS-17 and SS-22.

Intermediate Depth Ground Water Contamination

VOCs detected in intermediate-depth wells indicate a more far-reaching plume in this portion of the aquifer. Again, the highest VOC concentra-

tions were detected immediately downgradient of the plant, in this case, at MW 87-4I (3,941 µg/ℓ). Figure 26 presents TVOC isoconcentration contours for the intermediate-depth wells. VOCs were detected in these wells as far downgradient as MW 87-8I (4 µg/ℓ), located approximately 2,900 feet downgradient of the plant. Between wells MW 87-4I and MW 87-8I, VOCs were detected at MW 87-10I and at the Gehman residential well (Figure 26) on Main Street at 2,131 µg/ℓ and 730 µg/ℓ, respectively. Thus, concentrations decrease from the plant toward the east/northeast. Low and nondetected TVOCs at wells MW 86-5D and MW 87-11I, respectively, delineate the approximate lateral extent of the contaminant plume at this depth interval.

Deep Ground Water Contamination

The plume in the deepest portion of the aquifer appears to be stronger and more widespread than that portion defined by the shallow and intermediate-depth wells. The deepest part of the plume is defined by wells MW 87-12D, MW 87-10D, and Municipal Well Nos. 1 and 3. Municipal Well No. 3 is located within 100 feet of intermediate-depth well MW 86-5D. The municipal well demonstrated a TVOC concentration of 1,390 µg/ℓ, whereas MW 86-5D demonstrated only 2 µg/ℓ. Also, MW 87-10D exhibited 3,020 µg/ℓ, whereas the shallow well at this location, MW 87-10I, exhibited 2,131 µg/ℓ. Again, the greatest TVOC concentrations were detected nearest the plant, at MW 87-10D (3,020 µg/ℓ) and at MW 87-12D (2,240 µg/ℓ). Figure 27 presents TVOC isoconcentration contours for the deep wells.

Thus, the plume shape and pattern that emerges are as follows:

- The shallow VOC contamination is limited to the area within and immediately downgradient of the BES plant, with the downgradient wells occurring on plant grounds (MW86-4 and MW86-3S) exhibiting TVOC concentrations approximately one order of magnitude greater than those within the plant area (MW87-13S and plant well).

- The intermediate depth VOC contamination also is greatest immediately downgradient of the plant and is greater than the shallow contamination.

- The intermediate depth VOC contamination extends as far as well MW 87-8I (4 µg/ℓ TVOC approximately 2,900 feet from the plant).
- The deep portion of the VOC plume demonstrates the greatest TVOC concentrations, has migrated farthest from the plant, and exhibits the greatest lateral extent.

The sampling conducted during the RI indicates that both Municipal Well Nos. 1 and 3 are contaminated with VOCs as they historically have been. Analysis of samples from both of these wells indicated the presence of TCA, TCE, and DCE. The maximum concentrations (a replicate was also collected) of the VOCs detected in samples from Municipal Well No. 3 were TCA at 840 µg/ℓ, TCE at 260 µg/ℓ, and DCE at 290 µg/ℓ for a TVOC concentration of 1,390 µg/ℓ. A TVOC concentration of 3,509 µg/ℓ was detected in a sample collected by ERM during May 1986, when Municipal Well No. 3 was still pumping. The comparison of these results indicates that this well was actively intercepting contaminated ground water when it was actively being pumped.

Municipal Well No. 1 demonstrated 107 µg/ℓ TVOC during the more recent RI activities, whereas it demonstrated 61 µg/ℓ during the May 1986 sampling. Although the difference here is less prominent, the continued pumping of Municipal Well No. 1 appears to be drawing the VOC contaminant plume in the direction of the well.

3.3.5.2 Discussion of Ground Water Contamination

Although a specific contamination source area has not been identified in this investigation, the shallow ground water contamination plume had the highest concentrations of contaminants in the vicinity of MW 86-3S and MW 86-4. From this area the plume appears to fan out to the east, in the direction of shallow ground water flow. This is reasonably consistent with ERM's findings from their ground water sampling in May 1986. ERM's ground water quality data also indicated that the highest levels of contamination occurred in the vicinity of MW 86-3S and MW 86-4.

Based on the current monitoring well configuration, the shallow ground water plume does not appear to be extensive because of the limited amount of horizontal flow in the unconsolidated materials. In addition, there is no indication of a continuing release of VOCs from the BES operations. The aquifer contamination attributable to the BES plant appears to have arisen via a historic release with no discernible current source.

There is a tendency for a vertical component of flow through the unconsolidated material and down into bedrock due to infiltrating precipitation and ground water pumping in the bedrock below. This vertical flow component, as well as the higher density of the VOCs themselves, appears to have caused the migration of contaminated ground water down into the bedrock. For example, the ERM ground water sampling of May 1986 found the highest levels of ground water contamination in MW 86-4 (TVOC of 7,244 µg/ℓ). The Remcor ground water sampling of January 1988 found the highest levels of ground water contamination in the bedrock directly below this shallow well. MW 87-4I had TVOCs at 3,941 µg/ℓ while TVOC concentrations in MW 86-4 had dropped substantially to 513 µg/ℓ during this time period.

Both the intermediate and deep wells installed in this RI were constructed as open boreholes in bedrock. These wells effectively define a wide distribution of the contamination plume in bedrock indicative of relatively high flow rates.

Ground water flow under nonpumping conditions in the bedrock is to the east. No ground water monitoring wells were located to confirm the existence of a ground water contamination plume in the vicinity of the unnamed tributary southeast of Route 100; however, the steep hydraulic gradient in this vicinity is anticipated to have drawn contaminants in this direction and the isoconcentration maps have been drawn to show the inferred migration of the plume into this area. One indication of a plume in this easterly direction is the trend of TVOCs at Great American

Knitting. In early 1983, TVOCs at this industrial well were 19.3 µg/ℓ. At the time of the ERM sampling in May 1986, the TVOC had reached 43 µg/ℓ. The Remcor sample obtained from this well in January 1988 evidenced a TVOC of 129 µg/ℓ.

The cone of depression that is developed around Municipal Well No. 1 during an eight-hour pumping cycle is not large enough to alter the background hydraulic gradient sufficiently to capture ground water directly from the BES facilities; however, a less direct route can explain the contamination found in this well. During past pumping of Municipal Well No. 3, contaminated ground water was drawn into this well. In the process, contaminants were also drawn closer to Municipal Well No. 1. When full-scale pumping of Municipal Well No. 3 ceased in December 1982, these contaminants were free to disperse in the area where the ground water gradient is low along Chestnut Street (Figure 15). This apparently introduced contaminants to the capture zone of Municipal Well No. 1. In addition, pumping of the Bally Ribbon Mill well at 30 gpm was continuous at this time. This continuous pumping would have expanded the capture zone of Municipal Well No. 1 since it is located nearby. In early 1983, VOCs were first detected at Municipal Well No. 1; however, it was not until late 1984 that the level of contaminants began to rise rapidly, as a result of the decreased influence of Municipal Well No. 3.

Only two deep monitoring wells and the two municipal wells were available to sample ground water below 150 feet. The relatively high concentrations of contaminants found in MW 87-12D and Municipal Well No. 3 indicate that contaminated ground water drawn into the vicinity of Municipal Well No. 3 by past pumping still exists at depth within bedrock.

4.0 SURFACE WATER INVESTIGATION

4.1 SITE HYDROLOGIC EVALUATION

4.1.1 Drainage Features

The BES Plant and its immediate surroundings, including Bally Municipal Well No. 3 are located within a drainage area of approximately 320 acres, as shown in Figure 29. Surface drainage is captured in two drainageways, both unnamed tributaries to the West Branch Perkiomen Creek. The principal perennial drainageway arises in the upper reaches of the watershed, fed at this point by outcropping springs in addition to surface runoff. A portion of the flow from these springs is collected in tile drainage fields and routed to the Bally reservoir located as shown in the figure. Flow in the principal drainageway is diverted to the southeast at its intersection with Sycamore Road, and flows past Bally Municipal Well No. 3 and into an abandoned mill pond near the BES plant. This drainage also receives storm water discharge from adjacent residential areas. Discharge from the abandoned pond is routed into the Bally storm drain system, conveyed under Route 100, and ultimately discharges to the West Branch Perkiomen Creek about 1.5 miles southeast of the BES plant.

The second drainageway currently becomes well-defined in an open field approximately 600 feet northwest of the BES plant and flows to the southwest, discharging to the West Branch Perkiomen Creek about 3,500 feet southwest of the BES plant. This second drainage may have been the primary drainageway for the watershed at one time. Flow was apparently diverted into the more easterly drainage a number of years ago, however, to supply the mill pond and to minimize saturated soil conditions in the pasture and croplands west of the BES plant. Tile drainage has been installed in these fields, and the current drainageway in this area has become an intermittent or ephemeral stream, flowing principally in response to rainfall events and delayed drainage from the tile drainage networks.

Because of the diversion of the drainage to the east, the watershed to the abandoned mill pond comprises almost 80 percent (approximately 250 acres) of the total watershed. The drainageway to the west of the BES plant collects approximately 40 acres, and the BES plant, itself, lies in a subbasin of about 22 acres. Surface runoff from the BES plant subbasin flows across the plant yard areas to catchments and thence into the Bally storm sewer system along Route 100.

In the lower reaches of the watershed, within 2,000 feet of the BES plant, the relief is relatively moderate; average land slopes are 5 percent or less. Further to the northwest, the land slope increases markedly, reaching 20 percent in the upper reaches of the watershed. Surface elevations within the watershed range from 480 ft-msl near the BES plant to 1,020 ft-msl at the top of the drainage.

4.1.2 Wetlands Characterization

In approving the final Work Plan for performance of the Bally RI/FS (Remcor, September 23, 1987), the U.S. Fish & Wildlife Service (USF&WS) requested that a wetland area immediately north of the BES plant be evaluated during the RI. The current wetland area is actually the former mill pond referenced in Section 4.1.1, and shown in Figure 28. This evaluation included sampling of surface waters and sediments within the wetland, as well as performance of a preliminary wetlands assessment. An assessment of the wetlands was performed on October 3, 1988 by a Remcor biologist to characterize the extent of the wetland and to evaluate its value as a habitat for local wetland species.

The wetland habitat has arisen through the siltation of a former mill pond. The pond was constructed as an on-channel basin. The earthen embankment is approximately seven feet in height, measured from the toe of the slope to the crest of the embankment. Discharge from the former impoundment was via a stone and concrete spillway. Water was provided to the mill via an elongation of the southwestern portion of the impoundment; the mill was located immediately adjacent to the end of

this section. The impoundment was also provided with a perimeter dike extending from both sides of the breastworks, and averaging about three feet in height. Archival aerial photographs dating to 1942 (EPIC, August 1986) show the mill pond and perimeter dikes in their current configuration.

The mill ceased operations some time ago, and the spillway was breached within the past five years to reduce hazards associated with the open impoundment. The elongated portion of the impoundment has been back-filled; this action apparently occurred in stages, and was concluded during 1988.

The former impoundment now exhibits no significant areas of open or ponded water. Drainage from the perennial stream noted in Section 4.1.1 still flows into the impoundment area, maintaining saturated soil conditions necessary to support wetland-type vegetation. The former impoundment is well-defined physically by the perimeter dikes and occupies a roughly triangular area of about 4,000 square feet. Upon entering the former impoundment the flow from the perennial stream channel becomes diffused and meanders to the southeast and back to the northwest across the former impoundment prior to turning south and discharging at the spillway. A humic soil horizon has developed within most of the former impoundment; within the meandering stream channel flow is sufficient to have eroded this material to expose a sandy clay substratum. In addition to the perimeter dikes, the wetland area is distinguished from the surrounding area by hummocky vegetation, consisting primarily of bur marigolds (Bidens cernua), grasses, and sedges. The periperal dikes and perennial stream channel leading into the former impoundment were colonized by the following vegetation typically found in moist areas:

- Pennsylvania smartweed (Polygonum pennsylvanicum)
- Jewel weed (Impatiens spp.)
- Gray dogwood (Cornus amomum)
- Alders (Alnus spp.) - occasional
- Willows (Salix spp.) - occasional.

Immediately beyond the perimeter dikes, the nature of the vegetation assumes a more upland character. The predominance of shrubby vegetation in this area is consistent with archival photography. This area is apparently former pasture or cropland in an early stage of succession. It is most definitely an upland habitat, as evidenced by the predominance of the following upland shrubby vegetation:

- Multiflora rose (Rosa sp.)
- Goldenrods (Solidago spp.)
- Daisy Fleabane (Erigeron spp.)
- Brambles (Rubus spp.)
- Greenbrier (Smilax rotundifolia).

Predominant upland woody species within the former agricultural area immediately northwest of the wetland included the following:

- Atlantic white cedar (Chamaecyparis thyoides)
- Yellow poplar (Liriodendron tulipifera)
- White pine (Pinus strobus)
- Wild black cherry (Prunus serotina) - occasional
- Box elder (Acer negundo) - immature trees, numerous in localized areas.

A small, even-aged stand of white pine in this area appeared to be about nine years old, indicating that the uplands northwest of the wetland may have been undisturbed for at least that period of time.

The wetlands in this area consist of the former impoundment and riparian areas associated with the stream channel feeding the former impoundment. With respect to the generally accepted classification scheme for wetlands (Cowardin, et al., 1979), the perennial stream may be considered a Riverine Wetland, Lower Perennial Subsystem. The former impoundment area is a Palustrine Emergent Wetland. It is apparent from an evaluation of the vegetation in the wetlands vicinity that the limits of the Palustrine Emergent Wetland are defined by the former impoundment. With

the exception of the old field area to the southwest, the area around the wetland has been developed for residential and commercial use. The USF&WS has determined by letter dated September 9, 1988 (McCoy, September 9, 1988) that, "Except for occasional transient species, no federally listed or proposed threatened or endangered species under our jurisdiction are known to exist in the project impact area [i.e., RI site area]." It is apparent that the wetland within the former impoundment is not a critical habitat, nor is it likely to become so due to the level of disturbance associated with surrounding development. In accordance with these findings, the wetlands within the site area are not considered to represent a unique habitat element.

As discussed in this chapter, the presence of VOCs in ground water will not adversely affect the wetland area because the wetland is not hydraulically connected to the contaminated aquifer. The hydraulic relationships between surface and ground water are discussed in more detail in Section 4.1.3. At the present time, the only potential impact to this wetland area via remedial action may be via increased flow. Potential impacts created by increased flow and release of low-level VOC contaminants (consistent with permit requirements) to the perennial stream are discussed in evaluation of remedial action alternatives for this site in the FS (Remcor, May 1989).

4.1.3 Interaction Between Surface and Ground Water

The unnamed tributary to the West Branch Perkiomen Creek, which flows southeast across the site, originates as springs about 0.8 mile northwest of Bally in the Reading Hills. These springs are probably a result of fractures in the shallow crystalline bedrock. Discharging ground water from these fractures is resulting in a wetland area in addition to the springs.

Within the site area northwest of State Route 100, the unnamed tributary is recharging some small amount of water to the unconsolidated materials. The base of the creek in this vicinity is well above the ground

water table. In the vicinity of the abandoned mill pond, the ground water table is over ten feet below the bottom of the wetland. There is no evidence of discharge of contaminated ground water to surface water at this point.

Southeast of State Route 100, it appears that ground water is discharging to the unnamed tributary. The water levels in MW 87-10I and MW 87-10D are generally within 0.5 foot of the base of the creek. Although ground water monitoring wells were not located further downstream, it is anticipated that the ground water table in the immediate proximity of the creek is at or slightly above the water level of the creek.

Drainage ditches and storm water sewers located at the BES facilities are all above the ground water table, which ranges from 9 to 30 feet below grade. Perching of surface water in drainage ditches is common, and it is expected that ground water may also be temporarily perching at the base of trenches and excavations.

4.2 SURFACE WATER AND SEDIMENT SAMPLING METHODS AND CHEMICAL-ANALYTICAL RESULTS

Surface water and sediment samples were collected from three locations within the wetland (i.e., former mill pond) to the northeast of the Bally plant during January 1988, as shown in Figure 8. The intent of this sampling was to verify that VOCs are not present in excess of Ambient Water Quality Criteria (AWQC) in the wetland area. Chemical-analytical results are presented in Table 10.

Surface water samples were collected directly into laboratory-cleaned sample containers at each location prior to collection of the sediment sample at each location. Sample SW1-001 was collected on January 7, 1988 within the stream emanating from upgradient springs and discharging into the wetland area; a replicate sample (SW1-001A) was also collected at this location. Samples SW2-002 and SW3-003 were collected on

January 22, 1988 from within the wetland. The downstream sample (SW2-002) was collected first to eliminate the potential for affecting the other sample location.

NUS reported methylene chloride at 3 µg/ℓ in both SW1-001 and SW1-001A, and acetone at 14 µg/ℓ and 13 µg/ℓ in SW1-001 and SW1-001A, respectively. Methylene chloride was also reported in the reagent blank. No VOCs were detected in either SW2-002 or SW3-003.

Sediment samples were collected at each surface water sampling location. A clean hand trowel (decontaminated prior to use as described in Section 3.1.7) was used to collect the sample at each location prior to filling the laboratory-cleaned sample jars. Each sampling location was marked with a wooden stake at the time of collection and was subsequently surveyed.

The laboratory reported methylene chloride at 5 µg/kg in both SD1-001 and SD1-001A, and acetone at 7 µg/kg and 15 µg/kg in SD1-001 and SD1-001A, respectively. Methylene chloride was also reported in the reagent blank. VOCs were also reported for SD3-003 including chloroform (79 µg/kg), methylene chloride (12 µg/kg), and acetone (200 µg/kg). Acetone was also reported in the reagent blank.

No evidence was found to indicate contamination of the wetland or adjacent stream by VOCs present in ground water.

During the additional source investigation performed in early March 1989, two additional surface water and sediment samples were collected in response to EPA comments on the draft RI Report. Each of these sample locations were along the main branch of the unnamed tributary east of Route 100 (Figure 28). These samples were collected at a time when treated effluent from Municipal Well No. 3 was discharging to the upstream portion of the tributary at a rate of approximately 280 gpm. Continuous pumping of Municipal Well No. 3 had been initiated on

February 6, 1989 to evaluate the effectiveness of the air stripping treatment system. Because this test was projected to last at least until June 1989, the decision was made to proceed with stream and sediment sampling, rather than to defer sampling indefinitely until pumping had ceased. Surface water sample RB-SW-01-1 was collected near monitoring well MW-10I. Sediment sample RB-SW-S1-1 was collected from the same point. Surface water sample RB-SW-02-1 and sediment sample RB-SW-S2-1 were collected approximately 550 feet downstream of RB-SW-01-1 and below the confluence of the stream with a drainage from the southwest. Each of the water samples was collected with a dedicated Teflon bailer. The sediment samples were each collected with a dedicated stainless steel trowel.

Sample results indicate no detectable VOCs in the upstream sample. The downstream water sample exhibited 1,1-DCE (18 µg/ℓ), 1,2-DCE (16 µg/ℓ), and 1,1,1-TCA (6 µg/ℓ). The concurrent sediment sample showed 11 µg/kg TCE. These results are summarized in Table 10. It should be noted that the results from this later sampling constitute Level III data quality and were not subjected to CLP validation.

Additional sampling may be necessary to determine whether the downstream contamination is the result of discharge of contaminated ground water. The estimated discharge of the drainage from the southwest was about one-half that of the main branch of the stream at the time of sampling (i.e., approximately one-third of the flow at the downstream sampling point is attributable to the drainage from the southwest). At the time of sampling, flow was estimated at 700 gpm at the downstream station.

5.0 PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS

5.1 HAZARD IDENTIFICATION

5.1.1 Selection of Indicator Compounds

The purpose of this section is to identify hazardous constituents detected at the BES site that pose a potential for adverse effects to human and environmental receptors and merit consideration in the assessment of risk.

Investigation of the BES site was initiated because chlorinated VOCs were detected in Bally Municipal Well No. 3 in October 1982. PADER subsequently performed an investigation and suggested that the BES plant was the most likely source of the VOC contamination. A PA/SI was performed by NUS as the EPA Region III Field Investigation Team Contractor in response to the contamination of Municipal Well No. 3. This investigation included analysis of samples for inorganics and ABN organics, as well as for VOCs. No contaminants of concern other than VOCs were identified. Since that time, the focus of the investigation has been primarily on the VOCs, including analysis of samples during the ERM Phase II study and during the current (Phase III) RI. For completeness, however, the most recent samples of Municipal Wells Nos. 1 and 3 were also analyzed for ABN organics in response to comments from EPA Region III; none were detected.

The selection of indicator compounds is based on the following factors:

- The concentrations of the contaminants detected, the frequency of detection, the extent of contamination in the various environmental media sampled, and the presence/absence of the compound in media presenting the greatest opportunities for human and environmental exposure.
- Physical and chemical characteristics of the contaminants, and their environmental fate and mobility in the environment (i.e., whether the compound will readily volatilize or solubilize or whether the compound is persistent).

- Toxicological properties of the contaminants including carcinogenicity, mutagenicity, teratogenicity, reproductive toxicity, and acute and chronic systemic toxicity.

The selection of contaminants of concern at the BES site was made in accordance with the following rationale:

- All detected contaminants are VOCs; most are chlorinated
- The BES plant history indicates use of chlorinated solvents, particularly TCE, TCA, PCE, and methylene chloride
- Ground water has historically been contaminated strictly with chlorinated solvents
- No medium other than ground water has been found to be significantly contaminated
- Most of the chlorinated solvents are toxic at low levels primarily because of suspected carcinogenicity
- The nonchlorinated solvents, such as acetone and toluene, are not toxic at the levels detected in any medium.

Thus, the list of contaminants of concern consists of the following chlorinated compounds:

- TCE
- TCA
- PCE
- DCE
- DCA
- Methylene chloride.

The chlorinated VOC chloroform was detected in only one sample, a sediment sample, and has never been associated with the site and, therefore, does not merit consideration as a critical contaminant.

5.1.2 Toxicological Evaluation

The purpose of this section is to identify the health and environmental hazards associated with the indicator compounds identified in the previous section. The toxicological evaluation characterizes the inherent toxicity of these compounds; it consists of a review of the

scientific data to determine the nature and degree of the health and environmental hazards associated with exposure to the various chemicals of concern. The end product is a toxicity profile of each chemical that provides the qualitative evidence relative to whether site-associated chemicals pose actual or potential hazards to human health and the environment. Toxic effects considered in these profiles include the following:

- Noncarcinogenic Health Effects - Effects in which a certain dose is required to result in a particular adverse effect. Toxicological effects, routes of exposure, and doses in humans and/or animal studies are provided where appropriate.

- Carcinogenic Health Effects - Effects to which any exposure could potentially be associated with adverse health implications. Routes of exposure and doses in humans and/or animal studies are provided. Also considered is the EPA classification of weight-of-evidence for a compound's carcinogenicity (i.e., Group A, known human carcinogens; Group B, probable human carcinogens; Group C, possible human carcinogens; Group D, not classifiable as to its carcinogenicity) (EPA, 1986).

- Environmental Effects - Acute and chronic toxic effects observed in aquatic biota and terrestrial wildlife.

Toxicity profiles for the indicator compounds are presented in Appendix H. Brief summaries extracted from chemical profiles developed by Clement Associates, Inc. (1986) are presented below.

Trichloroethene

TCE induced hepatocellular carcinomas in mice and was mutagenic when tested using several microbial assay systems. The EPA weight-of-evidence category is B2 (probable human carcinogen based on evidence in animals). Chronic inhalation exposure to high concentrations caused liver, kidney, and neural damage and dermatological reaction in animals.

1,1,1-Trichloroethane

Preliminary results suggest that TCA induces liver tumors in female

mice. It was shown to be mutagenic using the Ames assay, and causes transformation in cultured rat embryo cells. Inhalation exposure to high concentrations depressed the central nervous system; affected cardiovascular function; and damaged the lungs, liver, and kidneys in animals and humans. Irritation of the skin and mucous membranes has also been associated with human exposure to TCA. This chemical has not been categorized as to its carcinogenicity; it is currently under EPA review.

Tetrachloroethene

PCE induced liver tumors when administered orally to mice and was found to be mutagenic using a microbial assay system. The EPA weight-of-evidence category is B2. Reproduction toxicity was observed in pregnant rats and ice exposed to high concentrations. Animals exposed by inhalation of PCE exhibited liver, kidney, and central nervous system damage.

1,1-Dichloroethene

DCE caused kidney tumors and leukemia in one study of mice exposed by inhalation. Several bacterial assays showed DCE to be mutagenic. The EPA weight-of-evidence category is C (possible human carcinogen based on limited evidence in animals). Chronic exposure to oral doses of DCE as low as 5 milligrams per kilogram per day (mg/kg/day) caused liver changes in rats. Acute exposure to high doses causes central nervous system depression, but neurotoxicity has not been associated with low-level chronic exposure.

1,1-Dichloroethane

DCA is one of the least toxic of the chlorinated ethanes. DCA was not found to be mutagenic using the Ames assay. When inhaled at high concentrations, DCA causes central nervous system depression. There is some evidence that the compound is hepatotoxic in humans. Kidney and liver damage were seen in animals exposed to high levels. This chemical has not been characterized as to its carcinogenicity.

Methylene Chloride

Methylene chloride increased the incidence of lung and liver tumors and sarcomas in rats and mice. It was found to be mutagenic in bacterial test systems. The EPA weight-of-evidence category is B2. In humans, methylene chloride irritates the eyes, mucous membranes, and skin. Exposure to high levels adversely affects the central and peripheral nervous systems and the heart. In experimental animals, methylene chloride is reported to cause kidney and liver damage, convulsions, and slight paralysis.

5.2 DOSE-RESPONSE RELATIONSHIP

An important component of the risk assessment process is the determination of the relationship between the dose (amount of a compound to which a receptor is exposed per unit of body weight per unit time) and the potential for adverse health effects. The most applicable information on dose-response relationships are current standards, criteria, and guidelines that were developed through health effects studies and provide a quantitative indication of the potency of a compound. Applicable and relevant standards and/or criteria include maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), AWQC, and EPA health advisories. MCLs are enforceable standards for contaminants in drinking water. MCLGs, AWQC, and Health Advisories are nonenforceable guidelines/criteria for contaminants in drinking water and/or surface water. Carcinogenic potency factors (CPFs) and acceptable intakes - chronic (AICs) are also relevant criteria. CPFs and AICs are used to estimate the potential for health effects under the exposure scenarios developed in the exposure assessment. Table 11 lists the values for the standards, criteria, and guidelines for the contaminants of concern at the BES site. A discussion of the development and of the assumptions and limitations associated with these parameters follows:

- Maximum Contaminant Levels and Maximum Contaminant Level Goals - National Primary Drinking Water Standard MCLs, promulgated under the Safe Drinking Act, are enforceable standards for contaminants in public drinking water systems. MCLs are based on lifetime exposure to a

contaminant for a 70-kilogram (kg) adult who consumes two liters of water per day. MCLs are calculated to reflect exposure to a contaminant from all sources (air, food, water, etc.). They not only consider health factors but also the economic and technical feasibility of removing a contaminant from a water supply system. Secondary Drinking Water Standard MCLs are nonenforceable standards that consider the aesthetic quality of drinking water. The EPA has proposed MCLs and MCLGs for several organic and inorganic compounds in drinking water. Proposed MCLs and MCLGs are nonenforceable guidelines proposed in advance of setting the MCL. MCLGs do not consider the technical feasibility of contaminant removal.

- Ambient Water Quality Criteria - AWQCs are nonenforceable guidelines for the protection of human health from exposure to contaminants in ambient water. These criteria are estimates of the concentrations that will result in adverse health effects in humans; for known or suspected carcinogens, the concentrations are associated with incremental lifetime cancer risks of 10^{-4} through 10^{-7}. The criteria are established for both combined drinking water and consumption of fish, and for fish consumption only. These values were used to develop adjusted criteria for drinking water only, which are presented in Table 11. These adjusted values are not official EPA AWQC, but are more appropriate for Superfund sites with contaminated ground water (EPA, 1986).

- Health Advisories - Health Advisories are nonenforceable guidelines developed by the Office of Drinking Water for chemicals that may be intermittently encountered in public water supply systems. Short-term Health Advisories are calculated for a 10-kg child (one-year old infant) who ingests 1.0 liter of water per day for two exposure durations: 1 day and 10 days. Lifetime health advisories are calculated for a 70-kg adult who ingests two liters of water per day. Longer-term health advisories (1 to 2 years) are calculated for both a 10-kg child and a 70-kg adult. These guidelines do not consider carcinogenic risks or synergistic effects. One-day, 10-day, and longer-term health advisories are based on the assumption that drinking water contributes 100 percent of the total contaminant intake. Lifetime health advisories consider the relative contribution from drinking water (i.e., other potential sources are considered). Health advisories are used to evaluate the potential for noncarcinogenic health impacts associated with ingestion of contaminated drinking water.

- Carcinogenic Potency Factors - CPFs are upper 95 percent confidence limits on the slope of the dose-response curve. CPFs are used in conjunction with estimated dose to estimate incremental lifetime cancer risk.

- Chronic Acceptable Intakes - AICs are the amount of a toxicant (in mg/kg/day) that is not expected to result in adverse health effects (noncarcinogenic) after chronic exposure to the general population (including sensitive subgroups). AICs are either reference doses (RFDs) developed by an EPA interoffice work group chaired by the Office of Research and Development (ORD) or are values developed in Health Effects Assessments conducted by the EPA Environmental Criteria and Assessment Office. If EPA has completed verification of an RFD for a specific chemical, then that value should be used as the AIC. RFDs are calculated by dividing a quantitative indication of toxicity derived from human or animal toxicity studies by an appropriate uncertainty factor (e.g., 10, 100, 1,000, or greater) dependent upon the severity of the effect and factors including the type of observation and duration of exposure. AICs are used to evaluate the potential for noncarcinogenic effects associated with exposure to site-related chemicals.

5.3 EXPOSURE ASSESSMENT

The purpose of this section is to evaluate the potential for human and environmental exposure to hazardous constituents associated with the BES site. This section identifies potential routes of exposure, characterizes the populations exposed, and evaluates the degree or magnitude of exposure.

A complete exposure pathway has four necessary components:

- A source of chemical release to the environment
- A route of contaminant transport through an environmental medium
- An exposure or contact point
- A human or environmental receptor at the exposure point.

These components are addressed in relation to the BES site in the following subsections. In the final analysis, quantitative estimates of

exposure are provided for each viable route of exposure to site-related contaminants.

5.3.1 Source of Contamination and Routes of Contaminant Transport

The BES site consists of a 19-acre industrial facility located in Bally Borough, Berks County, Pennsylvania. BES was identified as the potential source of chlorinated VOCs that were first detected in Bally Municipal Well No. 3, located just a few hundred feet from the BES property, in 1982.

Several areas at the BES plant have been investigated as the potential source(s) of the ground water contamination. None of these investigations have identified any specific source areas for the VOCs in ground water. Only very low concentrations of VOCs were detected in soil samples collected from beneath a prime candidate source area, the former degreasing area, in the Phase III RI. A soil boring investigation conducted in March 1989 in response to EPA comments on the Phase III RI failed to locate a contaminant source in unsaturated zone soils along the northern perimeter of the BES plant buildings. Solvent chemicals used at the BES plant are the predominant chlorinated VOCs present in the aquifer. While the current VOC contamination may have arisen from activities at the BES plant, neither specific incidents of spillage nor specific source areas have been defined. The data suggest, however, that no active source exists.

5.3.2 Identification of Receptors and Routes of Exposure

The most viable route of human exposure to contaminants resulting from the BES site is exposure to contaminated ground water. All Bally residents use ground water supplied by the Borough as their source of domestic water supply. The municipal supply is contaminated, and those residents using it are exposed to low levels of VOCs. One private well that was determined to be contaminated is no longer in use as a potable supply. This well is a hand-pumped well located at the Mabel Gehman (Gehman) residence on Main Street (Figure 4). If not institutionally

prohibited, future owners of this property could access this well for potable uses, or other property owners in areas where ground water is contaminated could install new wells and exposure could occur.

The Bally water supply is currently derived from two sources: (1) springs and (2) Municipal Well No. 1 (Figure 2). Both of these sources feed a common reservoir. Municipal Well No. 1 contains low levels of VOCs. Bally came to rely on Well No. 1 to supplement the supply from the springs after Municipal Well No. 3 was taken out of service because of VOC concentrations detected at levels much higher than in Well No. 1. Under current conditions, Bally residents are, in a worst-case scenario, exposed to the VOC concentrations detected in Well No. 1. This is considered a worst-case scenario because these concentrations are likely to be reduced by dilution with clean water derived from the springs. During the spring of the year, the water supply is derived solely from springs, and exposure to contaminated ground water would be absent. Determination of the contribution of each source to the water arriving at the tap at any time is not possible, because a single line is used to supply water from Municipal Well No. 1 to the reservoir, and to distribute water from the reservoir to the system.

In parallel with this RI, Remcor has undertaken the design and implementation of an air stripping treatment unit at Municipal Well No. 3. Bally intends to place primary reliance on this well for water supply in June 1989, in addition to continuing to use the springs. After this system is implemented, exposure to VOCs will be dependent on the efficiency of the air stripping unit. Water Supply and National Pollutant Discharge Elimination System (NPDES) permits issued to Bally by PADER establish maximum allowable concentrations of the VOCs of concern in the treated ground water effluent from the air-stripping unit at Municipal Well No. 3 as follows: TCE, 1 μg/ℓ; TCA, 200 μg/ℓ; and DCE, 0.63 μg/ℓ. These are the concentrations that will be used to determine a worst-case exposure scenario for future municipal water supply conditions. Again, this is a conservative assumption because at

times the Municipal Well No. 3 water will be diluted by spring water, and, at other times, spring water alone will supply the Borough.

Residents can be exposed to VOCs through ingestion and other domestic uses of ground water. Dermal contact and inhalation exposure may occur through uses such as bathing, showering, dishwashing, and food preparation. Of particular concern to human health is the potential for VOC exposures to occur in the confined space of the shower (Foster and Chrostowski, 1987). Exposure scenarios for the use of contaminated ground water, including ingestion and showering, are evaluated quantitatively for both current and future (treated Municipal Well No. 3) water supply systems and contaminant levels. These exposure scenarios are also evaluated for the potential future use of a residential well, hypothetically installed a short distance downgradient of the BES plant, representing a worst-case exposure point. The location and contaminant concentrations of Monitoring Well MW 87-10I are used for this purpose. As a worst-case estimate of dose and risk under current ground water supply conditions, the VOC concentrations detected in Municipal Well No. 1 during the Phase III RI are used in conjunction with the assumption of reliance on this well throughout the year as the sole municipal water supply.

Ground water from wells located at both Great American Knitting and Bally Ribbon is contaminated with VOCs. Both wells are used for process water supply; both companies use municipal water for potable purposes. The process water is used for dying, fixing, and steaming socks at Great American Knitting; at Bally Ribbon it is used for dying and washing ribbon. In both operations, the water is heated and VOCs in the water are likely to volatilize. The model used for estimating inhalation exposure during showering (Foster and Chrostowski, 1987) has been modified to apply to the operations at these mills to estimate dose. Unless these mills convert to municipal water for process purposes, this exposure scenario will be the same under both current and future scenarios.

The installation and continued operation of the air stripping treatment unit at Municipal Well No. 3 may result in release of VOCs to the ambient air. This presents another potential route of exposure. Potential receptors are those individuals who reside in or otherwise frequent the area within a relatively short distance downwind of the air stripping units. The draft FS report (Remcor, May 1989) defines a number of treatment options for ground water extracted at Municipal Well No. 3. While all exhibit similar effectiveness for ground water treatment, some also involve off-gas collection and treatment. It is premature at this point to evaluate inhalation of VOCs from ground water treatment at Municipal Well No. 3 as a potential future risk. The nature of VOC emissions, if any, will depend on the remedial alternative selected and on the contaminant levels found in ground water in Municipal Well No. 3 during monitoring of continuous pumping (as well as the human activity pattern eventually assumed). Thus, risks posed by this exposure pathway will be evaluated in the FS in the context of a detailed evaluation of alternatives, rather than in the baseline risk assessment in the RI.

The potential for aquatic or terrestrial biota in the wetland area to be exposed to chemicals associated with the site is low. Hydrogeologic and chemical-analytical data do not indicate that contaminated ground water is discharging to the wetland area. Ground water levels are several feet below the base of the wetland in this area, indicating, if anything, a vertical downward gradient in this area. The only contaminants detected in the stream and wetland west of Route 100 (i.e., methylene chloride [3 µg/ℓ], and acetone, [14 µg/ℓ]), are likely to be a result of laboratory contamination. Neither methylene chloride nor acetone have criteria established for the protection of aquatic organisms, as do 65 other chemicals listed as toxic under Section 307(a)(1) of the Clean Water Act. Both of these compounds are very volatile, and, if present in the stream, would be lost to the atmosphere very rapidly. Neither compound is known to accumulate in living tissue.

There is some evidence that ground water may be discharging to the unnamed tributary to the southeast of the BES plant, in the area of MW87-10I and MW87-10D. In response to EPA comments on the initial draft of this RI report, Remcor collected two surface water and sediment samples (Figure 28) in this area. The downstream samples (surface water and sediment) exhibited low levels of VOCs. Two potential routes of exposure to these VOCs are dermal absorption and accidental ingestion by children potentially playing in the stream. Exposure scenarios for these pathways are evaluated to estimate dose and risk. Additionally, the VOC concentrations are compared to applicable AWQC for the protection of freshwater biota in the risk characterization.

5.3.3 Quantitative Estimates of Exposure Under Current Conditions

To estimate exposure to contaminated ground water via ingestion, it is assumed that an adult weighing 70 kg ingests two liters of water per day over a 70-year lifetime. It is also assumed that 100 percent of the organic chemicals are absorbed in the gastrointestinal tract. Thus, utilizing the VOC concentrations detected in Municipal Well No. 1 (Table 7), a daily dose for a 70-kg adult receptor is calculated as follows (in milligrams per kilogram of body weight per day {mg/kg/day}):

$$\text{Dose}\left(\frac{\text{mg}}{\text{kg/day}}\right) = \frac{\text{contaminant concentration}\left(\frac{\text{mg}}{\ell}\right) \times \text{water ingested}\left(\frac{2\ell}{\text{day}}\right)}{70\ \text{kg}}$$

Results of the ingestion dose calculations are presented in Table 12.

Inhalation of VOCs during domestic use of ground water is a viable exposure route. The activity likely to create the most significant exposure is showering. Inhalation doses are estimated using a model developed by Foster and Chrostowski (1987). This model considers many variables that influence the release of VOCs from water and their subsequent buildup in shower room air including volatility of the compound (Henry's Law Constant), water temperature and viscosity, and air exchange rate in the

room. In developing the estimated doses of VOC inhalation during showering, the following assumptions are made:

- Ten liters per minute of water are used during showering (Foster and Chrostowski, 1987)
- The estimated volume of the shower room is 8 cubic meters
- Fifteen minutes per day are spent in the shower; 30 minutes per day are spent in the shower room
- Fifteen liters of air per minute are inhaled during the time spent in the shower room (Foster and Chrostowski, 1987)
- The total volume of air in the shower room is exchanged once every 60 minutes (Foster and Chrostowski, 1987).

The exposure scenario considers a 70-kg adult who is exposed via inhalation daily during a 70-year lifetime. Doses calculated for inhalation during showering under the current ground water supply conditions are presented in Table 12. The calculations, along with the details of the model and all assumptions, are presented in Appendix I.

To estimate inhalation doses of VOCs during work at the Great American Knitting Mill and Bally Ribbon Mill, the Foster and Chrostowski model has been modified to apply to occupational exposure. The potential exposure at the Great American Knitting Mill is presented as a worst-case since the VOC levels in this well, although low in comparison to overall ground water contamination, were somewhat higher than those at the Bally Ribbon Mill. In developing the estimated doses of VOC inhalation during work at the Great American Knitting Mill, the following assumptions are made:

- The water flows through a process bath 1 x 2 x 20 feet at a rate of 300 gallons per hour, or 19 liters per minute
- The estimated volume of the process room is 500 cubic meters (m^3)
- Workers spend seven hours per day in the process room

- Fifteen liters of air per minute are inhaled during the work day
- The total volume of air in the process room is exchanged once every 60 minutes.

The occupational exposure scenario considers a 70-kg adult who is exposed 5 days per week, 48 weeks per year, for 30 years of a 70-year lifetime. Doses calculated for this exposure scenario at the Great American Knitting Mill are presented in Table 12. The dose calculations and all assumption are presented in Appendix I.

To estimate exposure to contaminated surface water via dermal absorption and accidental ingestion, the following assumptions are used:

- Surface water VOCs are those detected in Sample SW2-01 (Table 10)
- The flux rate of water through the skin controls the rate of VOC absorption; this value is 0.5 mg/cm^2-hr (EPA, 1988)
- A child is exposed dermally 2 hours per day, 12 days per year, for 10 years; during 5 of these yearly episodes, the child accidentally ingests 0.05 liter of water
- The total body surface area of the child is 12,000 square centimeters (cm^2), of which 20 percent is exposed during each episode
- The child weighs 45 kg
- Absorption is 100 percent for dermal and ingestion exposure.

Doses calculated for these exposure routes are presented in Table 13, and all calculations are shown in Appendix I.

5.3.4 Quantitative Estimates of Exposure Under Future Conditions

The same assumptions used to estimate exposure under current ground water supply conditions are used to estimate exposure under the future municipal ground water supply scheme, i.e., ground water extraction and treatment at Municipal Well No. 3. The only variables that change in

the calculations of dose for both ingestion and inhalation during showering exposure routes are the concentrations of the VOCs considered. Although Municipal Well No. 3 will be used in conjunction with the upgradient springs, as Well No. 1 is now, worst-case conditions are assumed by considering Well No. 3 as a sole source (i.e., no dilution by spring water). Doses calculated for ingestion and inhalation during showering for the future (treated Municipal Well No. 3) municipal ground water supply system are presented in Table 14. Calculations for inhalation-during-showering doses are presented in Appendix I.

Potential future exposure at the location of Well MW87-10I is also estimated. This is done to determine the risk involved with using a well in this area, should one be installed in the future. Doses calculated for ingestion and inhalation during showering for future contaminated residential well use are also presented in Table 14. The doses estimated for worker exposure at the Great American Knitting Mill and for exposure of children playing in the unnamed stream are assumed to be the same under future conditions as under present.

5.4 RISK CHARACTERIZATION

The hazard identification and exposure assessment presented in the previous sections provide a characterization of potential exposures and hazards posed by the ground water contaminants present at the BES site. In this section, the results of the hazard identification and exposure assessment are combined to determine the actual or potential public health and environmental risks resulting from exposure to site-related chemicals.

5.4.1 Public Health Risks

Both quantitative and qualitative assessments of potential human health risks are presented in this section. A quantitative risk assessment can be performed for carcinogenic compounds by converting estimated doses into incremental lifetime cancer risk by using unique potency factors developed for each known or suspected carcinogen. For noncarcinogens

and carcinogens that can produce noncarcinogenic effects, the ratio of the estimated dose to an acceptable dose provides a quantitative indication of the potential for noncarcinogenic effects. Potential risks will also be assessed qualitatively by comparing observed ground water and surface water concentrations to relevant regulatory standards and guidelines.

Exposure to several compounds present in an environmental medium can result in additive, synergistic, or antagonistic effects. Synergistic and antagonistic effects are difficult to evaluate in terms of estimating health effects. However, no synergistic or antagonistic effects are known for the combination of VOCs of concern detected in ground water at Bally. On the other hand, additive effects can be quantified, and additivity is assumed for carcinogenic compounds and noncarcinogenic compounds with similar toxicity end points (e.g., carcinogenicity) (EPA, 1986).

5.4.1.1 Carcinogenic Risks

For carcinogens, the estimated dose is converted to an incremental lifetime cancer risk, which represents the probability that a carcinogenic effect will occur. For example, a 10^{-6} risk represents one additional incidence of cancer in an exposed population of one million people. Carcinogenic risk is calculated using the following equation:

$$\text{Risk} = (q)\ (d)$$

where:

q = CPF $(\text{mg/kg/day})^{-1}$

d = dose (mg/kg/day).

Estimation of lifetime cancer risk is limited to those compounds for which an evaluation has been conducted by the EPA Carcinogenic Assessment Group (CAG) or the EPA Environmental Criteria and Assessment Office.

Two of the three VOCs detected in Municipal Well Nos. 1 and 3 are suspected carcinogens and have CPFs established for both oral and inhalation routes. Thus, a risk is calculated for each compound for each exposure route, and these are summed to derive a cumulative risk based on exposure to each receptor by both ingestion and inhalation during showering, and based on additivity of carcinogenic effects. This exercise is performed for the current ground water supply conditions using the doses calculated in the exposure assessment that considered the VOC concentration in Municipal Well No. 1, and for the future municipal ground water supply system using the doses calculated for the VOC concentrations in the treated Municipal Well No. 3 effluent. A risk based on potential future use of a residential well at the location of MW 87-10I is also calculated. The compound-specific, route-specific, individual, and cumulative carcinogenic risks for those three scenarios are shown in Tables 15, 16, and 17, respectively.

Carcinogenic risks are also calculated for inhalation exposures at the Great American Knitting Mill and for dermal and accidental ingestion exposure to contaminated surface water. These risks are shown in Table 18. It should be noted that the estimated VOC air concentrations which may result from use of ground water at the Great American Knitting Mill are well within acceptable work place levels established by the American Conference of Governmental Industrial Hygienists (ACGIH) for TCE and DCE. The estimated air concentrations for TCE and DCE, respectively, are 52,000 and 6,250 times less than the threshold limit values (time-weighted average) (TLV-TWA) established by the ACGIH. TLV-TWA are those values considered acceptable for an 8-hour day, 40-hour per week, working-lifetime occupational exposure.

5.4.1.2 Noncarcinogenic Risks

To evaluate the potential for noncarcinogenic effects, the estimated daily dose (mg/kg/day) is compared to an AIC (mg/kg/day). The ratio of the estimated dose to an acceptable dose provides a numerical indication of potential for adverse effects. Because additivity of effects is as-

sumed, total noncarcinogenic risk is calculated by summing the ratios determined for each compound and exposure route. The risk is presented as a hazard index (HI) such that:

$$HI = E_1/AL_1 + E_2/AL_2 + \ldots E_i/AL_i$$

where:

E_i = exposure level (dose in mg/kg/day) of the ith chemical

AL_i = acceptable level (AIC in mg/kg/day) for the ith chemical.

When an HI is greater than one, the potential for adverse noncarcinogenic effects is considered unacceptable. When an HI is less than or equal to one, no adverse noncarcinogenic effects are expected. The HI is not a mathematical prediction of the incidence or severity of effects, it is simply a numerical indicator of the transition from acceptable to unacceptable dose.

AICs have been established for all three VOCs detected in the Bally municipal wells. AICs for both the oral and inhalation routes have been established for TCA and AICs for the oral route only have been established for TCE and DCE. Where inhalation AICs are not available, oral AICs are used in determining the HI. The doses and AICs associated with ingestion and inhalation-during-showering exposure route under the current ground water supply scenario are shown along with the HI in Table 19. The HI is currently less than one, indicating acceptable concentrations relative to noncarcinogenic effects.

The HI for the future municipal ground water supply system and for the potential future use of a hypothetical contaminated residential well are presented in Tables 20 and 21, respectively. The future municipal supply system presents an HI far less than one, whereas use of a hypothetical residential well contaminated at the level of MW 87-10I presents an HI greater than one, which represents an unacceptable noncarcinogenic risk. The HIs for all other potential exposure pathways are less than

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one. The formulation of these is shown in Table 22.

A qualitative assessment of public health risk is provided by a comparison of ground water contaminants and concentrations to relevant regulatory standards and guidelines. Table 23 presents a comparison of current municipal and residential well contamination with MCLs, AWQC, and heath advisories; these criteria were discussed in the Dose-Response Relationship (Section 5.2). Table 23 shows that concentrations of TCE and DCE detected in Municipal Well No. 1 and the Gehman well exceed MCLs and AWQC adjusted for drinking water only. Additionally, the concentration of TCA detected in the Gehman well exceeds the MCL for this compound. Contaminant concentrations in the hypothetical future residential well, represented by MW87-10I, exceed all applicable MCLs and AWQC adjusted for drinking water only.

5.4.2 Environmental Risk

A qualitative assessment of environmental risk is provided by a comparison of surface water contaminant concentrations at Location SW2-01 to available AWQC established for the protection of freshwater aquatic organisms. These comparisons are presented in Table 24. The VOC concentrations in surface water at this location are one to two orders of magnitude lower than AWQC established for chronic exposure to these or similar compounds for the protection of freshwater biota. As discussed in Chapter 4.0, this surface water sample was collected during a period when treated ground water from Municipal Well No. 3 was being discharged to the stream. While it is possible that the discharge of treated ground water may have diluted the VOC concentrations by as much as one third, the observed VOC levels multiplied by a factor of 1.7 are still well below the acceptable limits.

5.5 SUMMARY

The historical problem at the BES site is VOC contamination of ground water. Site investigations have not identified significant contamination of any other media nor have the specific source or sources of the

ground water contamination been defined. The source is believed to be a historic release or releases associated with solvent use and management of spent solvents at the BES plant. The following compounds were selected as indicator compounds:

- TCE
- TCA
- PCE
- DCE
- DCA
- Methylene chloride.

These compounds were selected because of their presence in ground water and their potential chronic health effects at low levels, primarily suspected carcinogenicity.

Known current human exposure takes place through potable use of the contaminated municipal water supply. VOCs currently enter the supply via Municipal Well No. 1 which taps the contaminated aquifer. A cumulative carcinogenic risk estimated for use of the current municipal system, considering no dilution of well water with uncontaminated spring water, is 1.0×10^{-3}. This means that there is the potential for approximately one additional incidence of cancer in an exposed population of 1,000 people. The risk of noncarcinogenic health effects is deemed acceptable for the current municipal ground water supply system.

In June 1989, the Borough of Bally intends to initiate use of treated ground water from Municipal Well No. 3, which has been equipped with an air-stripping treatment unit. VOC concentrations to be achieved in the effluent of this well are those set forth in water supply and NPDES permits issued by the PADER. The cumulative carcinogenic risk estimated for use of this well and these VOC concentrations, again considering no dilution of the well water with spring water, is 3.3×10^{-5}, or approximately three additional incidences of cancer in an exposed population of 100,000 people. Put in perspective for the current population of about 1,200 residents served by the municipal water

supply, this represents the potential for 0.04 additional cases of cancer over a lifetime of use for the residents of Bally. Estimated noncarcinogenic health risks are acceptable.

Currently, no residential wells known to be contaminated are being used. Use of wells known to be contaminated, or installation of wells in contaminated areas, should be restricted. The carcinogenic risk estimated for use of a hypothetical residential well installed in a contaminated portion of the aquifer is 1.8×10^{-2}, or approximately two additional incidences of cancer in an exposed population of 100 people. The noncarcinogenic health risks associated with using this well are estimated to be unacceptable.

Potential occupational exposure to estimated levels of VOCs that may occur as a result of use of ground water in industrial processes at the Great American Knitting Mill and Bally Ribbon Mill is well within the limits of that deemed acceptable by the ACGIH.

Contaminated ground water is not discharging to surface water in the wetland adjacent to the BES plant. There is evidence that ground water discharges to the unnamed tributary further to the southeast. Surface water VOC concentrations in this stretch of the unnamed tributary do not present unacceptable risks to aquatic biota or humans.

6.0 CLOSING

Remcor has prepared this RI report to characterize aquifer contamination by VOCs within the Borough of Bally. We have examined potential sources of the contamination with respect to release of chlorinated solvents from the BES facility and have characterized the hydrogeologic conditions at the site. The RI data provide an adequate basis upon which to define remedial action objectives in the FS phase of this project.

Please feel free to contact us if you have any questions relative to this report.

Respectfully submitted,

John A. George

John A. George
Project Manager

TABLES

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TABLE 2

SUBSURFACE SOIL SAMPLE HEAD SPACE PID READINGS
SALLY ENGINEERED STRUCTURES SITE RI/FS

BORING/ SAMPLE No.	DEPTH INTERVAL (Ft.)	HEADSPACE PEAK (PPM)
SS1	0.0 - 2.0	-
SS1-001	2.0 - 4.0	0
SS1	4.0 - 6.0	-
SS1	6.0 - 8.0	-
SS1	8.0 - 10.0	-
SS1-002	10.0 - 12.0	0
SS1-003	12.0 - 14.0	0
SS2-001	0.0 - 2.0	0
SS2-002	2.0 - 4.0	-
SS2-003	4.0 - 6.0	0
SS2-004	6.0 - 8.0	0
SS2-005	8.0 - 10.0	0
SS2-006	10.0 - 12.0	0
SS3-001	0.0 - 2.0	<1
SS3-002	2.0 - 4.0	0
SS3-003	4.0 - 5.5	0
SS3-004	5.5 - 7.5	<1
SS3-005	7.0 - 8.5	0
SS3-006	8.5 - 12.0	0
SS3-007	12.0 - 13.5	-
SS3-008	13.5 - 15.0	-
SS4-001	0.0 - 2.0	0
SS4-002	2.0 - 4.0	<1
SS4-003	4.0 - 6.0	0
SS4-004	6.0 - 8.0	<1
SS4-005	8.0 - 10.0	1
SS4-006	10.0 - 12.0	1
SS5-001	3.9 - 4.2	5
SS6-001	3.0 - 3.2	6
SS6-002	4.8 - 5.3	25
SS6-003	7.0 - 7.3	20
SS7-001	2.0 - 2.3	3
SS7-002	3.5 - 3.8	-
SS7-003	4.2 - 4.5	4

BORING/ SAMPLE No.	DEPTH INTERVAL (Ft.)	HEADSPACE PEAK (PPM)
SS7-004	5.5 - 5.8	-
SS7-005	7.1 - 7.4	20
SS7-006	7.5 - 7.8	>20
SS7-007	7.8 - 8.0	9
SS8-001	2.5 - 2.8	-
SS9-001	4.0 - 6.0	7
SS9-002	6.0 - 8.0	<7
SS10	0.0 - 2.0	<1
SS10	2.0 - 2.5	0
SS10	3.0 - 5.0	0
SS10-001	5.0 - 7.0	0
SS10	7.0 - 9.0	-
SS10-002	10.0 - 12.0	-
SS10-003	12.0 - 14.0	0
SS11	0.0 - 0.8	<1
SS11-001	3.0 - 5.0	0
SS11	5.0 - 7.0	<1
SS11-002	7.0 - 9.0	1
SS11-003	10.0 - 12.0	-
SS12-001	0.0 - 1.8	0
SS12-002	3.0 - 5.0	2
SS12-003	5.0 - 7.0	-
SS12-004	10.0 - 12.0	0
SS12-005	15.0 - 17.0	<1
SS13	3.0 - 5.0	1
SS13	5.0 - 7.0	1
SS13-001	7.0 - 9.0	<1
SS13-002	10.0 - 12.0	<1
SS14	0.0 - 0.75	0
SS14-001	3.0 - 5.0	0
SS14-002	5.0 - 7.0	0
SS14-003	7.0 - 9.0	1
SS14-004	9.0 - 11.0	<1

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TABLE 2
(CONT)

BORING/ SAMPLE No.	DEPTH INTERVAL (Ft.)	HEADSPACE PEAK (PPM)
RB-SS-16-01	0.0 - 1.5	-
SS-16	2.0 - 4.0	-
SS-16	5.0 - 6.0	2.0
RB-SS-16-02	6.0 - 7.5	30.0
RB-SS-16-03	9.0 - 10.0	0.4
SS-16	11.0 - 12.0	2.6
RB-SS-17-01	1.0 - 2.0	0.8 ppm
SS-17	2.0 - 3.0	0.0 ppm
RB-SS-17-02	5.0 - 6.0	0.0 ppm
SS-17	7.0 - 8.0	0.0 ppm
RB-SS-17-03	9.0 - 10.0	0.8 ppm
SS-17	11.0 - 11.5	0.8 ppm
SS-17	13.0 - 13.5	1.0 ppm
SS-17	14.0 - 16.0	6.0 ppm
SS-17	18.0 - 20.0	20.0 ppm
SS-18	1.5 - 2.0	0.4
SS-18	3.5 - 4.0	0.4
SS-18	4.0 - 6.0	-
SS-18	6.0 - 8.0	-
SS-18	8.0 - 10.0	2.2
SS-18	10.0 - 12.0	1.3
RB-SS-18-01	12.0 - 14.0	1.0
RB-SS-18-02	15.0 - 16.0	1.0
SS-19	1.0 - 2.0	8.4 ppm
SS-19	2.0 - 4.0	-
SS-19	5.0 - 5.5	5.8 ppm
RB-SS-19-01	6.0 - 8.0	2.2 ppm
SS-19	9.5 - 10.0	16.0 ppm
SS-19	11.0 - 12.0	11.0 ppm
SS-19	13.0 - 14.0	12.0 ppm
RB-SS-19-02	14.0 - 16.0	42.0 ppm
SS-20	1.5 - 2.0	0.2
SS-20	2.0 - 4.0	-
SS-20	4.5 - 5.5	0.2
SS-20	7.0 - 8.0	0.4
SS-20	8.0 - 10.0	0.4
SS-20	10.0 - 12.0	-
SS-20	13.0 - 14.0	0.0
RB-SS-20-01	15.0 - 16.0	0.4

BORING/ SAMPLE No.	DEPTH INTERVAL (Ft.)	HEADSPACE PEAK (PPM)
SS-21	1.0 - 2.0	3.5
SS-21	3.5 - 4.0	0.4
SS-21	4.5 - 5.5	0.6
SS-21	7.0 - 8.0	0.2
SS-21	9.0 - 10.0	0.0
SS-21	11.0 - 12.0	1.0
RB-SS-21-01	13.0 - 14.0	0.0
RB-SS-21-02	15.0 - 16.0	0.0
SS-22	1.0 - 2.0	3.0 ppm
RB-SS-22-1	3.0 - 4.0	0.0 ppm
RB-SS-22-2	5.0 - 6.0	0.8 ppm
SS-22	7.0 - 8.0	20.0 ppm
SS-22	9.0 - 10.0	0.6 ppm
RB-SS-22-3	11.0 - 12.0	2.0 ppm
SS-22	14.0	2.8 ppm
SS-22	16.0	2.0 ppm
RB-SS-22-4	19.0 - 20.0	400.0 ppm
SS-22	20.0 - 22.0	1000.0 ppm
SS-23	0.0 - 2.0	-
SS-23	2.0 - 4.0	0.4
SS-23	5.0 - 6.0	0.4
SS-23	7.0 - 7.5	0.6
RB-SS-23-01	8.0 - 9.0	0.4
SS-23	10.5 - 11.5	0.4
SS-23	12.5 - 13.5	0.6
SS-23	15.5 - 16.0	0.4
SS-23	17.0 - 17.5	0.4
RB-SS-23-02	19.0 - 20.0	0.6
SS-24	0.5 - 2.0	0.2
SS-24	2.0 - 4.0	0.8
SS-24	5.0 - 6.0	0.2
SS-24	7.0 - 8.0	0.3
SS-24	8.5 - 9.5	0.7
SS-24	11.0 - 12.0	0.4
SS-24	13.0 - 14.0	0.2
RB-SS-24-01	15.0 - 16.0	0.4
SS-24	17.0 - 18.0	0.4
RB-SS-24-02	19.0 - 20.0	0.2
SS-24	23.0 - 24.0	0.4
RB-SS-24-03	25.0 - 26.0	0.6

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TABLE 2
(CONT.)

BORING/ SAMPLE No.	DEPTH INTERVAL (Ft.)	HEADSPACE PEAK (PPM)
SS-25	0.5 - 1.5	0.0
SS-25	2.0 - 4.0	-
SS-25	4.0 - 6.0	-
SS-25	6.0 - 7.0	0.3
SS-25	8.0 - 10.0	-
SS-25	10.0 - 10.0	-
SS-25	12.0 - 12.5	0.2
SS-25	14.0 - 16.0	-
SS-25	17.0 - 18.0	0.4
RB-SS-25-01	19.5 - 20.0	0.4
SS-26	0.0 - 2.0	-
SS-26	2.0 - 3.5	0.2 ppm
SS-26	5.0 - 5.5	0.2 ppm
RB-SS-26-01	6.5 - 7.5	0.2 ppm
SS-26	9.0 - 9.5	0.2 ppm
SS-26	11.0 - 11.5	0.2 ppm
SS-26	13.0 - 13.5	0.2 ppm
SS-26	14.0 - 14.5	0.0 ppm
SS-26	15.5 - 16.0	0.2 ppm
SS-26	16.0 - 18.0	-
SS-26	19.0 - 19.5	0.0 ppm
RB-SS-26-02	21.0 - 22.0	0.0 ppm
RB-SS-27-01	0.5 - 1.0	10.0 ppm
SS-27	2.0 - 3.5	0.0 ppm
WATER	4.0	7.0 ppm
RB-SS-27-02	4.0 - 5.0	2.0 ppm
SS-27	6.0 - 8.0	2.2 ppm
SS-27	9.0 - 9.5	0.0 ppm
SS-27	11.0 - 11.5	0.0 ppm
SS-27	13.5 - 14.0	0.0 ppm
SS-27	15.0 - 16.0	0.0 ppm
RB-SS-27-03	17.0 - 18.0	0.0 ppm
SS-27	18.5 - 19.0	0.0 ppm
RB-SS-27-04	20.0 - 22.0	-
SS-28	1.0 - 1.5	42.0
SS-28	2.5 - 3.0	0.20
RB-SS-28-01	5.0 - 6.0	0.30
SS-28	6.5 - 7.0	0.80
SS-28	8.5 - 9.0	0.20
SS-28	10.0 - 12.0	-
SS-28	12.0 - 14.0	-
SS-28	15.0 - 16.0	0.0
SS-28	17.0 - 18.0	1.0
RB-SS-28-02	19.0 - 20.0	7.0

BORING/ SAMPLE No.	DEPTH INTERVAL (Ft.)	HEADSPACE PEAK (PPM)
SS-29	0.0 - 2.0	-
SS-29	2.5 - 3.0	0.0 ppm
SS-29	4.0 - 6.0	-
SS-29	6.0 - 8.0	-
RB-SS-29-01	9.5 - 10.0	0.0 ppm
SS-29	11.0 - 12.0	0.0 ppm
RB-SS-29-02	13.0 - 14.0	0.0 ppm
SS-29	14.0 - 16.0	-
RB-SS-29-03	17.0 - 18.0	5.4 ppm
SS-30	1.0 - 2.0	0.0
SS-30	2.0 - 2.5	0.0
RB-SS-30-01	4.0 - 5.0	0.2
SS-30	7.0 - 7.5	0.0
SS-30	8.0 - 9.0	0.6
RB-SS-30-02	11.0 - 12.0	8.0
RB-SS-30-03	13.0 - 14.0	2.0
SS-30	15.0 - 16.0	8.0
SS-31	1.5 - 2.0	0.3
SS-31	2.0 - 4.0	-
SS-31	5.0 - 6.0	0.0
SS-31	7.5 - 8.0	0.2
SS-31	8.5 - 9.5	0.0
SS-31	11.0 - 12.0	0.4
RB-SS-31-01	13.0 - 14.0	0.4
SS-32	1.0 - 2.0	0.4 ppm
SS-32	2.0 - 4.0	-
SS-32	5.0 - 6.0	0.3 ppm
RB-SS-32-01	6.0 - 8.0	0.6 ppm
SS-32	8.0 - 9.0	0.3 ppm
RB-SS-32-02	11.0 - 12.0	0.0 ppm
SS-32	12.0 - 12.5	0.2 ppm

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NOTES:

- HEADSPACE READINGS TAKEN WITH AN HNU SYSTEMS PHOTOIONIZATION DETECTOR WITH A 10.2 ELECTRON VOLT PROBE.
- MEASUREMENTS MADE AFTER JARRED SAMPLES SAT AT ROOM TEMPERATURE FOR A PERIOD OF SEVERAL HOURS.
- MEASUREMENT INDICATES PEAK READINGS IN PARTS PER MILLION. INSTRUMENT CALIBRATED WITH C4H8 GAS.

TABLE 7
CHEMICAL-ANALYTICAL DATA
SOIL
BALLY ENGINEERED STRUCTURES RI/FS
BALLY, PENNSYLVANIA

	S	A	M	P	L	E		N	U	M	B	E	R
COMPOUND (ug/kg)	SS1-002 2.0-4.0	SS1-003 4.0-6.0	SS2-004 6.0-8.0	SS3-005 7.0-9.5	SS4-005 8.0-10.0	SS6-001 3.0-3.2	SS6-002 4.9-5.3	SS6-002A 4.9-5.3	SS6-003 7.0-7.3	SS7-002 3.5-3.8	SS7-005 7.1-7.4		
1,1,1-Trichloroethane	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6		
Trichloroethene	<6	<6	<6	<6	<6	<6	<6	3J	<6	<6	<6		
Toluene	R	R	R	R	R	<6	<6	<6	<6	<6	<6		
Methylene Chloride	R	R	R	R	R	R	R	R	R	R	R		
Acetone	R	R	R	R	R	R	R	R	R	R	R		

COMPOUND (ug/kg)	SS9-001 4.0-6.0	SS9-001A 4.0-6.0	SS9-002 6.0-8.0	SS10-001 0-2.0	SS11-001 3.0-5.0	SS11-002 7.0-9.0	SS11-003 10.0-12.0	SS12-002 3.0-5.0	SS12-003 5.0-7.0	SS13-001 7.0-8.0	SS13-002 10.0-12.0	SS14-001 3.0-5.0	SS14-003 7.0-9.0
1,1,1-Trichloroethane	<6	<6	<6	<6	6	13	10	<6	<6	<6	<6	<6	<6
Trichloroethene	<6	<6	<6	<6	8	<6	<6	<6	<6	<6	<6	<6	<6
Toluene	R	R	R	<6	43	6	5J	13	36	<6	<6	<6	<6
Methylene Chloride	R	R	R	R	R	R	R	R	R	R	R	R	R
Acetone	R	R	R	R	R	R	R	11	12	R	R	R	R

NOTES: See Figure 3 for soil boring (SS1 etc.) locations; 4.0-6.0 etc. indicates depth from which sample was taken.
R indicates the chemical was rejected during the validation process.
J indicates an estimated concentration.

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TABLE 10
CHEMICAL-ANALYTICAL DATA
SURFACE WATER AND SEDIMENT
BALLY ENGINEERED STRUCTURES RI/FS
BALLY, PENNSYLVANIA

SURFACE WATER SAMPLE NUMBER

DETECTED COMPOUND (ug/l)	SW1-001	SW1-001A	SW2-002	SW3-003	RB-SW-01	RB-SW-02
Chloroform	ND	ND	ND	ND	ND	ND
Methylene Chloride	3BJ	3BJ	ND	ND	ND	ND
Acetone	14	13	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	18
1,2-Dichloroethene	ND	ND	ND	ND	ND	16
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	6
Trichloroethene	ND	ND	ND	ND	ND	ND

SEDIMENT SAMPLE NUMBER

DETECTED COMPOUND (ug/l)	SD1-001	SD1-001A	SD2-002	SD3-003	RB-SW-S1	RB-SW-S2
Chloroform	ND	ND	ND	79	ND	ND
Methylene Chloride	5BJ	5BJ	ND	12J	ND	ND
Acetone	7BJ	15BJ	ND	200BJ	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	11

NOTES: See Figure 28 for sample locations.
SW or SW-0# indicates surface water.
SD or SW-S# indicates sediment.
ND indicates chemical was not detected above the method detection limit.
B indicates the chemical was also detected in the method blank.
J indicates the quantitation is estimated.

TABLE 11

DOSE-RESPONSE EVALUATION
HUMAN HEALTH EFFECTS
BALLY ENGINEERED STRUCTURES SITE

CHEMICAL	CPF (mg/kg/day)		AIC[1,2] (mg/kg/day)		MCL[3] (MCLG)	EPA DRINKING WATER HEALTH ADVISORIES			AWQC
	ORAL	INHALATION	ORAL	INHALATION	(mg/ℓ)	ONE-DAY 10 kg (mg/ℓ)	TEN-DAY 10 kg (mg/ℓ)	LIFETIME 70 kg (mg/ℓ)	(drinking water only)
1,1,1-Trichloroethane	NC[4]	NC	5.4×10^{-1}	6.3	0.20	140	35.0	1.0	NA
Trichloroethene	1.1×10^{-2}	1.3×10^{-2}	9.0×10^{-2}	NA[5]	0.005	NA	NA	NA	0
1,1-Dichloroethene	5.8×10^{-1}	1.16	9.0×10^{-3}	NA	0.007	1.0	1.0	NA	0
1,1-Dichloroethane	NC	NC	1.2×10^{-1}	1.38×10^{-1}	NA	NA	NA	NA	NA
Tetrachloroethene	5.1×10^{-2}	3.3×10^{-3}	1.0×10^{-2}	NA	(0)	NA	34.0	NA	0
Methylene Chloride	7.5×10^{-3}	1.43×10^{-2}	6.0×10^{-2}	NA	NA	NA	NA	NA	0

(1) AIC - Allowable Intake on a Chronic Basis.
(2) AICs given for 1,1,1-trichloroethane and methylene chloride are from Health Effects Assessment Documents; all others are RFDs.
(3) MCL - Maximum Contaminant Level - federal drinking water standard.
(4) "NC" indicates noncarcinogen.
(5) "NA" indicates not available.

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TABLE 12

ESTIMATED INGESTION AND INHALATION DOSES
CURRENT GROUND WATER SUPPLY CONDITIONS
BALLY, PENNSYLVANIA

RESIDENTIAL

COMPOUND	CONCENTRATION (mg/ℓ)	INGESTION DOSE (mg/kg/day)	INHALATION DOSE (mg/kg/day)
1,1-Dichloroethene	0.019	5.4×10^{-4}	5.8×10^{-4}
Trichloroethene	0.015	4.3×10^{-4}	4.0×10^{-4}
1,1,1-Trichloroethane	0.073	2.1×10^{-3}	2.0×10^{-3}

OCCUPATIONAL

COMPOUND	CONCENTRATION (mg/ℓ)	INHALATION DOSE (mg/kg/day)
1,1-Dichloroethene	0.019	4.7×10^{-4}
Trichloroethene	0.032	1.8×10^{-3}
1,1,1-Trichloroethane	0.078	4.2×10^{-3}

TABLE 13

ESTIMATED DERMAL ABSORPTION AND ACCIDENTAL INGESTION DOSES
CHILDREN PLAYING IN SURFACE WATER
BALLY, PENNSYLVANIA

COMPOUND	SURFACE WATER CONCENTRATION (mg/ℓ)	DERMAL ABSORPTION DOSE (mg/kg/day)	ACCIDENTAL INGESTION DOSE (mg/kg/day)
1,1-Dichloroethene	0.018	4.5×10^{-9}	3.9×10^{-8}
1,2-Dichloroethene	0.016	4.9×10^{-9}	3.5×10^{-8}
1,1,1-Trichloroethane	0.006	1.5×10^{-9}	1.3×10^{-8}

TABLE 14

ESTIMATED INGESTION AND INHALATION DOSES
FUTURE GROUND WATER SUPPLY CONDITIONS
INCLUDING MUNICIPAL WELL NO. 3 AND POTENTIAL
USE OF WORST-CASE RESIDENTIAL WELL

TREATED MUNICIPAL WELL NO. 3

COMPOUND	CONCENTRATION (mg/ℓ)	INGESTION DOSE (mg/kg/day)	INHALATION DOSE (mg/kg/day)
1,1-Dichloroethene	6.3×10^{-4}	1.8×10^{-5}	2.0×10^{-5}
Trichloroethene	0.001	2.9×10^{-5}	2.7×10^{-5}
1,1,1-Trichloroethane	0.200	5.7×10^{-3}	5.4×10^{-3}

WORST-CASE RESIDENTIAL WELL

COMPOUND	CONCENTRATION (mg/ℓ)	INGESTION DOSE (mg/kg/day)	INHALATION DOSE (mg/kg/day)
1,1-Dichloroethene	0.330	9.4×10^{-3}	1.0×10^{-2}
Trichloroethene	0.870	2.5×10^{-2}	2.3×10^{-2}
1,1,1-Trichloroethane	0.680	1.9×10^{-2}	1.8×10^{-2}
1,1-Dichloroethane	0.230	6.6×10^{-3}	5.9×10^{-3}
Methylene Chloride	0.021	6.0×10^{-4}	6.2×10^{-4}

TABLE 15

ESTIMATED CARCINOGENIC RISKS
CURRENT GROUND WATER SUPPLY CONDITIONS
BALLY, PENNSYLVANIA

EXPOSURE ROUTE: INGESTION

COMPOUND	CONCENTRATION (mg/ℓ)	DOSE (mg/kg/day)	CPF[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	0.019	5.4×10^{-4}	0.58	3.1×10^{-4}
Trichloroethene	0.015	4.3×10^{-4}	0.011	4.7×10^{-6}
Ingestion Risk (Total)				3.2×10^{-4}

EXPOSURE ROUTE: INHALATION

COMPOUND	CONCENTRATION (mg/ℓ)	DOSE (mg/kg/day)	CPF[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	0.019	5.8×10^{-4}	1.16	6.7×10^{-4}
Trichloroethene	0.015	4.0×10^{-4}	0.013	5.2×10^{-6}
Inhalation Risk (Total)				6.7×10^{-4}

Cumulative Carcinogenic Risk = $3.2 \times 10^{-4} + 6.8 \times 10^{-4} = 1.0 \times 10^{-3}$

[1] CPF - Carcinogenic Potency Factor (EPA, 1986).

TABLE 16

ESTIMATED CARCINOGENIC RISKS
FUTURE MUNICIPAL GROUND WATER SUPPLY CONDITIONS
BALLY, PENNSYLVANIA

EXPOSURE ROUTE: INGESTION

COMPOUND	CONCENTRATION (mg/ℓ)	DOSE (mg/kg/day)	CPF[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	6.3×10^{-4}	1.8×10^{-5}	0.58	1.0×10^{-5}
Trichloroethene	0.001	2.9×10^{-5}	0.011	3.1×10^{-7}
Ingestion Risk (Total)				1.0×10^{-5}

EXPOSURE ROUTE: INHALATION

COMPOUND	CONCENTRATION (mg/ℓ)	DOSE (mg/kg/day)	CPF[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	6.3×10^{-4}	2.0×10^{-5}	1.16	2.3×10^{-5}
Trichloroethene	0.001	2.7×10^{-5}	0.013	3.5×10^{-7}
Inhalation Risk (Total)				2.3×10^{-5}

Cumulative Carcinogenic Risk = $1.0 \times 10^{-5} + 2.3 \times 10^{-5} = 3.3 \times 10^{-5}$

[1] CPF - Carcinogenic Potency Factor (EPA, 1986).

TABLE 17

ESTIMATED CARCINOGENIC RISKS
POTENTIAL FUTURE USE OF CONTAMINATED RESIDENTIAL WELLS
BALLY, PENNSYLVANIA

EXPOSURE ROUTE: INGESTION

COMPOUND	CONCENTRATION (mg/ℓ)	DOSE (mg/kg/day)	CPF[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	0.330	9.4×10^{-3}	0.58	5.5×10^{-3}
Trichloroethene	0.870	2.5×10^{-2}	0.011	2.8×10^{-4}
Methylene Chloride	0.021	6.0×10^{-4}	0.0075	4.5×10^{-6}
Ingestion Risk (Total)				5.8×10^{-3}

EXPOSURE ROUTE: INHALATION

COMPOUND	CONCENTRATION (mg/ℓ)	DOSE (mg/kg/day)	CPF[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	0.330	1.0×10^{-2}	1.16	1.2×10^{-2}
Trichloroethene	0.870	2.3×10^{-2}	0.013	3.0×10^{-4}
Methylene Chloride	0.021	6.2×10^{-4}	0.0143	8.9×10^{-6}
Inhalation Risk (Total)				1.2×10^{-2}

Cumulative Carcinogenic Risk = $5.8 \times 10^{-3} + 1.2 \times 10^{-2} = 1.8 \times 10^{-2}$

[1] CPF - Carcinogenic Potency Factor (EPA, 1986).

TABLE 18

ESTIMATED CARCINOGENIC RISKS
POTENTIAL OCCUPATIONAL EXPOSURE TO VOCs VIA INHALATION
AND SURFACE WATER EXPOSURE VIA
DERMAL CONTACT AND ACCIDENTAL INGESTION

OCCUPATIONAL

COMPOUND	CONCENTRATION (mg/ℓ)	DOSE (mg/kg/day)	CPF[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	0.019	9.1×10^{-4}	1.16	1.1×10^{-3}
Trichloroethene	0.032	1.5×10^{-3}	0.013	2.0×10^{-5}
Risk (total)				1.1×10^{-3}

SURFACE WATER

COMPOUND	CONCENTRATION (mg/ℓ	DERMAL CONTACT DOSE (mg/Kg/day)	ACCIDENTAL INGESTION DOSE (mg/Kg/day)	CPR[1] $(mg/kg/day)^{-1}$	RISK
1,1-Dichloroethene	0.018	4.5×10^{-9}	3.9×10^{-8}	0.58	2.5×10^{-8}
Risk (total)					2.5×10^{-8}

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[1]CPF - Carcinogenic Potency Factor (EPA, 1986).

TABLE 19

HAZARD INDEX CALCULATION
CURRENT GROUND WATER SUPPLY CONDITIONS
BALLY, PENNSYLVANIA

COMPOUND	CONCENTRATION (mg/P)	INGESTION DOSE (mg/kg/day)	INHALATION DOSE (mg/kg/day)	AIC[1] ORAL (mg/kg/day)	AIC[2] INHALATION (mg/kg/day)
1,1-Dichloroethene	0.019	5.4×10^{-4}	5.8×10^{-4}	9.0×10^{-3}	9.0×10^{-3}[3]
Trichloroethene	0.015	4.3×10^{-4}	4.0×10^{-4}	9.0×10^{-2}	9.0×10^{-2}[3]
1,1,1-Trichloroethane	0.073	2.1×10^{-3}	2.0×10^{-3}	0.54	6.3

$$\text{Hazard Index} = \frac{5.4 \times 10^{-4}}{9.0 \times 10^{-3}} + \frac{5.8 \times 10^{-4}}{9.0 \times 10^{-3}} + \frac{2.1 \times 10^{-3}}{0.54} + \frac{2.0 \times 10^{-3}}{6.3}$$

$$+ \frac{4.3 \times 10^{-4}}{9.0 \times 10^{-2}} + \frac{4.0 \times 10^{-4}}{9.0 \times 10^{-2}} = 0.14 < 1.0$$

(1) AIC Oral - Acceptable Intake on a Chronic Basis for the oral exposure route (EPA, 1986).

(2) AIC Inhalation - Acceptable Intake on a Chronic Basis for the inhalation exposure route (EPA, 1986).

(3) The oral AIC is used for the inhalation dose because no AIC has been determined for 1,1-dichloroethene or trichloroethene for the inhalation route.

TABLE 20

HAZARD INDEX CALCULATIONS
FUTURE MUNICIPAL GROUND WATER SUPPLY CONDITIONS
BALLY, PENNSYLVANIA

COMPOUND	CONCENTRATION (mg/ℓ)	INGESTION DOSE (mg/kg/day)	INHALATION DOSE (mg/kg/day)	AIC ORAL[1] (mg/kg/day)	AIC INHALATION[2] (mg/kg/day)
1,1-Dichloroethene	6.3×10^{-4}	1.8×10^{-5}	2.0×10^{-5}	9.0×10^{-3}	9.0×10^{-3}[3]
Trichloroethene	0.001	2.9×10^{-5}	2.7×10^{-5}	9.0×10^{-2}	9.0×10^{-2}[3]
1,1,1-Trichloroethane	0.200	5.7×10^{-3}	5.4×10^{-3}	0.54	6.3

$$\text{Hazard Index} = \frac{1.8 \times 10^{-5}}{9.0 \times 10^{-3}} + \frac{2.0 \times 10^{-5}}{9.0 \times 10^{-3}} + \frac{5.7 \times 10^{-3}}{0.54} + \frac{5.4 \times 10^{-3}}{6.3}$$

$$+ \frac{2.9 \times 10^{-5}}{9.0 \times 10^{-2}} + \frac{2.7 \times 10^{-5}}{9.0 \times 10^{-2}} = 0.016 < 1$$

(1) AIC Oral - Acceptable Intake on a Chronic Basis for the oral exposure route (EPA, 1986).

(2) AIC Inhalation - Acceptable Intake on a Chronic Basis for the inhalation exposure route (EPA, 1986).

(3) The oral AIC is used for the inhalation dose because no AIC has been determined for 1,1-dichloroethene and trichloroethene for the inhalation route.

AR301419

TABLE 21

HAZARD INDEX CALCULATIONS
POTENTIAL FUTURE USE OF CONTAMINATED RESIDENTIAL WELLS
BALLY, PENNSYLVANIA

COMPOUND	CONCENTRATION (mg/P)	INGESTION DOSE (mg/kg/day)	INHALATION DOSE (mg/kg/day)	AIC ORAL(1) (mg/kg/day)	AIC INHALATION(2) (mg/kg/day)
1,1-Dichloroethene	0.330	9.4×10^{-3}	1.0×10^{-2}	9.0×10^{-3}	9.0×10^{-3}(3)
Trichloroethene	0.870	2.5×10^{-2}	2.3×10^{-2}	9.0×10^{-2}	9.0×10^{-2}(3)
1,1,1-Trichloroethane	0.680	1.9×10^{-2}	1.8×10^{-2}	0.54	6.3
1,1-Dichloroethane	0.230	6.6×10^{-3}	5.9×10^{-3}	0.12	0.138
Methyl Chloride	0.021	6.0×10^{-4}	6.2×10^{-4}	6.0×10^{-2}	6.0×10^{-2}(3)

$$\text{Hazard Index} = \frac{9.4 \times 10^{-3}}{9.0 \times 10^{-3}} + \frac{1.0 \times 10^{-2}}{9.0 \times 10^{-3}} + \frac{2.5 \times 10^{-2}}{9.0 \times 10^{-2}} + \frac{2.3 \times 10^{-2}}{9.0 \times 10^{-2}} + \frac{1.9 \times 10^{-2}}{0.54} + \frac{1.8 \times 10^{-2}}{6.3}$$

$$+ \frac{6.6 \times 10^{-3}}{0.12} + \frac{5.9 \times 10^{-3}}{0.138} + \frac{6.0 \times 10^{-4}}{6.0 \times 10^{-2}} + \frac{6.2 \times 10^{-4}}{6.0 \times 10^{-2}} = 2.8;$$

$$2.8 > 1$$

(1) AIC Oral - Acceptable Intake on a Chronic Basis for the oral exposure route (EPA, 1986).
(2) AIC Inhalation - Acceptable Intake on a Chronic Basis for the inhalation exposure route (EPA, 1986).
(3) The oral AIC is used for the inhalation dose because no AIC has been determined for these compounds.

AR301420

TABLE 22

HAZARD INDEX CALCULATIONS
OCCUPATIONAL AND SURFACE WATER EXPOSURE ROUTES
BALLY, PENNSYLVANIA

OCCUPATIONAL

COMPOUND	CONCENTRATION (mg/P)	DOSE (mg/kg/day)	AIC INHALATION (mg/kg/day)
1,1-Dichloroethene	0.019	9.1×10^{-4}	0.009[1]
Trichloroethene	0.032	1.5×10^{-3}	0.09[1]
1,1,1-Trichloroethane	0.078	3.5×10^{-3}	6.3

$$\text{Hazard Index} = \frac{9.1 \times 10^{-4}}{9.0 \times 10^{-3}} + \frac{1.5 \times 10^{-3}}{0.09} + \frac{3.5 \times 10^{-3}}{6.3} = 0.12 < 1.0$$

SURFACE WATER

COMPOUND	CONCENTRATION (mg/P)	ACCIDENTAL INGESTION DOSE (mg/kg/day)	DERMAL ABSORPTION DOSE (mg/kg/day)	AIC ORAL (mg/kg/day)	AIC INHALATION (mg/kg/day)
1,1-Dichloroethene	0.018	3.9×10^{-8}	4.5×10^{-9}	0.009	0.009[1]
1,1,1-Trichloroethane	0.006	1.3×10^{-8}	1.5×10^{-9}	0.54	6.3

$$\text{Hazard Index} = \frac{3.9 \times 10^{-8}}{0.009} + \frac{4.5 \times 10^{-9}}{0.009} + \frac{1.3 \times 10^{-8}}{0.54} + \frac{1.5 \times 10^{-9}}{6.3} = 4.9 \times 10^{-6} < 1$$

[1] No AICs for inhalation are available for these compounds; thus, oral AICs are used.

AR301421

TABLE 23

CONTAMINANTS EXCEEDING RELEVANT STANDARDS AND GUIDELINES
BALLY, PENNSYLVANIA

Compound	CONCENTRATION (mg/P)		MCL[1] (mg/P)	AWQC[2] (mg/P)	DRINKING WATER (mg/P) HEALTH ADVISORIES		
	MUNICIPAL WELL	GEHMAN WELL			1-DAY 10-kg	10-DAY 10-kg	LIFETIME 70-kg
Trichloroethene	0.015	0.19	0.005	2.8×10^{-3}	NA[3]	NA	NA
1,1-Dichloroethene	0.019	0.12	0.007	3.3×10^{-5}	1.0	1.0	NA
1,1,1-Trichloroethane	0.073	0.42	0.20	18.4	140	35.0	1.0

(1) MCL - Maximum Contaminant Level - federal drinking water standard.

(2) These Ambient Water Quality Criteria (AWQC) values are adjusted for drinking water only and represent the 10^{-6} cancer risk.

(3) "NA" indicates not available.

AR301422

TABLE 24

COMPARISON OF POTENTIAL SURFACE WATER VOC CONCENTRATIONS
TO AWQC FOR THE PROTECTION OF FRESHWATER BIOTA
BALLY, PENNSYLVANIA

CHEMICAL	CONCENTRATION SW02-1 (µg/ℓ)	CHRONIC AWQC[1] (µg/ℓ)
Trichloroethene	11[2]	2,190
1,1,1-Trichloroethane	6	940[3]
1,1-Dichloroethene	18	116
1,2-Dichloroethane	16	NA[4]

Source: 45 CFR 793.18, November 28, 1980.

[1] AWQC - Ambient Water Quality Criteria derived by dividing chronic Lowest Observed Effect Levels (LOELs) by 10 or acute LOELs by 100.

[2] TCE was detected at 11 µg/kg in sediment at SW02-1.

[3] This value was established for 1,1,2-trichloroethane; none has been established for 1,1,1-trichloroethane.

[4] "NA" indicates no value has been established.

BLE 7 (CONT)

S A M P L E N U M B E R

COMPOUND (ug/kg)	SS-16-1 0.0-1.5	SS-16-2 6.0-7.5	SS-17-3 9.0-10.0	SS-18-1 12.0-14.0	SS-19-1 6.0-8.0	SS-19-1 6.0-8.0 (SPLIT)	SS-19-2 14.0-16.0	SS-19-2 14.0-16.0 (SPLIT)	SS-20-1 15.0-16.0	SS-21-2 15.0-16.0	SS-22-2 5.0-6.0	SS-22-3 11.0-12.0	SS-22-4 19.0-20.0
1,1,1-Trichloroethane	<620	<125	<125	<125	<125	<6.0	<620	<6.0	<125	<125	<125	<125	<100
1,1,2-Trichloroethane	<620	<125	<125	<125	<125	<6.0	<620	12.0	<125	<125	<125	<125	<100
Trichloroethene	<620	<125	<125	<125	<125	<6.0	<620	520	<125	<125	<125	<125	<100
1,1-Dichloroethene	<620	<125	<125	<125	<125	<6.0	<620	12.0	<125	<125	<125	<125	<100
1,2-Dichloroethene	<620	<125	<125	<125	<125	<6.0	<620	6.0	<125	<125	<125	<125	<100
Tetrachloroethene	<620	<125	<125	<125	<125	<6.0	<620	<6.0	<125	<125	<125	<125	<100

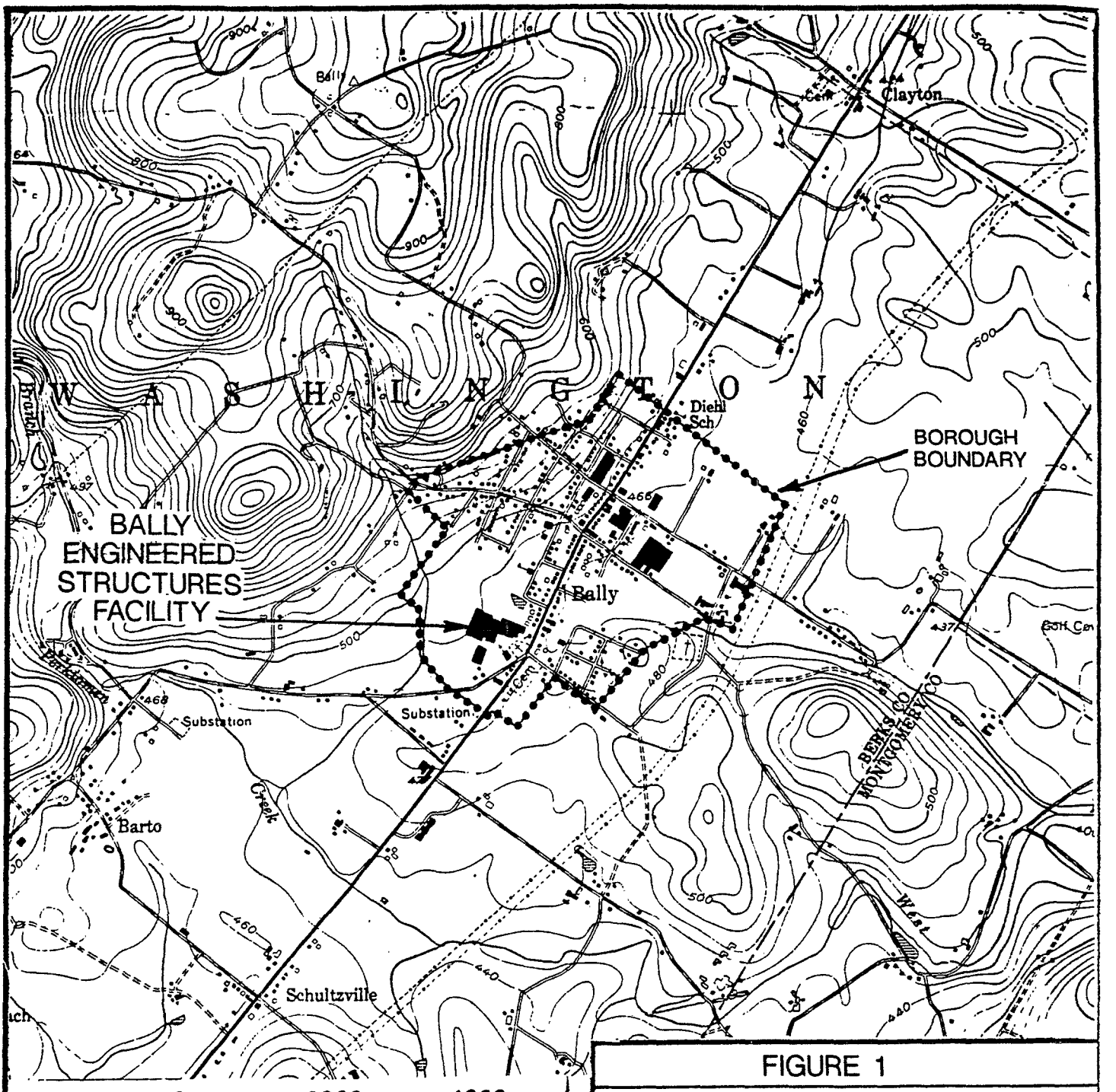
COMPOUND (ug/kg)	SS-23-1 8.0-9.0	SS-23-2 19.0-20.0	SS-25-1 19.5-20.0	SS-26-1 6.5-7.5	SS-26-2 21.0-22.0	SS-27-1 0.5-1.0	SS-27-2 4.0-6.0	SS-27-4 20.0-22.0	SS-28-1 5.0-6.0	SS-28-2 19.0-20.0	SS-29-3 17.0-18.0	SS-29-3 17.0-18.0 (SPLIT)
1,1,1-Trichloroethane	<125	<125	<125	<125	<125	<5.0	<125	<125	<125	<125	<125	<6.0
1,1,2-Trichloroethane	<125	<125	<125	<125	<125	<5.0	<125	<125	<125	<125	<125	<6.0
Trichloroethene	<125	<125	<125	<125	<125	<5.0	<125	<125	<125	<125	<125	<6.0
1,1-Dichloroethene	<125	<125	<125	<125	<125	<5.0	<125	<125	<125	<125	<125	<6.0
1,2-Dichloroethene	<125	<125	<125	<125	<125	<5.0	<125	<125	<125	<125	<125	<6.0
Tetrachloroethene	<125	<125	<125	<125	<125	<5.0	<125	<125	<125	<125	<125	<6.0

COMPOUND (ug/kg)	SS-30-2 11.0-12.0	SS-31-1 13.0-14.0	SS-32-1 6.0-8.0	SS-32-2 11.0-12.0
1,1,1-Trichloroethane	<125	<125	<125	<125
1,1,2-Trichloroethane	<125	<125	<125	<125
Trichloroethene	<125	<125	<125	<125
1,1-Dichloroethene	<125	<125	<125	<125
1,2-Dichloroethene	<125	<125	<125	<125
Tetrachloroethene	<125	<125	<125	<125

NOTES: See Figure 3 for soil boring (SS1 etc.) locations; 4.0-6.0 etc. indicates depth from which sample was taken.
Sample numbers listed on this page are each prefixxed by "RB-".
SPLIT" refers split sample submitted to separate laboratories for analysis.
Analytical data for samples RB-SS-16 to RB-SS-29 were not subjected to CLP validation protocols.

RB0014 24

FIGURES



2000 0 2000 4000

scale feet

N

REFERENCE:

USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE, EAST GREENVILLE, PA, 1956, PHOTOREVISED 1969 AND 1973. SCALE 1:24000

FIGURE 1

SITE LOCATION MAP

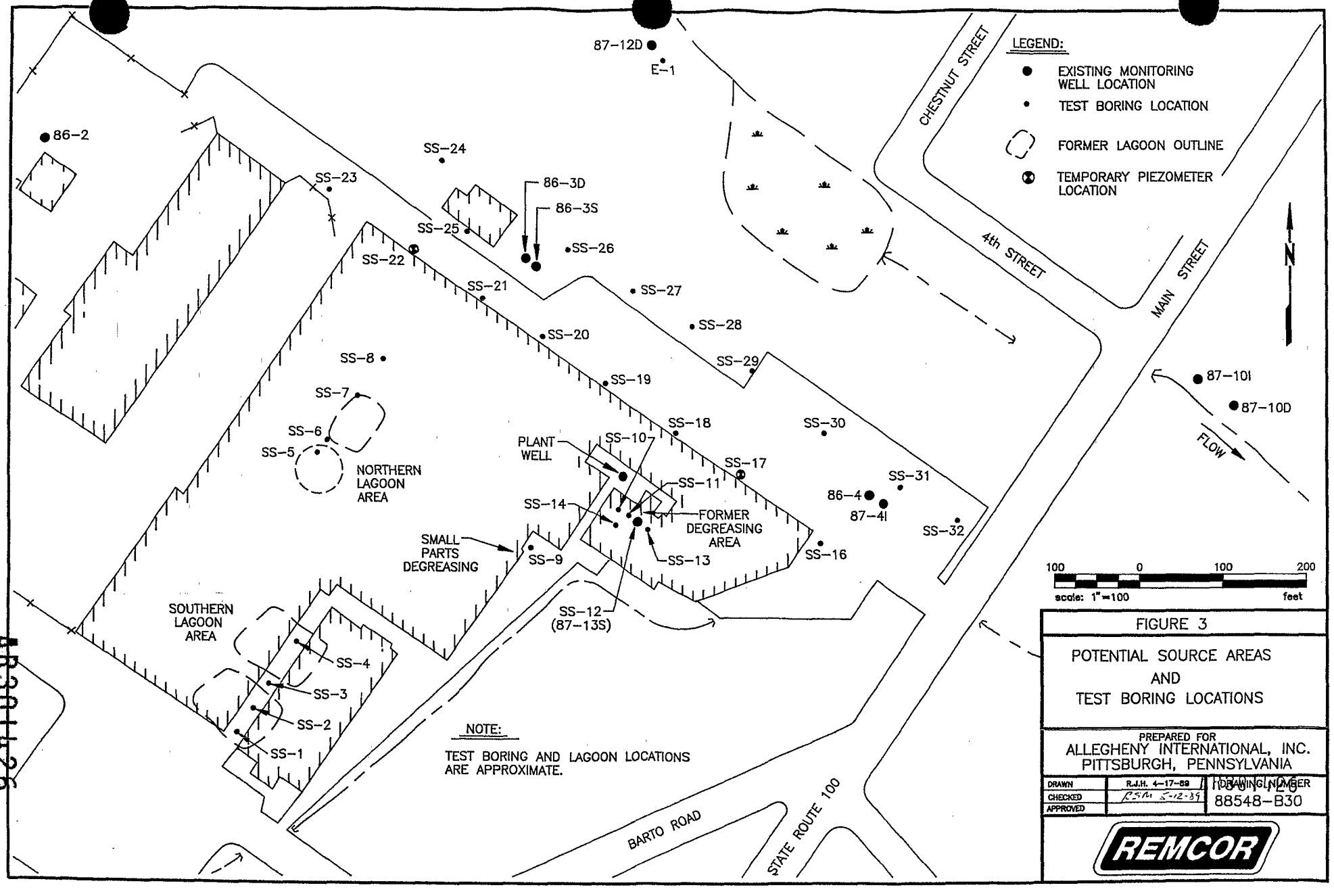
PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	LBL 11-11-88	DRAWING NUMBER
CHECKED	P.V.S. 12/6/88	88548-A2
APPROVED		

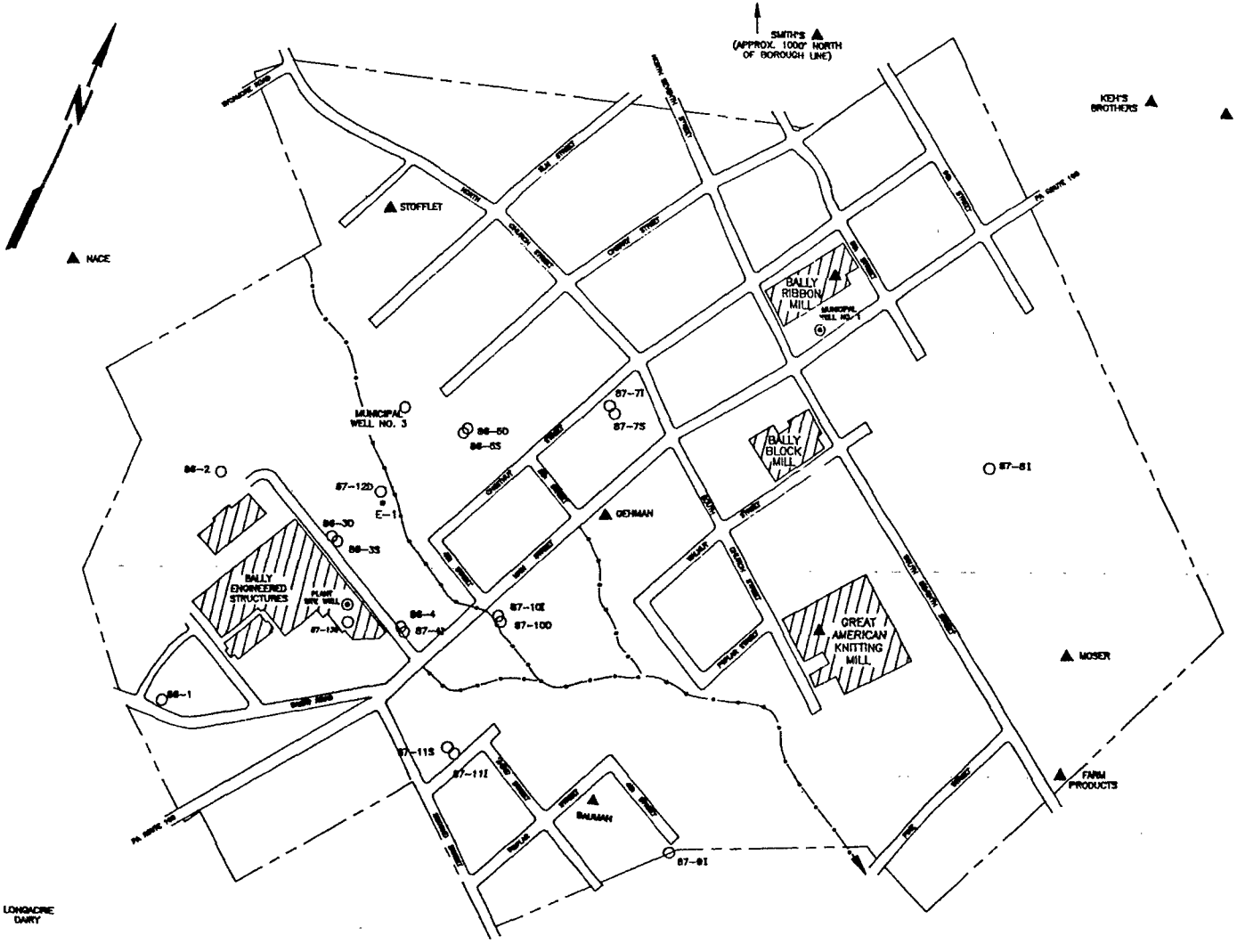
REMCOR

AR301425A

8579


LEGEND:
EXISTING MONITORING WELL LOCATION
TEST BORING LOCATION
FORMER LAGOON OUTLINE
TEMPORARY PIEZOMETER LOCATION
87-12D
E-1
86-2
SS-24
SS-23
86-3D
86-3S
SS-25
SS-26
SS-22
SS-21
SS-27
SS-28
SS-20
SS-29
SS-8
SS-19
SS-7
SS-6
SS-5
SS-18
SS-30
PLANT WELL
SS-10
SS-17
SS-11
SS-31
86-4
87-4I
SS-14
FORMER DEGREASING AREA
SS-32
SMALL PARTS DEGREASING
SS-9
SS-13
SS-16
NORTHERN LAGOON AREA
SOUTHERN LAGOON AREA
SS-12 (87-13S)
SS-4
SS-3
SS-2
SS-1
NOTE:
TEST BORING AND LAGOON LOCATIONS ARE APPROXIMATE.
BARTO ROAD
STATE ROUTE 100
CHESTNUT STREET
4th STREET
MAIN STREET
87-10I
87-10D
FLOW
N
100 0 100 200
scale: 1"=100 feet
FIGURE 3
POTENTIAL SOURCE AREAS AND TEST BORING LOCATIONS
PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA
DRAWN R.J.H. 4-17-89
CHECKED
APPROVED
DRAWING NUMBER
88548-B30
REMCOR

AN501426



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
~~	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

500 0 500 1000

scale: 1" = 500' (APPROX.) feet

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 4

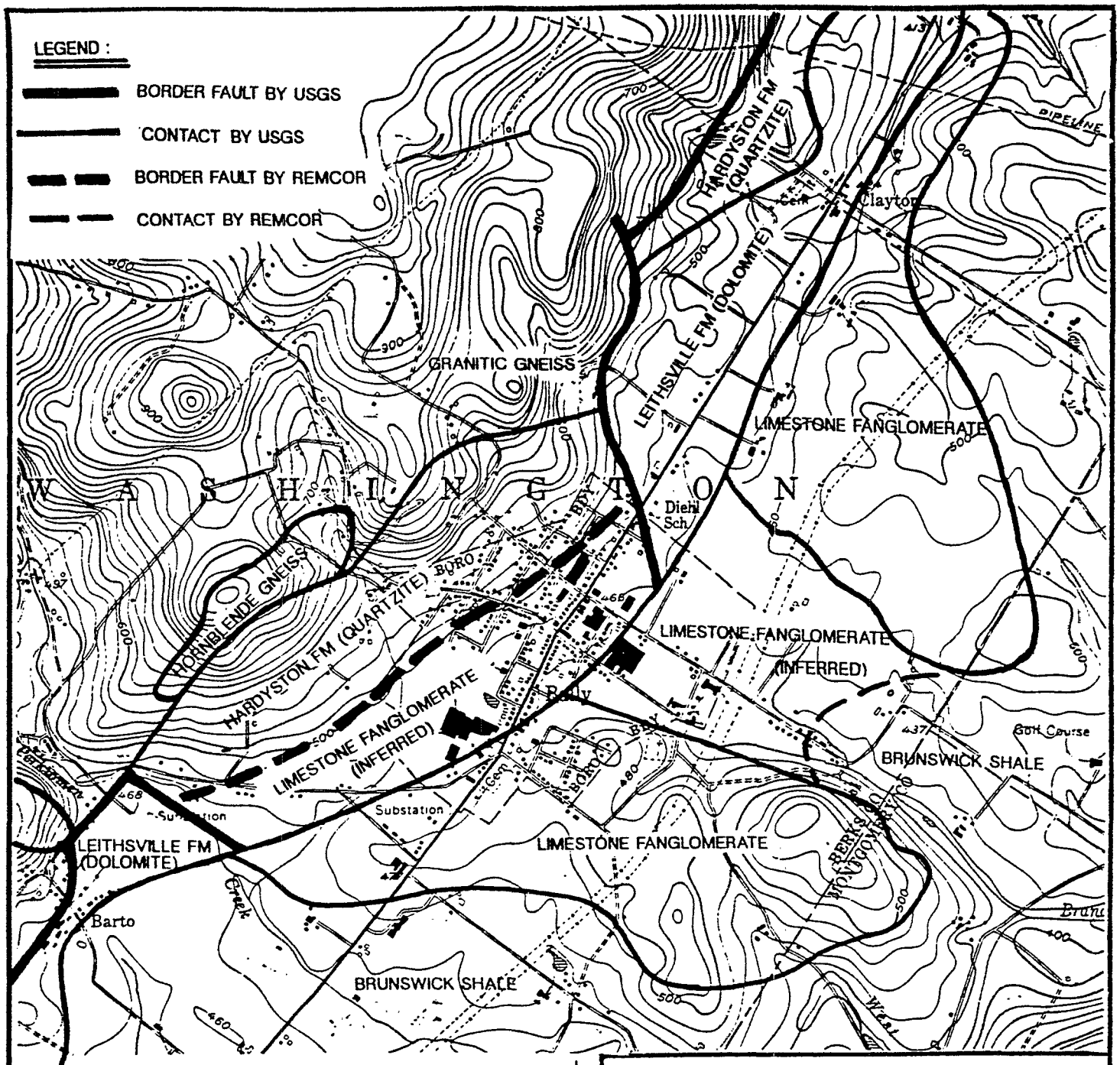
SITE PLAN WITH MONITORING, RESIDENTIAL, INDUSTRIAL AND MUNICIPAL WELL LOCATIONS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	LHK 11/23/88	DRAWING NUMBER
CHECKED	R.V.S. 12/6/88	88548-B24
APPROVED		

REMCOR

AR301426A



REFERENCE:

USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE, EAST GREENVILLE, PA, 1956, PHOTOREVISED 1969 AND 1973. SCALE 1:24000

ATLAS OF PRELIMINARY GEOLOGIC QUADRANGLE MAPS OF PENNSYLVANIA, 1981, PENNSYLVANIA GEOLOGIC SURVEY

COMPILED BY D.B. MACLACKLAN AND T.M. BEOG, 1976

FIGURE 5

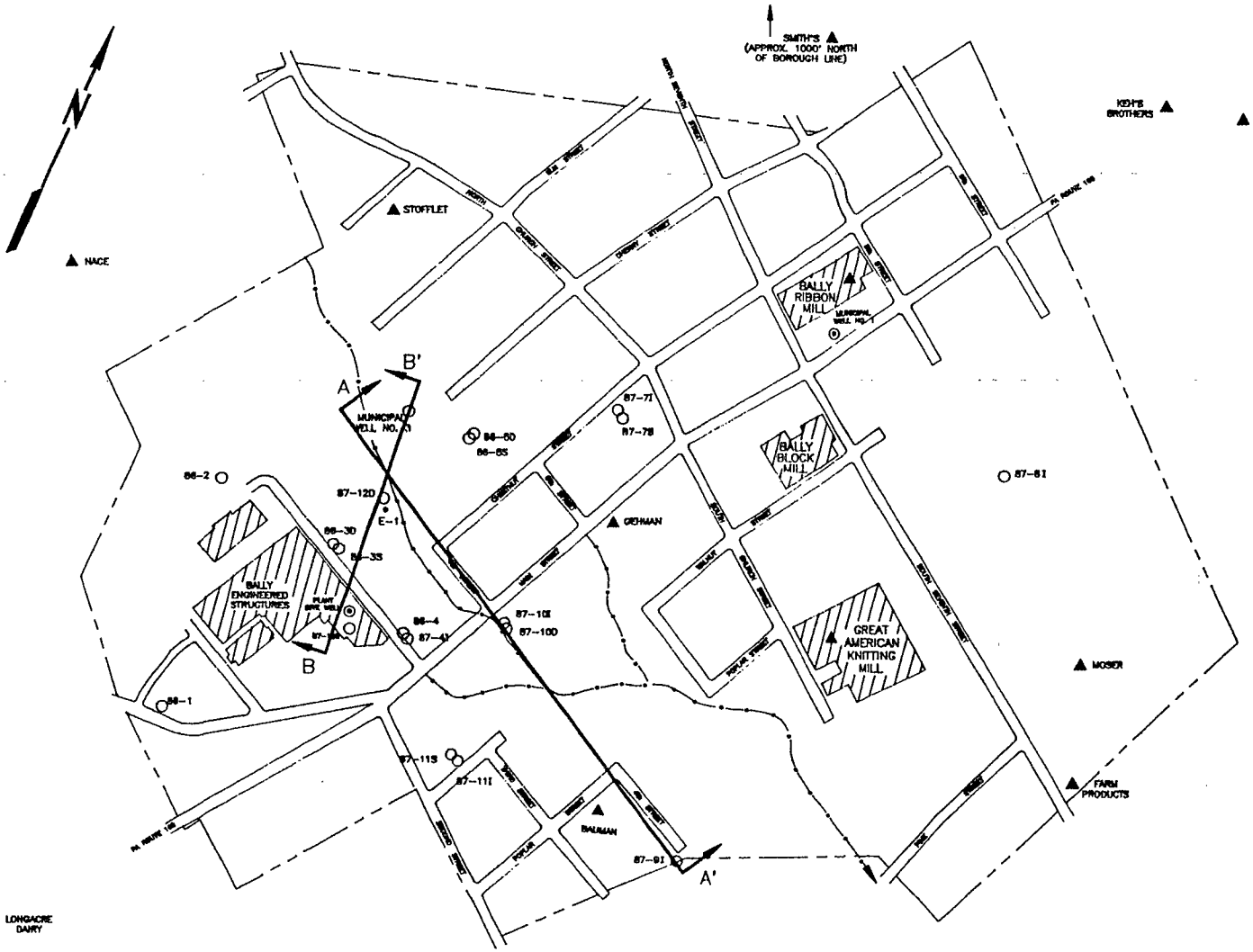
SITE GEOLOGY MAP

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	LBL 11/23/88	DRAWING NUMBER
CHECKED	[illegible]	88548-A3
APPROVED		

REMCOR

AR301426B



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 6

GEOLOGIC CROSS SECTION LOCATIONS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	C.E.B. 11/23/88	DRAWING NUMBER
CHECKED	P.V.S. 12/6/88	88548-B22
APPROVED		

REMCOR

AR301426-C
AR301426

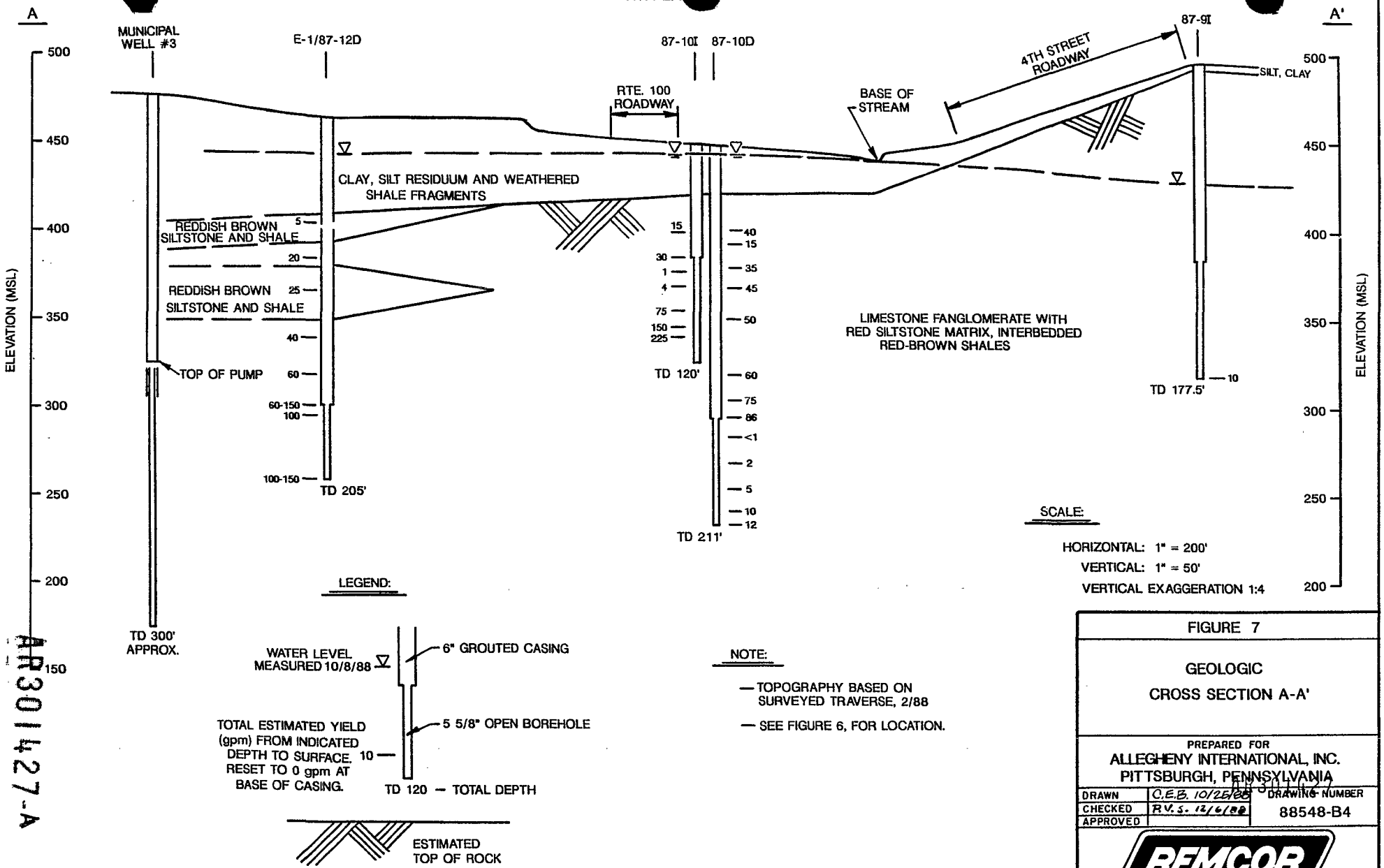


FIGURE 7

GEOLOGIC CROSS SECTION A-A'

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	C.E.B. 10/25/88	DRAWING NUMBER
CHECKED	R.V.S. 12/6/88	88548-B4
APPROVED		

REMCOR

AR301427-A

AR301427

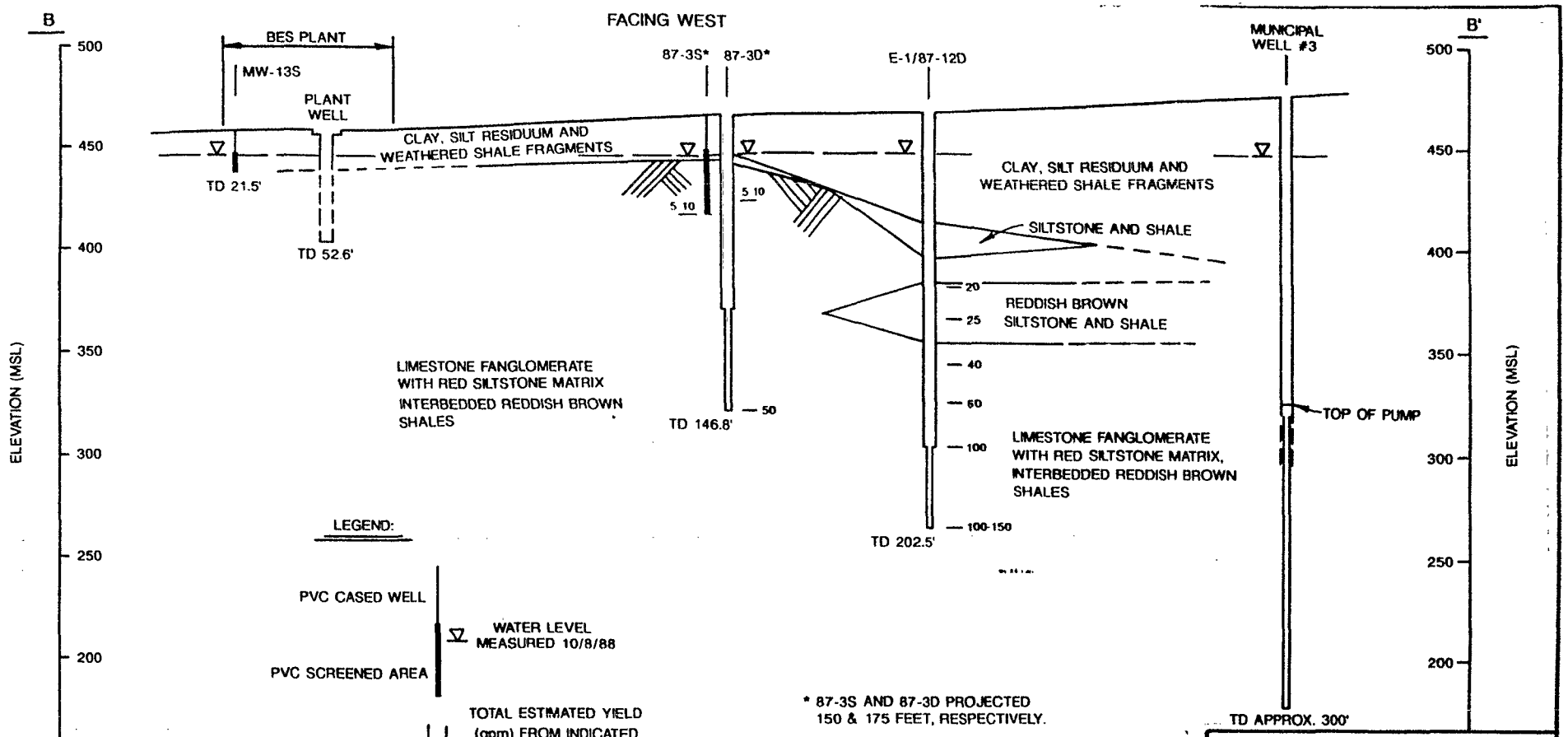


FIGURE 8

GEOLOGIC CROSS SECTION B-B'

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	C.E.B. 10/27/88	DRAWING NUMBER
CHECKED	P.V.S. 12/6/88	88548-B5
APPROVED		

REMCOR

AR301427D

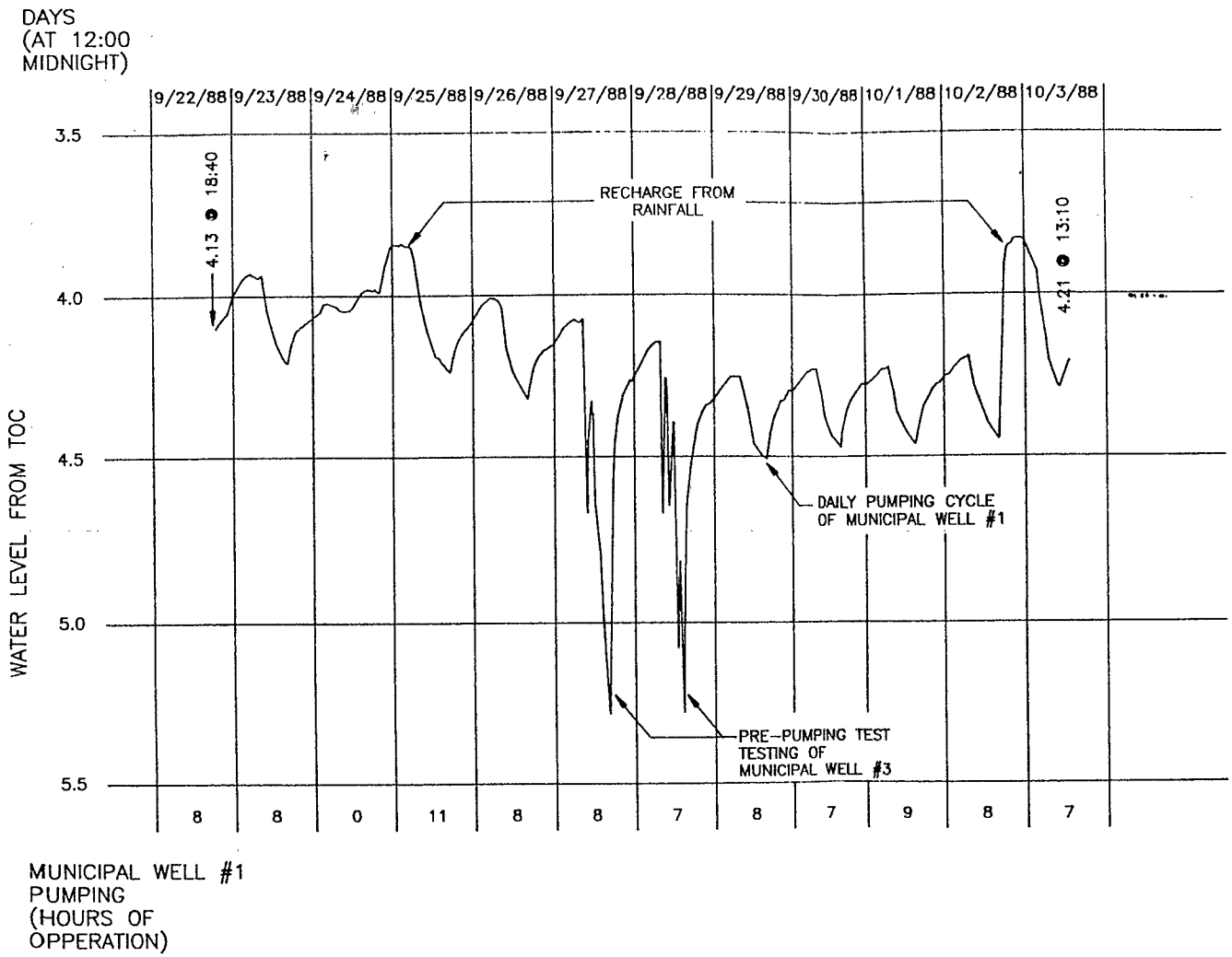


FIGURE 9

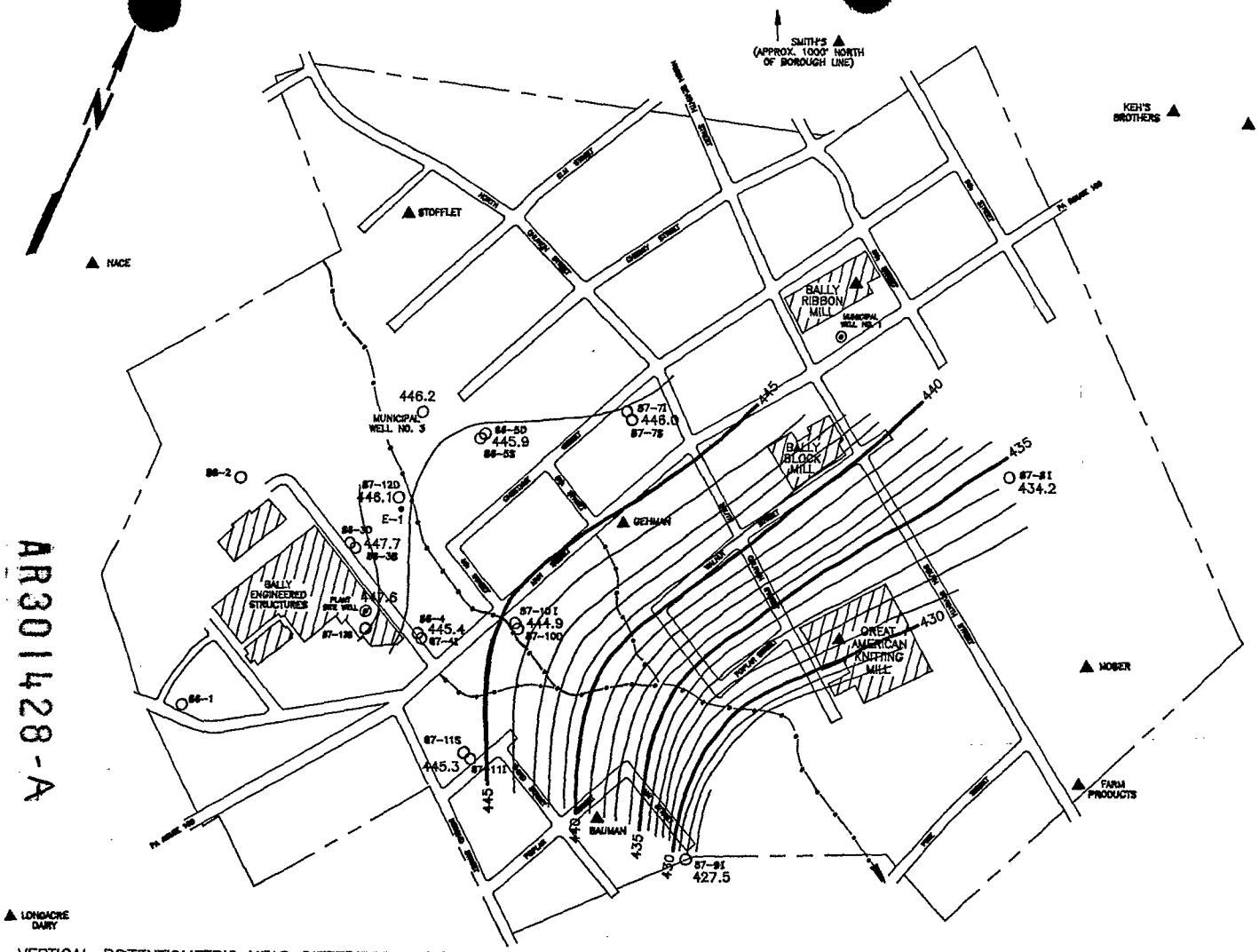
BASELINE WATER LEVEL RECORD
FOR MONITORING WELL
87-10D
9/22/88 – 10/3/88

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	10-31-88 LHK	DRAWING NUMBER
CHECKED	P.V.S. 12/6/88	88548-813
APPROVED		

REMCOR

AR301427C



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
————	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
~~	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

POTENTIOMETRIC CONTOUR LINE ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

500 0 500 1000

scale: 1" = 500' (APPROX.) feet

VERTICAL POTENTIOMETRIC HEAD DIFFERENTIAL AND VERTICAL FLOW DIRECTION AT WELL CLUSTERS:

86-3S & 86-3D —— 0.01 FT. UP
86-4 & 87-4I —— 0.78 FT. DOWN
86-5S & 86-5D —— 0.69 FT. DOWN
87-7S & 87-7I —— 0.20 FT. UP
87-10 & 87-10D —— 0.06 FT. UP
87-11S & 87-11I —— 0.12 FT. UP

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 11

POTENTIOMETRIC SURFACE FOR INTERMEDIATE & DEEP MONITORING WELLS

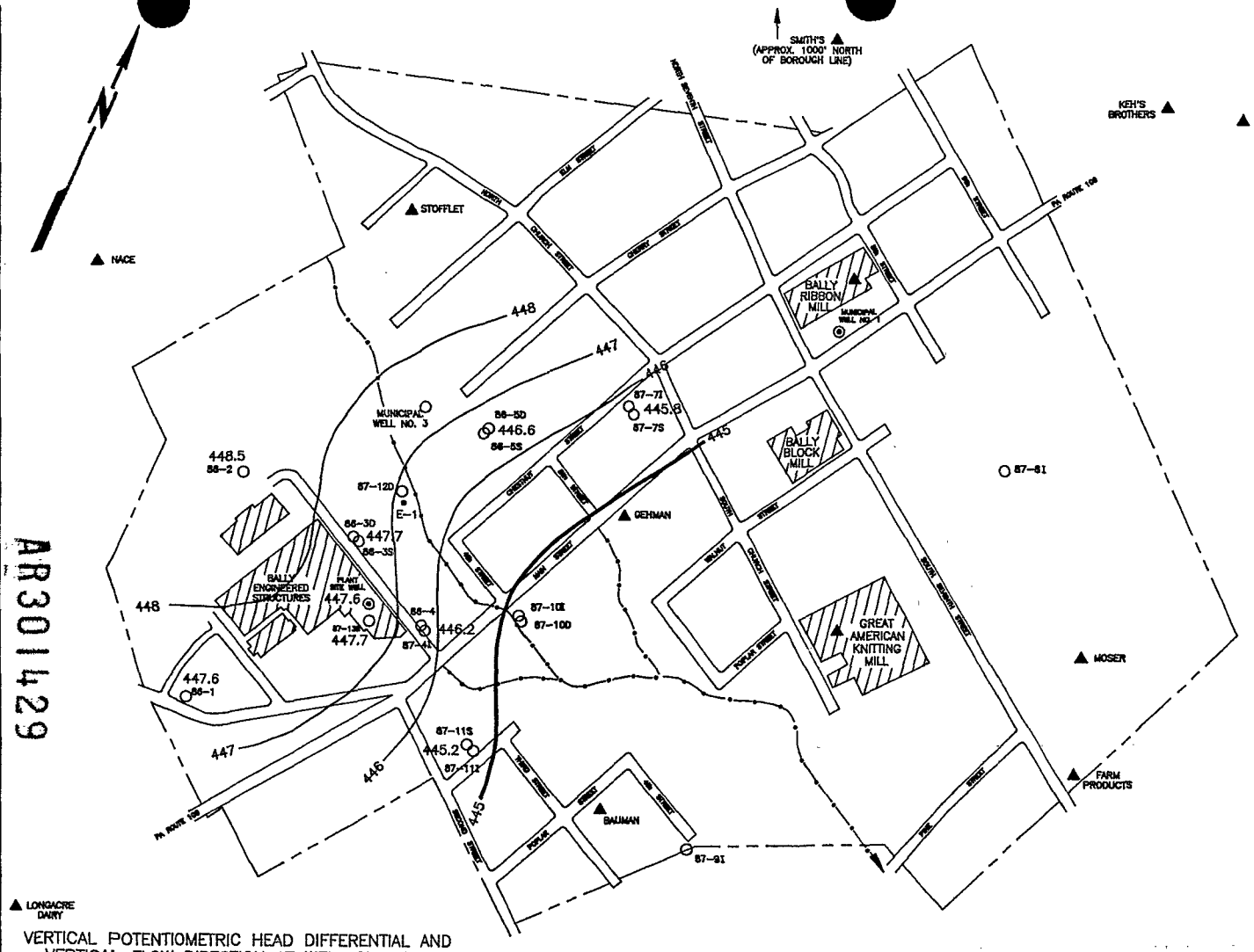
9:10 A.M. OCTOBER 4, 1988
PUMPING TEST TIME 0 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	C.E.B. 10/27/88	DRAWING NUMBER
CHECKED	SGK 5-11-89	88548-B8
APPROVED		

REMCOR

AR301428-A



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

POTENTIOMETRIC CONTOUR LINES ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

500 0 500 1000

scale: 1" = 500' (APPROX.) feet

VERTICAL POTENTIOMETRIC HEAD DIFFERENTIAL AND VERTICAL FLOW DIRECTION AT WELL CLUSTERS:

86-3S & 86-3D — 0.01 FT. UP
86-4 & 87-4I — 0.78 FT. DOWN
86-5S & 86-5D — 0.69 FT. DOWN
87-7S & 87-7I — 0.20 FT. UP
87-10 & 87-10D — 0.06 FT. UP
87-11S & 87-11I — 0.12 FT. UP

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 12

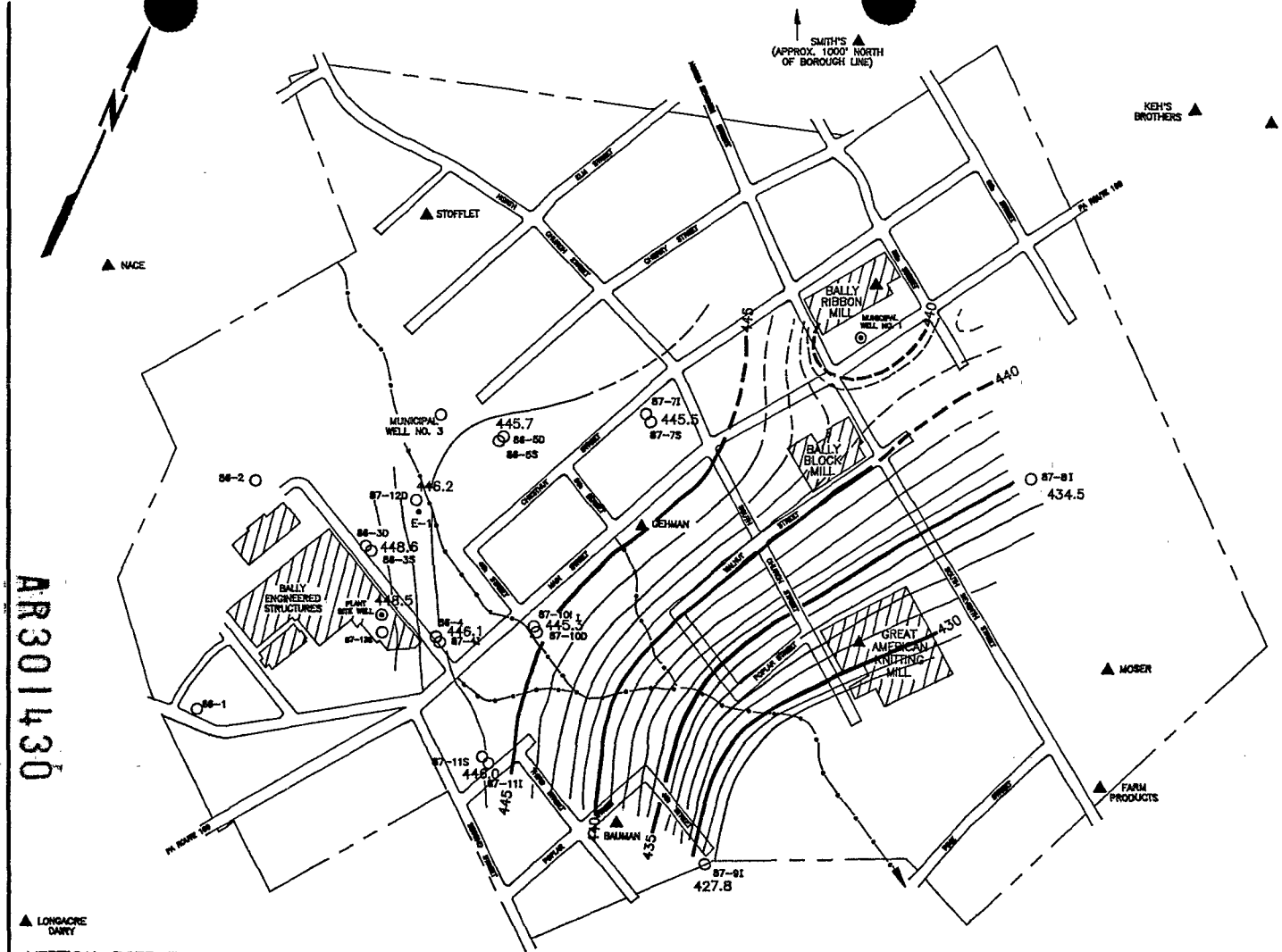
POTENTIOMETRIC SURFACE FOR SHALLOW WELLS
9:10 A.M. OCTOBER 4, 1988
PUMPING TEST TIME 0 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	10-31-88 LHK	DRAWING NUMBER
CHECKED	5-11-89 SCK	88548-B14
APPROVED		

REMCOR

AR301429



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
———	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

POTENIOMETRIC CONTOUR LINE (DASHED WERE INFERED) ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

VERTICAL POTENTIOMETRIC HEAD DIFFERENTIAL AND VERTICAL FLOW DIRECTION AT WELL CLUSTERS:

86-3S & 86-3D —— 0.01 FT. UP
86-4 & 87-4I —— 0.96 FT. DOWN
86-5S & 86-5D —— 1.52 FT. DOWN
87-7S & 87-7I —— 1.12 FT. DOWN
87-10 & 87-10D —— 0.01 FT. DOWN
87-11S & 87-11I —— 0.09 FT. UP

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 13

POTENTIOMETRIC SURFACE FOR INTERMEDIATE & DEEP MONITORING WELLS
2:40 P.M. – 4;15 P.M. AUG. 25, 1988
AT END OF PUMPING CYCLE AT MUNICIPAL WELL NO. 1

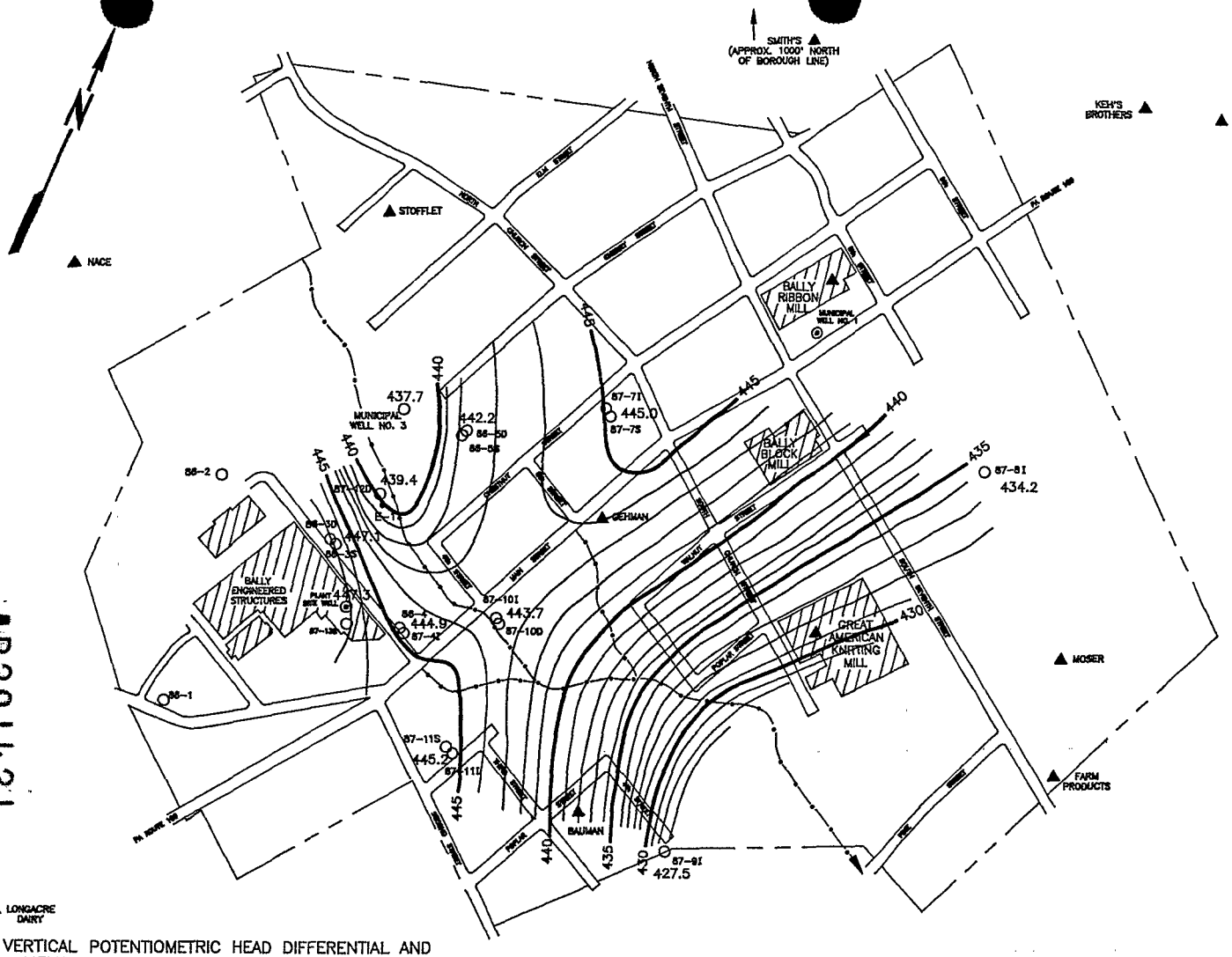
PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	R.J.H. 10-27-88	DRAWING NUMBER
CHECKED	SGK 5-11-89	88548-B7
APPROVED		

REMCOR

AR301430

AR301430



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
———	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

POTENTIOMETRIC CONTOUR LINE ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

VERTICAL POTENTIOMETRIC HEAD DIFFERENTIAL AND VERTICAL FLOW DIRECTION AT WELL CLUSTERS:

86-3S & 86-3D —— 0.00 FT. –
86-4 & 87-4I —— 1.01 FT. DOWN
86-5S & 86-5D —— 1.14 FT. DOWN
87-7S & 87-7I —— 0.52 FT. DOWN
87-10 & 87-10D —— 0.02 FT. UP
87-11S & 87-11I —— 0.11 FT. UP

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 14

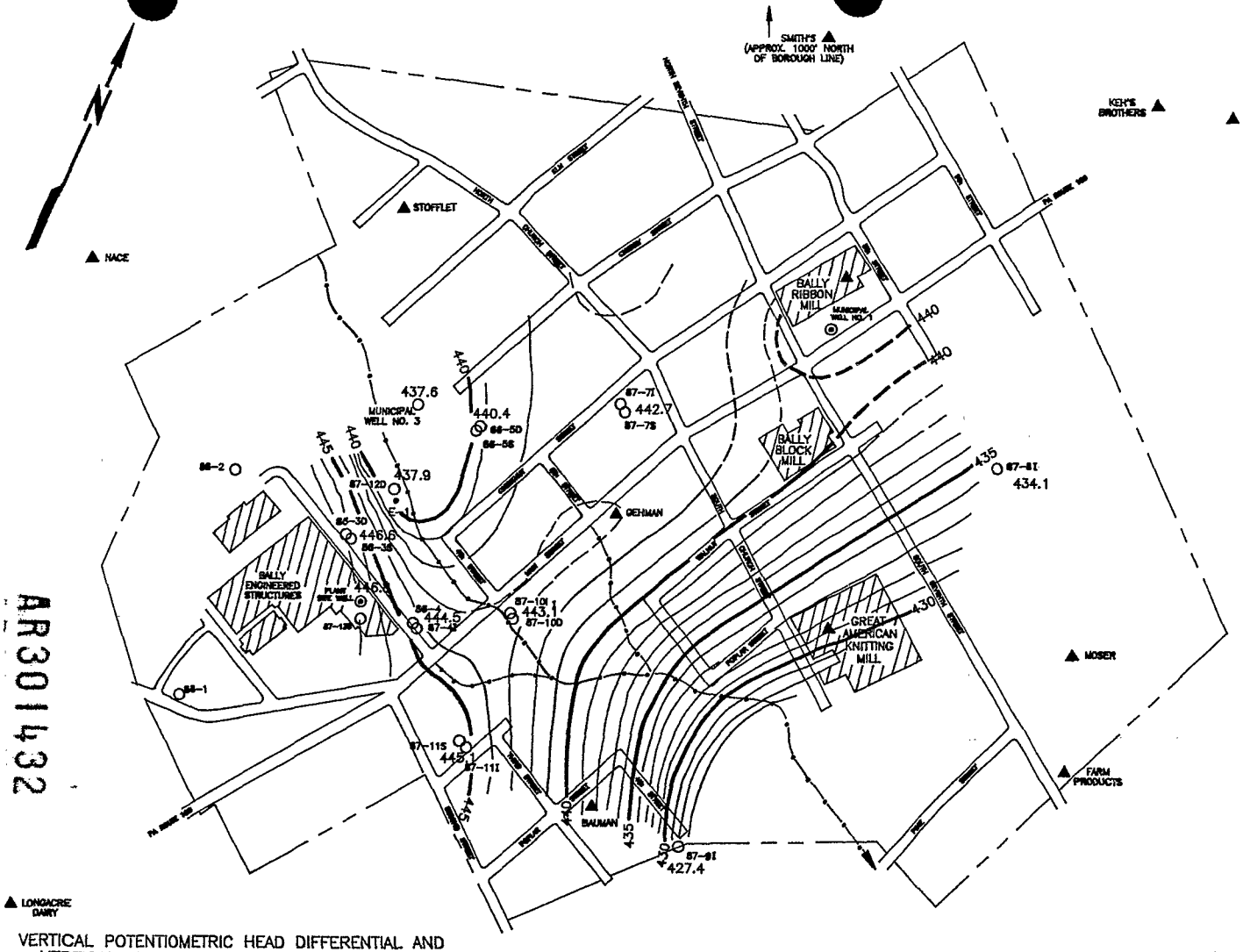
POTENTIOMETRIC SURFACE FOR INTERMEDIATE & DEEP MONITORING WELLS
5:00 A.M. OCTOBER 5, 1988
PUMPING TEST TIME 20 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	LHK 10-28-88	DRAWING NUMBER
CHECKED	SKK 5-11-89	88548-B9
APPROVED		

REMCOR

AR301431



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

POTENTIOMETRIC CONTOUR LINE (DASHED WERE INFERED) ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

VERTICAL POTENTIOMETRIC HEAD DIFFERENTIAL AND VERTICAL FLOW AT WELL CLUSTERS:

86-3S & 86-3D — 0.04 FT. DOWN
86-4 & 87-4I — 0.96 FT. DOWN
86-5S & 86-5D — 1.90 FT. DOWN
87-7S & 87-7I — 1.06 FT. DOWN
87-10 & 87-10D — 0.08 FT. DOWN
87-11S & 87-11I — 0.13 FT. UP

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 15

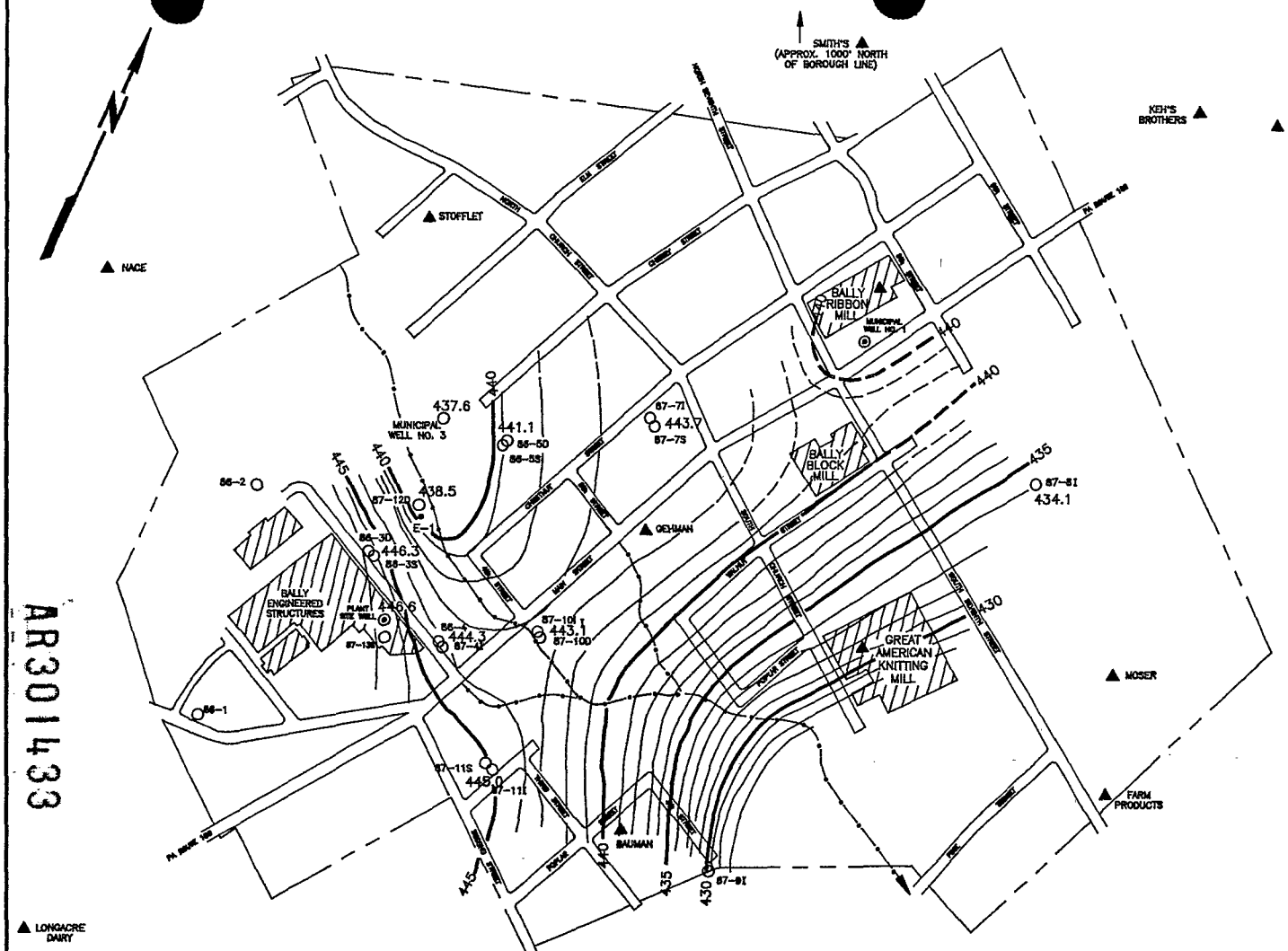
POTENTIOMETRIC SURFACE FOR INTERMEDIATE & DEEP MONITORING WELLS
10:00 A.M. OCTOBER 6, 1988
PUMPING TEST TIME 50 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	R.J.H. 10-27-88	DRAWING NUMBER
CHECKED	JEC 5-11-89	88548-B10
APPROVED		

REMCOR

AR301432



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

POTENTIOMETRIC CONTOUR LINES (DASHED WERE INFERED) ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

500 0 500 1000

scale: 1" = 500' (APPROX.) feet

VERTICAL POTENTIOMETRIC HEAD DIFFERENTIAL AND VERTICAL FLOW DIRECTION AT WELL CLUSTERS:

86-3S & 86-3D — 0.07 FT. DOWN
86-4 & 87-4I — 0.97 FT. DOWN
86-5S & 86-5D — 1.13 FT. DOWN
87-7S & 87-7I — 0.21 FT. DOWN
87-10 & 87-10D — 0.05 FT. DOWN
87-11S & 87-11I — 0.12 FT. UP

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 16

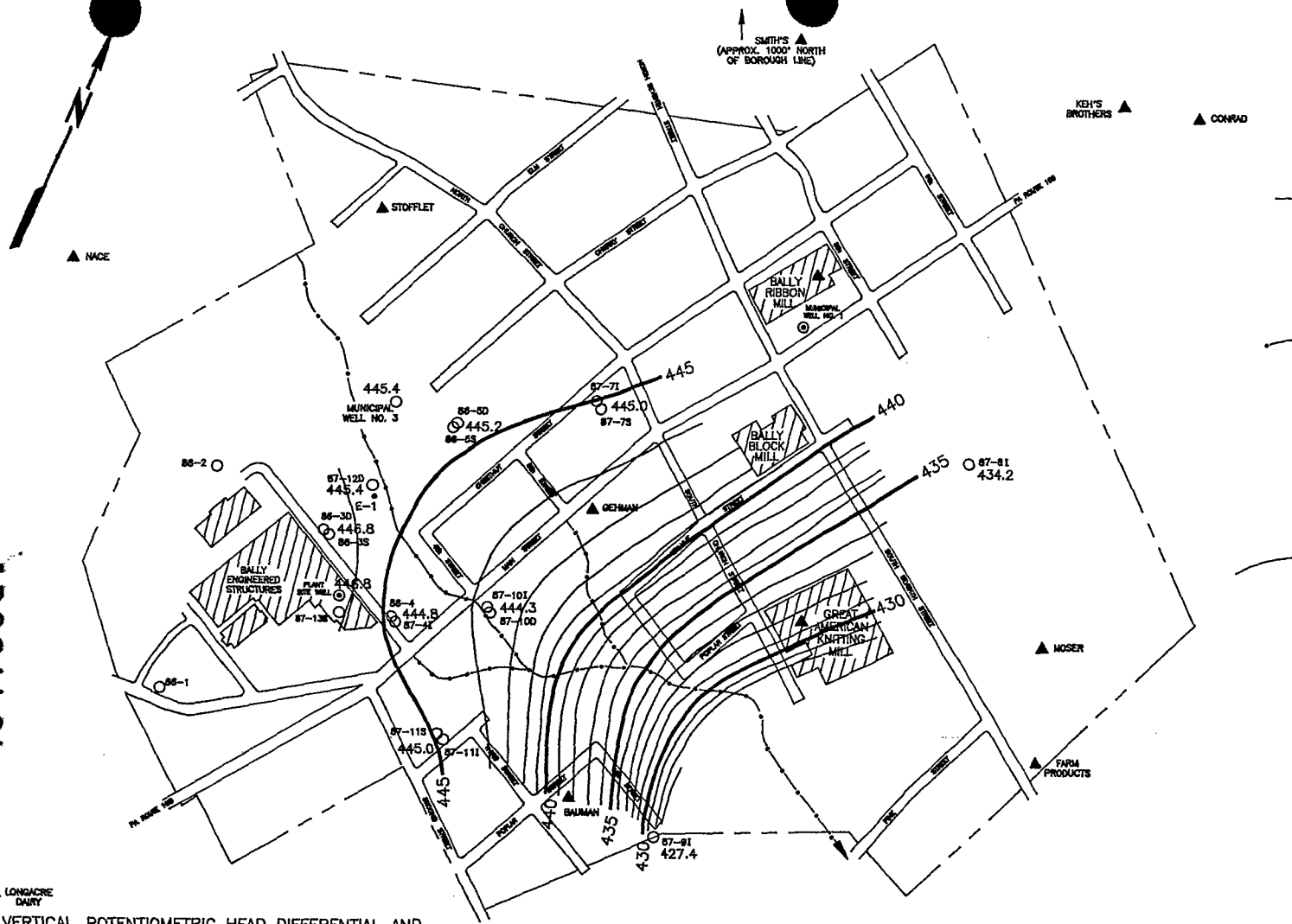
POTENTIOMETRIC SURFACE FOR INTERMEDIATE & DEEP MONITORING WELLS
9:10 A.M. OCT. 7, 1988
PUMPING TEST TIME 72 HRS.

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	R.J.H. 10-26-88	DRAWING NUMBER
CHECKED	SGR 5-11-89	88548-B6
APPROVED		

REMCOR

AR301433



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
~~	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

POTENTIOMETRIC CONTOUR LINE ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

500 0 500 1000

scale: 1" = 500' (APPROX.) feet

VERTICAL POTENTIOMETRIC HEAD DIFFERENTIAL AND VERTICAL FLOW DIRECTION AT WELL CLUSTERS:

86-3S & 86-3D — 0.00 FT. –
86-4 & 87-4I — 0.72 FT. DOWN
86-5S & 86-5D — 0.38 FT. DOWN
87-7S & 87-7I — 0.01 FT. DOWN
87-10 & 87-10D — 0.08 FT. UP
87-11S & 87-11I — 0.11 FT. UP

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 17

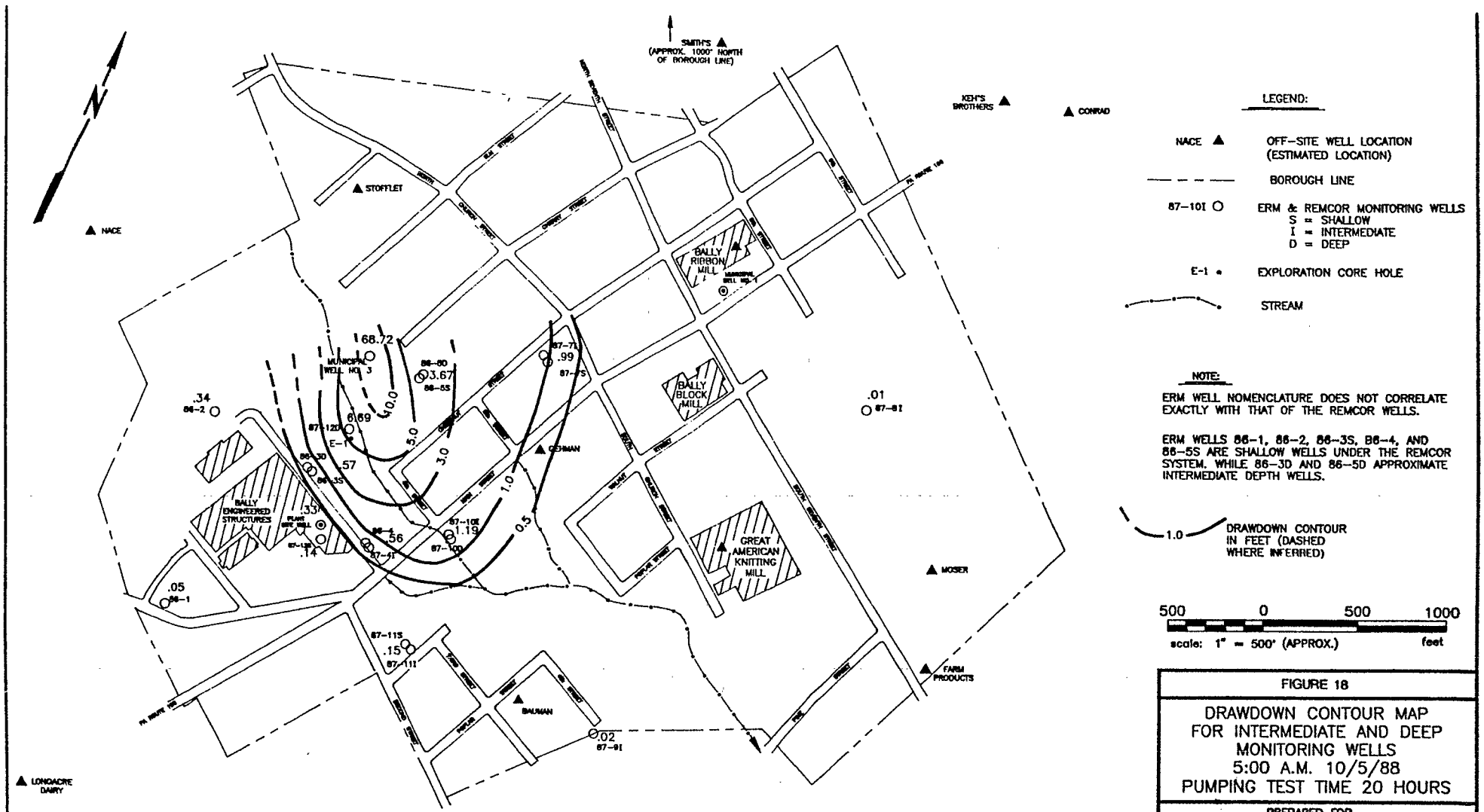
POTENTIOMETRIC SURFACE FOR INTERMEDIATE & DEEP MONITORING WELLS
9:00 A.M. OCTOBER 8, 1988
PUMPING TEST TIME 97 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	C.E.B. 10/28/88	DRAWING NUMBER
CHECKED	SGR 5-11-89	88548-B11
APPROVED		

REMCOR

AR301434



REFERENCE:
BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 18

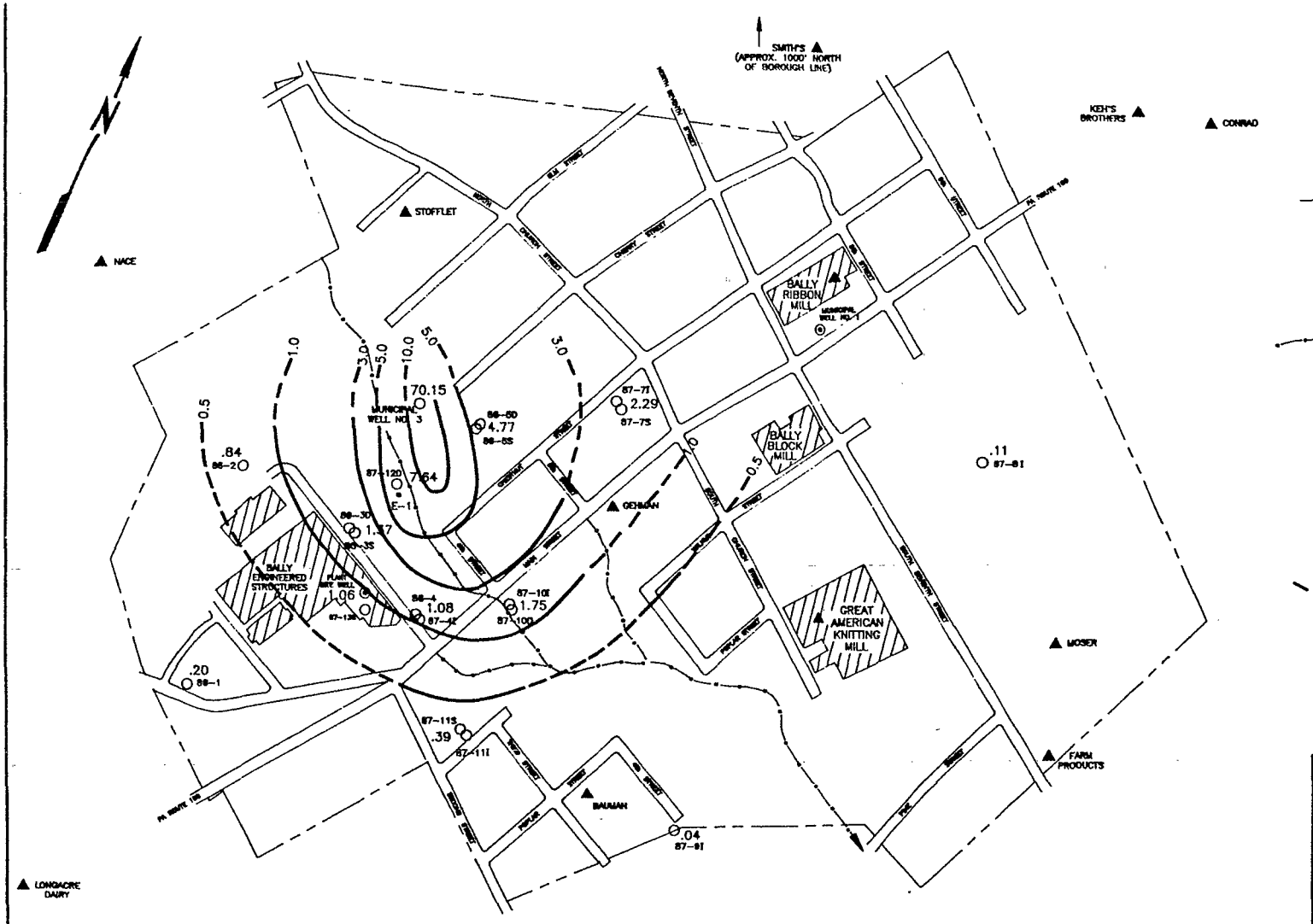
DRAWDOWN CONTOUR MAP FOR INTERMEDIATE AND DEEP MONITORING WELLS
5:00 A.M. 10/5/88
PUMPING TEST TIME 20 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	11-2-88 LHK	DRAWING NUMBER
CHECKED	P.V.S. 12/6/88	88548-B18
APPROVED		

REMCOR

AR301434A



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-101 ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

1.0 DRAWDOWN CONTOUR IN FEET (DASHED WHERE INFERRED)

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 19

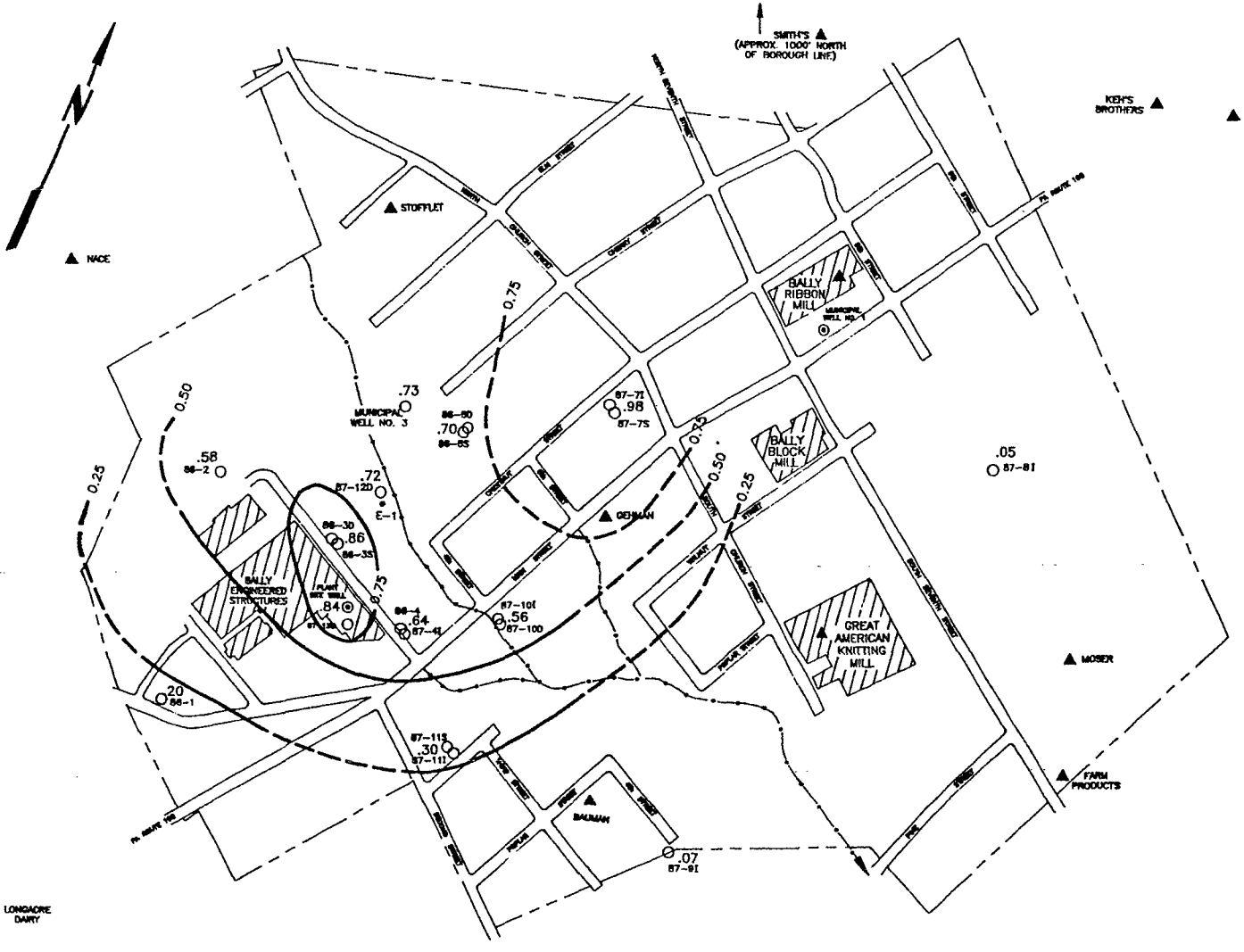
DRAWDOWN CONTOUR MAP FOR INTERMEDIATE AND DEEP MONITORING WELLS
9:10 A.M. 10/7/88
PUMPING TEST TIME 72 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	11-2-88 LHK	DRAWING NUMBER
CHECKED	P.V.S. 12/6/88	88548-B19
APPROVED		

REMCOR

AR301434B



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

1.0 — DRAWDOWN CONTOUR IN FEET (DASHED WHERE INFERRED)

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 20

RESIDUAL DRAWDOWN CONTOUR MAP FOR INTERMEDIATE AND DEEP WELLS
9:00 A.M. 10/8/88
PUMPING TEST TIME 97 HOURS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	11-2-88 LHK	DRAWING NUMBER
CHECKED	P.V.S. 12/6/88	88548-B20
APPROVED		

REMCOR

AR301434C

FIGURE 21
TIME/DRAWDOWN PLOT
MONITORING WELLS 87-7S AND 87-7I

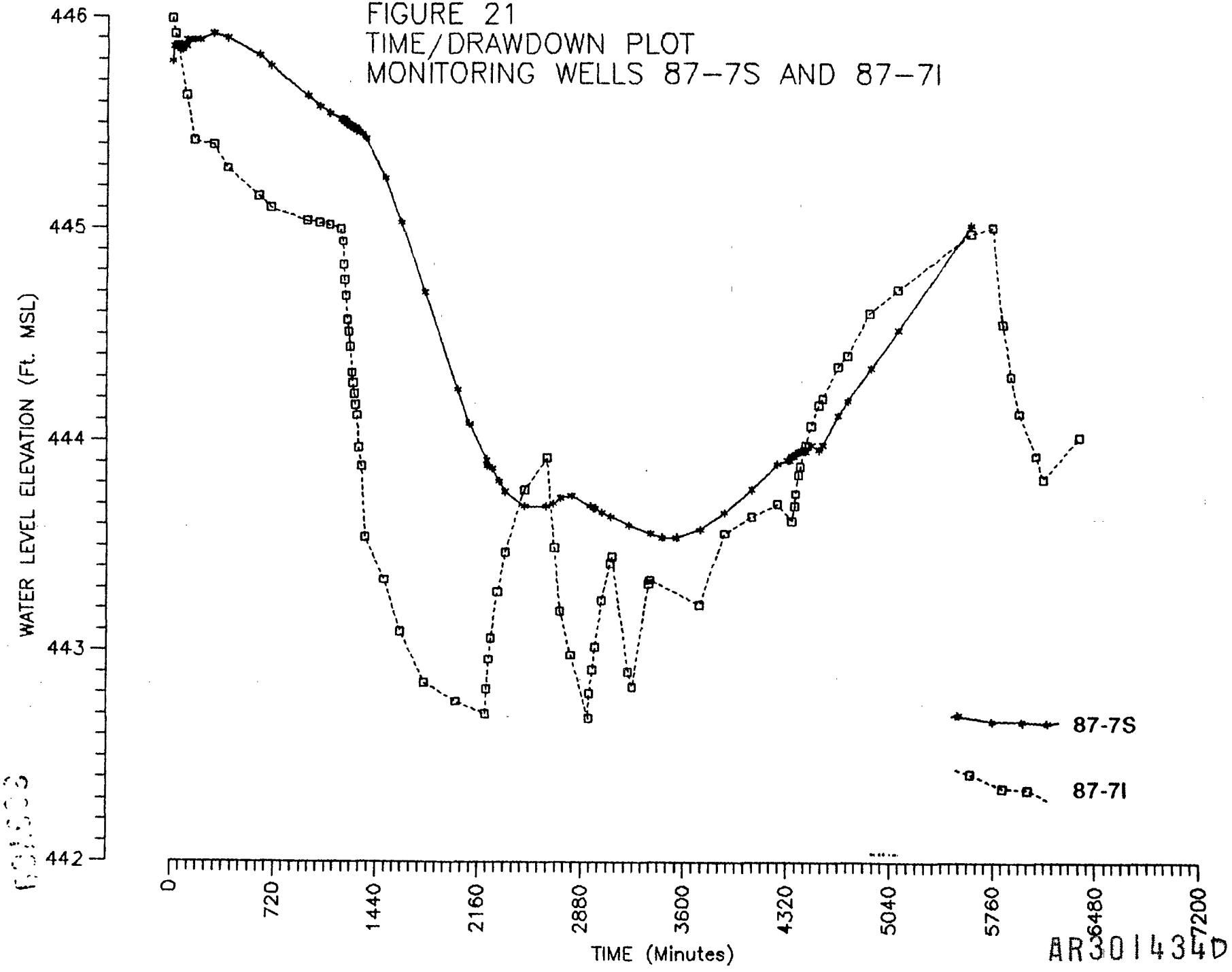
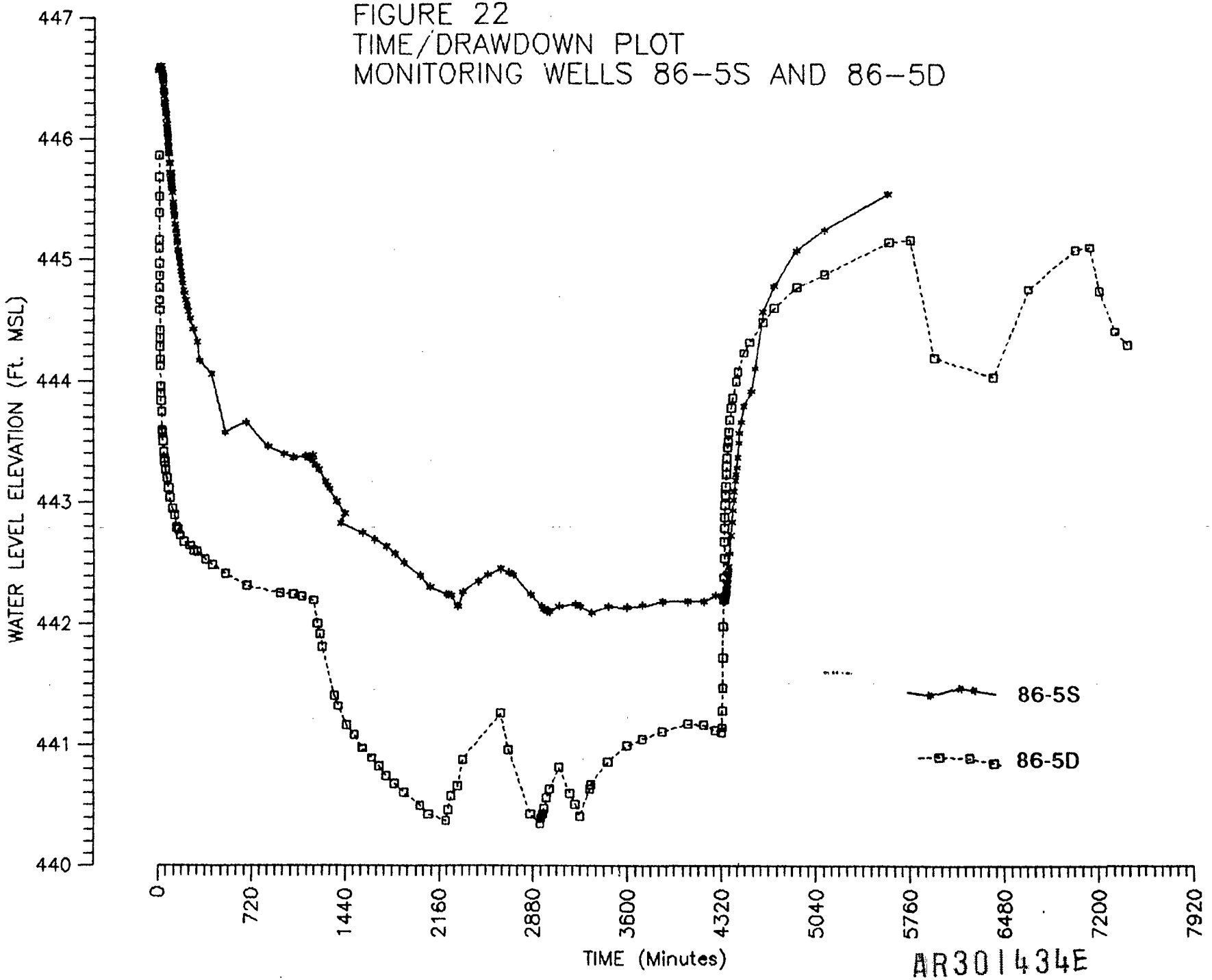
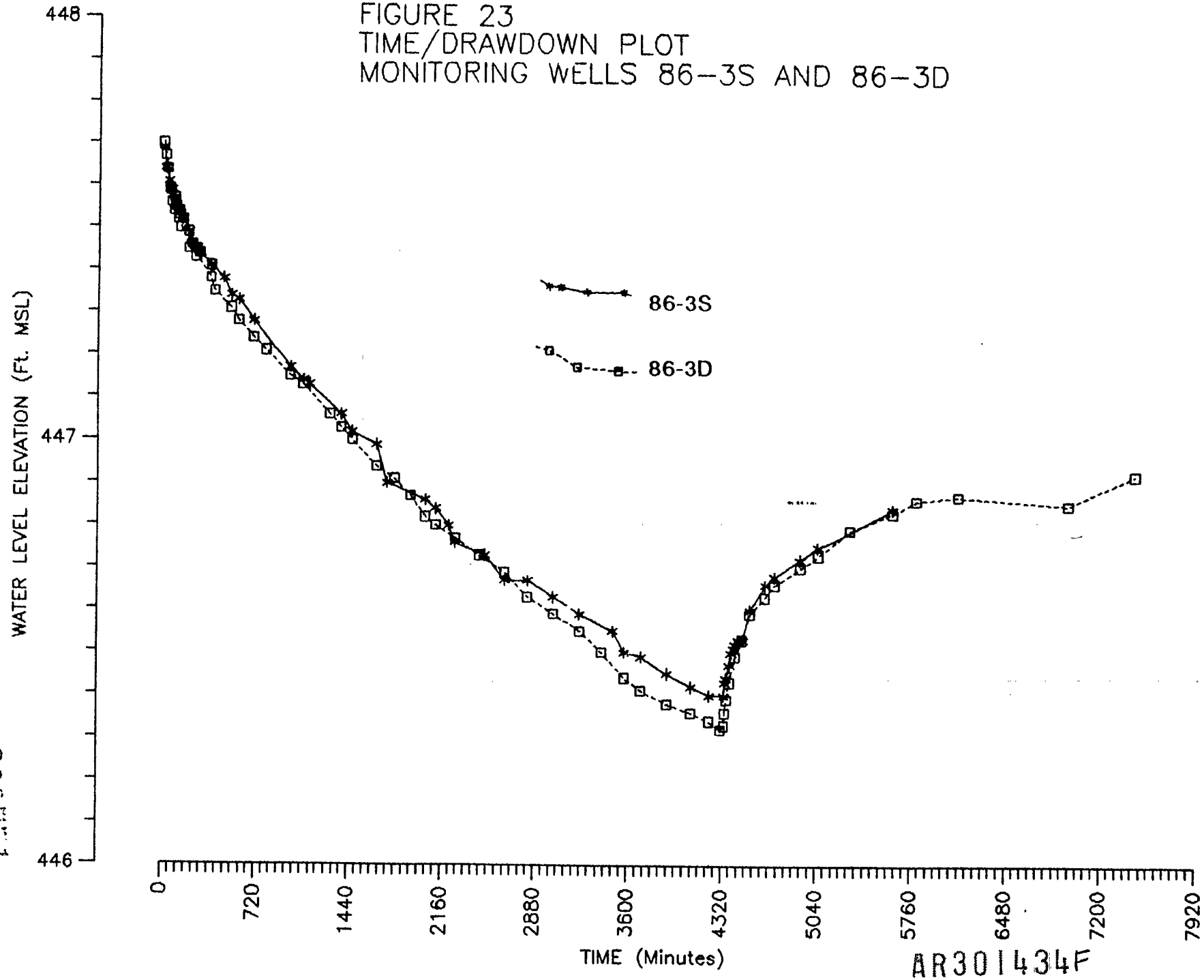


FIGURE 22
TIME/DRAWDOWN PLOT
MONITORING WELLS 86-5S AND 86-5D



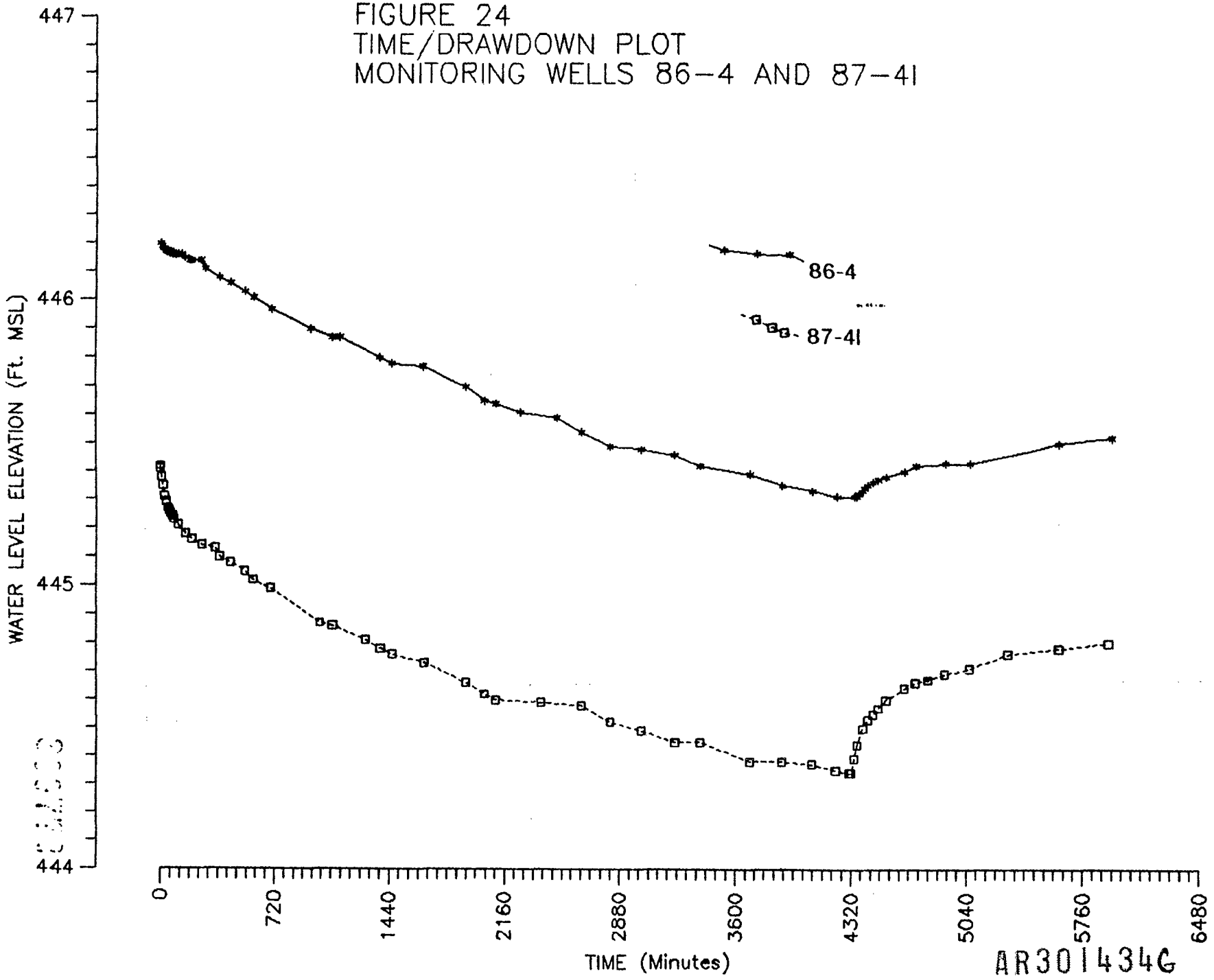
AR301434E

FIGURE 23
TIME/DRAWDOWN PLOT
MONITORING WELLS 86-3S AND 86-3D

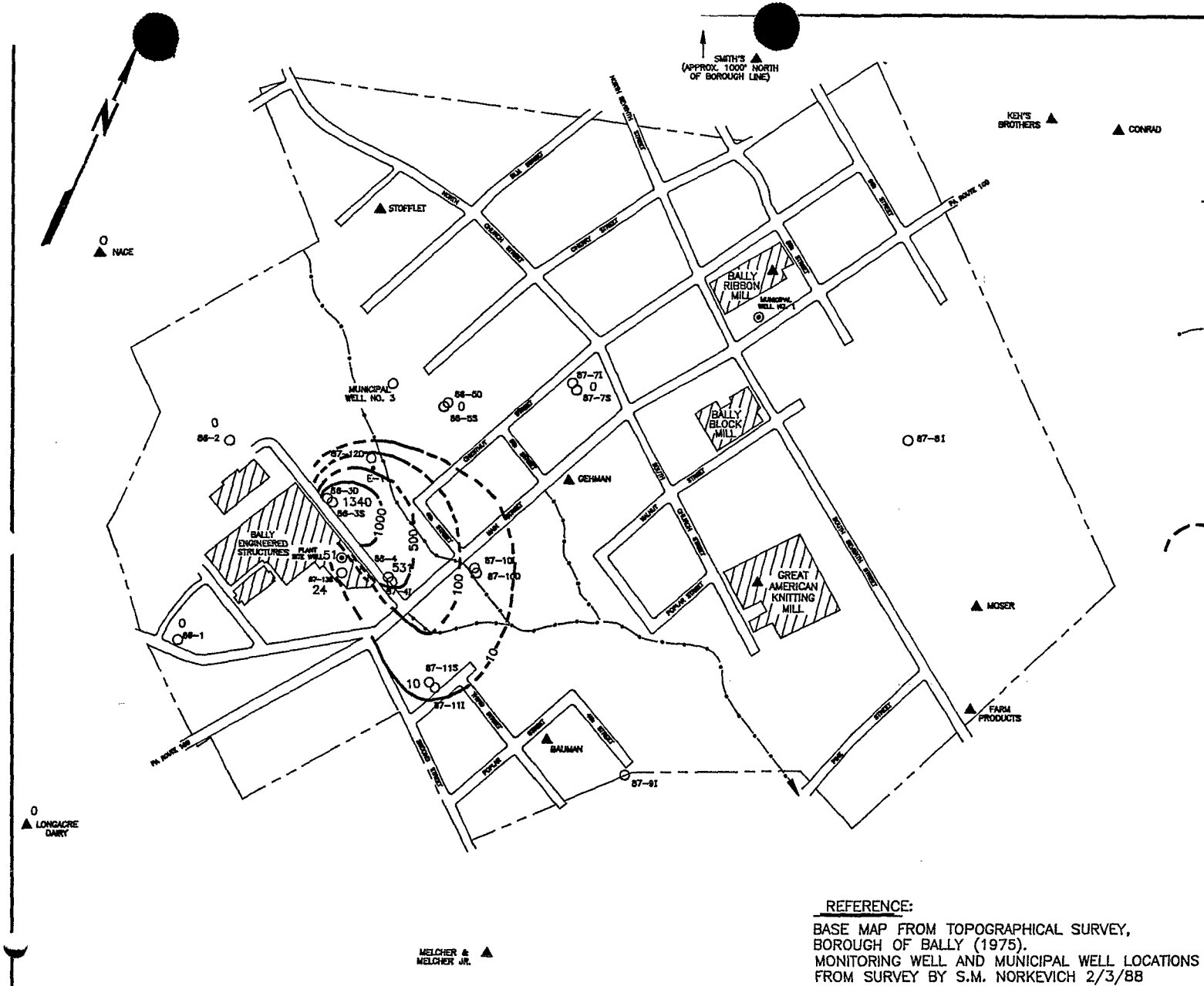


AR301434F

FIGURE 24
TIME/DRAWDOWN PLOT
MONITORING WELLS 86-4 AND 87-4I



AR301434G



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

ISOCONCENTRATION CONTOURS (DASHED WHERE INFERED) DATA IN PARTS PER BILLION

500 0 500 1000

scale: 1" = 500' (APPROX.) feet

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

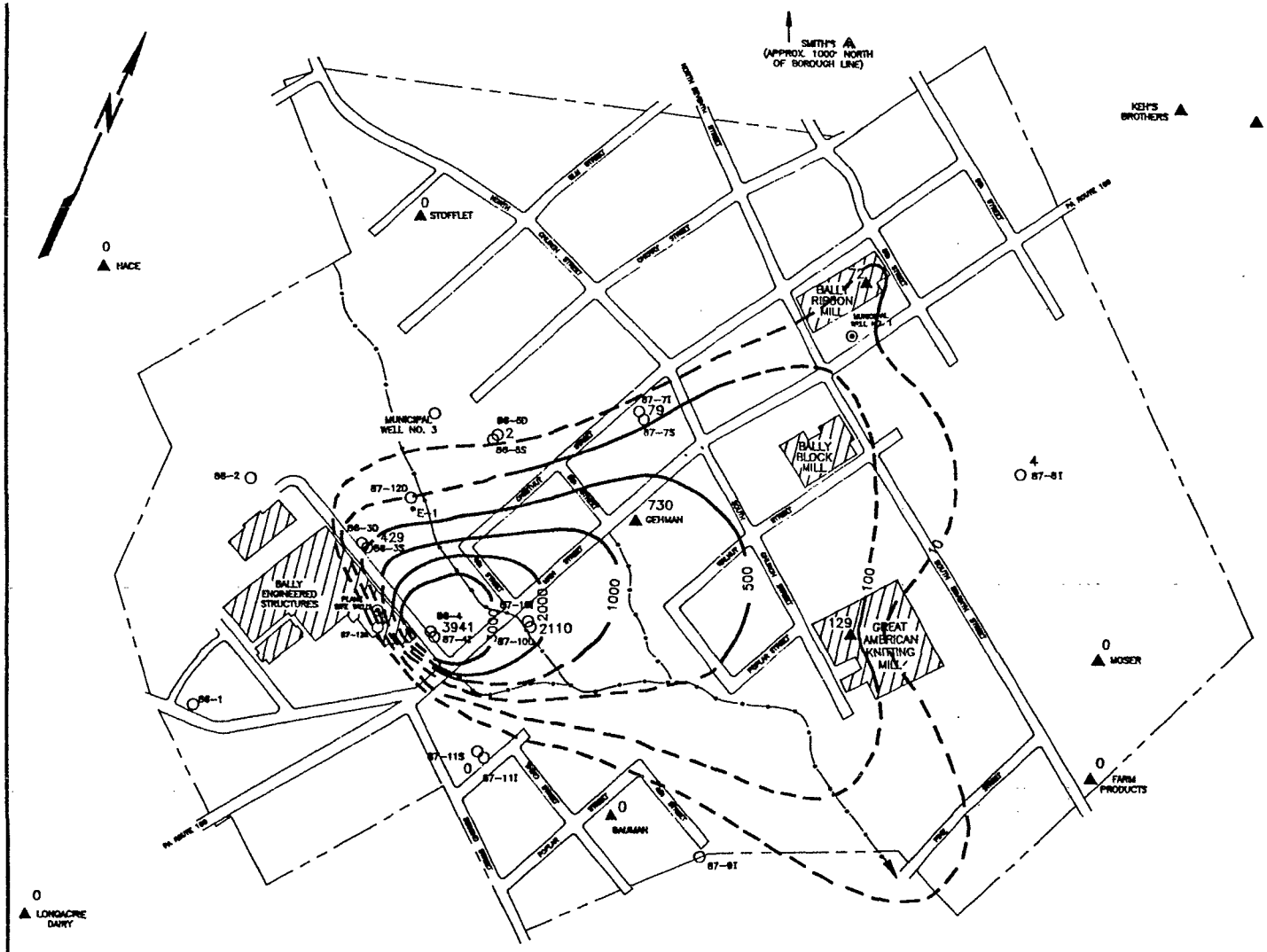
FIGURE 25

ISOCONCENTRATION OF TOTAL CHLORINATED VOLATILE ORGANICS SHALLOW DEPTH WELLS SAMPLED 1/88

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	10-31-88 LHK	JOB NO.
CHECKED	5-11-89 SGK	DRAWING NUMBER 88548-B15
APPROVED		

REMCOR



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-10I ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM. WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

ISOCONCENTRATION CONTOURS (DASHED WHERE INFERRED) DATA IN PARTS PER BILLION

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 26

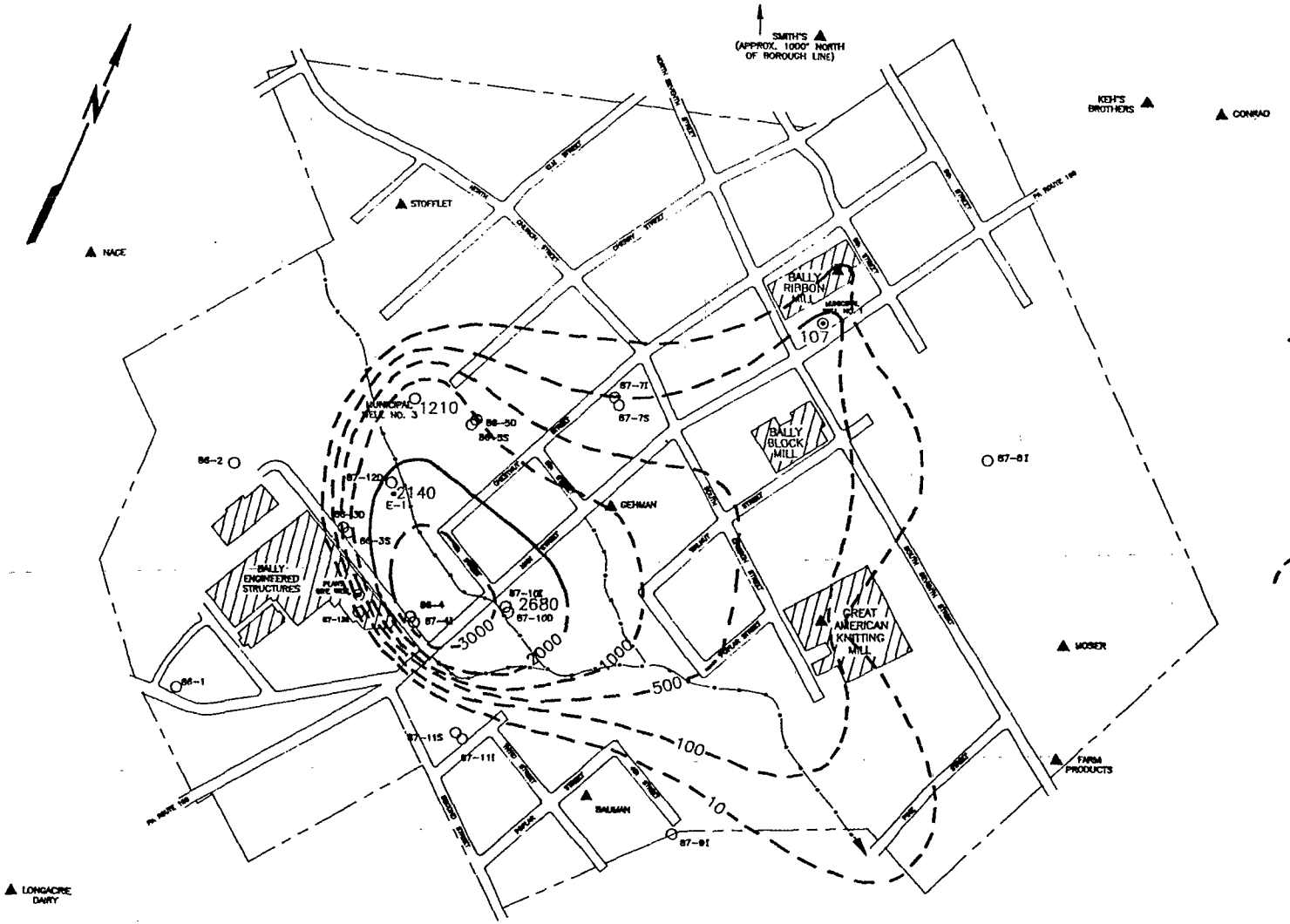
ISOCONCENTRATION OF TOTAL CHLORINATED VOLATILE ORGANICS IN INTERMEDIATE DEPTH WELLS SAMPLED 1/88

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	11-1-88 LHK	DRAWING NUMBER
CHECKED	P.U.S. 12/6/88	88548-B16
APPROVED		

REMCOR

AR301435A



LEGEND:

NACE ▲	OFF-SITE WELL LOCATION (ESTIMATED LOCATION)
— — — —	BOROUGH LINE
87-101 ○	ERM & REMCOR MONITORING WELLS S = SHALLOW I = INTERMEDIATE D = DEEP
E-1 •	EXPLORATION CORE HOLE
	STREAM

NOTE:

ERM WELL NOMENCLATURE DOES NOT CORRELATE EXACTLY WITH THAT OF THE REMCOR WELLS.

ERM WELLS 86-1, 86-2, 86-3S, 86-4, AND 86-5S ARE SHALLOW WELLS UNDER THE REMCOR SYSTEM, WHILE 86-3D AND 86-5D APPROXIMATE INTERMEDIATE DEPTH WELLS.

ISOCONCENTRATION CONTOURS (DASHED WHERE INFERRED) DATA IN PARTS PER BILLION

500 0 500 1000 feet

scale: 1" = 500' (APPROX.)

REFERENCE:

BASE MAP FROM TOPOGRAPHICAL SURVEY, BOROUGH OF BALLY (1975).
MONITORING WELL AND MUNICIPAL WELL LOCATIONS FROM SURVEY BY S.M. NORKEVICH 2/3/88

FIGURE 27

ISOCONCENTRATION OF TOTAL CHLORINATED VOLATILE ORGANICS IN DEEP WELLS SAMPLED 1/88

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	11-2-88 LHK	DRAWING NUMBER
CHECKED	P.V.S. 12/6/89	88548-B17
APPROVED		

REMCOR

AR301436

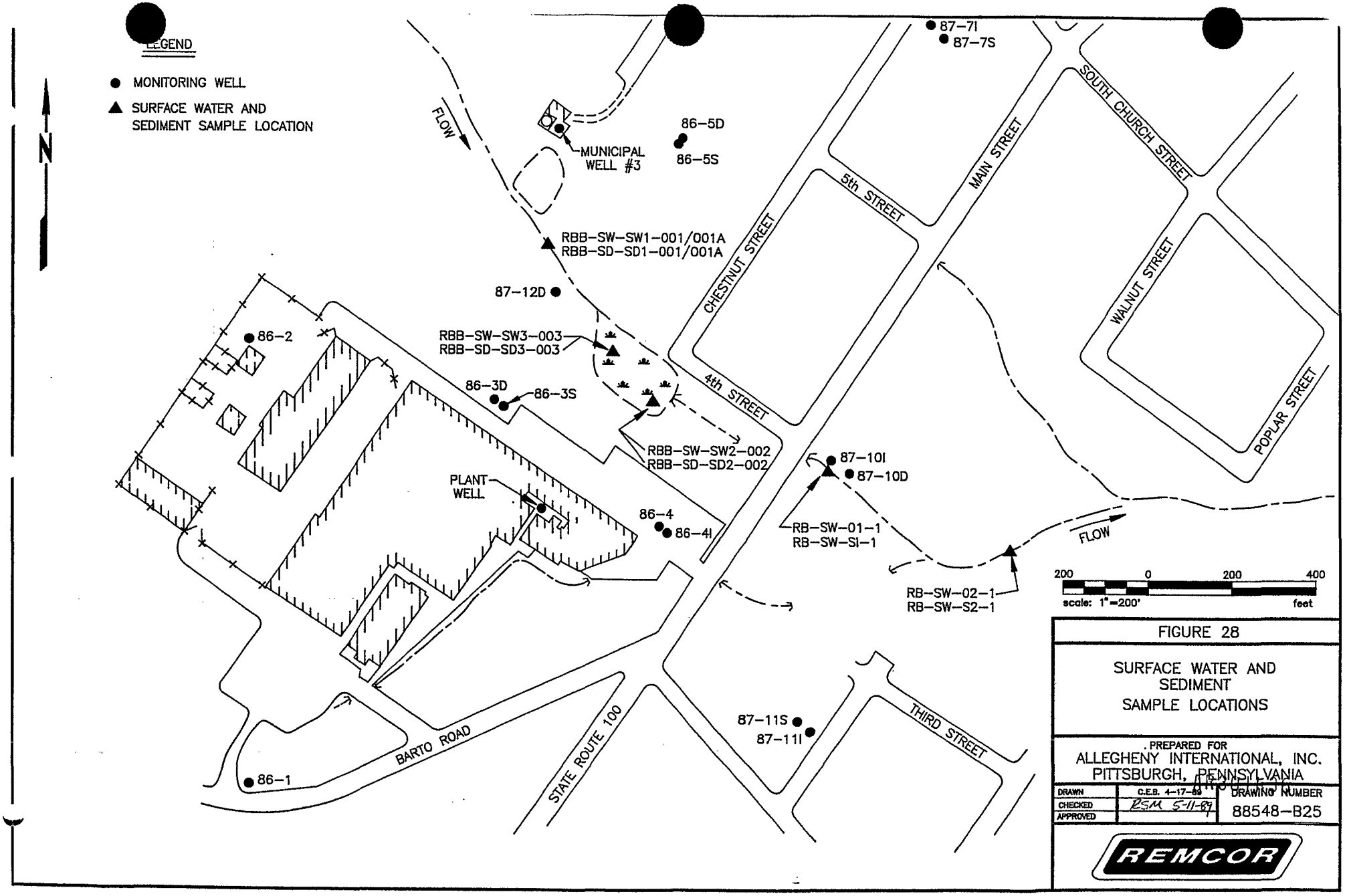


FIGURE 28

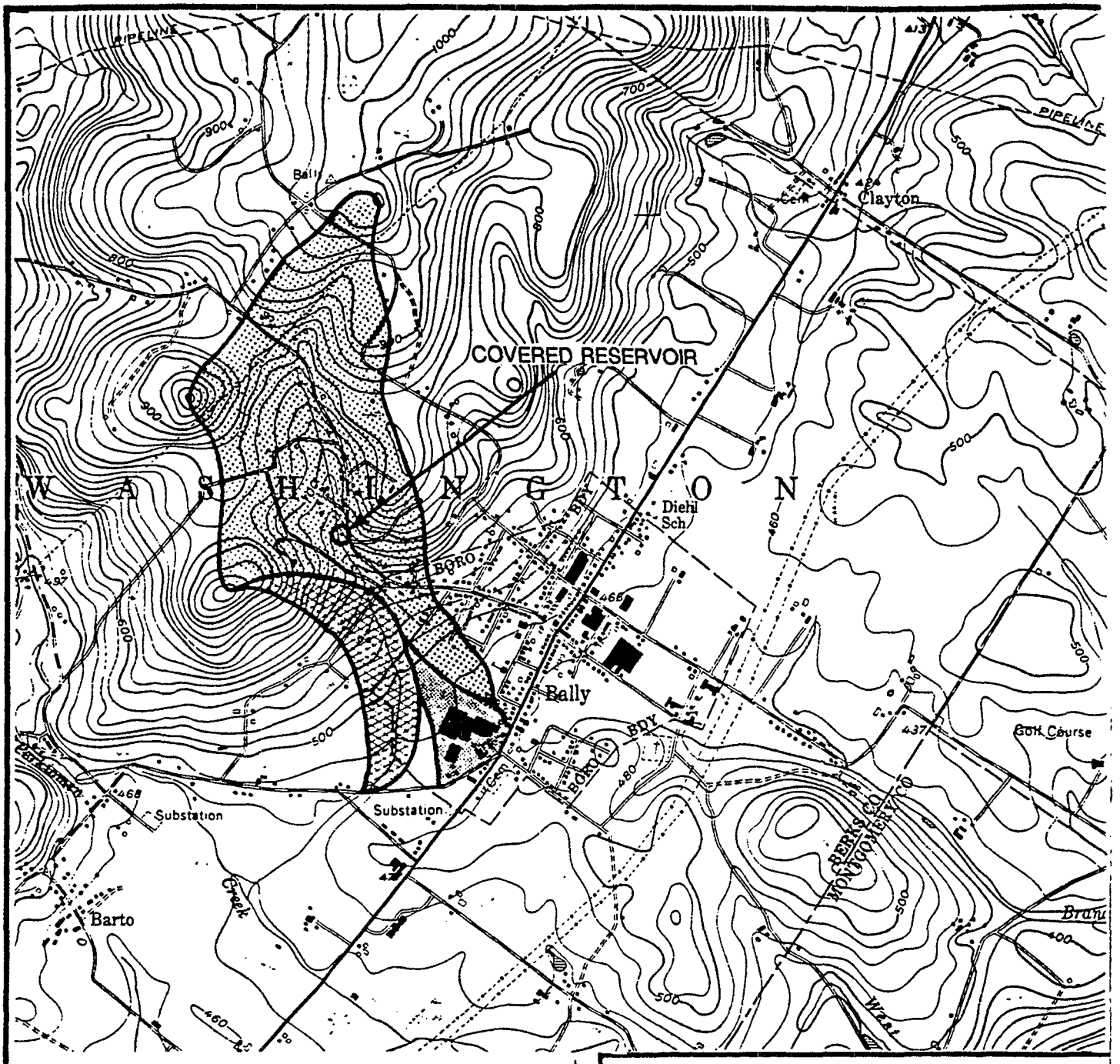
SURFACE WATER AND SEDIMENT SAMPLE LOCATIONS

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	C.E.B. 4-17-89	DRAWING NUMBER
CHECKED	RSM 5-11-89	88548-B25
APPROVED		

REMCOR

AR301436-A



2000 0 2000 4000

scale feet

REFERENCE:

USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE, EAST GREENVILLE, PA, 1956, PHOTOREVISED 1969 AND 1973. SCALE 1:24000

LEGEND:

- DRAINAGE AREA - FORMER IMPOUNDMENT
- DRAINAGE AREA - BES AREA
- DRAINAGE AREA - UNNAMED TRIBUTARY TO SOUTHWES

AR301437

FIGURE 29

SURFACE DRAINAGE FEATURES

PREPARED FOR
ALLEGHENY INTERNATIONAL, INC.
PITTSBURGH, PENNSYLVANIA

DRAWN	LBL 12/1/88	DRAWING NUMBER
CHECKED	PJC 12/1/88	88548-A4
APPROVED		

REM

AR301437-A

28579

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APPENDIX B
BORING LOGS

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation	
BORING NUMBER: SS-16	COORDINATES:	DATE: 3/23/89
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/11/89
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/11/89
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS 16-1	8	60	Black top Gravel Fill with Petroleum odor		9.4	SAMPLE RB-SS-16-1
	SS	50/5	5	DARK GRAY, HARD, MOIST SILT AND SAND	ML-SM	0.0	
5	SS	33	40	RED BROWN, VERY DENSE, DAMP SILT AND SAND with Quartz & GNEISS FRAGMENTS	SM	0.6	
	SS 16-2	69	50	RED / BROWN VERY DENSE DAMP SILT AND SAND WITH ROCK FRAGMENTS	GM-SM	6.0	SAMPLE RB-SS-16-2
10	SS 16-3	69	60			1.5	SAMPLE RB-SS-16-3
	SS	108	60			1.5	WATER AT 11.8'
				Total Depth of Boring = 12.0'			
15							
20							
25							

NOTES:

All blows are measure using 300 lb hammer

Headspace scan = 0.0 ppm (measured 2 and 3 Days after Drilling)

Boring Backfilled with cuttings, cement and Bentonite with Black Top Patch

AR301442

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-17	COORDINATES:	DATE. 3/22/89	
ELEVATION:	GWL: Depth 12.75 Date/Time 3/9/89 1400	DATE STARTED: 3/7/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED. 3/8/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS 17-1	33	60	Red Brown, Dense, damp, silt and fine sand, trace pebbles	SM	0.4	SAMPLE RB-SS-17-1
	SS	100/5	5	Biotite Gneiss fragments (colluvium)	GM	0.8	
5	SS 17-2	44	60	Red Brown, Dense, damp-dry, silt and medium sand, some Rock fragments	SW-SM	—	SAMPLE RB-SS-17-2
	SS	55	80			0.0	
	SS 17-3	82	70	- Tan silt and sand with trace clay and pebbles		0.2	SAMPLE RB-SS-17-3
10	SS	36	90	Red Brown, hard, damp-moist silt and fine sand with Rock fragments	ML-SM	—	
	SS	42	50			—	
15	SS	20	10	-sand coarse @ 15'		0.0	← water @ 14.0'
20				Total Depth of Boring = 20.0'			
25							

AR301443

NOTES:

Installed Temporary piezeometer in boring to collect ground water sample

See Piezeometer installation diagram for piezeometer construction details.

At completion of investigation retrieved Rizer [illegible]

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-18	COORDINATES:	DATE. 3/23/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/10/89	
ENGINEER/GEOLOGIST. D. Crowley	Depth Date/Time	DATE COMPLETED. 3/10/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft.)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER 1 Foot	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	45	50	Red/Brown, Hard, Damp to moist silt and sand with rock fragments	ML-SM	0.0	
	SS	50	70			0.2	
5	SS	15	0			0.0	
	SS	41	0	— — — ? — — — — — ? Red/Brown, V. Dense, wet silt and sand	SM	0.0	← Near by Roof drain could be contributing to presence of water
	SS	22	10			0.0	
10	SS	9	50	Red Brown, Dense to very dense, damp to moist, silt, sand, and rock fragments	SM-GM	1.0	
	SS 18-1	23	60			1.2	SAMPLE RB-SS-18-1
15	SS 18-2	13	60				← WATER @ 14.5'
						0.8	SAMPLE RB-SS-18-2
				↑ Total Depth of Boring = 16.0'			
20							
25							

NOTES:

All blows are measured using 300 lb. hammer

Headspace scan : 4.0 ppm (measured one day after drilling)

Boring Backfilled with cuttings, cement, and bentonite powder to ground surface.

AR301444

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-19	COORDINATES:	DATE: 3/22/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/9/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/9/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	100/3	15	Red/Brown, Hard silt & sand fill			
	SS	42	10	Red/Brown, Very stiff to Hard, Damp silt and sand	ML-SM	0.2	
5	SS	13*	80			0.0	
	SS 19-1	18*	100			1.2	
						2.2	SAMPLE RB-SS-19-1
	SS	17	30	RED/BROWN, VERY DENSE, DAMP SILT WITH ROCK FRAGMENTS AND FINE SAND	SW	0.2	
10	SS	12*	90	SANDY MOIST TO WET LENS		2.0	
	SS	10	70	- SAMPLE MOIST TO WET		2.5	WATER @ 14.5
15	SS 19-2	6	60			10.0	SAMPLE RB-SS-19-2
				Total Depth of Boring = 16.0'			
20							
25							

AR301445

NOTES:

Boring headspace scan 0.8 ppm (measured one day after drilling)

Boring Backfilled with cuttings, cement, powder bentonite to surface then patched blacktop.

* Split spoon sample collected using 300 lb Hammer instead of 140 lb

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-20	COORDINATES:		DATE: 3/23/89
ELEVATION:	GWL: Depth	Date/Time	DATE STARTED: 3/13/89
ENGINEER/GEOLOGIST: D. Crowley	Depth	Date/Time	DATE COMPLETED: 3/13/89
DRILLING METHODS: Hollow Stem Auger w/continuous sampling			PAGE 1 OF 1

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
				DARK GRAY SHALE FILL			
	SS	31	50	RED BROWN, Medium Dense to Dense, Damp, SILT AND SAND WITH ROCK FRAGMENTS		0.0	
	SS	13	80			0.0	
5	SS	10	80		SM-ML	0.0	
	SS	11	75			0.0	
	SS	13	20			0.0	
10	SS	14	0			—	
	SS	16	75	- SAMPLE MOIST		0.0	
15	SS 20-1	9	100			0.0	WATER AT 15.0' SAMPLE RB-SS-20-1
				Total Depth of Boring = 16.0'			
20							
25							

AR301446

NOTES:

All blows are measured using 300 lb hammer

Headspace Scan 0.0ppm measured 1 day after drilling

Boring backfilled with cuttings, cement, and bentonite with Blacktop patch at surface

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-21	COORDINATES:	DATE: 3/23/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/14/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/14/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (FT)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	30	60	Dark Gray Shale Fill			
	SS	40	50	RED BROWN, VERY DENSE, MOIST SILT AND SAND AND GRAVEL	SM	0.2	
5	SS	8	60	RED BROWN VERY STIFF TO HARD DAMP SILT AND SAND WITH SOME CLAY AND INCREASING AMOUNTS OF ROCK FRAGMENTS WITH DEPTH	ML-SM	0.0	
	SS	17	100			0.0	
10	SS	23	100			0.0	
	SS	18	80			0.0	
	SS 21-1	23	100			0.2	SAMPLE RB-SS-21-1
15	SS 21-2	17	100			0.0	WATER AT 15.5' SAMPLE RB-SS-21-2
20							
25							

NOTES:

All blows are measured using 300 lb hammer

Boring Backfilled with cuttings, cement, and bentonite with Black top patch at surface.

AR301447

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-22	COORDINATES:	DATE. 3/22/89	
ELEVATION:	GWL: Depth 20.40 Date/Time 3/9/89 1400	DATE STARTED: 3/7/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED. 3/7/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	48	50	Red/yellow, DENSE TO VERY DENSE damp silt and fine sand with trace clay	SM	0.0	
	SS 22-1	45	75			0.0	SAMPLE RB-SS-22-1
5	SS 22-2	18	75			1.0	SAMPLE RB-SS-22-2
	SS	23	80	Red/brown, DENSE to Hard, moist to damp silt and fine sand with Rock fragments	SW	0.0	
	SS	22	80			0.0	
10	SS 22-3	18	50	MOIST SILT LENS		0.0	SAMPLE RB-SS-22-3
	SS	34	0			—	
15	SS	24	0			—	
	SS	39	10			0.0	
	SS 22-4	16	70	Red Brown, very stiff, wet silt and sand	SM-ML	0.0	WATER @ 19.8' Sample RB-SS-22-4
20	SS	21	10			0.0	
25	SS	50	60	some Rock fragments @ 25 ft.		0.0	
				Total depth of Boring = 28.0'			

AR301448

NOTES:

Installed Temporary piezeometer in boring to collect ground water sample.

SEE Piezeometer installation diagram for piezometer construction details

AT COMPLETION OF Investigation, Piezometer WAS Retrieved, PVC screen broke AND WAS BACKFILLED WITH BENTONITE PELLETS. Boring WAS BACKFILLED

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-23	COORDINATES:	DATE: 3/23/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/10/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/10/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	22	40	Red/Brown, Hard, Damp, silt + sand fill w/ Rock fragments		0.0	
	SS	13	50	Red/Brown, Stiff, Damp, silt-clay	ML-CL	0.2	
5	SS	18	100	Red/Brown, Dense-V. Dense, Damp silt and sand some Rock fragments		0.2	
	SS	18	80			0.2	
10	SS 23-1	18	70		SM	1.0	Sample RB-SS-23-1
	SS	10	80	- Some clay, trace Rock fragments		0.2	
	SS	16	90	- Some Rock fragments		0.4	
15	SS	13	80			0.4	
	SS	15	100			0.2	
20	SS 23-2	12	100	- Moist in 18-20 sample		0.4	Sample RB-SS-23-2
	SS	10	50	- Wet		0.2	Water @ 20.0'
				Total Depth of Boring = 22.0'			
25							

AR301449

NOTES:
All blows are measured using 300 lb hammer
Headspace scan = 8.0 ppm (measured one day after drilling)
Boring backfilled with cuttings, cement, and bentonite to ground surface

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-24	COORDINATES:	DATE. 3/23/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED 3/13/89	
ENGINEER/GEOLOGIST. D. Crowley	Depth Date/Time	DATE COMPLETED 3/13/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft.)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER 1 Foot	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	10	100	RED BROWN VERY STIFF DAMP SILT AND FINE SAND	ML	0.0	
	SS	82	60	RED BROWN, HARD, DAMP SILT SAND AND BIOTITE GNEISS FRAGMENTS.	ML-SM	0.0	
5	SS	50/6	40			0.0	
	SS	14	70	RED BROWN, VERY STIFF, DAMP SILT AND SAND	ML	0.2	
	SS	31	60	TAN MED. DENSE, DAMP SAND AND Quartz Fragments	SP	0.0	
10	SS	10	70	RED BROWN, STIFF TO VERY STIFF SILT AND CLAY AND SAND WITH ROCK FRAGMENTS		0.0	
	SS	20	80			0.0	
15	SS 24-1	15	100			0.0	SAMPLE RB-SS-24-1
	SS	24	100	- MOIST AT 17.8'	ML-SM	0.0	
20	SS 24-2	14	100			0.0	SAMPLE RB-SS-24-2
	SS	16	0			—	
	SS	19	40	- MOIST AT 23.5		0.0	
25	SS 24-3	7	80	- WET AT 24.6		0.0	SAMPLE - RB-SS-24-3
				Total Depth of Boring = 26.0			

AR301450

NOTES:

All blows are measured using 300 lb hammer

Headspace SCAN = 0.0 1 DAY after Drilling

Boring Backfilled with cuttings, cement and bentonite to Ground Surface

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-25	COORDINATES:	DATE. 3/23/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/13/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED. 3/13/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER 1 Foot	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	11	80	RED BROWN, STIFF, DAMP, SILT AND SAND TRACE GRAVEL		0.0	
	SS	10	20		ML-SM	0.0	
5	SS	4	15			0.0	
	SS	24	10	TAN, DENSE, WET-MOIST SAND AND ROCK FRAGMENTS (GNEISS)	SP	0.0	
	SS	12	5	RED BROWN, VERY STIFF TO HARD, MOIST TO WET SILT AND SAND		0.0	
10	SS	11	5			0.0	
	SS	24	50	-DAMP AT 12.5'	ML-SM	0.0	
15	SS	16	100	-ROCK FRAGMENTS AT 16.0		0.0	
	SS	16	80			0.0	
20	SS 25-1	26	60			0.0	WATER AT 19.5' SAMPLE RB-SS-25-1
				Bottom of Boring at 20'			
25							

NOTES:

All blows are measured using 300 lb. hammer

Headspace scan 0.0 1 DAY after Drilling

Boring Backfilled with cuttings, cement and bentonite

AR301451

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-26	COORDINATES:	DATE: 3/22/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/9/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/9/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft.)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER 1 Foot	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	16	25	Red/Brown, Stiff, damp, silt and fine sand with Trace clay and Trace Rock fragments	ML	0.0	
	SS	100/5	60	Red/Brown silt and Gneissic Rock fragments (DAMP)	GM	0.0	
5	SS	44	80	Red/Brown, Hard, damp, silt and sand		0.0	
	SS 26-1	44	80	- Damp to wet in alternating layers of less silty material with Rock fragments		0.0	SAMPLE RB-SS-26-1
10	SS	31	50	-DAMP CONDITIONS to 21.3'	ML-SM	0.0	
	SS	35	60			0.0	
	SS	43	100			0.1	
15	SS	22	85	- Trace clay		0.2	
	SS	39	90			0.0	
	SS	50	80			0.0	Water @ 21.3'
20	SS 26-2	42	75			0.0	SAMPLE RB-SS-26-2
				Total Depth of Boring 22.0'			
25							

AR301452

NOTES:

Boring Headspace SCAN 0.0 ppm (measured day after drilling)

Boring Backfilled with cuttings, cement, and powder Bentonite with layer of bentonite pellets at wet zone near 7'.

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: DAGAN Inc., Source Investigation		
BORING NUMBER: SS-27	COORDINATES:	DATE. 3/22/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/9/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED. 3/9/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER 1 Foot	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS 27-1	29	90	Red/TAN, Very Stiff, MOIST, SILT AND FINE SAND AND TRACE TO SOME CLAY	ML	0.4	SAMPLE RB-SS-27-1
	SS	122	100	RED/Brown, V. DENSE, DAMP-WET SILT AND GNEISSIC Rock Fragments	GM	0.1	
5	SS 27-2	73	60	RED/BROWN, Hard, DAMP silt and SAND	ML-SM	0.6	Minor water @ 4' SAMPLE RB-SS-27-2
	SS	26	10	- WET IN 6.0-8.0 SAMPLE		0.0	
	SS	40	50	Red, Hard, DAMP, SILT AND CLAY WITH TRACE SAND	ML	0.2	
10	SS	24	80	Red/Brown, Very Stiff to Hard, DAMP, silt and fine to coarse SAND		0.0	
	SS	54	10			0.0	
15	SS	31	70	- some Rock fragments	ML-SM	0.0	
	SS 27-3	58	60			0.0	SAMPLE RB-SS-27-3
20	SS	98	70	- SOME CLAY - wet @ 20'		0.0	Water @ 20.0'
	SS 27-4	82	40			0.1	SAMPLE RB-SS-27-4
				Total Depth of Boring = 20.0'			
25							

AR301453

NOTES:
- Collected small sample of water encountered at 4' for Headspace screening
  - After one hour Headspace scan of water = 7.0 ppm
- Boring headspace scan 0.0 ppm (measured one day after drilling)
- Boring backfilled with cuttings, cement, powder bentonite and pelletized bentonite @ wet zone between 4 and 5'

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-28	COORDINATES:	DATE: 3/23/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/10/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/10/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	23	60	RED BROWN stiff, silty sand, with ORGANIC MATERIAL (TOPSOIL)			
	SS	50/4	50	RED/BROWN V. STIFF TO HARD, DAMP SILT AND FINE SAND WITH TRACE CLAY	ML	0.4	
				RED/TAN SILT AND SAND DAMP WITH ROCK FRAGMENTS	GM	0.0	
5	SS 28-1	39	50	RED/TAN, HARD, DAMP, SILT AND SAND		0.2	SAMPLE RB-SS-28-1
	SS	71	50	-SOME GNEISS FRAGMENTS	ML-SM	0.2	
	SS	32	50	-MOIST		0.2	
10	SS	20	10	RED/BROWN, DENSE, MOIST TO DAMP, MOTTLED SILT AND SAND WITH ABUNDANT ROCK FRAGMENTS		0.2	
	SS	26	10			0.0	
15	SS	15	50		SM-GM	0.0	
	SS	19	80			0.0	
	SS 28-2	17	60			0.8	WATER @ 18.0' SAMPLE RB-SS-28-2
20				Total Depth of Boring = 20.0'			
25							

AR301454

NOTES:
All blow counts are measured using 300 lb Hammer
Head space scan = 0.8 ppm (measured one day after drilling)
Boring Backfilled with cuttings, cement, Bentonite to ground surface.

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation	
BORING NUMBER: SS-29	COORDINATES:	DATE: 3/22/89
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/8/89
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/8/89
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER 1 Foot	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	13	5	Dark brown, stiff, organic rich silt (topsoil)	ML	0.0	
	SS	100/5	40	Red Brown, very dense, damp to dry silt and sand with tan Biotite Gneiss fragments	GW	0.0	
5	SS	100/4	0			0.0	
	SS	100/5	5			0.0	
	SS 29-1	24	70			0.0	SAMPLE RB-SS-29-1
10	SS	27	60	Red/Brown, very stiff, damp, silt and fine sand w/ some rock fragments	ML-SM	0.0	
	SS 29-2	35	90			0.0	SAMPLE RB-SS-29-2
15	SS	30	50			—	
							Water @ 16.0'
	SS 29-3	36	70			—	SAMPLE RB-SS-29-3
				Total Depth of Boring = 18.0'			
20							
25							

NOTES:

Boring Headspace scan 0.0 ppm (measured day after drilling)

Boring Backfilled with cuttings, cement, and Bentonite powder to ground surface

AR301455

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation		
BORING NUMBER: SS-30	COORDINATES:	DATE: 3/23/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/11/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/11/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft.)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	32	50	RED/TAN, HARD, DRY, SILT, SAND AND GRAVEL FILL		0.0	
	SS	57	60	RED/BROWN, V. DENSE, DRY, SILT AND SAND AND GNEISS GRAVEL	SM	0.0	
5	SS 30-1	60	60			0.2	SAMPLE RB-SS-30-1
	SS	19	60	RED/BROWN, DENSE, DAMP, SILT AND SAND TRACE ROCK FRAGMENTS	SM	0.0	
	SS	19	80	- MOIST AT 8.0-8.5 - QUARTZ FRAGMENTS @ 9.0-9.2		0.0	
10	SS 30-2	16	80			0.8	SAMPLE RB-SS-30-2
	SS 30-3	27	100			3.0	SAMPLE RB-SS-30-3
15	SS	40	60			0.0	← WATER AT 14.8'
				↖ Total Depth of Boring 16.0'			
20							
25							

NOTES:

All blows are measured using 300 lb hammer

Headspace Scan = 0.0 ppm (MEASURED 2 DAYS AFTER DRILLING)

Boring Backfilled with cuttings, cement and bentonite with Black Top patch

AR301456

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: Dagan Inc., Source Investigation	
BORING NUMBER: SS-31	COORDINATES:	DATE: 3/23/89
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/11/89
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED: 3/11/89
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	12	50	Dense Gravel Fill			
	SS	43	0	Red/Brown VERY DENSE DAMP silt and sand and Biotite Gneiss Fragments	SM	0.0	
						0.0	← Piece of Gneiss in shoe of sampler
5	SS	16	70	RED/BROWN VERY DENSE DAMP SILT AND SAND AND TRACE ROCK FRAGMENTS		0.2	
	SS	26	50		SM-GM	0.2	
	SS	53	70	- moist w/ Quartz-Gneiss FRAGMENTS		0.0	
10	SS	43	50			0.0	
	SS 31-1	22	50	-PREDOMINANTLY SILT AND SAND AT 12.0' -some GRAVEL		0.4	← Water @ 12.0' ← SAMPLE RB-SS-31-1
				← Total Depth of Boring = 14.0'			
15							
20							
25							

AR301457

NOTES:

All blows are measured using 300 lb hammer

Headspace scan = 0.0 (measured 2 days after Drilling)

Boring Backfilled with cuttings, cement, and bentonite with Black top patch.

REMCOR

VISUAL CLASSIFICATION OF SOILS

PROJECT NUMBER: 88835.1	PROJECT NAME: DAGAN Inc., Source Investigation		
BORING NUMBER: SS-32	COORDINATES:	DATE. 3/22/89	
ELEVATION:	GWL: Depth Date/Time	DATE STARTED: 3/8/89	
ENGINEER/GEOLOGIST: D. Crowley	Depth Date/Time	DATE COMPLETED. 3/8/89	
DRILLING METHODS: Hollow Stem Auger w/ continuous sampling		PAGE 1 OF 1	

DEPTH (Ft)	SAMPLE TYPE & NO.	BLOWS ON SAMPLER PER (Foot)	RECOVERY (%)	DESCRIPTION	USCS SYMBOL	Volatile Organics Scan (ppm)	REMARKS
	SS	17	30	Brown, stiff, Dry to Damp Silt and Gravel Fill		0.0	
	SS	10	0	——?——?——	—	0.0	
5	SS	83	60	Yellow Tan, very Dense, Damp Biotite Gneiss (colluvium)	GW	0.0	Encountered Refusal (blows 100/4) so move 5' and Resampled 4-6'
	SS 32-1	65	40	TAN, VERY DENSE, DAMP, SILT AND SAND with Rock Fragments	SW	0.0	SAMPLE RB-SS-32-1
	SS	32	30	RED/BROWN, DENSE, MOIST. SILTY SAND WITH SOME ROCK FRAGMENTS	SM	0.2	
10	SS 32-2	113	75			0.4	
	SS	100/2	0	top of Bedrock @ 13.1'			
				Total Depth of Boring = 13.1'			DID NOT ENCOUNTER GROUND WATER.
15							
20							
25							

NOTES:

Boring Headspace SCAN 0.0 ppm (measured day after drilling)

Boring Backfilled with cuttings, cement, and Bentonite powder to groundsurface then blacktop patched.

AR301458

APPENDIX I

CALCULATED ESTIMATES OF DOSE

REMCOR

By RSM Date 11/22/88 Subject _____ Sheet No. 1 of 8
Chkd. By ABR Date 11-28-88 _____ Proj. No. 88578

Problem 1:

Problem: Estimate for the current Bally municipal water supply system (Municipal Well No 1.) the rate of VOC release into the air during showering, the buildup and decay of VOCs in shower room air, and the quantity of airborne VOCs inhaled (dose) during the time the shower is running and during the time spent in the shower room after showering.

Dose is estimated for the following VOCs and concentrations, detected in Municipal Well No.1 during the Phase III RI:

1,1,1-Trichloroethane (TCA) - 73 µg/l
Trichloroethene (TCE) - 15 µg/l
1,1-Dichloroethene (DCE) - 19 µg/l

Estimation of the VOC release rate is based on an adaptation of the two-film gas-liquid mass transfer theory (Liss and Slater, 1974). The two film boundary theory provides the basis for estimating the overall mass transfer coefficient (K_L) for each VOC according to the following equation:

$$K_L = (1/k_l + RT/Hk_g)^{-1} \qquad (1)$$

where

K_L = overall mass transfer coefficient (cm/hr),
H = Henry's Law Constant (atm-m³/mole-K)
RT = 2.4×10^{-2} atm-m³/mole (gas constant of 8.2[illegible] atm-m³/mol-K times absolute temperature of 293 K
k_g = gas-film mass transfer coefficient (cm/hr), and
k_l = liquid-film mass transfer coefficient (cm/hr).

AR301460

AR301460

REMCOR

By _____ Date _____ Subject _____ Sheet No. 2 of 8

Chkd. By _____ Date _____ Proj. No. 88548

Values of k_l (20 cm/hr) and k_g (3000 cm/hr) for CO_2 and H_2O, respectively, can be used to estimate VOC-specific values for these parameters:

$$k_{g(TCE)} = k_g(H_2O)(18/MW_{(TCE)})^{0.5}, \text{ and}$$

$$k_{l(TCE)} = k_l(CO_2)(44/MW_{(TCE)})^{0.5}$$

where MW = molecular weight (g/
MW = 131

thus $k_{g(TCE)} = 3000\,(18/131)^{0.5}$
$= 1112$ cm/hr

$k_{l(TCE)} = 20\,(44/131)^{0.5}$
$= 11.6$ cm/hr

$$K_L = \left(\frac{1}{11.6} + \frac{2.4 \times 10^{-2}}{1.4 \times 10^{-2}(1112)}\right)^{-1} = 11.3 \text{ cm/hr-K}$$

K_L is adjusted for shower water temperature as follows (shower water temperature is assumed to be 35°C):

$$K_{2L} = K_L\,(T_1\mu_s / T_s\mu_1)^{-0.5} \qquad (2)$$

where

T_1 = calibration water temp. (293 K)
T_s = shower water temp. (308 K)
μ_1 = water viscosity @ T_1 = 1.0 cp
μ_s = water viscosity @ T_s = 0.76 cp

K_{2L} = 13.3 cm/hr

AR301461

REMCOR

By _____ Date _____ Subject _____ Sheet No. 3 of _____

Chkd. By _____ Date 11-23-88 _____ Proj. No. 88548

The concentration leaving the shower droplet, C_{wd}, is obtained from an integrated rate equation based on a mass-balance approach:

$$C_{wd} = C_{wo}\left(1 - \exp\left[-K_{aL}\, t_s / 60d\right]\right) \qquad (3)$$

where

C_{wd} = concentration leaving shower droplet after time t_s (µg/l),
C_{wo} = shower water concentration (µg/l),
d = shower droplet diameter = 1 mm
t_s = shower droplet drop time = 2 seconds

$$C_{wd} = 15\ \mu g/l\left(1 - \exp\left[-13.3\,(2)/60\,(1)\right]\right)$$

$$= 5.4\ \mu g/l$$

The VOC generation rate in the shower room, S, can then be calculated by the equation:

$$S = C_{wd}\,(FR)/SV \qquad (4)$$

where

S = indoor VOC generation rate (µg/m³-min),
FR = shower water flow rate = 10 liters/min
SV = shower room air volume = 8 m³

AR301462

$$S = 5.4\ \mu g/l\ (10\ l/min)/8\ m^3$$

$$= 6.75\ \mu g/m^3\text{-}min$$

A simple one-box indoor air pollution model is used to estimate VOC air concentrations in the shower room and can be expressed as a differential equation describing the rate of change of the indoor pollutant concentration with time:

$$dC_a/dt = -RC_a + S \qquad (5)$$

where

C_a = indoor VOC air concentration ($\mu g/m^3$),
R = air exchange rate = $\frac{1}{60 \text{ min}}$

Integrating equation 5, the indoor air concentration can be estimated as follows:

$$C_a(t) = (S/R)(1 - \exp[-Rt]) \quad \text{for } t \leq D_s$$

and

$$C_a(t) = (S/R)(\exp[RD_s] - 1)\exp(-Rt) \quad \text{for } t >$$

where

$C_a(t)$ = indoor air VOC concentration @ time t (μg
D_s = shower duration = 15 min
t = time (min).

The inhalation exposure per shower (and day) can then be calculated according to the equation:

$$E_{inh} = [V_r/(BW)(10^6)] \int_0^{D_t} C_a(t)\,dt \qquad (6)$$

AR301463

where

V_r = ventilation rate = 15 liters/min
BW = body weight = 70 Kg
D_t = total duration in shower room = 30 min

REMCOR

By _____ Date _____ Subject _____ Sheet No. 5 of [illegible]

Chkd. By [illegible] Date 11-28-8[illegible] Proj. No. 88540

This equation can be solved for both the duration of the shower and the duration in the room after the shower has been turned off as follows:

$$E_{inh} = (V_r)(S) / [(BW)(R)(10^6)]$$

$$[D_s + \exp(-RD_t)/R - \exp[R(D_s - D_t)]/R]$$

$$= (15)(6.75) / [(70)(\tfrac{1}{60})(10^6)]$$

$$[15 + \exp(-\tfrac{30}{60})\cancel{\tfrac{1}{R}}60 - \exp[\tfrac{-15}{60}\cancel{\tfrac{1}{R}}60]$$

$$= \boxed{4.0 \times 10^{-4} \ \frac{mg}{Kg\text{-}day}}$$

Following are the inhalation dose estimates for DCE and TCA. The only variables that change are the Henry's Law Constants, the molecular weights, and the ground water concentrations.

Compound	Henry's Law Constant (atm-m³/mol-K)	Molecular Wt. (g/mol)	Concentrat (µg/l)
DCE	0.19	97	19
TCA	0.03	134	73

AR301464

REMCOR

By _____ Date _____ Subject _____ Sheet No. 6 of 8

Chkd. By _____ Date _____ Proj. No. 88548

DCE:

$$K_L = (1/k_l + RT/Hk_g)^{-1}$$

$$k_{g(DCE)} = 3000\,(18/97)^{0.5} = 1292 \text{ cm/hr}$$

$$k_{l(DCE)} = 20\,(44/97)^{0.5} = 13.5 \text{ cm/hr}$$

$$K_L = \left(\frac{1}{13.5} + \frac{2.4 \times 10^{-2}}{0.19\,(1292)}\right)^{-1} = 13.5 \text{ cm/hr}$$

$$K_{2L} = K_L\,(1.18) = 15.9 \text{ cm/hr}$$

$$C_{wd} = C_{wo}\left(1 - \exp\left[-K_{2L}\,t_s/60d\right]\right)$$

$$C_{wd} = 19\,\mu g/l\left(1 - \exp\left[-15.9\,(2)/60(13)\right]\right)$$

$$= 7.8\,\mu g/l$$

$$S = C_{wd}\,(FR)/SV$$

$$= 7.8\,(10)/8$$

$$= 9.75\,\mu g/m^3\text{-min}$$

AR301465

REMCOR

By _____ Date _____ Subject _____ Sheet No. 7 of 8

Chkd. By RL Date 11-28-88 Proj. No. 88548

$$E_{inh} = (V_r)(S) / [(BW)(R)(10^6)]$$

$$[D_s + \exp(-RDt)/R - \exp[R(D_s - Dt)]/R]$$

$$= (15)(9.75) / [(70)(\tfrac{1}{60})(10^6)]$$

$$[15 + \exp(-\tfrac{30}{60})(60) - \exp[-\tfrac{15}{60}](60)]$$

$$= \boxed{5.8 \times 10^{-4} \ \frac{mg}{kg\text{-}day}}$$

TCA:

$$K_L = (1/K_l + RT/HK_g)^{-1}$$

$$K_{g(TCA)} = 3000 \left(\frac{18}{134}\right)^{0.5} = 1100 \text{ cm/hr}$$

$$K_{l(TCA)} = 20 \left(\frac{44}{134}\right)^{0.5} = 11.5 \text{ cm/hr}$$

$$K_L = \left(\frac{1}{11.5} + \frac{2.4 \times 10^{-2}}{0.03(1100)}\right)^{-1} = 11.4 \text{ cm/hr}$$

AR301466

$$K_{aL} = K_L(1.18) = 13.5 \text{ cm/hr}$$

REMCOR

By _____ Date _____ Subject _____ Sheet No. 8 of 8

Chkd. By JSR Date 11-28-88 _____ Proj. No. 88548

$$C_{wd} = C_{wo}\left(1 - \exp\left[-K_{2L}\, t_s / 60\, d\right]\right)$$

$$C_{wd} = 73\ \mu g/l\left(1 - \exp\left[-13.5(2)/60(1)\right]\right)$$

$$= 26.5\ \mu g/l \checkmark$$

$$S = C_{wd}\,(F\ell)/SV$$

$$= 26.5\,(10)/8$$

$$= 33.1\ \mu g/m^3\text{-min} \checkmark$$

$$E_{inh} = (15)(33.1)/\left[(70)\left(\tfrac{1}{60}\right)(10^6)\right]\ \left[4.66\right]$$

$$= \boxed{2.0 \times 10^{-3}\ \frac{mg}{kg\text{-day}}} \checkmark$$

AR301467

REMCOR

By RSM Date 4/12/89 Subject _____ Sheet No. 1 of 3
Chkd. By DAR Date 5-1-89 _____ Proj. No. 88548

Problem 2:

Estimate for the future Bally water supply system (treated Municipal Well No. 3) the rate of VOC release into the air during showering, the buildup and decay of VOCs in shower room air, and the quantity of airborne VOCs inhaled during the time the shower is running and during the time spent in the shower room after showering. The contaminants are the same as in Problem 1; the concentrations are the lower of the maximums allowed by the Water Supply and NPDES permits. All assumptions are also the same as in Problem 1.

Compound	Concentration (µg/l)
TCE	1
DCE	0.63
TCA	200

$K_{L(TCE)} = 11.3$ cm/hr-K

$K_{aL(TCE)} = 13.3$ cm/hr

$C_{wd} = 1\ \mu g/l\ (1 - \exp[-13.3(2)/60(1)])$

$= 0.36\ \mu g/l$

$S = 0.36\ \mu g/l\ (10\ l/min)/8\ m^3$

$S = 0.45\ \mu g/m^3\text{-}min$

AR301468

REMCOR

By RSM Date 4/12/87 Subject _____ Sheet No. 2 of 3

Chkd. By ____ Date ____ Proj. No. 88548

$$E_{inh\,(TCE)} = (15)(0.45) \Big/ \left[(70)\left(\tfrac{1}{60}\right)(10^6)\right]$$

$$\cdot \left[15 + \exp\left(\tfrac{-30}{60}\right)(60) - \exp\left[\tfrac{-15}{60}\right](60)\right]$$

$$= \boxed{2.7 \times 10^{-5} \ \frac{mg}{kg\text{-}day}}$$

$$K_{L\,(DCE)} = 13.5 \text{ cm/hr}$$

$$K_{OL\,(DCE)} = 15.9 \text{ cm/hr}$$

$$C_{wd\,(DCE)} = 0.63 \ \mu g/l \left(1 - \exp\left[-15.9(2)/60(1)\right]\right)$$

$$C_{wd\,(DCE)} = 0.26 \ \mu g/l$$

$$S = 0.26 \ \mu g/l \ (10 \ l/min)/8 \ m^3$$

$$= 0.33 \ \mu g/m^3\text{-}min$$

$$E_{inh\,(DCE)} = (15)(0.33) \Big/ \left[(70)\left(\tfrac{1}{60}\right)(10^6)\right]$$

$$\cdot \left[15 + \exp\left(\tfrac{-30}{60}\right)(60) - \exp\left[\tfrac{-15}{60}\right](60)\right]$$

$$= \boxed{2.0 \times 10^{-5} \ \frac{mg}{kg\text{-}day}}$$

AR301469

REMCOR

By RSM Date 4/12/89 Subject _____ Sheet No. 3 of 3

Chkd. By ____ Date _____ Proj. No. 88548

$K_{L(TCA)} = 11.4$ cm/hr

$K_{GL(TCA)} = 13.5$ cm/hr

$C_{wd} = 200\ \mu g/l\ (1 - \exp[-13.5\ (2)/60\ (1)])$

$= 72.5\ \mu g/l$

$S = 72.5\ \mu g/l\ (10\ \frac{l}{min})/8\ m^3$

$= 90.6\ \mu g/m^3\text{-min}$

$E_{inh(TCA)} = (15)(90.6)/[(70)(\frac{1}{60})(10^6)] = [4.66]$

$= \boxed{5.4 \times 10^{-3}\ \frac{mg}{kg\text{-day}}}$

AR301470

REMCOR

By RSM Date 4/12/89 Subject _____ Sheet No. 1 of 6
Chkd. By DAR Date 5-1-89 _____ Proj. No. 88548

Problem 3:

Estimate for the potential future use of a residential well in the area of MW87-10I the rate of VOC release into the air during showering, the buildup and decay of VOCs in shower room air, and the quantity of airborne VOCs inhaled during the time the shower is running and during the time spent in the shower room after showering. The contaminants and concentrations used for this hypothetical well and exposure scenario are those detected in monitoring well MW87-10I during the Phase III RI. All assumptions are the same as for Problem 1.

Compound	Concentration (µg/l)
TCE	870
DCE	330
TCA	680
DCA	230
Methylene Chloride	21

$K_{L(TCE)} = 11.3$ cm/hr

$K_{GV(TCE)} = 13.3$ cm/hr

$C_{wd} = 870\ \mu g/l\ (1 - \exp[-13.3(2)/60(1)])$

$= 312\ \mu g/l$

AR301471

$S = 312\ \mu g/l\ (10\ l/min)/8\ m^2 = 390\ \mu g/m^3\text{-}min$

REMCOR

By RSM Date 4/12/89 Subject _____ Sheet No. 2 of 6
Chkd. By DAC Date 5-1-89 _____ Proj. No. 88548

$$E_{inh(TCE)} = (15)(390)/[(70)(\tfrac{1}{60})(10^6)] \cdot [4.66]$$

$$= \boxed{2.3 \times 10^{-2} \ \frac{mg}{kg\text{-}day}}$$

$$K_{L(DCE)} = 13.5 \ cm/hr$$

$$K_{gc(DCE)} = 15.9 \ cm/hr$$

$$C_{wd(DCE)} = 330 \ \mu g/l \ (1 - exp[-15.9(2)/60(1)])$$

$$= 136 \ \mu g/l$$

$$S = 136 \ \mu g/l \ (10 \ \tfrac{l}{min})/8 \ m^3$$

$$= 170 \ \mu g/m^3\text{-}min$$

$$E_{inh(DCE)} = (15)(170)/[(70)(\tfrac{1}{60})(10^6)] \cdot [4.66]$$

$$= \boxed{1.0 \times 10^{-2} \ \frac{mg}{kg\text{-}day}}$$

AR301472

REMCOR

By RSM Date 4/12/89 Subject _____ Sheet No. 3 of 6
Chkd. By DAR Date 5-1-89 _____ Proj. No. 88548

$K_{L(TCA)} = 11.4$ cm/hr

$K_{3L(TCA)} = 13.5$ cm/hr

$C_{wl} = 680\ \mu g/l\ (1 - \exp[-13.5(2)/60(1)])$

$= 246\ \mu g/l$

$S = 246\ (10/8)$

$= \cancel{3\ldots}$ 308 $\mu g/m^3$-min

$E_{inh(TCA)} = (15)(308) / [(70)(\frac{1}{60})(10^6)] = [4.66]$

$= \boxed{1.8 \times 10^{-2}\ \frac{mg}{kg\text{-}day}}$

$K_{L(DCA)} = (1/K_1 + RT/HK_g)^{-1}$

H = Henry's Law Constant = 4.26×10^{-3}

$K_1 = K_1(CO_2)\ (44/MW_{(DCA)})^{0.5}$

$K_g = K_g(H_2O)\ (18/MW_{(DCA)})^{0.5}$

where $MW_{(DCA)} = 99$ g/mole

AR301473

REMCOR

By RSM Date 4/12/89 Subject _____ Sheet No. 4 of 6

Chkd. By DAR Date 5-1-89 _____ Proj. No. 88598

$$K_{l(DCA)} = 20\,(44/99)^{0.5} = 13.3 \text{ cm/hr}$$

$$K_{g(DCA)} = 3000\,(18/99)^{0.5} = 1279 \text{ cm/hr}$$

$$K_{L(DCA)} = \left(\frac{1}{13.3} + \frac{2.4 \times 10^{-2}}{(4.26 \times 10^{-3})\,1279}\right)^{-1} = 12.6 \ \frac{\text{cm}}{\text{hr-K}}$$

$$K_{2L} = K_L\,(T_{1\mu g}/T_{5\mu g})^{-0.5}$$

$$= 12.6\,(1.18)$$

$$= 14.8 \text{ cm/hr}$$

$$C_{wd} = 230 \text{ mg/l}\,\left(1 - \exp\left[-12.6\,(2)/60(1)\right]\right)$$

$$= 78.9 \text{ mg/l}$$

$$S = 78.9\,(10/8)$$

$$= 98.6 \text{ mg/m}^3\text{-min}$$

$$E_{inh} = (15)(98.6) \Big/ \left[(70)\left(\tfrac{1}{60}\right)(10^6)\right] = [4.66]$$

$$= \boxed{5.9 \times 10^{-3} \ \frac{\text{mg}}{\text{kg-day}}}$$

AR301474

REMCOR

By RSM Date 4/12/89 Subject _____ Sheet No. 5 of 6
Chkd. By DAR Date 5-1-89 _____ Proj. No. 88548

$$K_{L(M.C)} = \left(1/k_l + RT/Hk_g \right)^{-1}$$

$$H_{M.C.} = 2.03 \times 10^{-3}$$

$$K_{l(MC)} = K_{l(CO_2)} \left(44/MW_{(MC)} \right)^{0.5}$$

$$K_{g(MC)} = K_{g(H_2O)} \left(18/MW_{(MC)} \right)^{0.5}$$

$$Mol.wt._{(MC)} = MW = 85 \text{ g/mole}$$

$$K_{l(MC)} = 20 \left(44/85 \right)^{0.5} = 14.4 \text{ cm/hr}$$

$$K_{g(MC)} = 3000 \left(18/85 \right)^{0.5} = 1381 \text{ cm/hr}$$

$$K_L = \left(1/14.4 + \frac{2.4 \times 10^{-2}}{(2.03 \times 10^{-3})(1381)} \right)^{-1}$$

$$= 12.8 \text{ cm/hr}$$

$$K_{2c} = 15.1 \text{ cm/hr}$$

$$C_{wd} = 21 \mu g/l \left(1 - \exp\left[-15.1(2)/60(1) \right] \right)$$

$$= 8.3 \mu g/l$$

$$S = 8.3 \left(10/8 \right)$$

$$= 10.4 \mu g/m^3\text{-min}$$

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$$E_{ing} = (15)(10.4) / [(70)(\tfrac{1}{60})(10^6)] \cdot [4.66$$

$$= \boxed{6.2 \times 10^{-4} \ \frac{mg}{kg\text{-}day}}$$

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By RSM Date 4/11/89 Subject Estimated Inhalation Doses @ Great American Knitting Mills Sheet No. 1 of 6
Chkd. By DAL Date 5-1-89 Bally RI Proj. No. 88548

Problem 4

Problem: Estimate the VOC inhalation exposure (dose) for workers at Great American Knitting Mills as a result of heated process water containing the following VOC concentrations:

TCE	32 µg/l
1,1-DCE	19 µg/l
TCA	78 µg/l

The estimation is made using a modification of the shower model developed by Foster and Chrostowski (1987) that was presented for the residential showering exposure scenario (Problems 1, 2, + 3). In the occupational scenario, water is assumed to flow through a process bath 1 foot x 2 feet x 2 feet at a rate of 300 gallons per hour, or 19 liters per minute (FR). The water column thickness (d) replaces the shower droplet diameter. Additionally, the process (daily exposure) is assumed to last 7 hours a

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By RSM Date 4-11-89 Subject _____ Sheet No. 2 of 6
Chkd. By DAR Date 5-1-89 _____ Proj. No. 8858

the process room is assumed to be 500 m^3 in volume. The employee ventilation rate is 15 liters per minute (V_r) and the air is exchanged in the process room once every 60 minutes (R).

Thus:

FR = 19 liters/min
SV = 500 m^3
V_r = 15 liters/min
D_t = 7 hrs
R = $\frac{1}{60}$ min
t_s = 1 hr (300 gallon bath capacity is replaced hourly)

Mass Transfer Coefficients (K_{gc}) adjusted for water temperature (assumed to be 35°C) for the VOCs are as follows:

$K_{gc_{TCE}}$ = 13.3 cm/hr

$K_{gc_{DCE}}$ = 15.9 cm/hr

$K_{gc_{TCA}}$ = 13.5 cm/hr

The daily doses calculated via this method are for the actual exposure days (i.e. work days). To use these values in the formulation of

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carcinogenic risk, they must be adjusted for daily dose over a lifetime (70 years). This is accomplished by multiplying by the fraction of the lifetime days hypothetically spent in this operation, assuming this to be 240 days per year for 30 years.

$$\frac{\frac{240 \text{ days}}{\text{yr}} \times 30 \text{ yrs}}{365 \frac{\text{days}}{\text{yr}} \times 70 \text{ yrs}} = 0.28$$

TCE

$$C_{wd} = C_{wo}\left(1 - \exp\left[-k_{2c}\, t_s/60d\right]\right)$$

$C_{wo} = 32$ µg/l $t_s = 3600$ seconds (1 hr.)
$d = 305$ mm (1 ft.)

$$C_{wd} = 32 \text{ µg/l}\left(1 - \exp\left[-13.3\,(3600)/60\,(305)\right]\right)$$

$$= 29.7 \text{ µg/l}$$

$$S = C_{wd}\,(FR/SV)$$

$$= 29.7 \text{ µg/l}\,(19 \text{ l/min}/500 \text{ m}^3)$$

$$= 1.13 \text{ µg/m}^3\text{-min}$$

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By RSM Date 4/11/89 Subject _____ Sheet No. 4 of _____
Chkd. By DHR Date 5-1-89 _____ Proj. No. 88548

C_a = indoor air concentration ($\mu g/m^3$)

$$E_{inh} = [V_r/(BW)(10^6)] \int_0^{D_t} C_a(t)\,dt$$

BW = Body Weight = 70 kg

$$E_{inh} = (V_r)(S)/[(BW)(R)(10^6)]$$

$$[D_s + \exp(-RD_t)/R - \exp[R(D_s - D_t)]/R]$$

$$= (15)(1.13)/[(70)(\tfrac{1}{60})(10^6)] \cdot$$

$$[420 + \exp[-\tfrac{420}{60}](60) - \exp[\tfrac{1}{60}(0)](60)]$$

$$= 5.2 \times 10^{-3} \ \frac{mg}{kg\text{-}day}$$

$$5.2 \times 10^{-3} \frac{mg}{kg\text{-}day} \times \frac{30\ yrs \times 240\ days}{365\ \frac{days}{yr} \times 70\ yrs}$$

$$= \boxed{1.47 \times 10^{-3} \ \frac{mg}{kg\text{-}day}}$$

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By RSM Date 4/11/89 Subject _____ Sheet No. 5 of 6
Chkd. By DAR Date 5-1-89 _____ Proj. No. 88548

DCE

$C_{wd} = 18.2\ \mu g/l$

$S = 0.70\ \mu g/m^3\text{-min}$

$E_{inh} = (15)(0.7) / [(70)(\frac{1}{60})(10^6)] \cdot [360]$

$= 3.2 \times 10^{-3}\ \frac{mg}{kg\text{-day}}$

$3.2 \times 10^{-3} \times \frac{30 \times 240}{365 \times 70}$

$= \boxed{9.1 \times 10^{-4}\ \frac{mg}{kg\text{-day}}}$

TCA

$C_{wd} = 72.5\ \mu g/l$

$S = 2.76\ \mu g/m^3\text{-min}$

$E_{inh} = (15)(2.76) / [(70)(\frac{1}{60})(10^6)] \cdot [360]$

$= 1.26 \times 10^{-2}\ mg/kg\text{-day}$

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By RSM Date 4/11/89 Subject _____ Sheet No. 6 of 6

Chkd. By OAR Date 5-1-89 _____ Proj. No. 88548

$$1.26 \times 10^{-2} \frac{mg}{kg\text{-}day} \times \frac{30\,yrs \times 240 \frac{days}{yr}}{365 \frac{days}{yr} \times 70\,yrs}$$

$$= \boxed{3.5 \times 10^{-3} \frac{mg}{kg\text{-}day}}$$

Back-Calculation of air Concentrations

TCE

$$5.2 \times 10^{-3} \frac{mg}{kg\text{-}day} \times 70\,kg \times \frac{1\,day}{21.6\,m^3} \times \frac{7\,hr}{24\,hr}$$

$$= \boxed{4.9 \times 10^{-3} \frac{mg}{m^3}}$$

DCE

$$3.2 \times 10^{-3} \frac{mg}{kg\text{-}day} \times 70\,kg \times \frac{1\,day}{21.6\,m^3} \times \frac{7\,hr}{24\,hr}$$

$$= \boxed{3.0 \times 10^{-3} \frac{mg}{m^3}}$$

TCA

$$1.26 \times 10^{-2} \frac{mg}{kg\text{-}day} \times 70\,kg \times \frac{1\,day}{21.6\,m^3} \times \frac{7\,hr}{24\,hr}$$

$$= \boxed{1.2 \times 10^{-2} \frac{mg}{m^3}}$$

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By RSM Date 4/13/89 Subject Accidental Ingestion of Surface Water Doses Sheet No. 1 of 2
Chkd. By DAR Date 5-1-89 Proj. No. 88548

Problem 5

Problem: Estimate the dose of VOCs ingested accidentally by children playing in the stream using the same concentration as for dermal absorption and the following assumptions:

- 50 milliliters (0.05 liters) of water are accidentally ingested during 5 incidences per year for 10 years
- 100% VOC absorption occurs in the stomach
- The child weighs 45 kg

Thus doses are calculated as follows:

$$\text{Dose}_{\text{ingestion}} = \frac{18\,\frac{\mu g}{l} \times 0.05\,\text{liters} \times 5\,\frac{\text{days}}{yr} \times 10\,\text{years} \times \frac{1\,mg}{10^3\,\mu g}}{45\,kg \times 70\,yrs \times 365\,\frac{\text{days}}{yr}}$$

$$= \boxed{3.9 \times 10^{-8}}$$

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By RSM Date 4/13/89 Subject accidental ingestion of Surface Water Doses Sheet No. 2 of 2

Chkd. By DAR Date 5-1-89 Proj. No. 88578

Dose 1,2 DCE = 3.5×10^{-8} $\frac{mg}{kg\text{-}day}$

Dose 1,1,1 TCA = 1.3×10^{-8} $\frac{mg}{kg\text{-}day}$

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By RSM Date 4/13/89 Subject Surface Water Dermal absorption Exposure Sheet No. 1 of 2
Chkd. By DAR Date 5-1-89 Proj. No. 88548

Problem 6

Problem: Estimate the dermal absorption dose of VOCs for children playing in the stream south of Route 100 where VOCs were detected @ the following concentrations:

1,1-DCE - 18 µg/l
1,2-DCE - 16 µg/l
1,1,1-TCA - 6 µg/l

Assumptions used in this exposure scenario are:

- The flux rate of water through the skin controls the rate of VOC absorption; this value is 0.5 mg/cm²-hr (USEPA, 1988)
- The child is exposed two hours per day, 12 days per year, for 10 years.
- The total body surface area of the child is 12,000 cm², and 20% (0.2) of this body surface is exposed during each episode
- The child weighs 45 kg
- One hundred percent absorption

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By RSM Date 4/13/89 Subject Surface Water Dermal Absorption Exposure Sheet No. 2 of 7

Chkd. By DAR Date 5-1-89 Proj. No. 88548

Thus, dose is calculated as follows:

$$\text{Dose}_{1,1\,DCE} = \frac{18\,\mu g/l \times \frac{0.5\,mg}{cm^2\text{-}hr} \times \frac{2\,hr}{day} \times \frac{12\,days}{yr} \times 10\,y \times \frac{1\,l}{10^3\,cm^3} \times \frac{cm^3}{g} \times \frac{1\,g}{10^6\,\mu g} \times 12000\,cm^2 \times 0.2}{45\,Kg \times 70\,yr. \times 365\,\frac{days}{yr}}$$

$$= \boxed{4.5 \times 10^{-9}\ \frac{mg}{Kg\text{-}day}}$$

$$\text{Dose}_{1,2\,DCE} = \boxed{4.0 \times 10^{-9}\ \frac{mg}{Kg\text{-}day}}$$

$$\text{Dose}_{1,1,1\text{-}TCA} = \boxed{1.5 \times 10^{-9}\ \frac{mg}{Kg\text{-}day}}$$

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