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Hydrogeological Investigation of Waste Disposal Sites at the Former Naval Training Center Bainbridge, Port Deposit, Cecil County, Maryland

U.S. Navy Contract No: N62470-87-8-8901

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December 7, 1988

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APPENDICES

Appendix A. Well Logs, Well Narratives, and State of Maryland Well Completion Reports

Appendix B. Monitoring Well Surveying Data

Appendix C. Hazard Ranking Score

1.0 INTRODUCTION

This document presents the results of the investigation of environmental impacts from past disposal areas at the former U.S. Naval Training Center (NTC), Bainbridge, Maryland (Figure 1-1). The Navy identified two sites at NTC Bainbridge that pose a potential threat to human health and the environment: a former on-base sanitary landfill, and a former oil separator pit used to drain waste fuel oil used during fire fighting training activities. Versar installed ground-water monitoring wells at each site and collected samples of ground-water, surface water, and sediments to verify the existence of environmental contamination from the landfill area and the oil separator pit area. Versar also used the data collected to apply the U.S. EPA's Hazard Ranking System (HRS) model to the sites.

Section 1.0 of this report contains a description of past disposal activities at the landfill and the oil separator pit, and presents a discussion of the local environmental setting and demographics. Section 2.0 describes Versar's site investigations, and Section 3.0 presents the analytical results of sediment, ground-water and surface water sampling. Analytical data is evaluated in Section 4.0 and Versar's conclusions and recommendations based on findings from the site investigations are presented in Section 5.0. This report also includes three appendices. Appendix A contains Versar's well installation narratives, well logs, well construction diagrams, and State of Maryland well completion reports for each of the wells installed. Appendix B contains well survey data. The HRS package, including references, is included as Appendix C.

1.1 History of Disposal Activities

1.1.1 Base Landfill

The base landfill occupies an area between the former base golf course and State Route 276 (Figure 1-2). The site was used as a dump site for sanitary wastes generated from daily operations at NTC Bainbridge for a period of approximately 30 years starting in the early

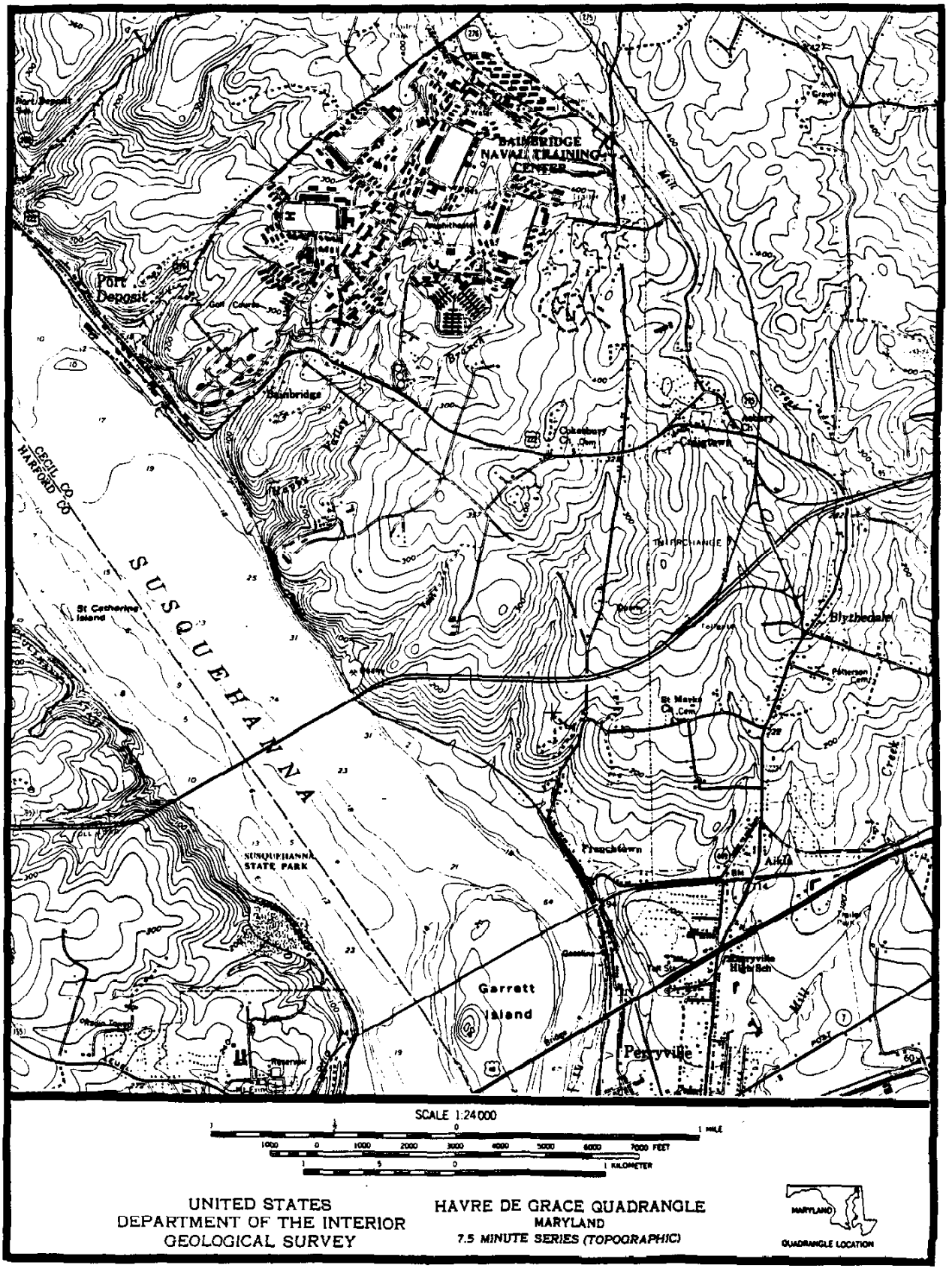


Figure 1-1: Location Map of Bainbridge Naval Training Center

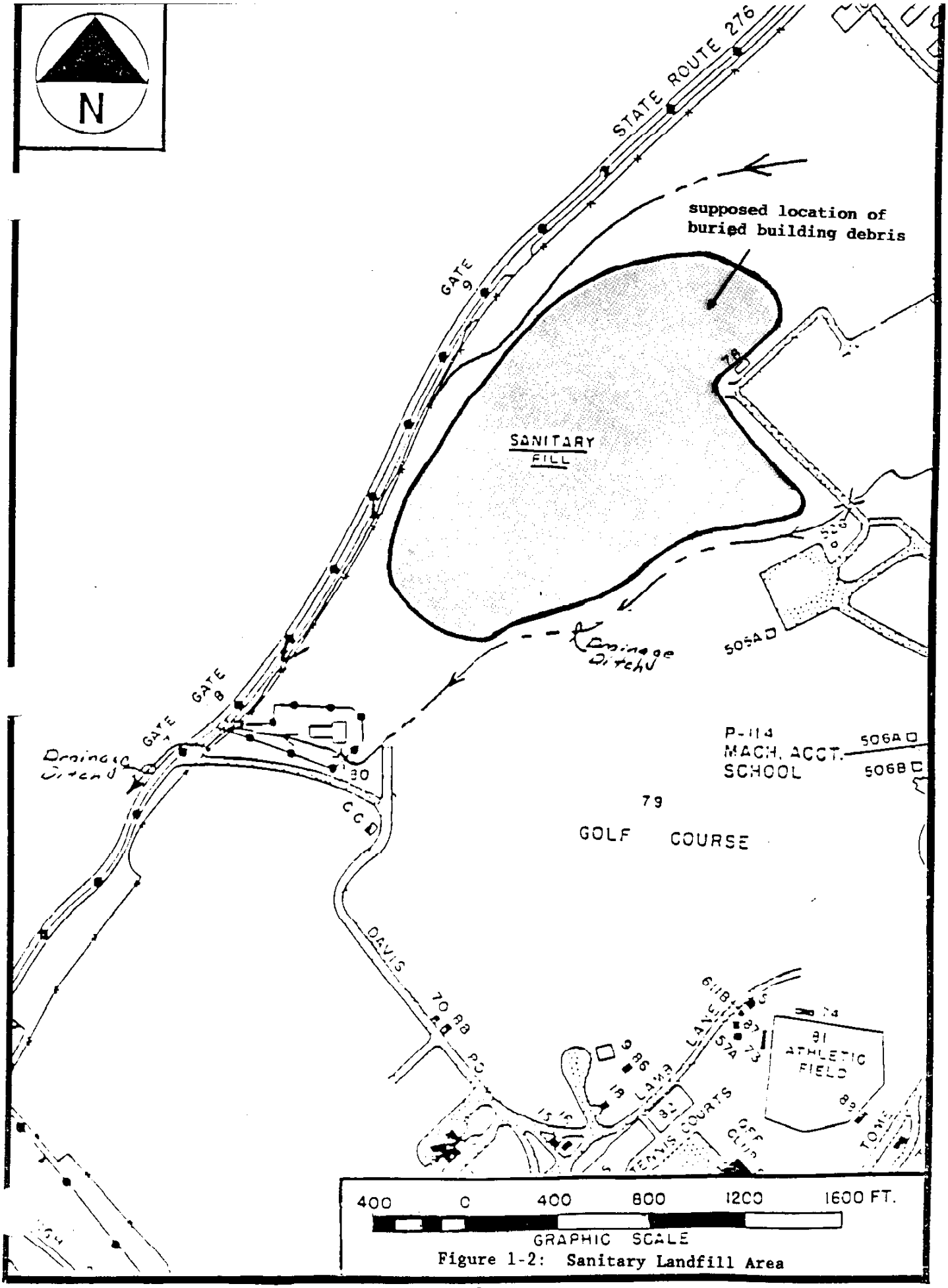


Figure 1-2: Sanitary Landfill Area

1940's. Based on a Pest Control Program Review performed by the Navy in 1968, the Navy determined that a number of pesticides were also disposed of at the landfill. The types and amounts of pesticides disposed are as follows:

Aramite 15-W (Miticide)	60 lbs
BHC 11% E.C.	150 gal
Block Leaf 40 (Nicotine Sulfate)	60 gal
Captan 50 WP	110 lbs
Copper Sulfate	20 lbs
DDT 25% E.C.	350 gal
DDT 20% O.S.	350 gal
DDT 5% O.S.	100 gal
Ferbam	20 gal
Karathane	80 lbs
Red Squill	15 lbs
Ryania	60 lbs

Pesticides in dry form were reported to have been buried at a depth of 3 feet, while liquids were poured into pits excavated to a depth of 30 inches. Empty containers were punched with holes to prevent re-use and then buried along with their former contents. The exact location of pesticide disposal at the base landfill is not known, however, it is probable that it occurred in the northwestern part of the landfill.

Debris from approximately 40 demolished buildings was also reportedly buried at the north-western portion (Figure 1-2) of the landfill. The buildings, formerly located to the east and northeast of the landfill, were demolished and dumped into the landfill by the U.S. Department of Labor (DOL) in the early 1970s when the DOL leased a parcel of NTC Bainbridge property adjacent to the landfill area for use as a Job Corps Center. The condition or contents of the buildings prior to demolition was not specified. The pesticides may have also been buried at or near the northwestern portion of the landfill.

1.1.2 Oil Separator Pit

The oil separator pit was constructed in 1944 as part of the NTC Bainbridge fire fighter's training school (Figure 1-3). The pit was constructed adjacent to and downgradient from a concrete pad used for

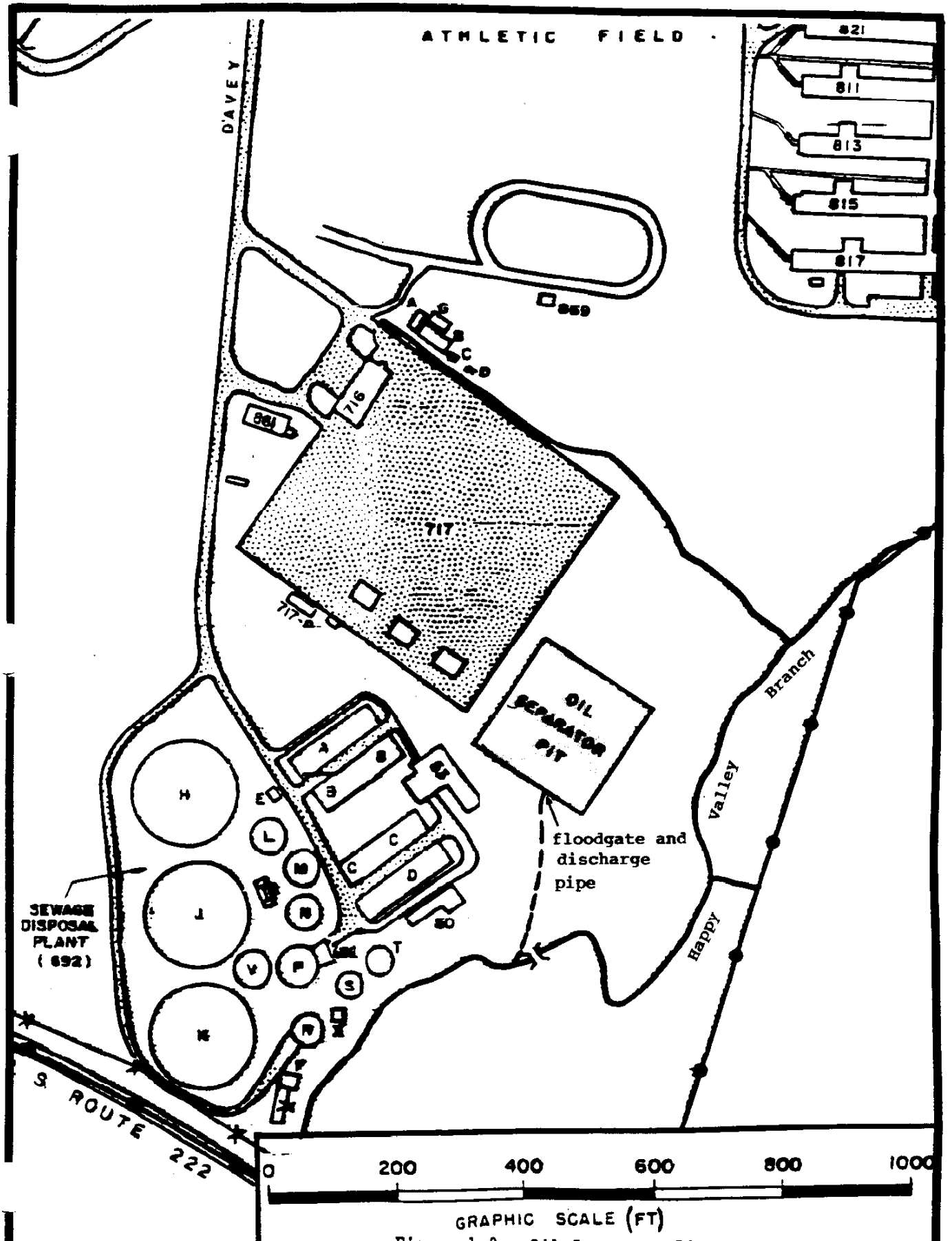


Figure 1-3: Oil Separator Pit Area

fire fighting training. Concrete and steel structures on the pad were sprayed with a mixture of crude oil cut with fuel oil, ignited, and then dowsed with water from fire hoses to simulate fire fighting techniques. Excess water mixed with oil drained off the concrete pad via an 18-inch diameter underground pipe and into the separator pit. The pit was constructed as an un-lined, square depression, 220 feet long on each side and 9 feet deep (measured from grade level at the center of the pit). Total capacity of the pit at the time of construction was approximately 2.5 million gallons (12,000 cubic yards). The pit received an unknown quantity of oil and water during its use. Separator pits of this type are normally used to "separate" the oil and water mixtures so that the oil component can be collected from the top and the water collected or discharged from the bottom. Historical records do not indicate the collection or disposal methods employed for this separator pit. The southern corner of the pit was equipped with a floodgate leading to a discharge pipe (Figure 1-3) which may have been used to periodically drain fluids from the pit.

Paul Arnold says the pit was periodically torched and would burn for days SNM.

1.2 Environmental Setting

1.2.1 Topography and Drainage

The NTC Bainbridge is located on a portion of the Piedmont Physiographic Province, a region of low hills and ridges with an overall topography that slopes gently to the southeast. The hills and ridges are a result of stream erosion and differential resistance to weathering of the underlying igneous and metamorphic bedrock (Higgins, 1986). Surface elevations at the base range from 400 feet above mean sea level (MSL) in the northern corner of the property to approximately 200 feet above MSL at the southern border. The slope of the NTC Bainbridge property follows the overall gentle topographic slope of the region, to the southeast, and is cut abruptly at the NTC southern border by the nearly vertical cliff which drops approximately 200 feet to the Town of Port Deposit, on the northern shore of the Susquehanna River.

The southern portion of the NTC Bainbridge is drained by Happy Valley Creek, which flows in a southerly direction and discharges into the Susquehanna River. As Figure 1-3 indicates, Happy Valley Creek passes approximately 400 feet to the south of the oil separator pit. Mill Creek, flowing in a southeasterly direction, drains the area immediately to the north of NTC property. Several drainage ditches intersect the study areas, including an intermittent drain ditch which leads from the oil separator pit to Happy Valley Creek and two drainage ditches that flow around the eastern and western portions of the landfill area and eventually join together near the Port Deposit Reservoir water tank on Route 276 (Figure 1-2).

1.2.2 Climate and Vegetation

The climate of Cecil County is classified as humid continental, characterized by warm, humid summers and moderately cold winters. Average annual temperature ranges between 65°F and 43°F, with an average daily maximum of 88°F (July) and an average daily minimum of 25°F (January). The average total precipitation is 45 inches per year, with snowfall comprising an average of 21 inches of the total precipitation. Monthly distribution of precipitation is fairly uniform. August generally has slightly more precipitation (1-2 inches more) than other months, however drought conditions can occur in any month particularly during the summer months. Thunderstorms occur on an average of 30 days per year. Tornadoes are rare, yet tropical storms and hurricanes historically occur about once a year between the months of August and October. Local flooding can occur during periods of extended rain. Prevailing winds are from the northwest, and shift to southerly directions during the summer months. Average prevailing wind speed is 9-10 miles per hour (USDA, 1973).

Resulting from lack of use over the years, much of the NTC Bainbridge property is covered heavily with vegetation. The dominant vegetation type is hardwoods, including oak, scrub oak, swamp maple, beech, locust, and hickory (USDA, 1973). Virginia pine and white pine

occur in some areas as second growth, along with thick underbrush of varying types. The heavy vegetation is likely to contribute to considerable evapotranspiration, although no exact figures are available.

1.2.3 Geologic Environment

1.2.3.1 Soils

Soils on the NTC Bainbridge property may be characterized in two general associations: the Glenelg-Manor-Glenville (GMG) Association occupying the central and southern portions of the property, and the Keyport-Beltsville (KB) Association occupying the northern portions. The GMG Association soils, derived from micaceous bedrock, are loamy, moderately well drained, and steep to gently sloping soils. The KB Association soils are also moderately well drained and level-to-steep, but are derived from coastal plain deposits ranging from gravelly, loamy sand to clay (USDA, 1973).

Both the oil separator pit area and the landfill area are situated on soils of the GMG Association. The soils at these locations may be further subdivided into specific soil series, or types.

Base Landfill

The soils at the base landfill are also composed primarily of Made Land and Manor Loam series soils. The slope of the landfill soils ranges from 15 to 25 percent, somewhat steeper than soils at the oil separator pit. Downgradient from the landfill, toward the Port Deposit Reservoir water tank (Figure 1-2), Manor Loam soils occur at slopes up to 45 percent. At these locations, the Manor Loam soils grade intermittently with soils of the Chester and Glenelg series. The latter two series are very similar to Manor Loam soils; all three series, derived from schist and gneiss bedrock, are well drained, with a top layer of silt loam followed by underlying layers of highly micaceous, loam saprolite, varying in thickness near the landfill area from 15 to 25 feet.

Oil Separator Pit

The soils at the oil separator pit location are composed primarily of the gently sloping Made Land series (MaB) soils. A portion of the soils immediately west of the oil pit and surrounding Building 53 (red barn) are composed of the Manor Loam series (MlB2), a soil with a 3 to 8 percent slope. The Made Land soil, as the name suggests, is simply fill material which has been graded and mixed. It consists of a random mix of sand, clay, gravel, and miscellaneous materials arranged in a gentle slope as a result of grading. The depth of the Made Land soils varies between 2-4 feet. The Manor Loam series is a well drained soil of gentle slope formed from weathering of the underlying mica schist and granite bedrock. A representative profile of the Manor series consists of a 2-8 inch surface layer of very dark grayish-brown and brown loam followed by an 8 to 19 inch layer of friable, brown loam. The underlying material, to a depth of six to ten feet or more, is a banded, loamy saprolite (weathered bedrock). Soft, weathered schist or hard quartzite fragments occur randomly in the soil profile (USDA, 1973).

1.2.3.2 Stratigraphy

Crystalline bedrock occurs below the saprolite layers at NTC Bainbridge, as indicated in the geologic map and cross-section in Figures 1-4 and 1-5. The study areas are underlain predominantly by the Port Deposit Gneiss, a gray, quartz-rich granite gneiss of Lower Paleozoic age (Higgins and Conant, 1986). The Port Deposit Gneiss occurs in both fine-grained and coarse-grained phases. The fine-grained phase underlies most of the study area and is composed of fine- to medium-grained quartz, hornblende, biotite, and plagioclase feldspar. The coarse-grained phase, differing only in grain size, meets the fine-grained phase in a gradational contact along the western border of the Bainbridge NTC property, near Route 276 (Figure 1-2). Near the southeastern border of the property the fine-grained phase of the Port Deposit Gneiss forms a gradational contact with the Happy Valley Branch member of the James Run Formation. The Happy Valley Branch member is

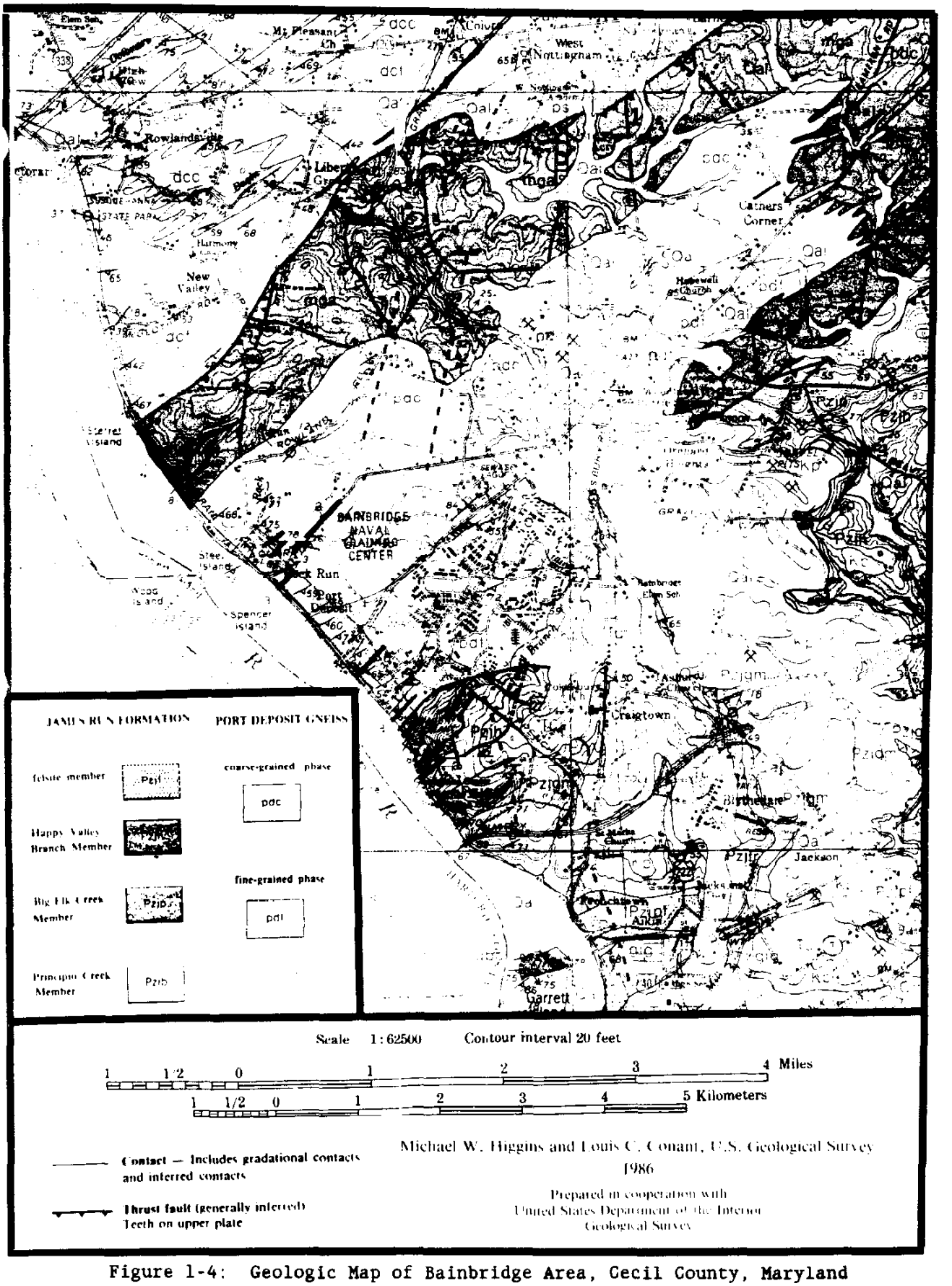


Figure 1-4: Geologic Map of Bainbridge Area, Cecil County, Maryland

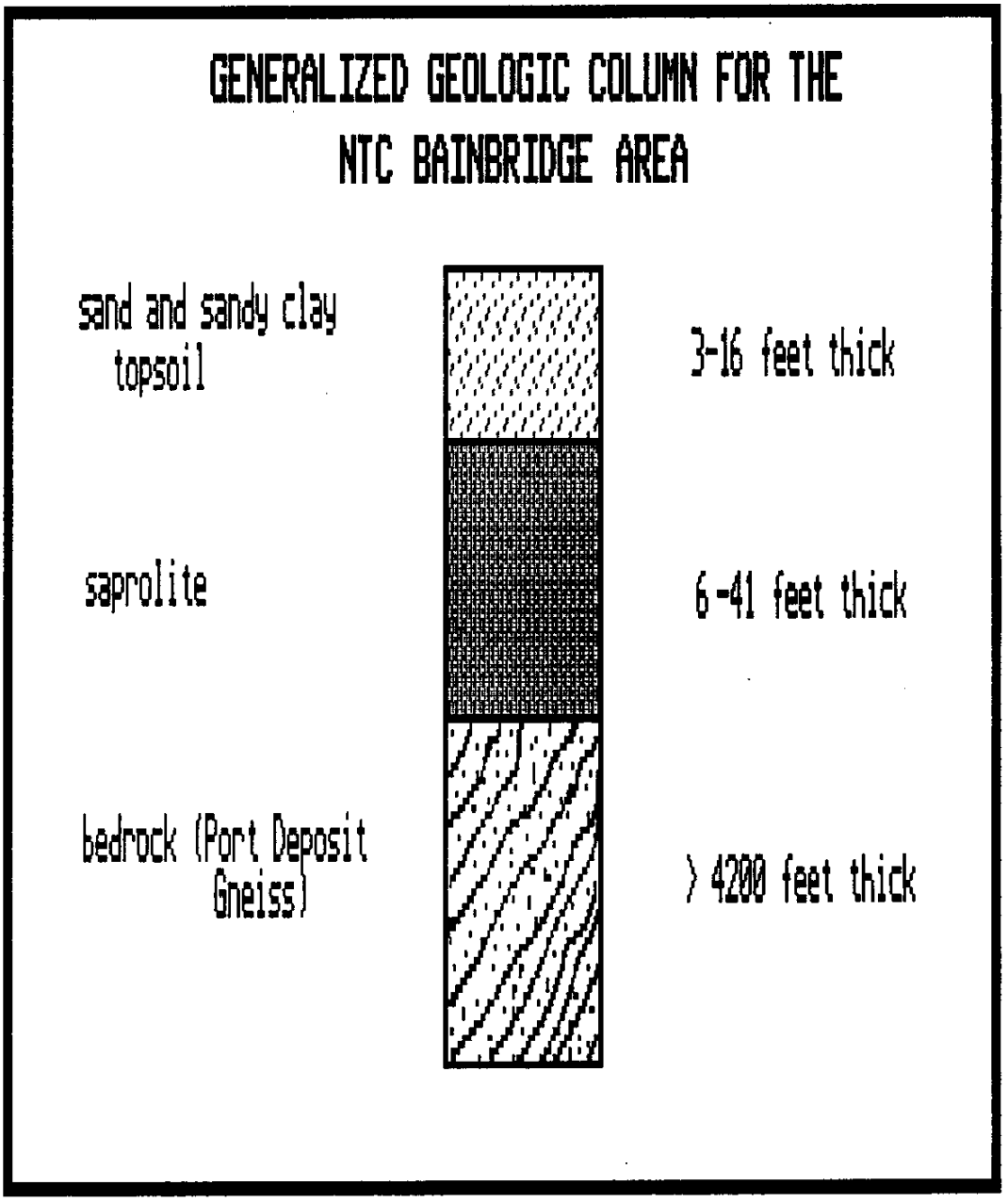


Figure 1-5: Generalized Cross-Sectional Diagram Showing Type and Thickness of Geological Units Underlying NTC Bainbridge

also of Lower Paleozoic age and is composed of fine-grained, light gray to white metamorphosed felsite. It is similar in appearance and composition to the Port Deposit Gneiss and, as such, the exact placement of the Happy Valley Branch member's gradational contact with the Port Deposit Gneiss is not firmly defined (Higgins, 1986). The strike of both the Port Deposit Gneiss and Happy Valley Branch felsite is northeast-southwest, and dip is approximately 72 degrees to the southeast (Higgins and Conant, 1986).

The Port Deposit Gneiss and Happy Valley Branch felsite also contain numerous dikes of blackish-green hornblende and veins of opaque, milky white quartz (Higgins, 1986). The hornblende dikes range in thickness from a few centimeters to about 6 meters and have varying orientations. Quartz veins also occur as thin as a few centimeters, but several veins as much as 30 meters thick have been mapped in the Piedmont area (Higgins, 1986). Although no hornblende dikes were encountered during drilling operations, a milky white quartz vein was penetrated at Well 1-GW5 at a depth of 28 feet and extended through the total well depth of 33 feet (see well log in Appendix A).

Bedrock beneath NTC Bainbridge, and throughout the Piedmont area in general, is heavily jointed and fractured. Joints and fractures, resulting from compression and relaxation of rock masses, provides the principal means for the occurrence of ground-water in an otherwise impervious medium. Thickness of the joints and fractures will vary. Most joints and fractures thin and disappear at depth, however some may continue to depths of hundreds or even thousands of feet (Nutter and Otton, 1969). In the Port Deposit Gneiss, joints are spaced on an average of 10 feet apart and dip on an average of 73 degrees from the horizontal. Several joints on the order of 1 to 2 inches were seen in the rock core samples from Wells 1GW-2 and 2GW-4 (Appendix A). Faults also occur in the Piedmont bedrock and, similar to joints and fractures, can provide conduits for ground-water flow. A fault in the vicinity of the oil separator pit area (Figure 1-4) has been mapped along the contact of the Happy Valley Branch member and the Port Deposit Gneiss.

1.2.3.3 Hydrogeology

Ground-water in the NTC Bainbridge region occurs primarily in the joints and fractures of bedrock. Water is also contained within bed plane partings, along lines of cleavage and schistosity (banded foliations), and to a small degree within the weathered saprolite zone (Nutter and Otton, 1969). The saprolite, however, displayed a relatively high clay content as a result of weathering of the potassium feldspar in the bedrock. Consequently, the saprolite at the two study locations was dry in most cases and appeared relatively impermeable. The ground-water table was encountered at or near the bedrock surface in all wells. Water levels rose, however, after well installation, indicating that the water table zone is not a true water table but rather is semi-confined by the low-permeability saprolite layers. Water levels measured on four separate occasions for each of the ten monitoring wells are shown in Table 1-1. Water table contours are discussed in Section 2.0.

In addition to the water table zone, a 1 to 2 foot zone of perched water was encountered just above the saprolite (see well logs in Appendix A). The perched zone disappeared after penetrating the saprolite. Since well drilling occurred during January and February, the perched zone may have been the result of seasonal conditions of increased precipitation and snow melt during the winter months. Regional ground-water flow is to the south and southeast, along the dip of bedrock and towards the Susquehanna River (Nutter and Otton, 1969). Local ground-water occurrence and flow is further discussed in Sections 2.1.1.1 and 2.2.1.1.

As mentioned previously, a thrust fault has been mapped (Higgins and Conant, 1986) along the contact of the Port Deposit Gneiss and the Happy Valley Branch felsite, located downgradient from the oil separator pit (Figure 1-4). The fault line may be traced by a portion of Happy Valley Creek, as streams often run along zones of weakness created by faults. This thrust fault zone may have an effect on local ground-water flow (i.e., creating a zone of increased permeability or a possible recharge/discharge zone).

Table 1-1: Total Depths, Ground Elevations and Water Level Elevations of Monitoring Wells Installed at the Base Landfill and Oil Separator Pit

Well No.	Total Well Depth	Ground Elevation (MSL)[a]	Water Level Elevations (MSL) March 14, 1988 (Round 1)	April 21, 1988 (Supplementary Round)	May 16, 1988 (Round 2)	July 25, 1988 (Round 3)
Landfill:						
1GW-1	47.17	295.20	260.74	260.08	261.33	259.47
1GW-2	31.0	242.98	229.66	229.68	230.66	229.14
1GW-3	29.5	227.43	206.27	206.23	206.65	206.05
1GW-4	36.0	249.48	225.78	225.88	227.44	225.25
1GW-5	33.0	196.46	181.88	181.51	182.95	179.21
Oil Separator Pit:						
2GW-1	42.26	265.13	262.22	261.58	264.55	258.69
2GW-2	27.36	249.76	242.73	242.63	243.06	241.69
2GW-3	30.0	254.77	246.88	246.63	247.24	245.24
2GW-4	29.0	247.06	240.19	239.98	240.24	239.20
2GW-5	23.03	243.01	236.88	235.83	236.17	235.58

[a]MSL = relative to mean sea level

1.3 Demographics

1.3.1 Land Use

The land surrounding NTC Bainbridge is mostly wooded area and rural farmland. Farmland is used primarily for dairy and poultry farming. Much of the local topography is too steep and rocky for cultivated crop production and is best suited as woodland. The forested areas, in addition to adding aesthetic value, provide protection for the watershed (USDA, 1973).

The nearest population center is the Town of Port Deposit (pop. 667) along the north bank of the Susquehanna River and to the southwest of Bainbridge NTC (Figure 1-1). Residents of Port Deposit are primarily retirees or are employed at local industries such as a dock facility along the river and two Army installations in neighboring Hanover County. A small residential area of fewer than 100 homes is located just beyond the northeastern border of NTC Bainbridge. The next closest population center is the Town of Perryville, approximately 6 miles to the southeast. Within the property limits of the NTC Bainbridge, a Department of Labor-sponsored Job Corps Center for disadvantaged youth is located in several buildings on the southwestern end of the property. The Job Corps Center houses approximately 300 students and approximately 200 staff members.

1.3.2 Water Supply

The local residents of Port Deposit and vicinity obtain their entire domestic water supply from the Port Deposit Reservoir water tank located on State Route 276. Water is obtained directly from the Susquehanna River and is processed at a water treatment facility at the northern end of Port Deposit before it is pumped to the holding tank. The Job Corps Center and staff personnel also obtain their water from this supply. Other residents to the northeast of the NTC Bainbridge property obtain their water supply from private wells.

2.0 PAST DISPOSAL SITE INVESTIGATION

This study involved the installation of ground-water monitoring wells, followed by three successive rounds of ground-water, surface water, and stream sediment sampling at two locations on the NTC Bainbridge property. As discussed in Section 1.1, these two locations, the base landfill and the oil separator pit at the firefighters training area, were identified by NAVFACENGCOM-Atlantic Division as areas on the base where subsurface and/or surface contamination may have resulted from facility operations or disposal practices. To evaluate any contamination, five ground-water monitoring wells were to be installed at each of these two locations to monitor ground-water quality. Ground-water, surface water, and stream sampling and analyses were proposed to assess and characterize any contaminant releases. Analytical parameters were determined by NAVFACENGCOM-Atlantic Division and are described in detail in the QA/QC plan for this investigation (Versar 1988a).

2.1 Base Landfill

The purpose of this investigation is to identify and characterize contamination of various environmental media resulting from past disposal practices at the base landfill. Records indicate that the landfill was used from the early 1940's until the mid-1970's for disposal of base municipal refuse, concentrated pesticides, and building debris possibly containing friable asbestos (see Section 1.1). The location of the landfill is shown in Figure 1-2. The site characterization performed by Versar involved the installation of several ground-water monitoring wells, and the collection and analyses of ground-water, surface water, and sediment samples.

2.1.1 Monitoring Well Installation

Five ground-water monitoring wells were installed on the NTC Bainbridge property surrounding the landfill as part of the site characterization during February 1988. The locations of the wells are

indicated on Figure 2-1. The locations of the 5 monitoring wells at the base landfill were initially predetermined by NAVFACENGCOM-Atlantic Division with the final locations set following a reconnaissance survey of the site by Versar. Well 1GW-1 is hydraulically upgradient of the landfill and serves as the background monitoring well. The remaining four wells are downgradient of the landfill. Initially, the well sites were cleared with a bulldozer, since access was limited due to overgrown vegetation. A metal detector survey was then performed by Versar at each well location to insure the absence of any buried metal debris, electric lines, or pipelines before drilling commenced. The wells were installed at the landfill's perimeter and were not placed in landfilled material.

All wells were drilled with a Mobile B61 drilling rig by a driller licensed in the State of Maryland (Hardin/Huber, Inc). The hollow-stem auger method was utilized to drill in the unconsolidated sediments and saprolite overlying the bedrock. Split-spoon samples of the overburden were collected at 5 foot intervals during augering. The boreholes were then advanced into the bedrock by using a pneumatic hammer that was advanced through the auger string. At Well 1GW-2, bedrock samples were collected by diamond coring through the auger string after auger refusal. All of the wells were completed in the saprolite and upper bedrock aquifer by installation of a ten foot length of 4-inch ID (internal diameter) Schedule 40 PVC well screen. For each well, sand pack was installed around the screen followed by a two-foot bentonite seal immediately above the sand pack. The remaining well annulus was filled with a 5% bentonite/cement grout to approximately three feet below ground surface. A locking protector casing was then installed and cemented in place. A 5 foot square concrete apron with four steel guard posts were placed around each well head for protection. The guard posts and protector casings were subsequently painted international orange. A dedicated State of Maryland well tag has been secured onto each of the monitoring well protector casings. Lastly, a sign containing the phrase, "Monitoring well - property of U.S. Navy, Not for Potable Use or

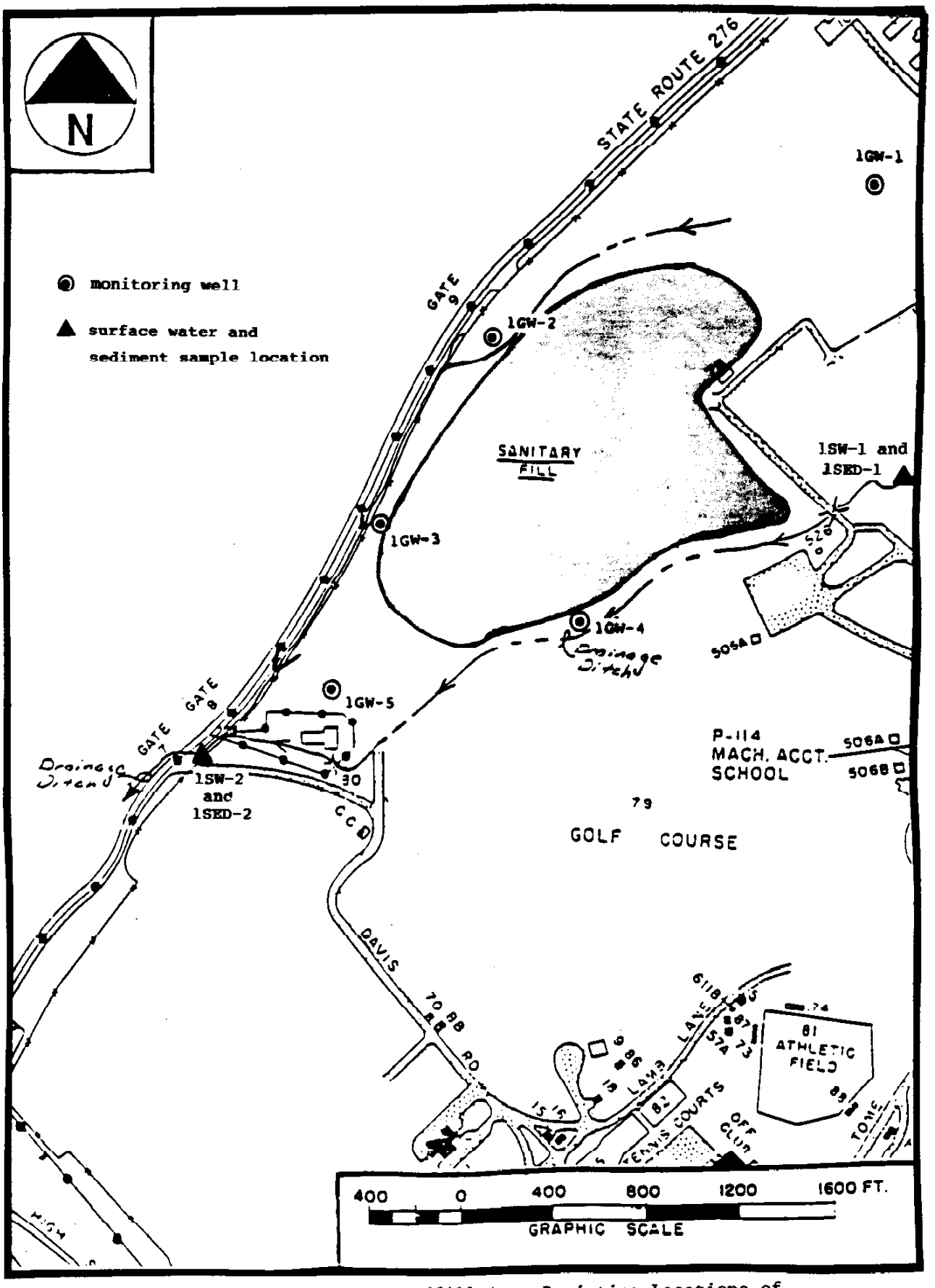


Figure 2-1: Map of Landfill Area Depicting Locations of Monitoring Wells and Surface Water and Stream Sediment Samples

Disposal" has been emplaced at each monitoring well site. Appendix A contains detailed narrative discussions, well construction records and diagrams, and a geologic log for each well.

The drilling rig and all tools and equipment were fully steam cleaned prior to the drilling of each well. Decontamination was conducted away from drilling locations at a staging and decontamination area adjacent to the water treatment building where clean water and electric power were available. All visible mud, sediment, and dirt were removed from the equipment.

During all well drilling and installation, Versar personnel conducted air monitoring with a photoionization detector or an organic vapor analyzer. No contamination was detected in the breathing zone at any location and, as a result, all activities were performed using Level D personal protection. Action levels requiring an upgrade to Level C protection were never encountered during the investigation.

2.1.1.1 Local Geology and Hydrogeology

Surface grab and split-spoon samples were collected in the unconsolidated soils and saprolite during the drilling of each borehole. The soils primarily consisted of brown, plastic clays, fine grained micaceous sands, and black silt containing various amounts of pebbles, saprolite fragments, and organic materials. Well 1GW-2 was located on an old road as indicated by the presence of asphalt and cinder blocks from 2 to 4 feet overlying slag and other fill materials. ie old gate #9

Saprolite, a friable, weathered product of the Port Deposit Gneiss, was encountered beneath the surficial soils in all wells drilled at the landfill. A hydrogeologic cross section along a line A-A' across the landfill (Figure 2-2) is shown in Figure 2-3. As shown in the cross section, the depth to saprolite from land surface varied from less than five feet at most locations to a maximum of approximately 16 feet at well 1GW-2. The saprolite consists of bedrock that has been weathered in place by ground-water, and as a result, displays the texture and

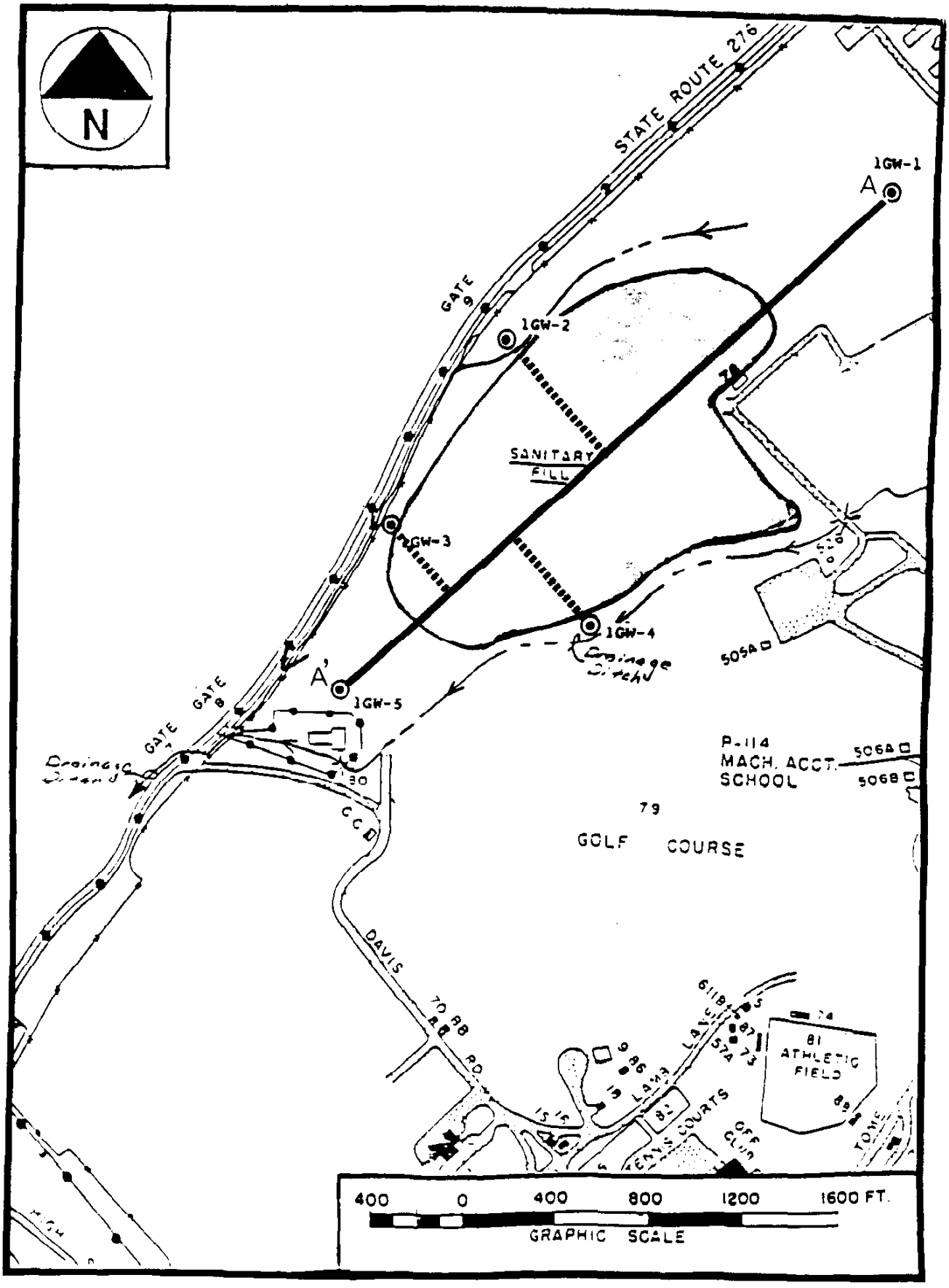


Figure 2-2: Location of Cross Section A-A' Through Landfill Area

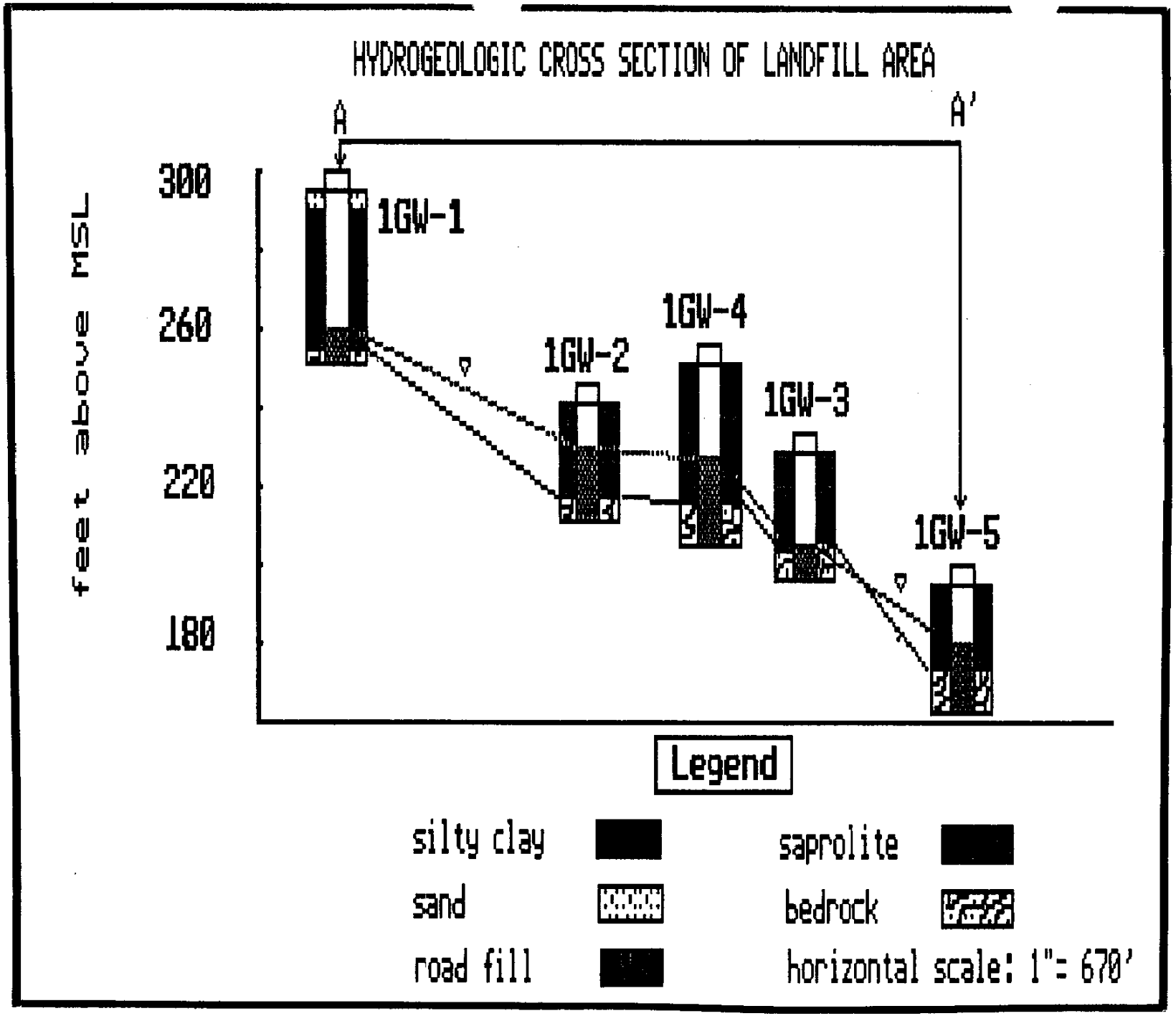


Figure 2-3: Hydrogeologic Cross Section of Landfill Area Depicting Lithology, Slope of Bedrock, and Slope of Potentiometric Ground Water Level

laminations characteristic of the parent rock, the Port Deposit Gneiss. The saprolite consists of subangular quartz grains with micaceous and mafic minerals in a matrix of clays and silts. In most locations the saprolite was very dense, well compacted, and very dry. The thickness of the saprolite zone varied from 6 feet in well 1GW-2 to approximately 41 feet in well 1GW-1.

Bedrock, consisting of the coarse and fine-grained phases of the Port Deposit Gneiss, was encountered beneath the saprolite zone of each well location. Depth to bedrock from land surface ranged from 20 feet at well 1GW-3, to a maximum of 46 feet at background well 1GW-1 (Figure 2-3). The gneiss, as described from a diamond core sample taken at well 1GW-2 and from cutting samples collected from all landfill wells, consists of quartz rich, dense, very competent rock of igneous and metamorphic origin with gneissic laminations. Distinct fractures, displaying heavy dark brown staining, were observed in the bedrock core. Geologic logs for all of the wells are included in Appendix A and provide detailed lithologic descriptions, formation depths and additional information collected during drilling and sampling activities.

The bedrock beneath the landfill acts as the most significant aquifer at the site. A prominent fracture system in the upper portion of the Port Deposit Gneiss allows for the storage and transport of ground water. The saprolite immediately overlying the unweathered bedrock also contained water-bearing fractures and likely acts as part of the aquifer. This was particularly prominent in well 1GW-1 where a water seam was encountered approximately 5 feet above the bedrock surface. However, the majority of the saprolite zone was dense, compacted, and very dry and did not contain or transmit any significant amounts of water at any of the well locations. A localized, perched water table was encountered in the unconsolidated sediments above the dense saprolite zone at well 1GW-2. The perched zone is probably the result of precipitation that infiltrated and accumulated above the relatively impervious saprolite.

The bedrock zone exhibits properties of a confined aquifer. The fine-grained low permeability saprolite overlying the bedrock appears to act as a confining layer, preventing water from flowing upward from the bedrock. For example, when drilling well 1GW-4, water was first encountered at 35.5 feet below land surface (b.l.s.). However, the water column in the well-bore immediately rose to 24 feet b.l.s. (Figure 2-3) after penetrating the dense saprolite and drilling into the fractured bedrock. Ground-water flow at the landfill area is predominantly to the south. Flow also appears to curve slightly to the southwest, along the dip in topography towards State Route 276 as deduced from static water elevation data collected over the course of this investigation (Figure 2-4). Ground-water elevation contour lines shown in Figures 2-5 through 2-7 further illustrate the southwesterly ground-water flow direction.

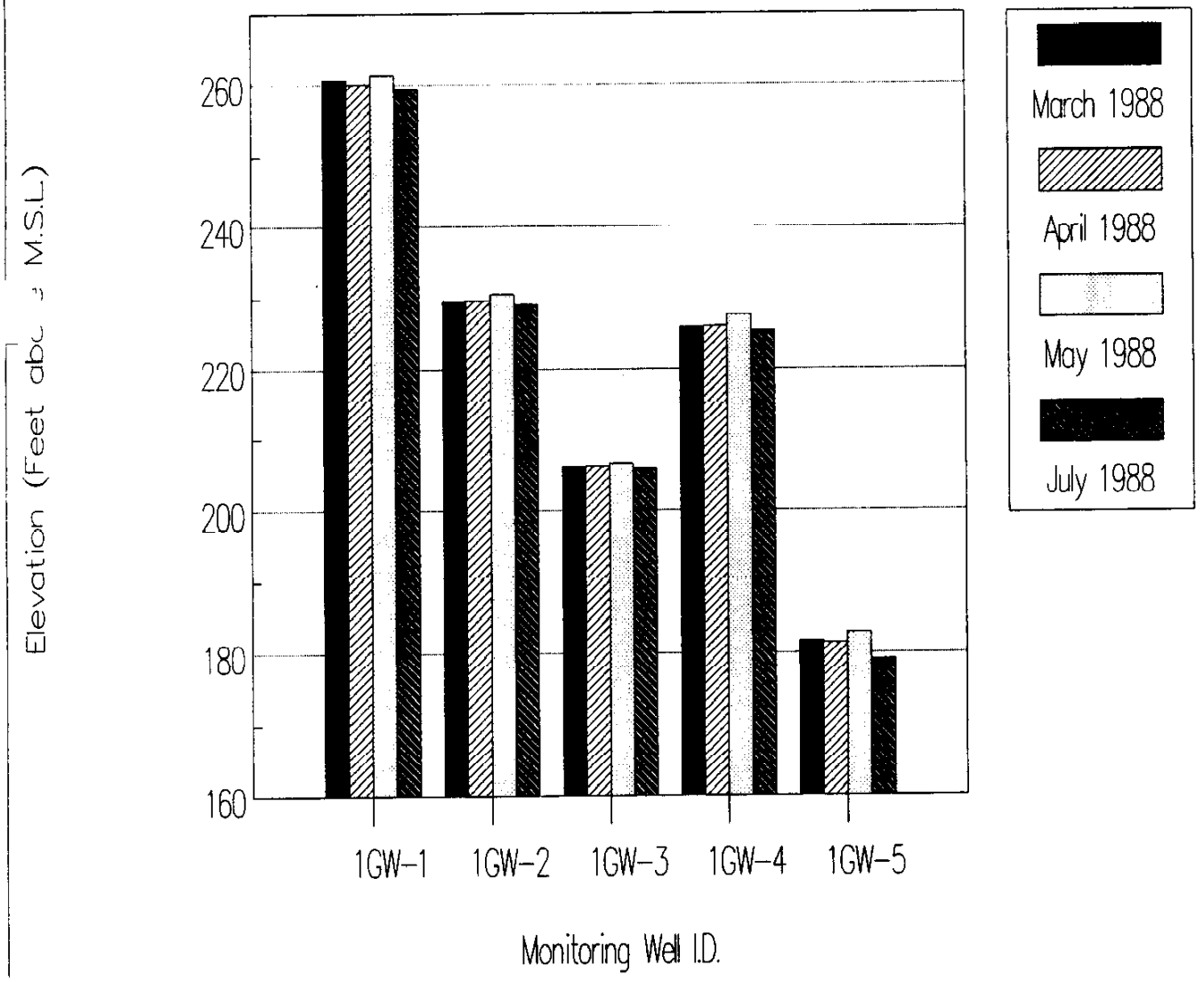
2.1.1.2 Surveying and Development

Subsequent to installation, all wells were surveyed by a licensed surveyor in the State of Maryland, Fredrick Ward & Associates. Measurements were taken from the well casings, the protector casings, and the surface of the concrete apron at each well and surveyed to the nearest .01 foot above the National Geodetic Vertical Datum of 1929. The surveyor closed the loop to insure the accuracy of the relative elevations. Notches were cut in the casings and markers were placed in the concrete pads to act as permanent reference points. The surveyed elevations for all wells are provided in Appendix B.

All wells were developed after construction and after allowing sufficient time for the grout to properly set. The wells were purged of several times the well volume of water at a rate of 12 to 16 gallons per minute using a 4-inch submersible 3/4-horsepower Jacuzzi pump placed at the bottom of the well. Ground-water parameters including temperature, specific conductivity, and pH were monitored periodically during development. Purging continued until these parameters stabilized. Final volumes for the stabilized parameters are listed on the well construction

FIGURE 2-4. STATIC WATER ELEVATIONS

(Base Landfill Wells)



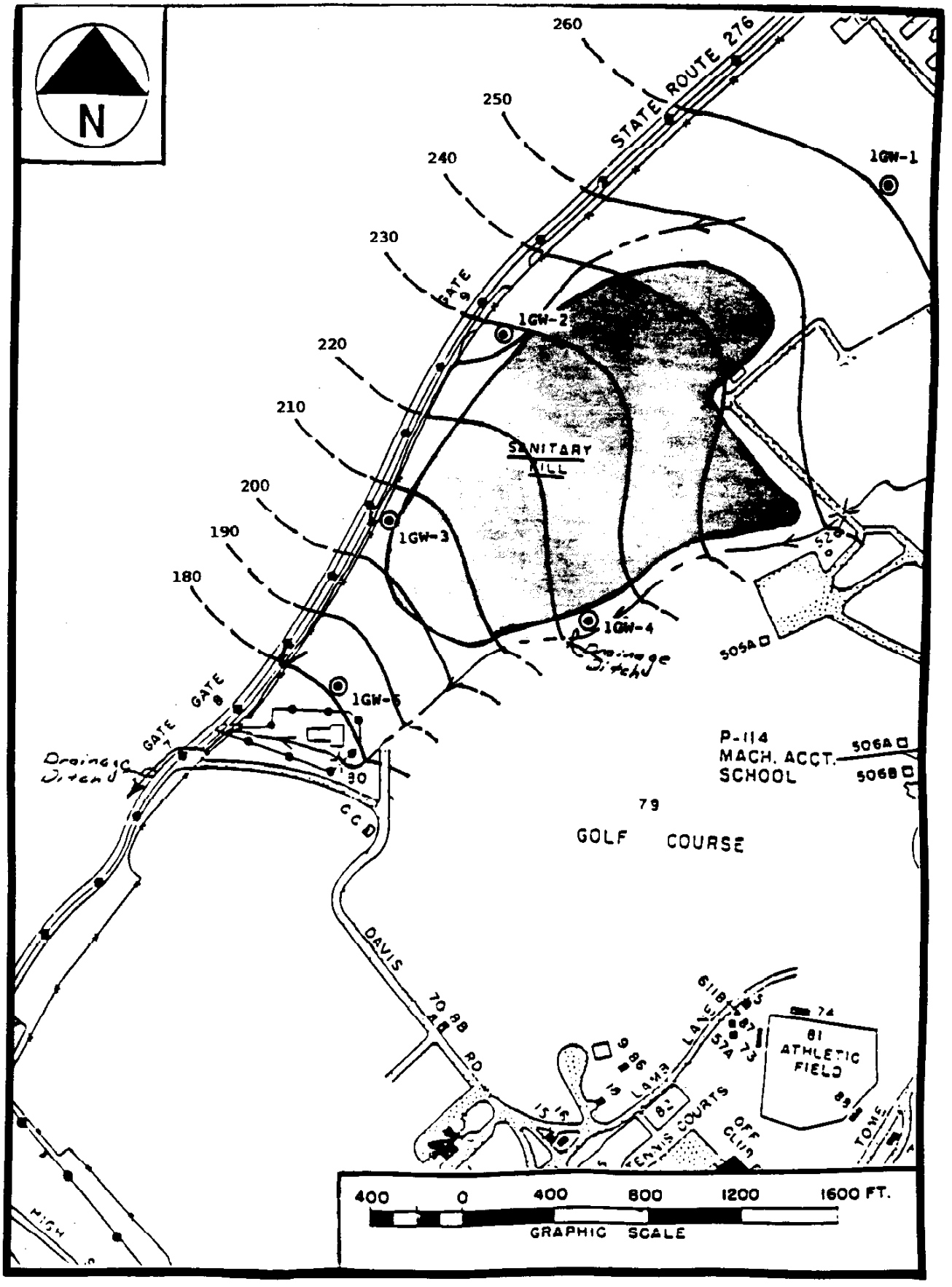


Figure 2-5: Contour Map of Ground Water Potentiometric Surface (In Feet Above Mean Sea Level) for Landfill Area on March 14, 1988. Contour Lines are Dashed Where Approximate

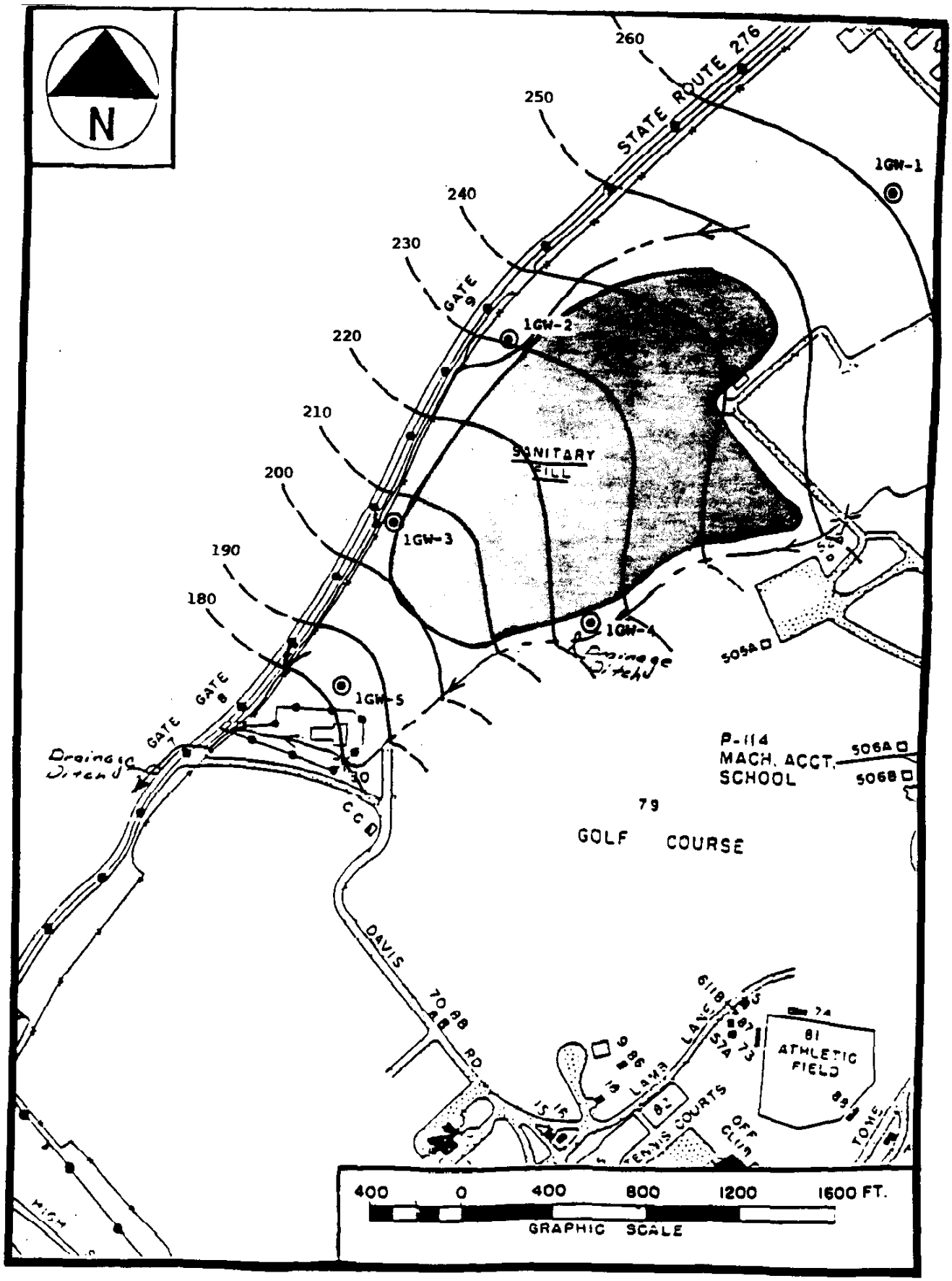


Figure 2-6: Contour Map of Ground Water Potentiometric Surface (In Feet Above Mean Sea Level) for Landfill Area on May 16, 1988. Contour Lines are Dashed Where Approximate

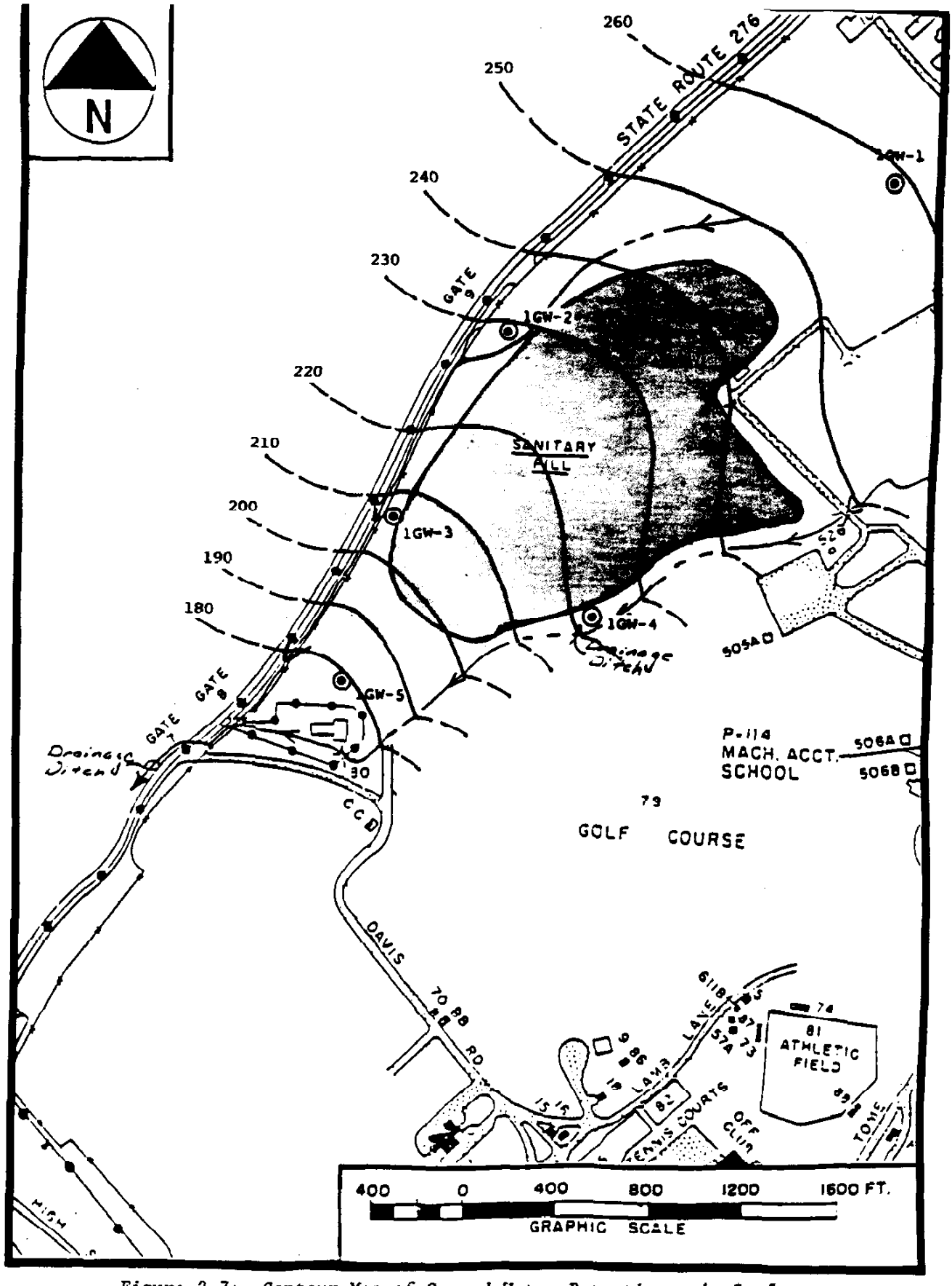


Figure 2-7: Contour Map of Ground Water Potentiometric Surface (In Feet Above Mean Sea Level) for Landfill Area on July 25, 1988. Contour Lines are Dashed Where Approximate

records provided in Appendix A. All wells at the landfill produced sufficient volumes of clear ground water. The pumps and hoses used for development were decontaminated after each well was developed by pumping clean tap water obtained from the water treatment building through the pump and hoses and then rinsing the hoses and pump with deionized water.

2.1.1.3 Problems and Resolutions

As discussed in Section 2.1.1.1, a perched water table aquifer was encountered at a depth of 13.5 feet b.l.s. during the drilling of Well 1GW-2. However, the well was screened in the bedrock aquifer. Although the objective of this investigation was to monitor the first occurrence of ground-water below ground surface, Versar decided not to complete the well in the perched zone because it was unlikely that the zone was capable of yielding sufficient water volumes for year-round monitoring. Also, the four additional wells surrounding the landfill were screened in the bedrock aquifer and it was decided that Well 1GW-2 should also monitor the same aquifer such that chemical results could be compared and properly evaluated.

2.1.2 Ground-Water Sampling

Ground-water samples were collected from the five monitoring wells installed surrounding the base landfill during three separate sampling events held in March, May, and July 1988. All samples were analyzed for volatile organic compounds and organochlorine pesticides. The three sampling rounds were conducted on March 15/16, 1988, May 16/17, 1988, and July 25/26, 1988. For each sampling event, depth to water and total depth of each well was initially measured and casing water volumes were calculated. Depth to water was also measured on a separate occasion on April 21, 1988. Static water elevations for all three sampling rounds and the additional April round are shown in Table 1-1 and are depicted graphically for the five landfill wells in Figure 2-4.

The 4-inch ID wells were purged using dedicated Teflon bailers with dedicated 5 foot Teflon-coated stainless steel wire leaders attached to

each bailer and nylon rope attached to these leaders. New nylon rope was used for each well. The nylon rope was never in contact with the well water. A minimum of three well volumes was removed from each well prior to sampling. After purging, samples were collected using the dedicated Teflon bailers. The samples were placed in pre-cleaned glass containers (I-Chem), labelled, packaged, placed on ice, and returned to the Versar laboratory in Springfield, Virginia according to the protocol described in the QA/QC Plan (Versar, 1988a)(see Section 3.0 of this report). In situ field measurements were taken for temperature, specific conductivity, and pH for each well during each round of sampling. The Maryland Department of the Environment, Hazardous and Solid Waste Management Administration, also collected split ground-water samples for volatile organic analysis, and pesticide analyses for the first two ground-water sampling events. Sample containers for split samples were provided by the Maryland Department of the Environment.

2.1.3 Surface Water Sampling

Surface water samples were collected from two locations along streams adjacent to the base landfill as shown on Figure 2-1 during each of the 3 sampling events. The locations were determined by Versar and agreed to by NAVFACENGCOM-Atlantic Division prior to the first surface water sampling event. Samples were collected in conjunction with the ground-water sampling events of March 15/16, 1988, May 16/17, 1988, and July 25/26, 1988, respectively. The surface water samples were collected by submerging sample bottles into the stream. In situ field measurements were taken for temperature, specific conductivity, and pH. Samples were packaged and shipped to the Versar laboratory according to the protocol described in the project QA/QC Plan (Versar, 1988a)(see Section 3.0 of this report). Split samples were collected for analyses by the Maryland Department of the Environment, Hazardous and Solid Waste Management Administration, who provided their own sample containers. Splits were collected by immersing both Versar and Maryland containers into the stream simultaneously at each sampling location.

2.1.4 Stream Sediment Sampling

For each of the three sampling events, sediment samples were collected from the two stream locations adjacent to the base landfill immediately following surface water sample collection. Sampling locations are shown on Figure 2-1. Samples were collected by using dedicated stainless steel scoops. Sediment aliquots, taken from the stream bed, were mixed and homogenized in dedicated stainless steel bowls and placed in sample jars. Samples were shipped to the Versar laboratory according to the protocol outlined in the QA/QC Plan (Versar, 1988a). The samples were analyzed for volatile organic compounds and pesticides. Split sediment samples were not collected by the Maryland Department of the Environment, Hazardous and Solid Waste Management Administration.

2.2 Oil Separator Pit

The purpose of this investigation was to identify and characterize contamination of various environmental media resulting from past disposal practices conducted at the oil separator pit. Records indicate that the Navy operated a Fire Fighters' Training area which generated waste fuel oils mixed with water at NTC Bainbridge. The oil/water mixture flowed to an adjacent unlined pit where separation occurred (see Section 1.1). The location of the oil separator pit is shown on Figure 1-3. The scope of this investigation involves only the contamination assessment for the waste oil pit and was not intended to include other areas of the Fire Fighters Training area where contamination problems may exist. As with the investigation at the base landfill, the site characterization at the oil separator pit area involved the installation of ground-water monitoring wells, and the collection and analyses of ground-water, surface water, and sediment samples.

2.2.1 Monitoring Well Installation

Five ground-water monitoring wells were installed on the NTC Bainbridge property surrounding the oil separator pit during February 1988 as the initial task of the site characterization. The locations of

the wells are shown on Figure 2-8. As with wells installed at the base landfill, the locations of the five monitoring wells were modified from original locations proposed by NAVFACENGCOM-Atlantic Division. The final locations determined by Versar in the field were agreed to by the EIC, and included one hydraulically upgradient (background) monitoring well (2GW-1) and four downgradient monitoring wells. Initially, the drill sites were cleared with a bulldozer where necessary. A metal detector was used at each drill site to insure the absence of any buried metal debris, utility lines, or pipelines. No wells were installed within the actual oil separator pit.

The wells were drilled and installed in February, 1988 with a Mobile B61 drilling rig by a driller licensed in the State of Maryland; Hardin/Huber, Inc. The hollow-stem auger method was utilized to drill in the unconsolidated sediments and saprolite overlying the bedrock. Split-spoon samples of the overburden were collected at 5 foot intervals during augering for sample description. The boreholes were then advanced into the bedrock using a pneumatic hammer advanced through the auger string that remained in place to prevent caving of the overburden. A diamond core sample was collected from the bedrock in borehole 2GW-4. The initial borehole drilled at location 2GW-1 was abandoned and filled with grout to ground surface due to broken auger flights which became stuck at the bottom of the hole. This borehole is designated as 2GW-1A.

A total of five wells were installed around the oil separator pit. With the exception of 2GW-3, all of the wells were completed in the upper bedrock aquifer. Two wells, the upgradient well (2GW-1) and the furthest downgradient well (2GW-5), were installed with 6-inch PVC conductor casing set into the top of competent bedrock with an open borehole in the bedrock serving as the well. Two wells adjacent to the oil separator pit (2GW-2 and 2GW-4) were constructed in a similar manner, but with 6-inch stainless steel conductor casing. The four wells installed with 6-inch conductor casings were constructed by setting the conductor approximately 1-2 feet into the top of competent bedrock. The casing was emplaced into

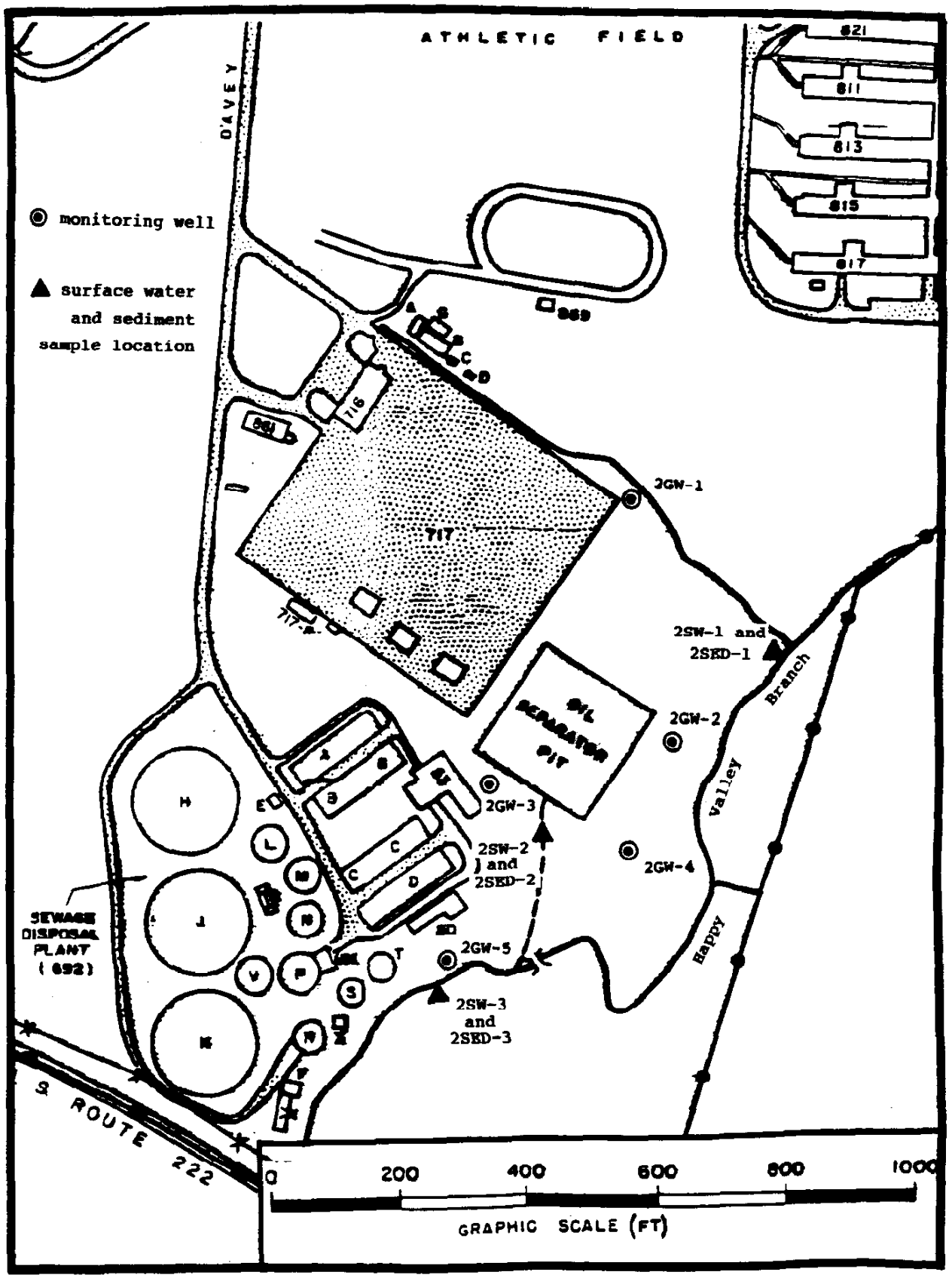


Figure 2-8: Map of Oil Separator Pit Area Depicting Locations of Monitoring Wells as well as Surface Water and Stream Sediment Locations

1-foot of bentonite to form a seal at the base of the casing. Hammer drilling then proceeded through the conductor casing (and bentonite seal) into bedrock. An open borehole into the fractured Port Deposit Gneiss served as the completed well. A bentonite/cement slurry was brought to ground surface around the conductor casing, and a locking protective casing was installed for all five wells. A 5-foot by 5-foot square concrete apron and four steel guard posts were placed around each well head for protection. The guard posts and the locking protector casing around each well were painted in international orange and a dedicated State of Maryland well tag has been secured onto each of the protector casings. Lastly, a permanent sign containing the phrase "Monitoring Well - Property of U.S. Navy, Not for Potable Use or Disposal" was emplaced at each well site. Appendix A contains detailed narrative discussions, well construction records, diagrams, and a geologic log for each well.

The drilling rig and all tools and equipment were fully steam cleaned prior to the drilling of each monitoring well. Decontamination was conducted at the staging and decontamination area adjacent to the water treatment facility where clean water and electric power were available. Decontamination as not performed at any of the well locations. All visible mud, sediment, and dirt were removed from the equipment. Additionally, all drilling equipment received an isopropanol rinse followed by a water rinse during decontamination activities.

During all drilling and well installation, Versar personnel conducted air monitoring with an organic vapor photoionization detector. No significant contamination was detected in the breathing zone at any location and as a result, all activities were performed using Level D personal protection. Action levels requiring an upgrade to Level C protection were never encountered during the investigation at the oil separator pit.

2.2.1.1 Local Geology and Hydrogeology

Surface grab and split-spoon samples were collected in the unconsolidated soils and saprolite while drilling each borehole at the

oil separator pit. The soils consisted of yellowish-brown silts, clays, and fine to coarse-grained silty sands with varying amounts of pebbles, saprolite, and organic materials.

Beneath the surface soils, saprolite was encountered in all wells drilled at the oil separator pit with the exception of monitoring well 2GW-3. A hydrogeologic cross section along a line B-B' across the oil separator pit (Figure 2-9) is shown in Figure 2-10. The cross section illustrates that the depth to saprolite from ground surface varied from 6 feet to a maximum of 15 feet at background location 2GW-1. The saprolite zone formed from the effects of in situ weathering of the bedrock by ground-water, and consequently displays the texture and lamination characteristics of the parent rock. The saprolite consists of subangular very fine to coarse quartz grains with micaceous and mafic minerals in a matrix of clays and silts. At most locations the saprolite was highly compacted and dry. The thickness of the saprolite zone varied from 3 feet in monitoring well 2GW-5, to approximately 16 feet in monitoring well 2GW-1.

At well 2GW-3, fluvial river bed deposits, consisting of cobbles and pebbles, were encountered at a depth of 18 feet, beneath a zone of silts and sands. These deposits were likely emplaced by a stream that cut into the existing saprolite. Since the sediments at this location were saturated, a stainless steel screen and casing were set to monitor the water table, and the well was not advanced to the top of the bedrock or into the bedrock aquifer. The total depth of the fluvial sediments at this location was not determined however, they existed to a depth of at least 30 feet b.l.s. Aerial photographic analysis indicates the presence of an ephemeral drainage channel along the southern side of the oil separator pit, where 2GW-3 is located.

Bedrock, consisting of the fine grained phase of the Port Deposit Gneiss, was encountered beneath the saprolite zone on all wells except 2GW-3. Depth to bedrock from land surface ranged from 12.5 feet at the furthest downgradient well, 2GW-5, to a maximum of 31 feet at background

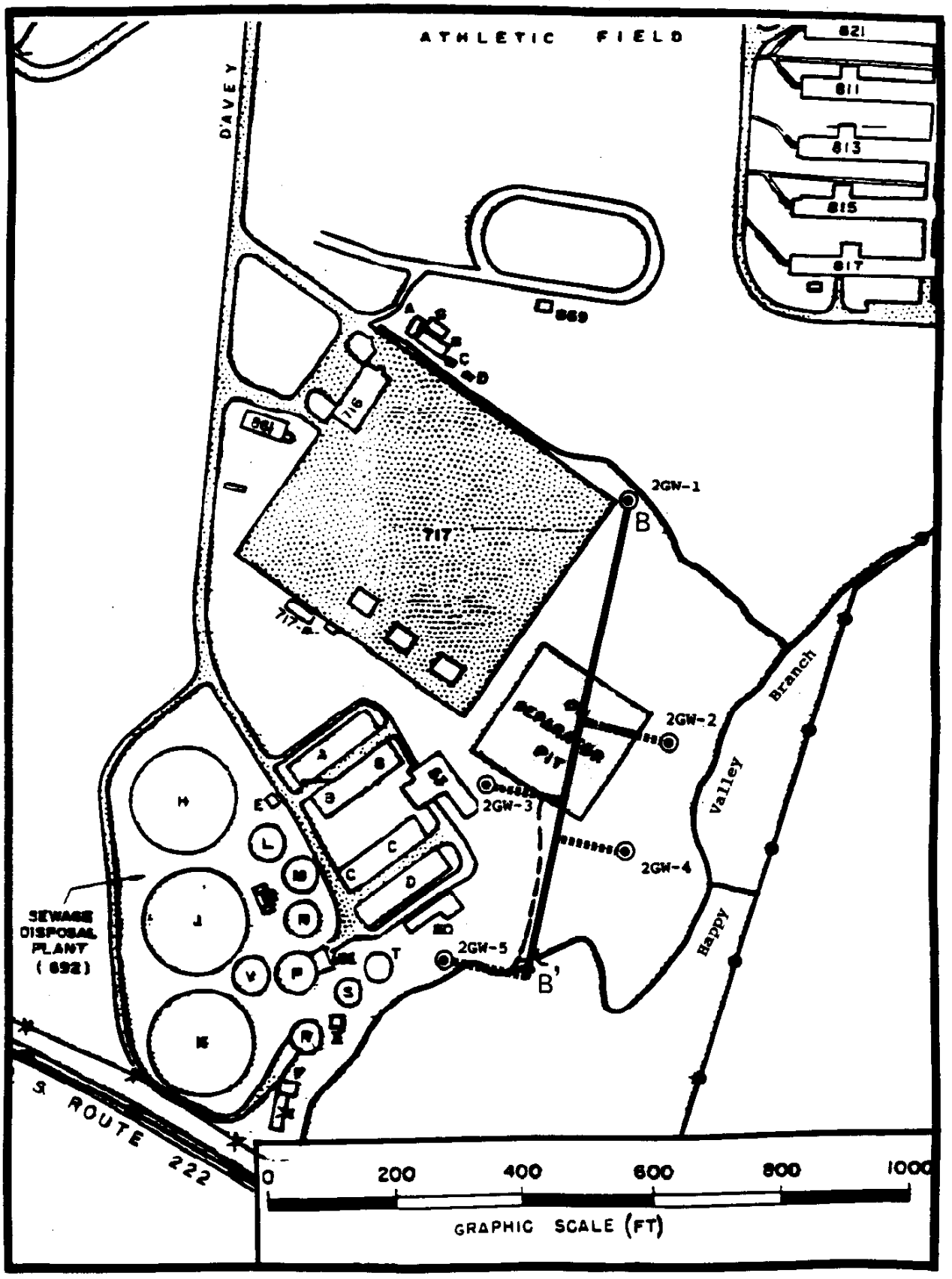


Figure 2-9: Location of Cross Section B-B' Through the Oil Separator Pit Area

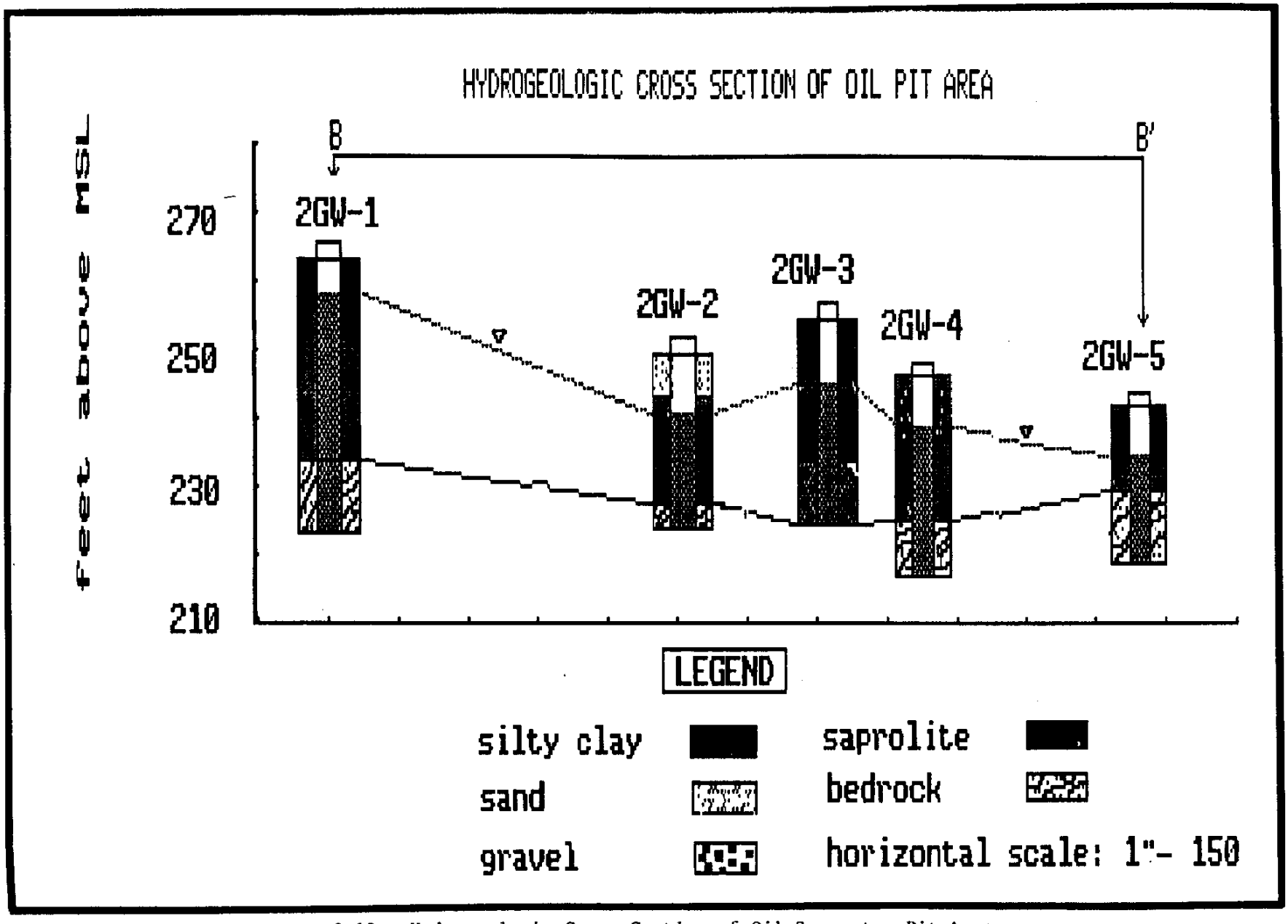


Figure 2-10: Hydrogeologic Cross Section of Oil Separator Pit Area Depicting Lithology, Slope of Bedrock, and Slope of Potentiometric Ground Water Level

Well 2GW-1. The gneiss, as described from a diamond core sample taken while drilling well 2GW-4 and from cutting samples collected at the other wells, consists of quartz rich, dense, very competent rock of igneous and metamorphic origin with gneissic laminations. Distinct fractures displaying brown staining are present in the core. Geologic logs for all of the wells are included in Appendix A and provide detailed lithologic descriptions, formation depths, and additional information collected during drilling and sampling activities. Also included in Appendix A are well completion records and diagrams for each of the 5 wells installed at the oil separator pit.

The fractured bedrock beneath the oil separator pit acts as the most significant aquifer at the site. A prominent fracture system in the upper portion of the Port Deposit Gneiss allows for the storage and movement of ground water. All wells at the oil separator pit site were completed in bedrock through open holes, with the exception of well 2GW-3 which was screened in the overlying fluvial sediments.

The fine-grained saprolite overlying the bedrock was found to be dry and dense at most locations and appears to act as a confining layer. A perched water table was encountered on all wells above the saprolite in the unconsolidated sediments. The perched zone is probably the result of precipitation that infiltrated and accumulated above the relatively impervious saprolite.

Ground-water elevation data was acquired four times during the course of this investigation (Figure 2-11). As the water table contours in Figures 2-12, 2-13, and 2-14 depict, ground water at the oil separator pit location follows local topography and flows in a southerly direction towards Happy Valley Creek. Due to the scope of this investigation, Versar could not determine if ground-water is discharging into the creek or if the predominant ground-water flow pathways continue under the creek and towards the Susquehanna River. Ground-water elevations were slightly lower during the summer sampling event than during winter and spring sampling events.

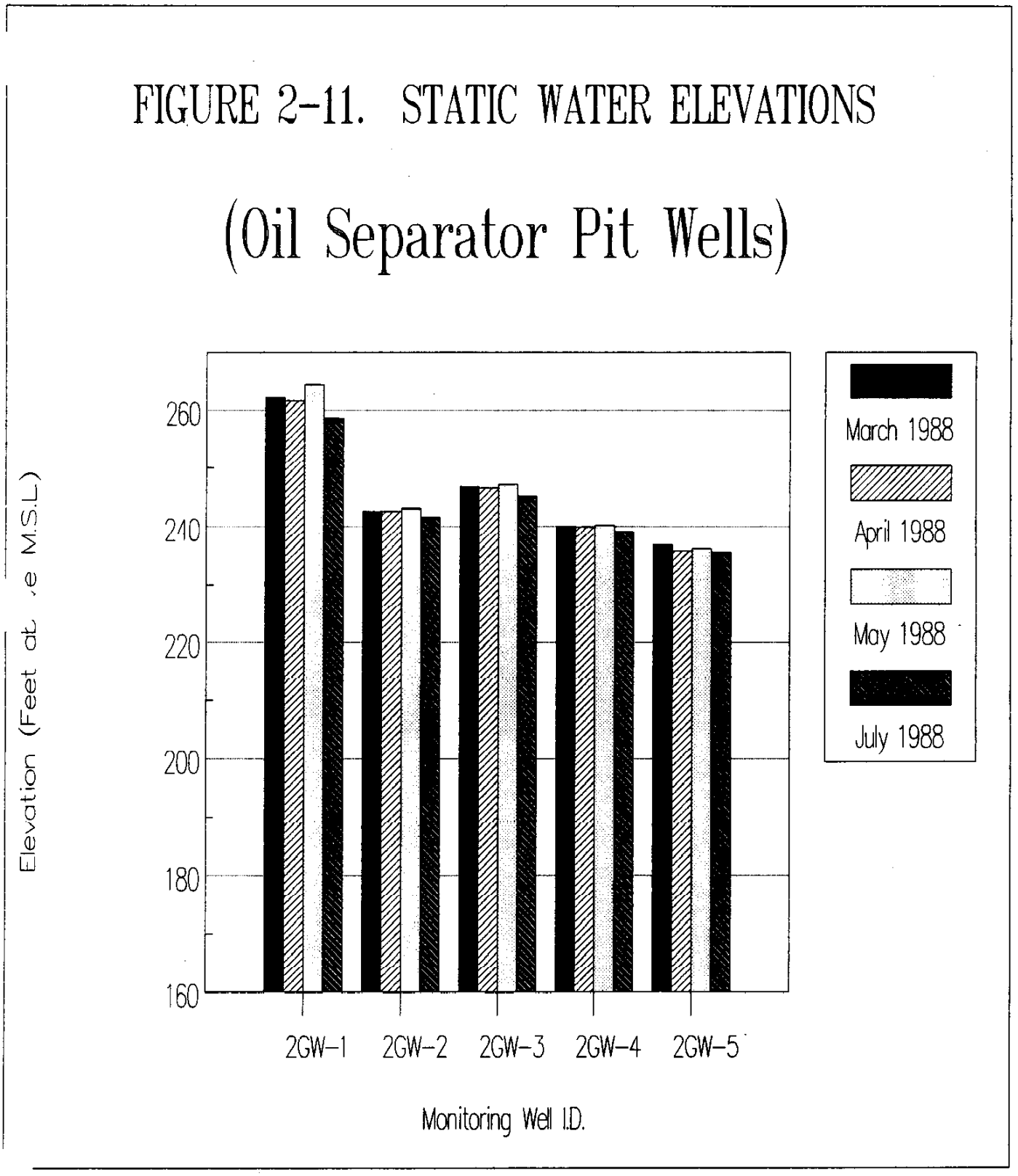


Figure 2-11: Static Water Elevations (Oil Separator Pit Wells)

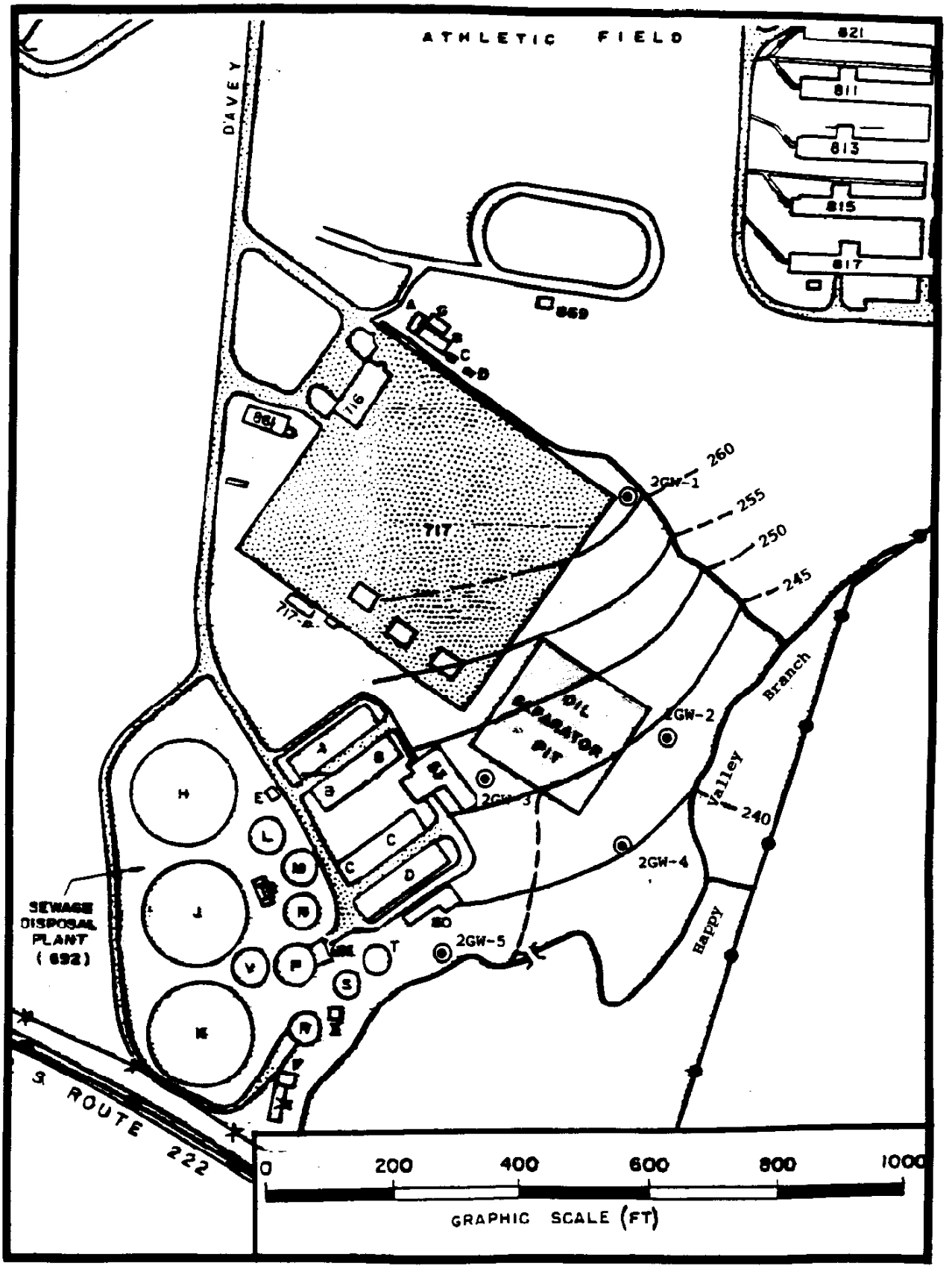


Figure 2-12: Contour Map of Ground Water Potentiometric Surface (In Feet Above Mean Sea Level) for Oil Separator Pit Area on March 14, 1988.
Contour Lines are Dashed Where Appropriate

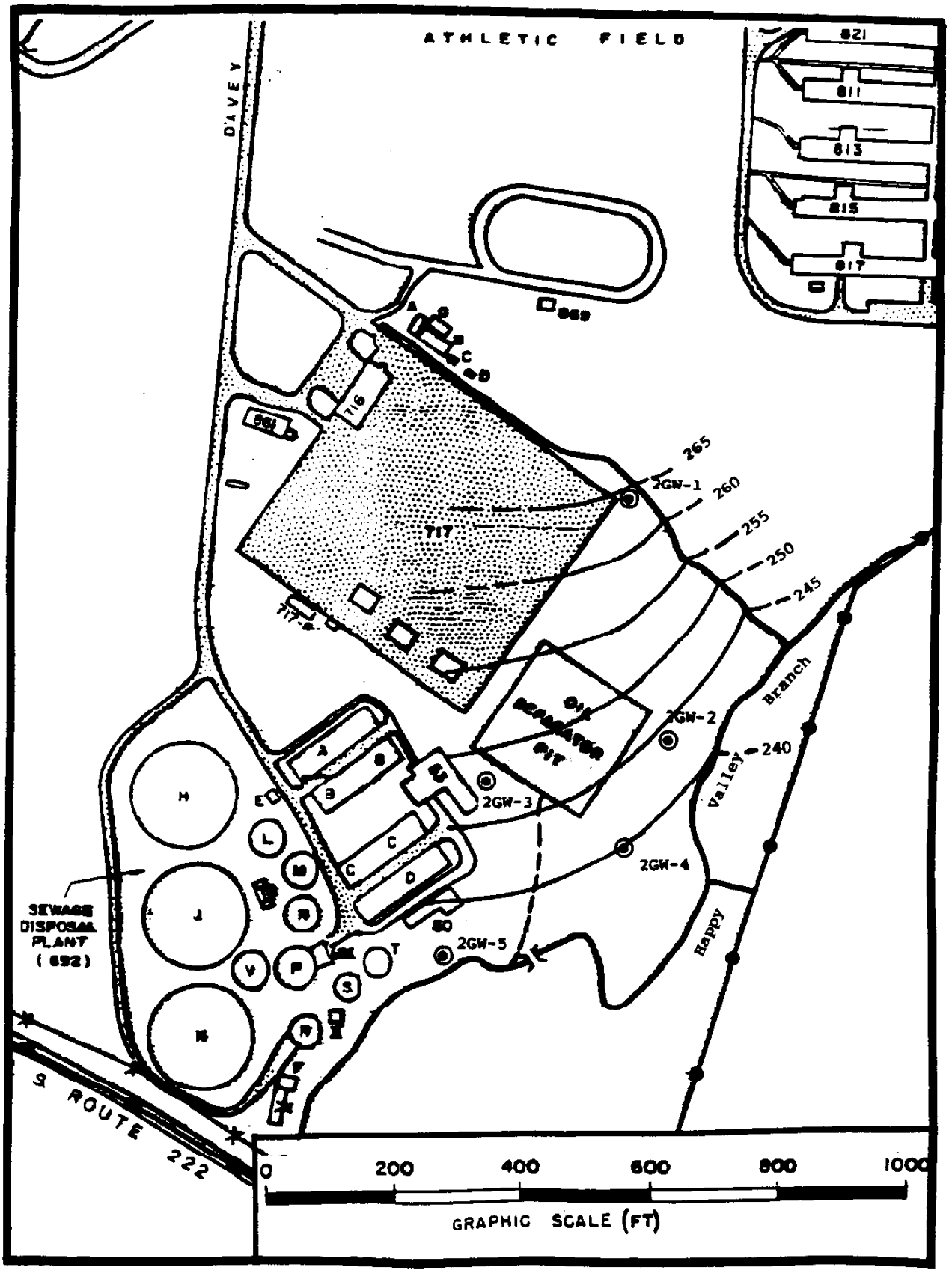


Figure 2-13: Contour Map of Ground Water Potentiometric Surface (In Feet Above Mean Sea Level) for Oil Separator Pit Area on May 16, 1988.
Contour Lines are Dashed Where Appropriate

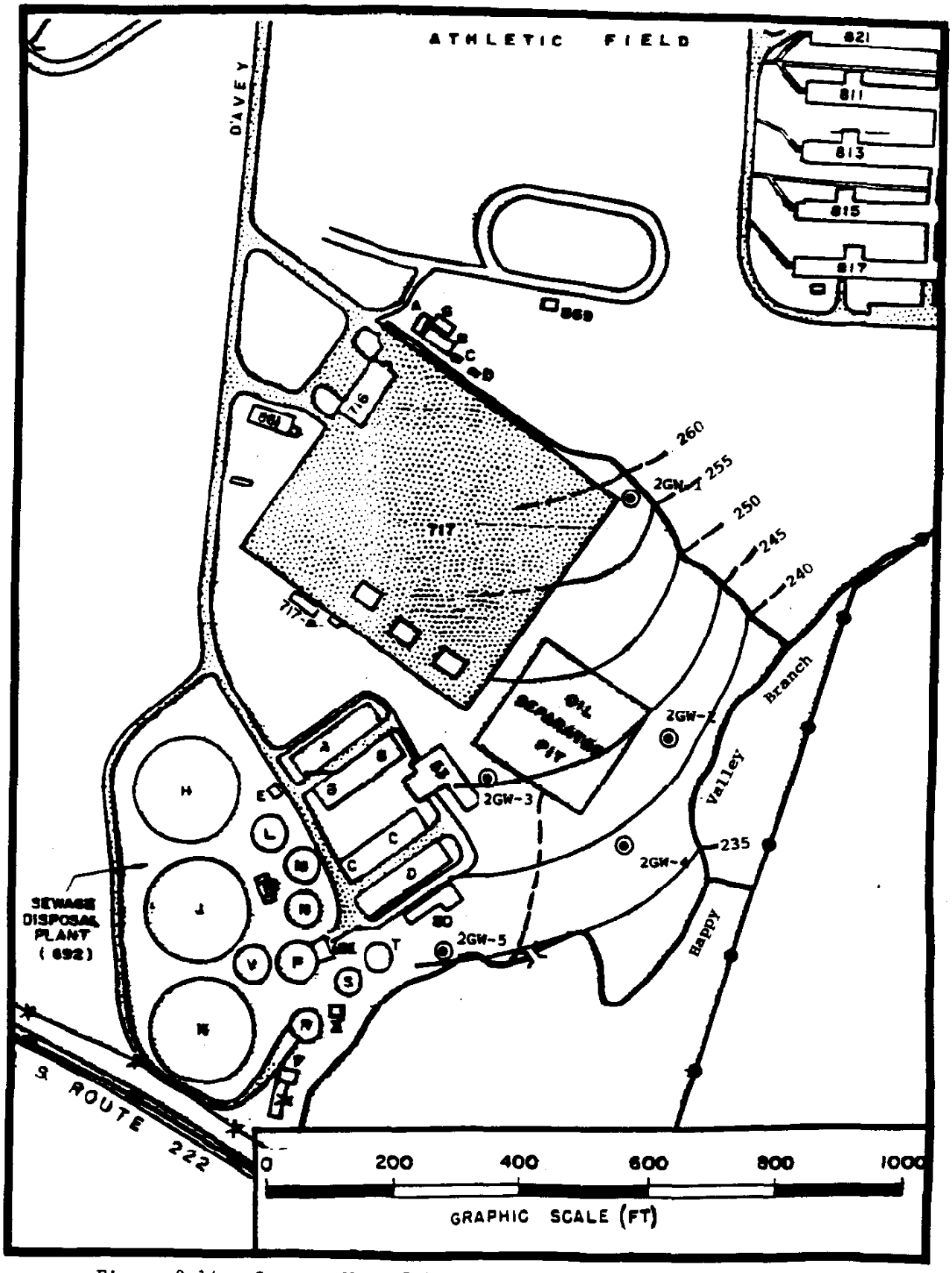


Figure 2-14: Contour Map of Ground Water Potentiometric Surface (In Feet Above Mean Sea Level) for Oil Separator Pit Area on July 25, 1988.
Contour Lines are Dashed Where Appropriate

2.2.1.2 Surveying and Development

After installation, all wells were surveyed by a licensed surveyor in the State of Maryland, Frederick Ward & Associates. Measurements were taken from the well casings, the protector casings, and the surface of the concrete apron at each well and surveyed to the nearest 0.01 foot above the National Geodetic Vertical Datum of 1929. The surveyor closed the loop to insure the accuracy of each of the measured elevations. Notches were cut in the casings and markers were placed in the concrete pads to act as permanent reference points. The surveyed elevations for all monitoring wells installed at the oil separator pit are provided in Appendix B

All wells were developed after construction and after allowing sufficient time for the grout to properly set (minimum 48 hours). The wells were purged of several times the well volume at a rate of 12 to 16 gallons per minute using a 4-inch submersible 3/4-horsepower Jacuzzi pump placed at the bottom of the well. The wells were periodically surged during pumping to remove sediments. Ground water parameters including temperature, specific conductivity, and pH were monitored periodically during development. Purging continued until these in situ parameters stabilized and until water appeared clear and free of suspended sediments. All wells at the oil separator pit produced sufficient volumes of ground water for monitoring purposes, although several of the wells were pumped dry and were allowed to recover for a few minutes before pumping proceeded. The pumps and hoses used for development were decontaminated after each well was completely developed, by pumping clean tap water and rinsing the hoses with deionized water. Final development (in situ) parameters are included on each of the well construction records provided in Appendix A.

2.2.1.3 Problems and Resolutions

As discussed in Section 2.2.1.1, a perched water table aquifer was encountered above the saprolite zone while drilling some of the wells at the oil separator pit. However, the wells were not screened in the

perched zone, but rather in the bedrock aquifer below saprolite or, in the case of well 2GW-3, in the fluvial sediments at that location. Although the objective of the investigation was to monitor the first occurrence of ground water, Versar decided not to complete the wells in the perched zone because it was unlikely that the zone was capable of yielding sufficient volumes of water on an annual basis. During periods of low recharge, likely during the summer months, the perched water table probably becomes dry and would not yield water if screened. The bedrock aquifer is considered to be the uppermost aquifer of significance. Due to the presence of extensive fractures at the top of the Port Deposit Gneiss, it is likely that the bedrock aquifer is contiguous with the ground-water encountered in fluvial sediments at 2GW-3.

Stainless steel (type 304) was chosen as the construction material for wells 2GW-2, 2GW-3, and 2GW-4 because of their proximity to the oil separator pit and the possibility of higher concentrations of oil products in the ground water. Stainless steel is considered to be the best well construction material in this type of environment and will not degrade or absorb contaminants in the presence of volatile organic compounds. Metal concentrations in the surrounding ground water may potentially be affected by the casing at low ground water pH, however, with the exception of lead, metals do not present an environmental concern at this location. In addition, ground-water pH at these locations was not acidic; approximately pH = 6. Alternatively, Schedule 40 PVC conductor casing was installed on wells 2GW-1, upgradient of the oil pit, and 2GW-5, the furthest downgradient well because of the expected lower oil concentrations at these locations.

During drilling activities at Well 2GW-3, indications of organic contamination were identified. Readings taken in the open borehole with a HNu photoionization detector were as high as 5 parts per million. Also, a slight petroleum odor was detected in the split-spoon samples and the borehole. Monitoring of the breathing zone did not, however, reveal levels high enough to require Level C personal protection.

2.2.2 Ground-Water Sampling

Ground-water samples were collected from the five monitoring wells installed surrounding the oil separator pit. Three separate sampling events were conducted and samples were analyzed for volatile organic compounds (VOCs), PCB's, oil and grease, and lead. After the wells were completed and developed, sampling rounds were conducted on March 15/16, 1988, May 16/17, 1988, and July 25/26, 1988. Depth to water and total depth of each well was initially measured and well casing water volumes were calculated. Depth to water was also measured on a separate occasion on April 21, 1988. Static water elevations for all three sampling rounds and the additional April round are shown in Table 1-1 and are depicted graphically for the five oil separator pit wells in Figure 2-11.

The 6-inch diameter bedrock wells were purged using a stainless-steel Jacuzzi submersible pump attached to polyethylene drinking-water grade tubing. The pump was decontaminated between wells by pumping tap water and rinsing the purge hose with deionized water. The 4-inch screened well (2GW-3) was purged with a dedicated Teflon bailer. A minimum of three well volumes were removed from each well prior to sampling. After purging, samples were collected using dedicated Teflon bailers connected to 3 feet of dedicated teflon-coated stainless steel cable which was subsequently affixed to new nylon rope. The nylon rope was never in contact with well water, and new rope was used for each well. The samples were placed in the appropriate containers, labelled, packaged, placed on ice, and returned to the Versar laboratory in Springfield, Virginia as specified in the QA/QC Plan (Versar, 1988a) (see section 3.0 of this report). Lead samples were preserved with concentrated nitric acid to ph <2 in the field. In situ field measurements were taken for temperature, specific conductivity, and pH during each sampling event. The Maryland Department of the Environment, Hazardous and Solid Waste Management Administration, collected split ground-water samples for volatile organic analysis and PCB analyses during the first two sampling events. Split sample containers were provided by the Maryland Department of the Environment.

2.2.3 Surface Water Sampling

Surface water samples were collected from two locations along Happy Valley Creek adjacent to the oil separator pit and a third from a tributary leading from the oil separator pit to Happy Valley Creek (Figure 2-8) during each of the three rounds of sampling. The surface water samples were collected by submerging sample bottles into the stream at the predetermined sample locations. In situ field measurements were taken for temperature, specific conductivity, and pH. Samples were preserved, labelled, packaged and transported to the Versar laboratory according to the protocol described in the project QA/QC Plan (Versar, 1988a). Split surface water samples for VOCs and PCBs were collected for analyses by the Maryland Department of the Environment during the first and second sampling events. Versar and Maryland samples were collected by immersing the two sample containers into the stream simultaneously.

2.2.4 Stream Sediment Sampling

Sediment samples were collected from the two stream locations along Happy Valley Creek (2SED-1 and 2SED-3) as well as a third sample from the tributary leading from the oil separator pit to Happy Valley Creek. There sediment samples were obtained concurrent with surface water sample collection at identical stream locations. Sediment samples were collected immediately after each surface water sample to avoid water clouding as a result of disturbed sediment. Sampling locations are shown on Figure 2-8. Samples were collected during each of the three sampling events which occurred on March 15/16, 1988, May 16/17, 1988, and July 25/26, 1988 respectively. Samples were collected by using dedicated stainless steel scoops. Sediment aliquots, taken from the stream bottom, were mixed and homogenized in dedicated stainless steel bowls and placed in sample jars. Samples were shipped to the Versar laboratory according to the protocol outlined in the QA/QC Plan (Versar, 1988a). Analyses were performed on the sediment samples for volatile organic compounds, PCB's, oil and grease, and lead. Split sediment samples were not collected by the Maryland Department of the Environment, Hazardous and Solid Waste Management Administration.

3.0 ANALYTICAL RESULTS

The environmental samples collected from the past disposal areas at NTC Bainbridge were analyzed to assess the existence of contamination at the base landfill and the oil separator pit, and to collect the information required to apply EPA's Hazard Ranking System (HRS) model to this site. Versar collected and analyzed ground-water, surface water, and sediment samples from each location during three separate sampling events, which occurred approximately 60 days apart. The analytical data from these sampling events was evaluated for precision and accuracy. The data meeting the project QA/QC requirements were used to assess the extent of contamination at NTC Bainbridge. A summary of the analytical methods, including sample preparation and calibration procedures, is presented in Section 3.1. The analytical results are discussed in Sections 3.2 and 3.3, and the QA/QC evaluation of these results is presented in Section 3.4.

3.1 Analytical Methods

Before these samples could be analyzed, most of them had to be prepared using some type of digestion or extraction procedure. Then, the analytical instruments had to be calibrated by analyzing chemical calibration standards to establish that the instrument was functioning properly with the desired sensitivity.

After the analytical instruments were calibrated, the samples of ground water, surface water, and sediment for the base landfill were analyzed for volatile organic compounds (VOCs) and organochlorinated pesticides. The ground-water, surface water, and sediment samples from the oil separator pit were analyzed for lead, oil and grease, VOCs, and PCBs. The sample preparation, calibration, and analysis procedures for each analytical method are briefly described in Sections 3.1.1 through 3.1.5 (for a more detailed discussion of the sample preparation, calibration, and analysis procedures, see Sections 7.0 and 8.0 of the

Quality Assurance/Quality Control Plan for the Site Investigation at the Former Naval Training Center, Bainbridge, Maryland [Versar, 1988]).

3.1.1 Field Analyses

During each of the 3 sampling events, the Versar field team members made in situ measurements of temperature, pH, and specific conductance of the ground-water and surface water samples in the field. [These measurements were inadvertently not made for surface water samples collected during the second sampling event.] To determine reliable temperature readings, the thermometers are calibrated on a monthly basis against a National Bureau of Standards certified thermometer. Prior to measuring the temperature, the thermometer was checked for separations in the mercury and was rinsed with deionized water. If no separations were found, the temperature was measured by immersing the thermometer in the sample to the manufacturer's indicated immersion level, allowing the temperature to stabilize, and reading the temperature to the nearest 0.1°C. The measured temperature was recorded on the temperature/pH data sheet and in the sampling log book. Finally, the thermometer was rinsed with deionized water after each measurement to prevent cross-contamination of samples.

The pH meter was calibrated daily prior to any field measurements using pH 4.0, 7.0, and 10.0 buffer solutions with temperature compensation. To determine the pH, the sample was collected and poured into an intermediate sample container, and the temperature of the sample was measured and recorded. Then, the temperature compensation dial of the pH meter was set to the measured temperature, and the sample pH was determined by immersing the electrode in the sample and stirring gently for a few seconds. After determining the pH, the meter was rechecked by measuring the pH of a buffer solution, and the sample pH was recorded in the sampling log book. To prevent sample cross-contamination, the probe was rinsed with deionized water before and after each measurement.

Similarly, the conductivity meter was calibrated daily using a potassium chloride standard prior to any field measurement. After the meter was calibrated, the cell constant was determined to evaluate the performance of the instrument probe. The cell constant was determined by measuring the temperature and conductance of a 0.01N KCl standard solution, then dividing the measured conductance by the actual conductance at the measured temperature. To determine the specific conductance, the sample was placed in the intermediate sample container, and the temperature of the sample was measured and recorded. Then, the probe was immersed in the sample and moved up and down to ensure proper circulation through the probe. Next, the probe was held steady, away from the sides and bottom of the container, and the specific conductance was read. Finally, the obtained value was corrected by using the temperature compensation factor. The temperature of the sample, the specific conductance, and the cell constant were recorded on the specific conductance data sheet and in the sampling log book. To prevent sample cross-contamination, the probe was rinsed with deionized water before and after each measurement.

3.1.2 Lead Analysis

The ground-water, surface water, and sediment samples from the oil separator pit were analyzed for lead using the graphite furnace technique Method 239.2 CLP-M (U.S. EPA, 1983). The graphite furnace technique uses an atomic absorption (AA) spectrophotometer to determine the concentration of lead in the sample.

Prior to analysis, the water and sediment samples were prepared according to the Contract Laboratory Program (CLP) procedures for furnace AA water and soil samples, respectively. For the water samples, a portion of the sample was transferred to a beaker, and this portion was digested on a hot plate with nitric acid and hydrogen peroxide. Then, the sample was cooled and filtered to remove insoluble matter. Finally, the sample volume was adjusted using distilled/deionized water, and lanthanum nitrate (i.e., inhibit interferences) solution was added to each sample.

For the sediment, the sample was thoroughly mixed to achieve homogeneity, and a portion of the sample was weighed, slurried in a beaker with nitric acid, and refluxed. After the sample cooled, additional nitric acid was added, and the sample was again refluxed. After the sample had cooled from the second reflux, ASTM Type II water and hydrogen peroxide were added to the sample, and it was heated until the effervescence from the peroxide reaction subsided. This cycle was repeated as often as required using additional aliquots of hydrogen peroxide until the effervescence was minimal, or until the general sample appearance remained unchanged. Next, the sample volume was reduced; ASTM Type II water was added, and the sample was heated again. Finally, the sample was filtered and diluted, and lanthanum nitrate solution was added.

After the samples were prepared, the atomic absorption spectrophotometer was calibrated according to manufacturer's specifications by analyzing a blank and three standards that bracketed the anticipated sample concentrations. An internal calibration curve was prepared and was verified using an instrument check standard and a calibration blank after each 10 samples.

After a valid calibration was obtained, a representative aliquot of a digested sample was placed in a graphite tube within the furnace, evaporated to dryness, charred, and atomized. Concurrently, energy was directed through the graphite tube containing excited energy level atoms of the vaporized lead. The intensity of this transmitted energy was used to determine the absorbence (A=2-log %T), which is directly proportional to the concentration of the lead atoms contained in the vapor. The absorbence was measured, and the lead concentration was determined by direct comparison to the standards (i.e., the calibration curve).

3.1.3 Oil and Grease Analysis

The samples of ground water, surface water, and sediment from the oil separator pit were analyzed for oil and grease. The water samples were analyzed using EPA Method 413.2 (EPA, 1983), which is an infrared

spectrophotometric method. The sediment samples were analyzed using the oil and grease extraction method for 9071 sludge samples (EPA, 1986), which is a gravimetric technique.

The ground-water and surface water samples were prepared by acidifying the samples with hydrochloric acid and pouring them into separatory funnels. Each sample was then extracted three times with trichlorotrifluoroethane (fluorocarbon-113) by vigorously shaking the funnel, allowing the layers to separate, filtering the solvent layer into a volumetric flask, and diluting the sample with fluorocarbon-113.

For the sediment, the samples were first acidified using hydrochloric acid. Then, magnesium sulfate was added to the sediment to form a thick paste, which was spread on the inside of a beaker to facilitate evaporation. Once the paste had solidified, it was removed from the beaker and ground to a fine powder using a mortar and pestle. Next, the powder was added to a paper extraction thimble and was extracted in a Soxhlet apparatus using fluorocarbon-113. Finally, the extract was filtered through grease-free cotton into a preweighed boiling flask.

Prior to analysis of the water samples, the infrared spectrophotometer was calibrated by analyzing five standards that bracketed the expected sample concentrations. To prepare the calibration standards, a reference oil was prepared using n-hexadecane, isooctane, and chlorobenzene. Then, the reference oil was weighed and diluted with fluorocarbon-113 to form a stock solution. Next, appropriate aliquots of the stock solution were diluted with fluorocarbon-113 to form the calibration standards, which were analyzed. Finally, a calibration curve was constructed by plotting the absorbence of the standards versus their respective concentrations.

After the calibration was completed, the water extract was placed in the cell of the infrared spectrophotometer, and the absorbence was

measured. The absorbence of the sample was then compared to the absorbence from the calibration standards to determine the concentration of oil and grease in the sample.

For the sediment samples, no calibration procedures were required. After the sediment was extracted, the extract was placed in a tared 250-ml boiling flask, and the solvent was evaporated. The flask was then cooled in a desiccator and weighed. The oil and grease concentration was determined by dividing the weight gain of the flask by the dry weight of the sample extracted.

3.1.4 Volatile Organic Compound Analysis

All of the ground water, surface water, and sediment samples from both the base landfill and the oil separator pit were analyzed for volatile organic compounds. These samples were analyzed by the CLP-VOA method (EPA, 1987b) using purge and trap gas chromatograph/mass spectrometry (GC/MS).

The ground-water and surface water samples from both locations did not require any special sample preparation prior to analysis. However, the sediment samples had to be prepared according to the CLP-VOA procedures. Two different preparation procedures were used, one for low level sediment and one for medium level sediment. The sample was assumed to be low level, and if the peaks were saturated from the analysis of this sample, the sample was re-extracted and analyzed as a medium level sediment.

For the low level sediment sample preparation, a small sample aliquot was weighed and placed into a tared purge device. A separate sample aliquot was then weighed into a tared crucible and dried to determine percent solids. Then, reagent water containing both the surrogate spiking solution and internal standard solution was added to the purge device. Finally, the purge device was connected to the purge and trap system, and the sample was purged.

For the medium level sediment sample preparation, a sample aliquot was weighed and placed into a tared vial. Again, a separate sample aliquot was weighed into a tared crucible and dried to determine percent solids. Then, methanol and surrogate spiking solution were added to the vial, and the vial was capped and shaken. Next, a portion of the methanol extract was transferred into a GC vial for storage. Prior to analysis, the appropriate volume of methanol extract was added to a syringe containing reagent water and internal standards. The sample was then analyzed according to the procedures for water samples.

Prior to analyzing the first batch of samples, the GC/MS system was tuned using p-bromofluorobenzene (BFB). After the tuning criteria were met, the GC/MS system was calibrated at a minimum of five concentrations to determine the linearity of the response. The calibration standards were spiked with the three internal standards (i.e., bromochloromethane, 1,4-difluorobenzene, and chlorobenzene-d_5) and contained all the target analytes and surrogate compounds. These calibration standards were analyzed to determine the area response of the characteristic ions and the relative response factors for each compound at each concentration level.

Before the calibration curve could be used, the responses of the five system performance check compounds (i.e., chloromethane, 1,1-dichloroethane, bromoform, 1,1,2,2-tetrachloroethane, and chlorobenzene) were evaluated to determine the minimum average response factor. Finally, the responses from the six calibration check compounds (1,1-dichloroethene, chloroform, 1,2-dichloropropane, toluene, ethylbenzene, and vinyl chloride) were evaluated to determine the relative standard deviations of their relative response factors over the working range of the curve. Continuing calibration was performed every 12 hours by reanalyzing a calibration standard, a system performance check, a calibration check, and evaluating the relative response factors.

After sample preparation, tuning, and calibration, the samples were analyzed. The samples were allowed to warm to room temperature, and then

were placed into a syringe (except for the low level sediment samples). Then, surrogates and internal standards were added to the syringe. Next, the syringe was connected to the purging device, and the sample was injected. The sample was purged at ambient temperature and was swept through a sorbent column where the compounds were trapped. Then, the sorbent column was heated, and the sample was desorbed onto the gas chromatographic column. The gas chromatograph was temperature-programmed to separate the purgeable compounds, which were detected with a mass spectrometer. Then, the compounds were tentatively identified by comparison of the sample mass spectrum to the mass spectrum of a standard. Finally, the identified compounds were quantified by the internal standard method using: the volume of sample that was injected; the concentration of the internal standard; the relative response factor of the compound, which was determined during calibration; and the extracted ion current profile areas of the characteristic ions for the compound to be measured and for the specific internal standard.

3.1.5 Pesticide and PCB Analyses

Samples of ground water, surface water, and sediment from the base landfill were analyzed for organochlorine pesticides, and samples of ground water, surface water, and sediment from the oil separator pit were analyzed for Polychlorinated Biphenyls (PCBs). These samples were analyzed using a gas chromatograph with an electron capture detector. The analytical method for PCBs was the same as that used for pesticides (i.e., CLP-PEST, EPA, 1987b). Therefore, the preparation procedures for these samples did not depend on the analytical parameter, but rather on the sample matrix.

The surface and ground-water samples from the past disposal areas were prepared using a continuous liquid-liquid extractor. A sample aliquot was measured and placed into the continuous extractor. Then, surrogate spiking solution was added to the extractor, and the sample was mixed. The pH was then checked and adjusted to between 5 and 9.

Finally, methylene chloride and sufficient reagent water were added to the distilling flask, and the sample was extracted for 18 hours.

After the sample had been extracted, the sample extract was poured through a drying column containing anhydrous granular sodium sulfate and was collected in a Kuderna-Danish (K-D) concentrator. Then, the K-D concentrator was connected to a three-ball Snyder column and was placed in a hot water bath to concentrate the sample. Next, additional solvent (e.g., hexane) was added, and the sample was concentrated as before. If sulfur crystals were present at this time, an optional sulfur cleanup was performed. If matrix interferences were noted in previous analyses of NTC Bainbridge samples, the PCB samples were subjected to an acid cleanup to remove these interferences.

After the appropriate cleanup procedure, or if additional cleanup was unnecessary, the sample volume was concentrated further by placing the concentrator tube in a warm water bath and evaporating using a gentle stream of clean, dry nitrogen. The sample volume was diluted with acetone and transferred to the top of an alumina column and eluted with hexane. Finally, the elute was collected in a clean concentrator tube, and the final volume was adjusted using hexane. The extract was subsequently analyzed or stored in the dark at 4°C (± 2°C) until analysis.

The sediment samples were prepared using the CLP-PEST preparation procedure for sediments and soils (EPA, 1987b). Prior to preparation, the samples were screened to determine whether the low level or medium level preparation procedures were necessary. For the low level sediment samples, an aliquot of the sample was weighed and placed into a beaker. Anhydrous powdered sodium sulfate was mixed into the sample, and 1:1 methylene chloride-acetone was added to the sample. Then, surrogate spiking solution was added to all samples. After adding the surrogates, the sample was sonicated using an ultrasonic probe. The extract was then decanted and filtered using vacuum filtration, and the sonification was

repeated two more times with two additional portions of 1:1 methylene chloride-acetone.

After the final sonification, the extract was transferred to a K-D apparatus, which was attached to a three-ball Snyder column. Then, the K-D apparatus was placed in a hot water bath, and the sample was concentrated. Then, gel permeation chromatography (GPC) cleanup was performed, if required.

After GPC cleanup, or if GPC cleanup was omitted, an aliquot of the extract was transferred to a concentrator tube and diluted with hexane. Then, a two-ball micro-Snyder column was attached to the K-D apparatus, which was placed in a hot water bath. The extract was concentrated, and then, nitrogen blowdown was used to reduce the volume further. Next, the extract was diluted using acetone and cleaned up using an alumina column. If matrix interferences were noted in previous analyses, the PCB samples were subjected to an acid cleanup to remove these interferences.

If the medium level preparation procedure was used, an aliquot of the sample was weighed and placed in a vial, and anhydrous powdered sodium sulfate was mixed into the sample. Then, surrogate spiking solution and hexane were added to the sample, and the sample was sonicated using an ultrasonic probe. Next, the sample extract was filtered through glass wool, and the hexane extract was transferred to a glass concentrator tube and concentrated using the nitrogen blowdown technique. Finally, acetone was added to the hexane extract, and the extract was mixed. These extracts were then subjected to the GPC, alumina, and acid cleanup procedures as described for the low level sediments.

Prior to analyzing the samples, the gas chromatograph was tuned to produce the required retention time windows. The tuning was accomplished by analyzing three separate injections of all single pesticide mixtures (e.g., mixtures containing endrin, aldrin, heptachlor, etc.), multi-response pesticides (e.g., toxaphene), and PCBs (e.g., Aroclor 1242) evenly spaced throughout the course of a 72-hour period. The

chromatograms from these analyses were used to determine the standard deviation of the three absolute retention times for each compound. The standard deviations of the retention times for each compound were then used to establish the retention time windows for all subsequent 72-hour sequences, until a new column was installed and retuned.

Once the gas chromatograph has been tuned, the GC column was evaluated for linearity and degradation using three evaluation standard mixtures. These evaluation standard mixtures were prepared using aldrin, endrin, 4,4'-DDT, and dibutylchlorendate. The evaluation standards were analyzed at the beginning of the 72-hour analytical sequence, and the calibration factor for each compound in each evaluation standard was calculated. Then, the percent relative standard deviation (% RSD) of the calibration factors for each compound at the three concentration levels was calculated to establish linearity, and the chromatograms were examined to determine whether degradation had occurred.

After meeting the linearity and degradation requirements with the evaluation standard mixtures, a single point calibration was performed using individual standard mixtures containing the single component pesticides and separate solutions of all multi-response pesticides and PCBs. From the analyses of these standards, the calibration factors and retention time windows were calculated for each compound. The retention time windows were calculated from the absolute retention time for each compound in the initial standard and the standard deviation of the retention time, which was determined during tuning.

Throughout the 72-hour analytical sequence, evaluation standards and individual standards were analyzed for continuing calibration. Either the evaluation standard or one of the individual standards were analyzed after each set of five samples on an alternating basis. For each evaluation standard, the degradation criterion for endrin and/or 4,4'-DDT was evaluated, and for each individual standard, the calibration factor and retention time criteria were evaluated to ensure that the current calibration was still valid.

The samples were analyzed by injecting an aliquot of the sample or standard according to the specified 72-hour sequence. Then, the chromatograms were evaluated to tentatively identify unknown compounds by comparing the retention time of the unknown to the retention time of the corresponding standard. After primary analysis was completed, a confirmation analysis was performed by analyzing the samples and required standards using a modified 72-hour sequence and a different column. Finally, the concentrations of the confirmed compounds were calculated by comparing the responses of the samples to the external standards.

3.2 Base Landfill Results

Samples of ground water, surface water, and stream sediment were collected from the base landfill during three different sampling events in March, May, and July, 1988. These samples were analyzed for volatile organic compounds (VOCs) and organochlorine pesticides. Additionally, the temperature, pH, and conductivity of the water samples were determined in the field during each sampling event. Sections 3.2.1 through 3.2.3 present the analytical results for each parameter summarized by sample matrix and a narrative evaluation of these results.

3.2.1 Ground Water

The ground-water samples were collected from five different monitoring wells installed at the base landfill. These monitoring wells were designated at 1GW-1 (upgradient well) and 1GW-2 through 1GW-5 (downgradient wells) (see Figure 2-1). As stated previously, Versar collected ground-water samples from each well during three separate sampling events in March, May, and July, 1988. The samples collected in March and May were split with the State of Maryland's Department of the Environment, Hazardous and Solid Waste Management Administration (State of Maryland). During each sampling event, the temperature, pH, and specific conductance were determined in the field prior to collecting the samples for laboratory analysis of volatile organics and pesticides. The results of both the field and laboratory analyses are presented in Table 3-1.

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TABLE 3-1. GROUNDWATER SAMPLE TESTING DATA - LANDFILL AREA

Parameter	Units	Sampling Event	Date	1GW-1	1GW-2	1GW-3	1GW-4	1GW-5
pH		1 VERSAR	16-Mar-88	5.83	6.94	6.40	6.12	6.21
		2 VERSAR	17-May-88	5.43	6.91	6.12	5.87	6.01
		3 VERSAR	26-Jul-88	5.68	6.89	6.19	5.70	6.12
Specific Conductance	umhos	1 VERSAR	16-Mar-88	225	578	1,269	556	687
		2 VERSAR	17-May-88	246	447	1,337	602	721
		3 VERSAR	26-Jul-88	251	655	1,267	582	776
Temperature	deg C	1 VERSAR	16-Mar-88	9.9	12.5	10.8	10.3	10.0
		2 VERSAR	17-May-88	15.2	14.2	15.7	13.1	12.6
		3 VERSAR	26-Jul-88	16.3	23.0	17.7	15.1	18.2
VOLATILE ORGANICS	ug/L							
Methylene Chloride		1 VERSAR	16-Mar-88	<5	<5	<10	<5	<5
		1 MARYLAND	16-Mar-88	<1	--	<1	<1	<1
		2 VERSAR	17-May-88	<5	10 B	40 B	8 B	9 B
		2 MARYLAND	17-May-88	<1	<1	<1	<1	<1
		3 VERSAR	26-Jul-88	2 B	2 B	2 B	2 B	2 B
Acetone		1 VERSAR	16-Mar-88	<10	<10	<20	<10	<10
		1 MARYLAND	16-Mar-88	ND	--	ND	ND	ND
		2 VERSAR	17-May-88	<10	<10	76 B	<10	<10
		2 MARYLAND	17-May-88	ND	ND	ND	ND	ND
		3 VERSAR	26-Jul-88	8	<10	17	18	13
Trans-1,2-Dichloroethene		1 VERSAR	16-Mar-88	<5	<5	<10	<5	5
		1 MARYLAND	16-Mar-88	<1	--	<1	<1	4
		2 VERSAR	17-May-88	<5	<5	<20	<5	5
		2 MARYLAND	17-May-88	<1	<1	<1	<1	4
		3 VERSAR	26-Jul-88	<5	<5	<5	<5	11
Chloroform		1 VERSAR	16-Mar-88	<5	<5	<10	<5	<5
		1 MARYLAND	16-Mar-88	1	--	<1	<1	5
		2 VERSAR	17-May-88	<5	<5	<20	<5	<5
		2 MARYLAND	17-May-88	<1	1	<1	<1	<1
		3 VERSAR	26-Jul-88	1	<5	<5	<5	<5
1,2-Dichloropropane		1 VERSAR	16-Mar-88	<5	<5	<10	<5	<5
		1 MARYLAND	16-Mar-88	<1	--	<1	1	<1
		2 VERSAR	17-May-88	<5	<5	<20	<5	<5
		2 MARYLAND	17-May-88	<1	<1	<1	<1	<1
		3 VERSAR	26-Jul-88	<5	<5	<5	<5	<5
Trichloroethene		1 VERSAR	16-Mar-88	<5	<5	<10	<5	<5
		1 MARYLAND	16-Mar-88	<1	--	<1	2	1
		2 VERSAR	17-May-88	<5	<5	<20	<5	1
		2 MARYLAND	17-May-88	<1	<1	<1	<1	1
		3 VERSAR	26-Jul-88	<5	<5	<5	<5	2
Benzene		1 VERSAR	16-Mar-88	<5	<5	<10	<5	<5
		1 MARYLAND	16-Mar-88	<1	--	2	<1	<1
		2 VERSAR	17-May-88	<5	<5	<20	<5	<5
		2 MARYLAND	17-May-88	<1	<1	3	<1	<1
		3 VERSAR	26-Jul-88	<5	<5	3	<5	1

TABLE 3-1. GROUNDWATER SAMPLE TESTING DATA - LANDFILL AREA (Continued)

Parameter	Units	Sampling Event	Date	1GW-1	1GW-2	1GW-3	1GW-4	1GW-5
VOLATILE ORGANICS	ug/L							
Toluene		1 VERSAR	16-Mar-88	<5	<5	<10	<5	<5
		1 MARYLAND	16-Mar-88	<1	--	<1	<1	<1
		2 VERSAR	17-May-88	<5	<5	<20	1	1
		2 MARYLAND	17-May-88	<1	<1	<1	<1	<1
		3 VERSAR	26-Jul-88	<5	2	1	<5	<5
Chlorobenzene		1 VERSAR	16-Mar-88	<5	<5	270	<5	82
		1 MARYLAND	16-Mar-88	<1	--	300	<1	75
		2 VERSAR	17-May-88	<5	<5	350	<5	82
		2 MARYLAND	17-May-88	<1	<1	319	<1	108
		3 VERSAR	26-Jul-88	<5	<5	290 E	<5	160
1,2-Dichlorobenzene		1 VERSAR	16-Mar-88	ND	ND	ND	ND	ND
		1 MARYLAND	16-Mar-88	ND	--	ND	ND	ND
		2 VERSAR	17-May-88	ND	ND	ND	ND	ND
		2 MARYLAND	17-May-88	ND	ND	ND	ND	ND
		3 VERSAR	26-Jul-88	ND	ND	ND	16	ND
1,4-Dichlorobenzene		1 VERSAR	16-Mar-88	ND	ND	ND	ND	ND
		1 MARYLAND	16-Mar-88	ND	--	67	ND	20
		2 VERSAR	17-May-88	ND	ND	ND	ND	ND
		2 MARYLAND	17-May-88	ND	ND	71	ND	33
		3 VERSAR	26-Jul-88	ND	ND	3.8	ND	ND
Xylene		1 VERSAR	16-Mar-88	<5	<5	<10	<5	<5
		1 MARYLAND	16-Mar-88	<2	--	<2	<2	<2
		2 VERSAR	17-May-88	<5	<5	<20	<5	<5
		2 MARYLAND	17-May-88	<2	<2	<2	<2	<2
		3 VERSAR	26-Jul-88	<5	<5	<5	<5	<5
Methyl Ethyl Ketone (MEK)		1 VERSAR	16-Mar-88	<10	<10	<20	<10	<10
(2-Butanone)		1 MARYLAND	16-Mar-88	ND	--	ND	ND	ND
		2 VERSAR	17-May-88	<10	<10	<40	<10	<10
		2 MARYLAND	17-May-88	ND	ND	ND	ND	ND
		3 VERSAR	26-Jul-88	<10	<10	<10	<10	<10
Methyl Isobutyl Ketone (MIBK)		1 VERSAR	16-Mar-88	<10	<10	<20	<10	<10
(4-Methyl-2-Pentanone)		1 MARYLAND	16-Mar-88	ND	--	ND	ND	ND
		2 VERSAR	17-May-88	<10	<10	<40	<10	<10
		2 MARYLAND	17-May-88	ND	ND	ND	ND	ND
		3 VERSAR	26-Jul-88	<10	<10	<10	<10	<10
1,1,2-Trichlorotrifluoroethane		1 VERSAR	16-Mar-88	ND	ND	ND	ND	ND
		1 MARYLAND	16-Mar-88	ND	--	ND	ND	ND
		2 VERSAR	17-May-88	13 B	19 B	ND	17 B	17 B
		2 MARYLAND	17-May-88	ND	ND	ND	ND	ND
		3 VERSAR	26-Jul-88	ND	ND	ND	ND	ND
PESTICIDES	ug/L	1 VERSAR	16-Mar-88	****** None Detected (<0.1 ug/L) *******				
		2 VERSAR	17-May-88	****** None Detected (<0.1 ug/L) *******				
		3 VERSAR	26-Jul-88	****** None Detected (<0.1 ug/L) *******				

ND - Not Detected
B - Parameter was detected in laboratory blanks; possible contamination.
E - The reported value is an estimate; the linear range of the instrument was exceeded.
Dashes (--) indicate that the sample was not collected.

A review of the pH readings listed in Table 3-1 indicates that the ground-water is slightly acidic, with a pH ranging from 5.43 to 6.91. The upgradient well (1GW-1) consistently had the lowest pH, suggesting that any landfill leachates may be slightly basic, which resulted in the slightly elevated pH levels of the downgradient wells. Conversely, well 1GW-2 consistently had the highest pH, which was essentially neutral (i.e., approximately pH = 7). As a general rule, the pH increased as the temperature increased. However, the variability of the pH data between sampling events was relatively low. The ground-water pH for the base landfill area wells is represented graphically in Figure 3-1. None of the data suggests that the ground-water is excessively acidic or basic.

The specific conductances (i.e., conductivity) ranged from 225 μmhos to 1,337 μmhos in base landfill well water. The variability between sampling events for conductivity was relatively low with no general trends apparent. As was the case for the pH, the upgradient well (1GW-1) consistently had the lowest conductivity measurements. This was expected because the conductivity is an indicator parameter for total dissolved solids (e.g., dissolved metals, chlorides, etc.), and this well is a background well believed to be free of contaminants. Monitoring well 1GW-3 consistently had the highest specific conductance readings, and well 1GW-5 consistently had the second highest conductivities suggesting that these two wells were the most contaminated of the base landfill monitoring wells. The laboratory analytical data supports this conclusion. Figure 3-2 depicts the ground-water conductivity at the base landfill area graphically.

The volatile organic compounds (VOCs), that were detected in at least one of the base landfill ground-water samples are listed in Table 3-1; all other volatile compounds analyzed for, that were not detected in any of the samples, are not listed. However, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are listed whether they were detected or not because these parameters were specifically requested by NAVFACENGCOM-Atlantic Division in the Scope of Work for this Site Investigation.

FIGURE 3-1. GROUND-WATER pH

(Base Landfill Area)

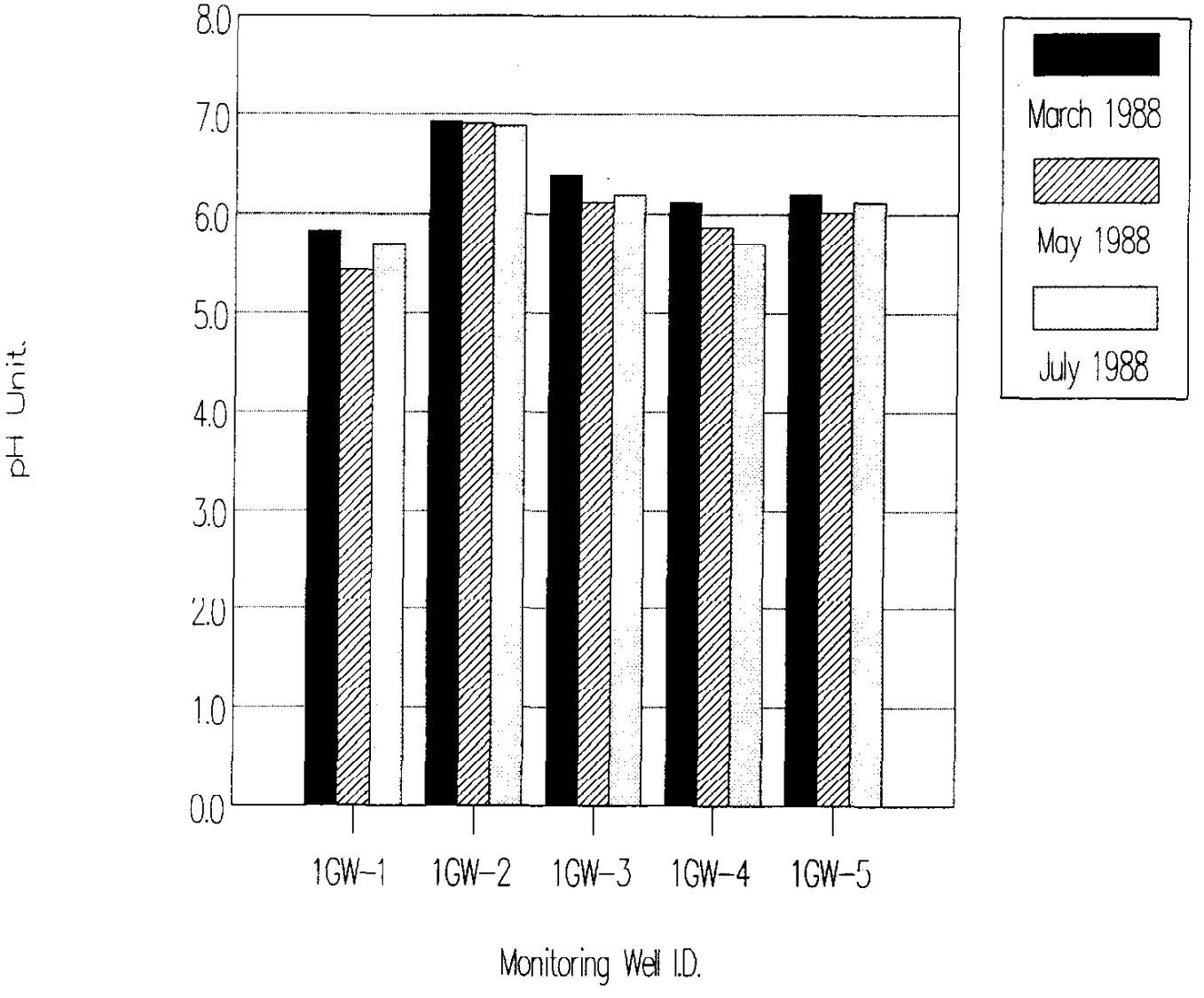
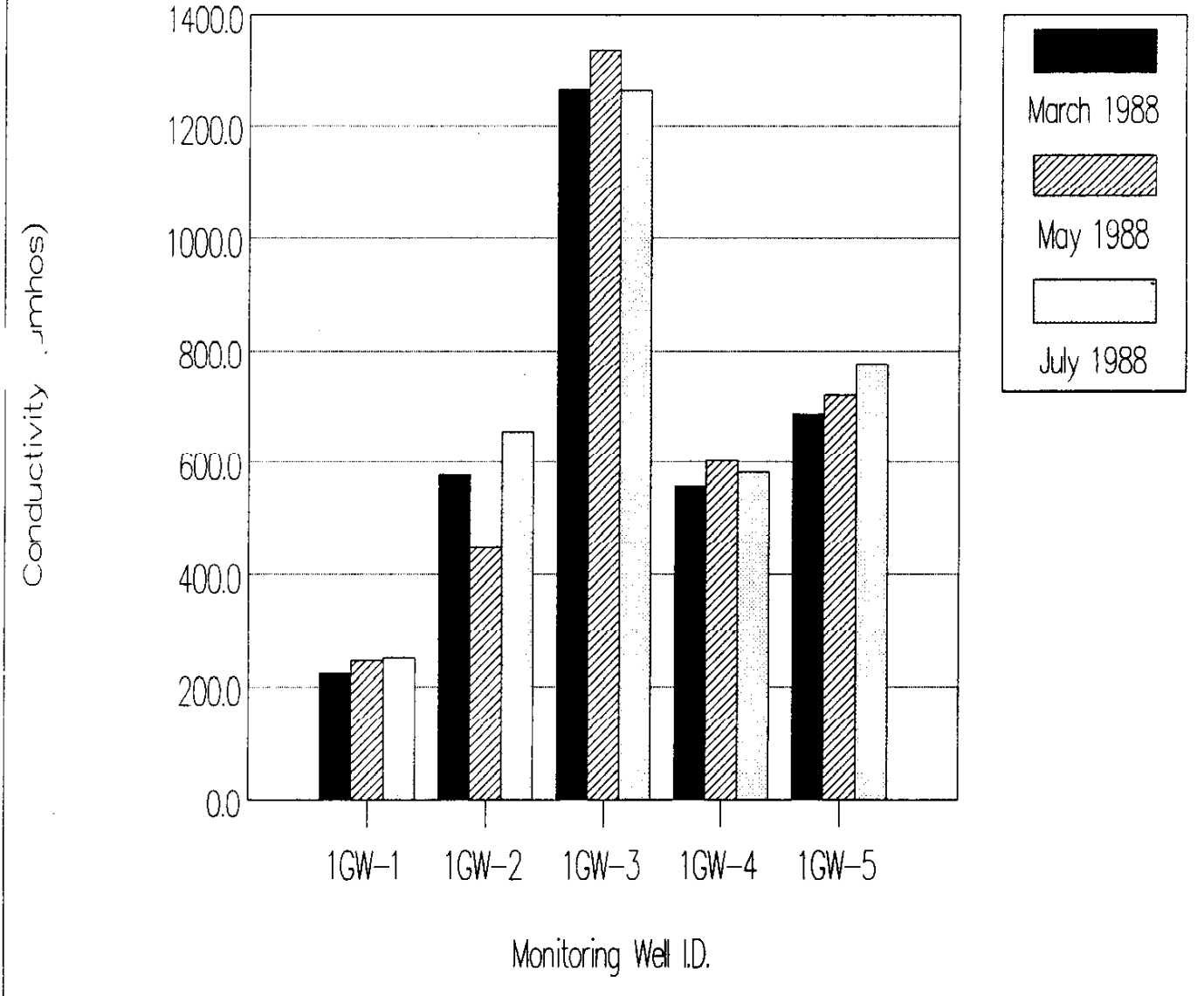


FIGURE 3-2. GROUND-WATER CONDUCTIVITY

(Base Landfill Area)



The analytical results in Table 3-1 indicate that 1GW-5 and 1GW-3 were the most contaminated wells, as expected from the conductivity measurements. Both of these wells contained the two most prevalent volatile organic compounds, which were chlorobenzene, with concentrations ranging from 75 μg/L to 350 μg/L, and 1,4-dichlorobenzene, which had positive concentrations ranging from 3.8 μg/L to 71 μg/L. Several other VOCs (e.g., trans-1,2-dichloroethene; chloroform; 1,2-dichloropropane; trichloroethene; benzene; and toluene) were detected in several samples, primarily in those from monitoring Wells 1GW-3 and 1GW-5, but all of these VOCs were quantified at or below the detection limit. Methylene chloride, acetone, and 1,1,2-trichlorotrifluoroethane (fluorocarbon-113) were also found in several samples at varying concentrations; however, these compounds were all also found in laboratory blanks. Finally, xylenes, MEK, and MIBK were not detected in any of the ground-water samples.

The split sample results for the Versar and Maryland splits were comparable for all the VOCs, detected except for the laboratory blank contaminants listed above and 1,4-dichlorobenzene. The blank contaminants were only detected in the Versar splits, while 1,4-dichlorobenzene was generally only detected in the Maryland splits. Other than these exceptions, the variability of the volatile organic data between the sampling events was low.

Table 3-1 also shows that organochlorinated pesticides were not detected in any of the base landfill area ground-water samples. The pesticide detection limits ranged from 0.05 μg/L to 1.0 μg/L.

3.2.2 Surface Water

The surface water samples were collected from two different monitoring locations at the base landfill area designated as 1SW-1 (upgradient) and 1SW-2 (downgradient) (see Figure 2-1). Versar collected the surface water samples from each location during three separate sampling events in March, May, and July, 1988. The samples collected in March were split with the State of Maryland. During the first and third

sampling event, the temperature, pH, and specific conductance were determined in the field prior to collecting the samples for laboratory analysis of VOCs and pesticides. The results of both the field and laboratory analyses are summarized in Table 3-2.

The surface water pH readings listed in Table 3-2 range from 6.04 to 7.47. The samples from location 1SW-1 were slightly acidic and consistently had the lowest pH, while the pH readings for the samples from location 1SW-2 were consistently higher and slightly basic. As a general rule, the pH increased as the temperature increased. However, the variability of the pH data between sampling events was relatively low.

The surface water conductivities ranged from 175 μmhos to 334 μmhos and were significantly higher during the July 1988 sampling event than in March 1988. This is likely related to low flow conditions experienced during the July sampling event. The conductivity measurements for the samples from location 1SW-1 were consistently lower than those from location 1SW-2.

With respect to the volatile organics compounds analyzed for those VOCs that were detected in at least one of the base landfill surface water samples are listed in Table 3-2; all other VOCs that were not detected in any of the samples are not listed. However, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are listed whether they were detected or not because these parameters were specifically requested by NAVFACENGCOM-Atlantic Division in the Scope of Work for this Site Investigation.

The volatile organic compound analytical results in Table 3-2 do not suggest that samples from either location were significantly more contaminated, and do not highlight any specific compound as being particularly prevalent. The most common volatile organic compound was toluene, which had detected concentrations ranging from 1 μg/L to 5 μg/L in base landfill surface water samples. Toluene was detected in samples from both locations during the second and third sampling event, but was not detected in either sample during the first event. Both

TABLE 3-2. SURFACE WATER SAMPLE TESTING DATA - LANDFILL AREA

Parameter	Units	Sampling Event	Date	1SW-1	1SW-2
pH		1 VERSAR	15-Mar-88	6.81	7.07
		2 VERSAR	17-May-88	N/D	N/D
		3 VERSAR	25-Jul-88	6.04	7.47
Specific Conductance	umhos	1 VERSAR	15-Mar-88	175	200
		2 VERSAR	17-May-88	N/D	N/D
		3 VERSAR	25-Jul-88	182	334
Temperature	deg C	1 VERSAR	15-Mar-88	4.4	5.2
		2 VERSAR	17-May-88	N/D	N/D
		3 VERSAR	25-Jul-88	23.1	25.7
VOLATILE ORGANICS	ug/L				
Methylene Chloride		1 VERSAR	15-Mar-88	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1
		2 VERSAR	17-May-88	8 B	10 B
		3 VERSAR	25-Jul-88	6 B	2 B
Acetone		1 VERSAR	15-Mar-88	<10	<10
		1 MARYLAND	15-Mar-88	ND	ND
		2 VERSAR	17-May-88	<10	4 B
		3 VERSAR	25-Jul-88	15	<10
Chloroform		1 VERSAR	15-Mar-88	<5	<5
		1 MARYLAND	15-Mar-88	<1	1
		2 VERSAR	17-May-88	<5	<5
		3 VERSAR	25-Jul-88	<5	<5
Toluene		1 VERSAR	15-Mar-88	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1
		2 VERSAR	17-May-88	1	1
		3 VERSAR	25-Jul-88	2	5
Xylene		1 VERSAR	15-Mar-88	<5	<5
		1 MARYLAND	15-Mar-88	<2	<2
		2 VERSAR	17-May-88	<5	<5
		3 VERSAR	25-Jul-88	<5	<5
Methyl Ethyl Ketone (MEK) (2-Butanone)		1 VERSAR	15-Mar-88	<10	<10
		1 MARYLAND	15-Mar-88	ND	ND
		2 VERSAR	17-May-88	<10	<10
		3 VERSAR	25-Jul-88	<10	<10
Methyl Isobutyl Ketone (MIBK) (4-Methyl-2-Pentanone)		1 VERSAR	15-Mar-88	<10	<10
		1 MARYLAND	15-Mar-88	ND	ND
		2 VERSAR	17-May-88	<10	<10
		3 VERSAR	25-Jul-88	<10	<10
Trichlorofluoromethane		1 VERSAR	15-Mar-88	ND	4
		1 MARYLAND	15-Mar-88	<1	<1
		2 VERSAR	17-May-88	ND	ND
		3 VERSAR	25-Jul-88	ND	ND
1,1,2-Trichlorotrifluoroethane		1 VERSAR	15-Mar-88	ND	ND
		1 MARYLAND	15-Mar-88	ND	ND
		2 VERSAR	17-May-88	14 B	17 B
		3 VERSAR	25-Jul-88	ND	ND
PESTICIDES	ug/L	1 VERSAR	15-Mar-88	* None Detected *	
		2 VERSAR	17-May-88	* None Detected *	
Heptachlor Epoxide		3 VERSAR	25-Jul-88	0.20	<0.05
alpha-Chlordane		3 VERSAR	25-Jul-88	0.35	<0.10
gamma-Chlordane		3 VERSAR	25-Jul-88	0.22	<0.10

ND - Not Detected; N/D - Not Determined
B - Parameter was found in laboratory blanks; possible contamination.

chloroform and trichlorotrifluoromethane (fluorocarbon 113) were found in one sample each at or near the method detection limit. As was also noted for the ground water sample, methylene chloride, acetone, and 1,1,2-trichlorotrifluoroethane were also found in several samples at varying concentrations; however, these compounds were all also found in laboratory blanks. Xylenes, MEK, and MIBK were not detected in any of the surface water samples. The results for the Versar samples and the State of Maryland splits were comparable for all the volatile organics detected, and the variability of the volatile organic data between the sampling events was low.

A review of the organochlorine pesticide results in Table 3-2 shows that three different pesticides (heptachlor epoxide, alpha-chlordane, and gamma-chlordane) were detected in the July 1988 sample from location 1SW-1. These pesticides were found at extremely low concentrations ranging from 0.20 μg/L to 0.35 μg/L. As was the case for the VOCs, only the pesticides that were detected in at least one sample of the specified matrix type are listed in Table 3-2.

3.2.3 Sediment

The base landfill area sediment samples were collected from two different locations, which were the same as for the base landfill surface water samples. These sediment sampling locations were designated as 1SED-1 (upgradient) and 1SED-2 (downgradient). [See Figure 2-1.] Versar collected the sediment samples from each location during three separate sampling events in March, May, and July, 1988. These samples were analyzed for the presence of volatile organic compounds (VOCs) and organochlorine pesticides, and the results are summarized in Table 3-3.

With respect to the VOCs, those that were detected in at least one of the base landfill sediment samples are listed in Table 3-3; those VOCs that were not detected in any samples are not listed. However, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are listed whether they were detected or not because these parameters were specifically requested by NAVFACENGCOM-Atlantic Division in the Scope of

TABLE 3-3. STREAM SEDIMENT SAMPLE TESTING DATA - LANDFILL AREA

Parameter	Units	Sampling Event	Date	1SED-1	1SED-2
VOLATILE ORGANICS	ug/kg				
Methylene Chloride		1 VERSAR	15-Mar-88	<7	<6
		2 VERSAR	17-May-88	9 B	<8
		3 VERSAR	25-Jul-88	<5	<5
Acetone		1 VERSAR	15-Mar-88	<13	<12
		2 VERSAR	17-May-88	16 B	23 B
		3 VERSAR	25-Jul-88	<10	<10
Xylene		1 VERSAR	15-Mar-88	<7	<6
		2 VERSAR	17-May-88	<7	<8
		3 VERSAR	25-Jul-88	<5	<5
Methyl Ethyl Ketone (MEK) (2-Butanone)		1 VERSAR	15-Mar-88	<13	<12
		2 VERSAR	17-May-88	<14	<16
		3 VERSAR	25-Jul-88	<10	<10
Methyl Isobutyl Ketone (MIBK) (4-Methyl-2-Pentanone)		1 VERSAR	15-Mar-88	<13	<12
		2 VERSAR	17-May-88	<14	<16
		3 VERSAR	25-Jul-88	<10	<10
1,1,2-Trichlorotrifluoroethane		1 VERSAR	15-Mar-88	ND	ND
		2 VERSAR	17-May-88	5 B	8 B
		3 VERSAR	25-Jul-88	ND	ND
Hexamethylcyclotrisiloxane		1 VERSAR	15-Mar-88	ND	ND
		2 VERSAR	17-May-88	ND	ND
		3 VERSAR	25-Jul-88	ND	4 B
PESTICIDES	ug/kg				
Heptachlor		1 VERSAR	15-Mar-88	29	<4
		2 VERSAR	17-May-88	97	<17
		3 VERSAR	25-Jul-88	38	<17
4,4'-DDE		1 VERSAR	15-Mar-88	56	21
		2 VERSAR	17-May-88	180	<34
		3 VERSAR	25-Jul-88	95	<34
4,4'-DDD		1 VERSAR	15-Mar-88	61	23
		2 VERSAR	17-May-88	<45	<34
		3 VERSAR	25-Jul-88	77	<34
4,4'-DDT		1 VERSAR	15-Mar-88	170	53
		2 VERSAR	17-May-88	360	41
		3 VERSAR	25-Jul-88	170	<34
alpha-Chlordane		1 VERSAR	15-Mar-88	46	<8
		2 VERSAR	17-May-88	190	<34
		3 VERSAR	25-Jul-88	180	<34
gamma-Chlordane		1 VERSAR	15-Mar-88	49	<8
		2 VERSAR	17-May-88	350	<34
		3 VERSAR	25-Jul-88	260	<34

ND - Not Detected
B - Parameter was detected in laboratory blanks; possible contamination

Work for this Site Investigation. Similarly, for the pesticides, only those compounds that were detected in at least one sediment sample are listed in this summary table.

The volatile organic compound analytical results in Table 3-3 indicate that a total of only four different volatile organic compounds were detected in the samples from both locations, and all four of these compounds were also detected in laboratory blanks. Xylenes, MEK, and MIBK were not detected in any sediment samples. The variability of the volatile organic data between the sampling events was relatively low.

A review of the pesticide results in Table 3-3 shows that several different pesticides were detected in the drainage ditch samples from location 1SED-1. Some of these pesticides were also detected in samples from location 1SED-2, but at concentrations at least two times less than those from location 1SED-1. The pesticides that were found suggest that this area was contaminated with DDT and technical chlordane. The most prevalent pesticides are 4,4'-DDT, with concentrations ranging from 170 μg/kg to 360 μg/kg, and gamma-chlordane, with concentrations ranging from 49 μg/kg to 350 μg/kg. The variability of the pesticide concentrations between the sampling events is moderate, with the concentrations from the second event generally higher than those from the first and third event.

3.3 Oil Separator Pit Results

Samples of ground water, surface water, and stream sediment were collected from the oil separator pit area during three different sampling events in March, May, and July, 1988. These samples were analyzed for lead, oil and grease, volatile organic compounds and PCBs. Additionally, the temperature, pH, and specific conductance of the water samples were determined in the field. The analytical results for each parameter, summarized by sample matrix, and a narrative evaluation of these results are presented in Sections 3.3.1 through 3.3.3.

3.3.1 Ground Water

The ground-water samples were collected from five different monitoring wells installed at the oil separator pit area, which were designated as 2GW-1 (upgradient well) and 2GW-2 through 2GW-5 (downgradient wells) (see Figure 2-8). Versar collected ground-water samples from each well during three separate sampling events in March, May, and July, 1988. The samples collected in March and May were split with the State of Maryland. During each sampling event, the temperature, pH, and specific conductance were determined in the field prior to collecting the samples for laboratory analysis. After arriving at the laboratory, the samples were analyzed for lead, oil and grease content, volatile organic compounds (VOCs), and PCBs. The results of both the field and laboratory analyses for the oil separator pit ground-water samples are summarized in Table 3-4.

A review of the pH measurements in Table 3-4 indicates that the ground water is slightly acidic, with the pH ranging from 5.34 to 6.79. The upgradient well (2GW-1) consistently had the lowest pH, suggesting that any leachates from the oil separator pit area may be slightly basic, hence the elevated pH levels of the downgradient wells. Conversely, monitoring Wells 2GW-2 and 2GW-5 consistently had the highest pH readings. The pH readings appeared to remain relatively constant over time for each well with only minor variations between the three sampling events. The ground-water pH for the oil separator pit wells is depicted graphically in Figure 3-3.

The specific conductances ranged from 112 μmhos to 507 μmhos with well 2GW-1 consistently having the lowest conductivity and well 2GW-5 having the highest. It was anticipated that well 2GW-1 would have the lowest specific conductance readings because the conductivity is an indicator parameter for total dissolved solids (e.g., dissolved metals, chlorides, etc.), and this well is a background well believed to be free of contaminants. The variability between sampling events for conductivity was relatively low with no general trends apparent.

TABLE 3-4. GROUNDWATER SAMPLE TESTING DATA - OIL SEPARATOR PIT AREA

Parameter	Units	Sampling Event	Date	2GW-1	2GW-2	2GW-3	2GW-4	2GW-5
pH		1 VERSAR	15-Mar-88	5.34	6.79	6.04	6.15	6.13
		2 VERSAR	16-May-88	5.82	6.51	5.98	6.16	6.55
		3 VERSAR	25-Jul-88	5.68	5.86	5.98	5.76	6.23
Specific Conductance	umhos	1 VERSAR	15-Mar-88	133	112	153	254	426
		2 VERSAR	16-May-88	155	251	163	263	507
		3 VERSAR	25-Jul-88	162	231	182	288	432
Temperature	deg C	1 VERSAR	15-Mar-88	9.9	9.9	8.5	9.7	8.3
		2 VERSAR	16-May-88	13.2	12.3	12.8	13.5	15.0
		3 VERSAR	25-Jul-88	15.7	16.4	16.4	16.1	14.7
Lead	ug/L	1 VERSAR	15-Mar-88	<5.0	<5.0	<5.0	<5.0	<5.0
		2 VERSAR	16-May-88	<5.0	<5.0	<5.0	<5.0	<5.0
		3 VERSAR	25-Jul-88	<5.0	5.5	<5.0	5.8	<5.0
Oil and Grease	mg/L	1 VERSAR	15-Mar-88	0.94	0.55	1.69	0.44	0.40
		2 VERSAR	16-May-88	1.61	1.34	1.07	1.64	1.68
		3 VERSAR	25-Jul-88	0.66	0.73	1.19	0.70	1.14
VOLATILE ORGANICS	ug/L							
Methylene Chloride		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	<1	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	<1	<1	<1	<1
		3 VERSAR	25-Jul-88	<5	<5	<5	5 B	5 B
Acetone		1 VERSAR	15-Mar-88	<10	9 B	<10	<10	<10
		1 MARYLAND	15-Mar-88	ND	ND	ND	ND	ND
		2 VERSAR	16-May-88	9 B	<10	<10	7 B	<10
		2 MARYLAND	16-May-88	--	ND	ND	ND	ND
		3 VERSAR	25-Jul-88	9	<10	16	13	8
Carbon Disulfide		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	ND	ND	ND	ND	ND
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	ND	ND	ND	ND
		3 VERSAR	25-Jul-88	<5	<5	<5	1	<5
Trans-1,2-Dichloroethene		1 VERSAR	15-Mar-88	<5	6	<5	8	<5
		1 MARYLAND	15-Mar-88	<1	6	<1	8	<1
		2 VERSAR	16-May-88	<5	7	<5	9	<5
		2 MARYLAND	16-May-88	--	6	<1	8	1
		3 VERSAR	25-Jul-88	<5	6	<5	10	<5
Chloroform		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	2	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	<1	1	<1	<1
		3 VERSAR	25-Jul-88	<5	<5	<5	<5	<5
1,1,1-Trichloroethane		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	<1	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	<1	<1	1	<1
		3 VERSAR	25-Jul-88	<5	<5	<5	<5	<5
1,2-Dichloropropane		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	<1	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	<1	<1	<1	1
		3 VERSAR	25-Jul-88	<5	<5	<5	<5	<5

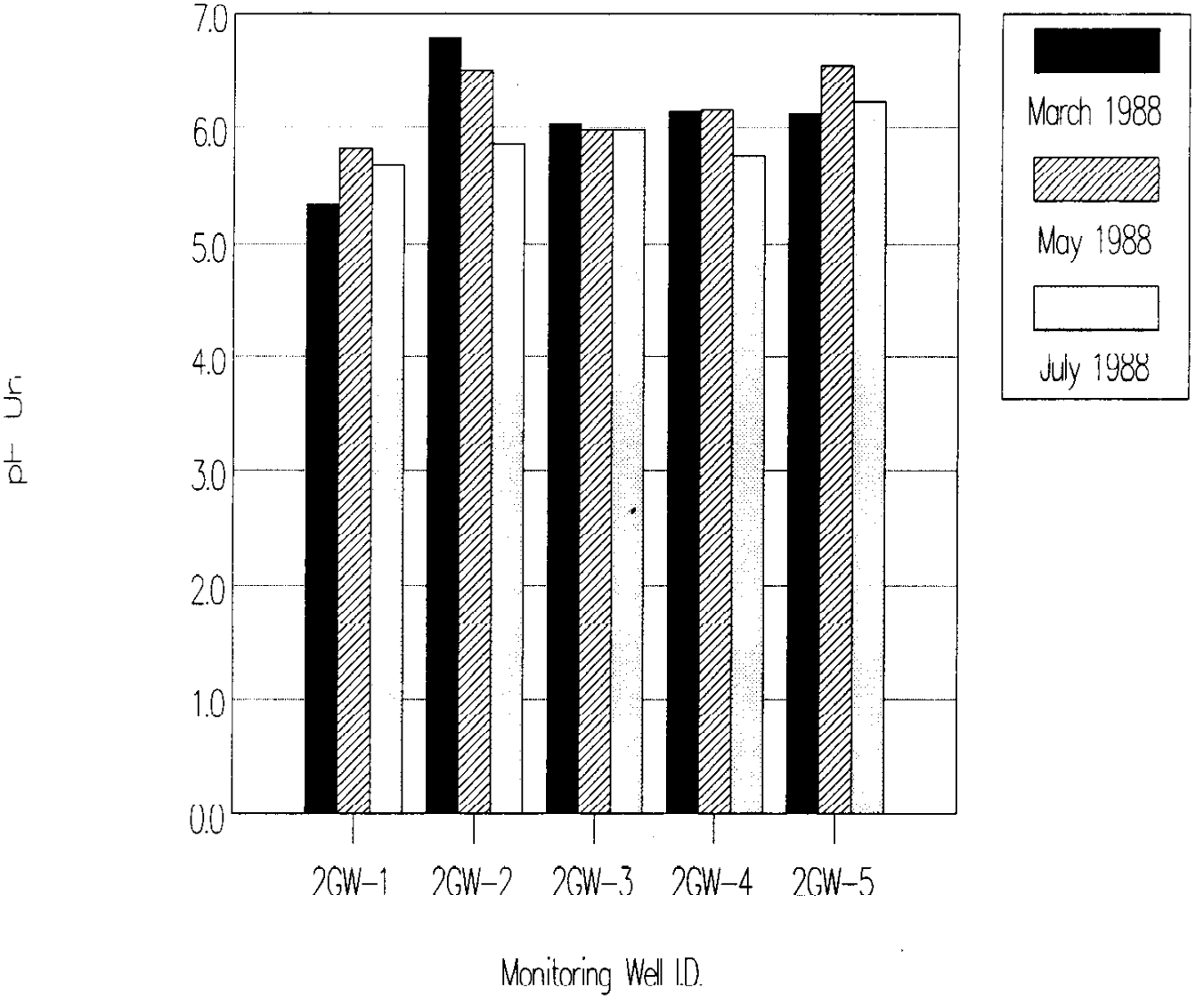
TABLE 3-4. GROUNDWATER SAMPLE TESTING DATA - OIL SEPARATOR PIT AREA (Continued)

Parameter	Units	Sampling Event	Date	2GW-1	2GW-2	2GW-3	2GW-4	2GW-5
VOLATILE ORGANICS	ug/L							
Trichloroethene		1 VERSAR	15-Mar-88	<5	6	<5	6	<5
		1 MARYLAND	15-Mar-88	1	6	<1	5	<1
		2 VERSAR	16-May-88	<5	7	<5	7	<5
		2 MARYLAND	16-May-88	--	5	<1	5	<1
		3 VERSAR	25-Jul-88	<5	6	<5	6	<5
Dibromochloromethane		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	<1	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	1	<1	1	<1
		3 VERSAR	25-Jul-88	<5	<5	<5	<5	<5
1,1,2,2-Tetrachloroethane		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	<1	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	<1	<1	1	<1
		3 VERSAR	25-Jul-88	<5	<5	<5	1	<5
Chlorobenzene		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	<1	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	<1	<1	<1	1
		3 VERSAR	25-Jul-88	<5	<5	<5	<5	<5
Xylene		1 VERSAR	15-Mar-88	<5	<5	<5	<5	<5
		1 MARYLAND	15-Mar-88	<2	<2	<2	<2	<2
		2 VERSAR	16-May-88	<5	<5	<5	<5	<5
		2 MARYLAND	16-May-88	--	<2	<2	<2	<2
		3 VERSAR	25-Jul-88	<5	<5	<5	<5	<5
Methyl Ethyl Ketone (MEK)		1 VERSAR	15-Mar-88	<10	<10	<10	<10	<10
(2-Butanone)		1 MARYLAND	15-Mar-88	ND	ND	ND	ND	ND
		2 VERSAR	16-May-88	<10	<10	<10	<10	<10
		2 MARYLAND	16-May-88	--	ND	ND	ND	ND
		3 VERSAR	25-Jul-88	<10	<10	<10	<10	<10
Methyl Isobutyl Ketone (MIBK)		1 VERSAR	15-Mar-88	<10	<10	<10	<10	<10
(4-Methyl-2-Pentanone)		1 MARYLAND	15-Mar-88	ND	ND	ND	ND	ND
		2 VERSAR	16-May-88	<10	<10	<10	<10	<10
		2 MARYLAND	16-May-88	--	ND	ND	ND	ND
		3 VERSAR	25-Jul-88	<10	<10	<10	<10	<10
Trichlorofluoromethane		1 VERSAR	15-Mar-88	ND	ND	ND	ND	ND
		1 MARYLAND	15-Mar-88	<1	<1	<1	<1	<1
		2 VERSAR	16-May-88	ND	ND	ND	5	ND
		2 MARYLAND	16-May-88	--	<1	<1	<1	<1
		3 VERSAR	25-Jul-88	ND	ND	ND	ND	ND
1,1,2-Trichlorotrifluoroethane		1 VERSAR	15-Mar-88	ND	ND	ND	ND	ND
		1 MARYLAND	15-Mar-88	ND	ND	ND	ND	ND
		2 VERSAR	16-May-88	17 B	17 B	14 B	16 B	11 B
		2 MARYLAND	16-May-88	--	ND	ND	ND	ND
		3 VERSAR	25-Jul-88	ND	ND	ND	ND	ND
Hexamethylcyclotrisiloxane		1 VERSAR	15-Mar-88	ND	ND	ND	ND	ND
		1 MARYLAND	15-Mar-88	ND	ND	ND	ND	ND
		2 VERSAR	16-May-88	ND	ND	ND	ND	ND
		2 MARYLAND	16-May-88	--	ND	ND	ND	ND
		3 VERSAR	25-Jul-88	ND	ND	ND	2 B	ND
PCB's	ug/L	1 VERSAR	15-Mar-88	****** None Detected (<1.0 ug/L) *******				
		2 VERSAR	16-May-88	****** None Detected (<1.0 ug/L) *******				
		3 VERSAR	25-Jul-88	****** None Detected (<1.0 ug/L) *******				

ND - Not Detected
B - Parameter was detected in laboratory blanks; possible contamination.
Dashes (--) indicate that the sample was not collected.

FIGURE 3-3. GROUND-WATER pH

(Oil Separator Pit)



The ground-water conductivity at the oil separator pit is represented graphically in Figure 3-4.

The lead analytical results provided in Table 3-4 show that only two ground-water samples (from Wells 2GW-2 and 2GW-4) were found to contain detectable quantities of lead. Both of these samples were collected during the third sampling event, and both lead concentrations are only slightly above the method detection limit.

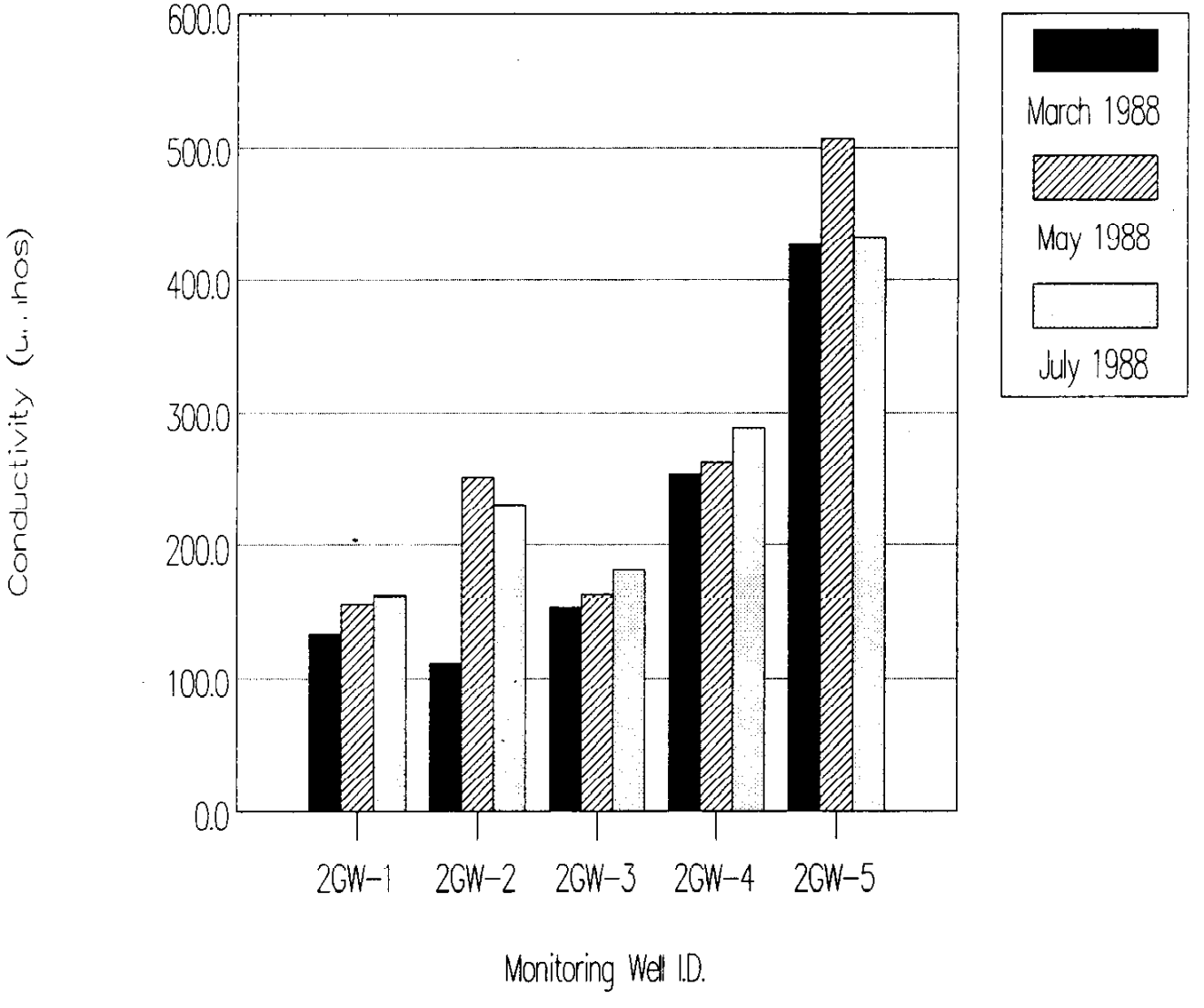
The oil and grease results in Table 3-4 range from 0.40 mg/L to 1.69 mg/L. The oil and grease concentrations appear to be more or less equal across all of the monitoring wells. The variability of the oil and grease concentrations was moderate between sampling events, and in general, the concentrations were higher for the second round than for the first and third sampling events. The background well did not exhibit consistently lower oil and grease content than downgradient wells.

The volatile organic compounds that were detected in at least one of the oil separator pit ground-water samples are listed in Table 3-4; those VOCs that were not detected in any sample are not listed. However, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are listed whether they were detected or not because these parameters were specifically requested by NAVFACENGCOM-Atlantic Division in the Scope of Work for this Site Investigation.

The results in Table 3-4 show that 2GW-2 and 2GW-4 were the most contaminated wells, respectively. No VOC was quantified in any sample at a concentration greater than 10 μg/L. All of the samples from each of these 2 wells contained the two most prevalent VOCs, which were trans-1,2-dichloroethene, with concentrations ranging from 6 μg/L to 10 μg/L, and trichloroethene, which had concentrations ranging from 5 μg/L to 7 μg/L. Several other VOCs were quantified in only one or two samples in concentrations at or below the method detection limit. Methylene chloride, acetone, hexamethylcyclotrisiloxane, and 1,1,2-trichlorotrifluoroethane were also found in several samples at varying concentrations; however, these compounds were all also found in

FIGURE 3-4. GROUND-WATER CONDUCTIVITY

(Oil Separator Pit)



laboratory blanks. These blank contaminants were detected in only the Versar samples and not in the State of Maryland splits. Finally, xylenes, MEK, and MIBK were not detected in any samples.

The split sample results for the Versar and State of Maryland splits were essentially equal for all the volatile organics, except for the laboratory blank contaminants listed above. Excluding the laboratory blank contaminants, the variability of the volatile organic data between each of the three sampling events was low.

Table 3-4 also shows that PCBs were not detected in any of the oil separator pit area ground-water samples. The PCB detection limits ranged from 0.5 μg/L to 1.0 μg/L.

3.3.2 Surface Water

The surface water samples were collected from three different monitoring locations at the oil separator pit area designated as 2SW-1 (upgradient) and 2SW-2 and 2SW-3 (downgradient) (see Figure 2-8). Versar collected the surface water samples from each location during three separate sampling events in March, May, and July, 1988. The samples collected in March were split with the State of Maryland. During the first and third sampling event, the temperature, pH, and specific conductance were determined in the field prior to collecting the samples for laboratory analysis of lead, oil and grease content, volatile organic compounds (VOCs), and PCBs. The analytical results from both the field and laboratory analyses are summarized in Table 3-5.

The surface water pH readings listed in Table 3-5 range from 6.60 to 7.33. The samples from location 2SW-2 were slightly acidic and consistently had the lowest pH, while the pH readings for the samples from locations 2SW-1 and 2SW-3 were consistently higher and slightly basic. The variability of the pH data between sampling events was relatively low.

The surface water conductivities ranged from 90 μmhos to 160 μmhos, and were higher during the July 1988 sampling event than

TABLE 3-5. SURFACE WATER SAMPLE TESTING DATA - OIL SEPARATOR PIT AREA

Parameter	Units	Sampling Event	Date	2SW-1	2SW-2	2SW-3
pH		1 VERSAR	15-Mar-88	6.83	6.74	7.24
		2 VERSAR	16-May-88	N/D	N/D	N/D
		3 VERSAR	25-Jul-88	7.27	6.60	7.33
Specific Conductance	umhos	1 VERSAR	15-Mar-88	90	90	90
		2 VERSAR	16-May-88	N/D	N/D	N/D
		3 VERSAR	25-Jul-88	160	115	160
Temperature	deg C	1 VERSAR	15-Mar-88	5.3	3.5	4.0
		2 VERSAR	16-May-88	N/D	N/D	N/D
		3 VERSAR	25-Jul-88	23.5	22.3	22.5
Lead	ug/L	1 VERSAR	15-Mar-88	<5.0	<5.0	<5.0
		2 VERSAR	16-May-88	<5.0	39.0	<5.0
		3 VERSAR	25-Jul-88	<5.0	<5.0	<5.0
Oil and Grease	mg/L	1 VERSAR	15-Mar-88	0.50	0.16	1.82
		2 VERSAR	16-May-88	0.44	2.46	0.58
		3 VERSAR	25-Jul-88	0.84	3.19	2.48
VOLATILE ORGANICS	ug/L					
Methylene Chloride		1 VERSAR	15-Mar-88	<5	<5	<5
		1 MARYLAND	15-Mar-88	<1	<1	<1
		2 VERSAR	16-May-88	<5	<5	<5
		3 VERSAR	25-Jul-88	3 B	3 B	3 B
Acetone		1 VERSAR	15-Mar-88	<10	<10	<10
		1 MARYLAND	15-Mar-88	ND	ND	ND
		2 VERSAR	16-May-88	<10	<10	<10
		3 VERSAR	25-Jul-88	<10	12	14
Xylene		1 VERSAR	15-Mar-88	<5	<5	<5
		1 MARYLAND	15-Mar-88	<2	<2	<2
		2 VERSAR	16-May-88	<5	<5	<5
		3 VERSAR	25-Jul-88	<5	<5	<5
Methyl Ethyl Ketone (MEK) (2-Butanone)		1 VERSAR	15-Mar-88	<10	<10	<10
		1 MARYLAND	15-Mar-88	ND	ND	ND
		2 VERSAR	16-May-88	<10	<10	<10
		3 VERSAR	25-Jul-88	<10	<10	<10
Methyl Isobutyl Ketone (MIBK) (4-Methyl-2-Pentanone)		1 VERSAR	15-Mar-88	<10	<10	<10
		1 MARYLAND	15-Mar-88	ND	ND	ND
		2 VERSAR	16-May-88	<10	<10	<10
		3 VERSAR	25-Jul-88	<10	<10	<10
1,1,2-Trichlorotrifluoroethane		1 VERSAR	15-Mar-88	ND	ND	ND
		1 MARYLAND	15-Mar-88	ND	ND	ND
		2 VERSAR	16-May-88	11 B	15 B	10 B
		3 VERSAR	25-Jul-88	ND	ND	ND
PCB's	ug/L	1 VERSAR	15-Mar-88	None Detected (<1.0 ug/L)		
		2 VERSAR	16-May-88	None Detected (<1.0 ug/L)		
		3 VERSAR	25-Jul-88	None Detected (<1.0 ug/L)		

ND - Not Detected; N/D - Not Determined
B - Parameter was detected in laboratory blanks; possible contamination.

in March 1988. As was the case for surface water samples collected at the base landfill, the elevated conductivities in July are likely related to low flow conditions preceding this sampling event. The conductivity measurements for all of the sample locations were approximately equal, with only slight variability between sampling events.

The lead analytical results provided in Table 3-5 show that only one surface water sample (2SW-2) contained lead at a concentration of 39 μg/L. This sample was collected during the second sampling event. This one data point appears to be an outlier when compared to the other surface water analytical results.

The surface water oil and grease results provided in Table 3-5 illustrate a range of concentrations from 0.44 mg/L to 3.19 mg/L. The oil and grease concentrations were highest for location 2SW-2 (in the tributary connecting the oil separator pit to Happy Valley Creek) and were lowest for background location 2SW-1. The variability of the oil and grease concentrations between sampling events was relatively low for location 2SW-1, but was relatively high for downgradient locations 2SW-2 and 2SW-3. The oil and grease concentrations were consistently higher for the third round than for the first and second sampling events.

Volatile organic compounds that were detected in at least one of the oil separator pit surface water samples are listed in Table 3-5; those VOCs that were not detected in any sample are not listed. However, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are listed whether they were detected or not because these parameters were specifically requested by NAVFACENGCOM Atlantic Division in the Scope of Work for this Site Investigation.

The volatile organic results presented in Table 3-5 do not suggest that the samples from any one location were significantly more contaminated than those from the other locations, and do not highlight any compound as being a serious problem. The most prevalent volatile organic compound was acetone, which had detected concentrations ranging from 12 μg/L to 14 μg/L. Acetone was detected in samples from

locations 2SW-2 and 2SW-3 during the third sampling event, but was not detected in either sample during the first or second sampling event. Additionally, both methylene chloride and 1,1,2-trichlorotrifluoroethane (fluorocarbon-113) were also found in several samples, but these compounds were all also found in laboratory blanks. Xylenes, MEK, and MIBK were not detected in any surface water samples. The split sample results for the Versar and Maryland splits collected during the first sampling event were identical for all the volatile organics because no volatiles were detected in either of the splits from each location.

Table 3-5 also shows that PCBs were not detected in any of the oil separator pit area surface water samples. The PCB detection limits ranged from 0.5 μg/L to 1.0 μg/L.

3.2.3 Sediment

The oil separator pit area sediment samples were collected from three different locations, which correspond to the locations for the oil separator pit surface water samples (see Figure 2-8). These sediment sampling locations were designated as 2SED-1 (upgradient), 2SED-2 (downgradient), and 2SED-3 (downgradient). Versar collected the sediment samples from each location during three separate sampling events in March, May, and July, 1988. These samples were analyzed for lead, oil and grease content, VOCs, and PCBs. Results are summarized in Table 3-6.

The lead analytical results provided in Table 3-6 show that lead was detected in all the samples at concentrations ranging from 5.6 mg/kg to 147 mg/kg. The concentrations of the samples collected from location 2SED-2 were significantly higher (approximately 10 times higher) than those of the samples collected at Happy Valley Creek locations 2SED-1 and 2SED-3, which were approximately equal. The lead concentration variability between the sampling events was relatively high, and in general, the samples collected during the second sampling event had higher lead concentrations than those collected during the first and third rounds of sampling. High variability is likely due to the random sampling of sediment at each location during each sampling round.

TABLE 3-6. STREAM SEDIMENT SAMPLE TESTING DATA - OIL SEPARATOR PIT AREA

Parameter	Units	Sampling Event	Date	2SED-1	2SED-2	2SED-3
Lead	mg/kg	1 VERSAR	15-Mar-88	5.6	63.0	15.0
		2 VERSAR	16-May-88	11.0	147.0	5.9
		3 VERSAR	25-Jul-88	5.9	44.0	6.2
Oil and Grease	mg/kg	1 VERSAR	15-Mar-88	252	123,000	1,030
		2 VERSAR	16-May-88	210	41,000	401
		3 VERSAR	25-Jul-88	278	17,200	190
VOLATILE ORGANICS	ug/kg					
Methylene Chloride		1 VERSAR	15-Mar-88	<6	<16	<10
		2 VERSAR	16-May-88	6 B	7 B	<7
		3 VERSAR	25-Jul-88	2	<5	<5
Acetone		1 VERSAR	15-Mar-88	<13	98 B	<20
		2 VERSAR	16-May-88	24 B	77 B	<14
		3 VERSAR	25-Jul-88	8 B	11 B	<10
Toluene		1 VERSAR	15-Mar-88	<6	<16	<10
		2 VERSAR	16-May-88	<9	4	<7
		3 VERSAR	25-Jul-88	<5	<5	<5
Xylene		1 VERSAR	15-Mar-88	<6	<16	<10
		2 VERSAR	16-May-88	<9	<15	<7
		3 VERSAR	25-Jul-88	<5	<5	<5
Methyl Ethyl Ketone (MEK) (2-Butanone)		1 VERSAR	15-Mar-88	<13	<33	<20
		2 VERSAR	16-May-88	<17	<30	<14
		3 VERSAR	25-Jul-88	<10	<10	<10
Methyl Isobutyl Ketone (MIBK) (4-Methyl-2-Pentanone)		1 VERSAR	15-Mar-88	<13	<33	<20
		2 VERSAR	16-May-88	<17	<30	<14
		3 VERSAR	25-Jul-88	<10	<10	<10
1,1,2-Trichlorotrifluoroethane		1 VERSAR	15-Mar-88	ND	ND	ND
		2 VERSAR	16-May-88	ND	ND	6 B
		3 VERSAR	25-Jul-88	ND	ND	ND
Hexamethylcyclotrisiloxane		1 VERSAR	15-Mar-88	ND	ND	ND
		2 VERSAR	16-May-88	ND	ND	ND
		3 VERSAR	25-Jul-88	ND	4 B	ND
1-Ethyl-3-Methyl-Benzene		1 VERSAR	15-Mar-88	ND	ND	ND
		2 VERSAR	16-May-88	ND	ND	ND
		3 VERSAR	25-Jul-88	1	ND	ND
PCB's	ug/kg	1 VERSAR	15-Mar-88	<43	<1,200	<83
		2 VERSAR	16-May-88	<58	<2,800	<58
		3 VERSAR	25-Jul-88	<330	<770	<340

ND - Not Detected
B - Parameter was detected in laboratory blanks; possible contamination.

The oil and grease results presented in Table 3-6 range from 190 mg/kg and 123,000 mg/kg. The oil and grease concentrations were substantially higher for location 2SED-2 samples. Again, this sample location was in the tributary connecting the oil separator pit to Happy Valley Creek. Background location 2SED-1 yielded the lowest oil and grease concentrations, as expected. The variability of the oil and grease concentrations between sampling events was relatively low for location 2SED-1, but was relatively high for locations 2SED-2 and 2SED-3. The oil and grease concentrations were generally higher for the first round than for the second and third rounds of sampling.

With respect to the results of volatile organic compound analyses, those VOCs detected in at least one of the oil separator pit sediment samples are listed in Table 3-6; those VOCs that were not detected in any sample are not listed. However, xylene, methyl ethyl ketone (MEK), and methyl isobutyl ketone (MIBK) are listed whether they were detected or not because these parameters were specifically requested by NAVFACENGCOM-Atlantic Division in the Scope of Work for this Site Investigation.

The volatile organic compound results in Table 3-6 indicate that a total of only six different VOCs were detected in the sediment samples from the three locations, with four of these compounds also detected in laboratory blanks. The two volatile organic compounds which were not detected in the laboratory blanks were found in one sample each, and both of these (toluene and 1-ethyl-3-methyl-benzene) were tentatively identified at concentrations below the method detection limit. Xylenes, MEK, and MIBK were not detected in any sediment samples. The variability of the volatile organic data between the sampling events was relatively low.

A review of the PCB results in Table 3-3 shows that PCBs were not detected in any of the oil separator pit stream sediment samples. The PCB detection limits ranged from 43 μg/kg to 2,800 μg/kg due to sample dilution.

3.4 Quality Assurance/Quality Control

The Versar laboratory implemented extensive quality control measures on all analyses. The procedures used by the Versar laboratory conformed to the EPA Contract Laboratory Program (CLP) requirements (EPA 1987a,b). During all analytical activities, quality control (QC) samples were introduced into the sampling scheme to monitor the performance of the analytical method. These QC samples were prepared using both standard and environmental matrices, and included laboratory-prepared QC samples (e.g., reagent blanks, duplicates, matrix spikes, surrogate spikes, and check standards) and field blanks. A detailed description of the QC samples, including sample preparation procedures, can be found in Section 10.0 of the QA/QC Plan for the NTC Bainbridge Site Investigation (Versar, 1988).

The specific QC samples used during analyses differ for each analytical method. However, in general, the QC samples used for all inorganic analyses are the same, and those used for all the organic analyses are the same. For the inorganic analyses, Versar analyzed calibration blanks, method (i.e., reagent or preparation) blanks, reference standards, calibration verification standards, laboratory control samples, duplicate samples, and spiked samples. The method blanks and calibration blanks were used to determine whether the samples were being contaminated by laboratory glassware or impure reagents. The reference and calibration verification standards were used to check the accuracy of the analytical method, excluding sample preparation and matrix interferences. The results from the laboratory control samples were used to check the accuracy of both the sample preparation and instrumental analysis procedures. Finally, the results of the duplicate analyses were used to assess the laboratory precision, and the spiked sample results were used to evaluate the matrix interferences and the accuracy (i.e., recovery).

For the organic analyses, Versar analyzed method (preparation or reagent) blanks, surrogate spikes, and matrix spike/matrix spike duplicate samples. The method blank was used to ensure that method

interferences caused by contaminants in solvents, reagents, glassware, and other sample processing equipment were minimized. All samples, including environmental samples, blanks, and other QC samples, were spiked with surrogate compounds prior to any extraction or sample preparation procedures to monitor the effect of preparation, analysis, and sample matrix interferences on recovery (i.e., accuracy). The results of the matrix spike/matrix spike duplicate analyses were used to evaluate the precision and accuracy of the analytical method. In addition to these QC samples, each organic analytical method has additional QC requirements (e.g., system performance checks and calibration checks for volatile organics, and evaluation standards and individual standards for pesticide/PCB analyses), which are specified in the analytical procedure. The results from the analyses of these QC standards were used to check for linearity and degradation and to determine whether calibration factor and retention time criteria were being met.

For both inorganic and organic analyses, field blanks were analyzed to isolate potential sources of contamination and to identify biases in the data. The results of the QA/QC analyses are summarized in the following subsections by analytical parameter -- lead, oil and grease, volatile organics, and pesticides/PCBs.

3.4.1 Lead QA/QC

The ground-water, surface water, and sediment samples from the oil separator pit were analyzed for lead. Each batch of samples was accompanied by blanks, standards, a duplicate, and a spiked sample. The results from these QC samples are summarized by matrix and sampling event in Table 3-7.

The results for the first sampling event indicate that all QC criteria were met for both the water and sediment samples. The calibration and preparation blanks did not contain lead, indicating that sample contamination was not a problem in the laboratory. Similarly, no lead was found in the field blanks, documenting that lead contamination

TABLE 3-7. QC SUMMARY FOR LEAD ANALYSES

QC Sample Description	Units	Groundwater and Surface Water		
		Round 1 (March 1988)	Round 2 (May 1988)	Round 3 (July 1988)
Reference Standard (initial)	% Recovered	101	97	104
Calibration Blank (initial)	ug/L	<1.0	<1.0	<1.0
Preparation Blank #1	ug/L	<1.0	<1.0	2.2*
Preparation Blank #2	ug/L	N.A.	<1.0	N.A.
Calibration Verification #1	% Recovered	96	96	92
Calibration Verification #2	% Recovered	100	100	92
Calibration Verification #3	% Recovered	96	100	96
Calibration Verification #4	% Recovered	N.A.	104	96
Laboratory Control Sample	% Recovered	84	97	103
Sample Duplicate	% RPD	0.0	N.C.	N.C.
Spike Recovery	% Recovered	100	100	95
Reference Standard (final)	% Recovered	102	N.A.	108
Calibration Blank (final)	ug/L	<1.0	N.A.	<1.0

QC Sample Description	Units	Sediment		
		Round 1 (March 1988)	Round 2 (May 1988)	Round 3 (July 1988)
Reference Standard (initial)	% Recovered	105	104	110
Calibration Blank (initial)	ug/L	<1.0	<1.0	<1.0
Preparation Blank #1	mg/kg	<0.2	<1.0	<0.2
Preparation Blank #2	mg/kg	<0.2	N.A.	<0.2
Calibration Verification #1	% Recovered	100	104	104
Calibration Verification #2	% Recovered	96	104	104
Calibration Verification #3	% Recovered	100	104	104
Calibration Verification #4	% Recovered	108	108	104
Laboratory Control Sample	% Recovered	92	109	105
Sample Duplicate	% RPD	17	30*	11
Spike Recovery	% Recovered	114	93	93
Reference Standard (final)	% Recovered	100	N.A.	108
Calibration Blank (final)	ug/L	<1.0	N.A.	<1.0

N.A. - Not available
N.C. - Not calculated; both sample and duplicate were less than the detection limit.
* - Indicates that the reported value is not within specified QC limits.

was not occurring in the field. The recoveries of the reference standards, calibration verification standards, and laboratory control samples were consistently between the QC criteria of 90% to 110%. Similarly, the recoveries of the spiked samples were within the QC criteria of 75% to 125%. Finally, the relative percent difference (RPD) for each duplicate sample was below the QC limit of 20%.

For the second sampling event, the results in Table 3-7 suggest that the analyses were again in control (i.e., within acceptable QA/QC guidelines). All QC criteria were met, with the exception of the RPD for the duplicate sediment sample. This higher RPD was the result of splitting a sediment sample that was wet, which made it extremely difficult to obtain equivalent homogeneous samples.

The analyses of the third sampling event samples were also in control. One blank (preparation blank #1) for the water samples did contain a negligible quantity of lead; however, none of the ground-water or surface water samples collected during that sampling event contained lead at detectable levels. Therefore, no positive bias from the blank contamination was introduced in the analyses of the samples. All other QC criteria were met for the samples collected and analyzed from the third sampling event.

3.4.2 Oil and Grease QA/QC

The ground-water, surface water, and sediment samples from the oil separator pit were analyzed for oil and grease. Each sample batch included blanks, a reference standard, a duplicate, and a spiked sample. The results from these QC samples are summarized by sample type and sampling round number in Table 3-8.

Although the calibration blank results and the duplicate RPD met the QC criteria for both the water and sediment samples collected from the first sampling event, the results in Table 3-8 indicate that several other QC criteria were not met. For the water samples, the reference standard recovery exceeded the upper QC limit of 110%. However, the

TABLE 3-8. QC SUMMARY FOR OIL AND GREASE ANALYSES

QC Sample Description	Units	Groundwater and Surface Water		
		Round 1 (March 1988)	Round 2 (May 1988)	Round 3 (July 1988)
Reference Standard	% Recovered	148*	179*	175*
Calibration Blank	mg/L	<0.2	<0.2	<0.2
Preparation Blank	mg/L	<0.2	<0.2	<0.2
Calibration Verification #1	% Recovered	93	103	181*
Calibration Verification #2	% Recovered	105	101	N.A.
Sample Duplicate	% RPD	0.6	1.6	0.0
Spike Recovery	% Recovered	92	104	N.A.

QC Sample Description	Units	Sediment		
		Round 1 (March 1988)	Round 2 (May 1988)	Round 3 (July 1988)
Reference Standard	% Recovered	83*	90	102
Calibration Blank	mg/L	<0.2	<0.2	<0.2
Preparation Blank	mg/kg	50*	5.0*	24*
Calibration Verification #1	% Recovered	N.A.	N.A.	101
Calibration Verification #2	% Recovered	N.A.	N.A.	N.A.
Sample Duplicate	% RPD	7.0	3.2	1.1
Spike Recovery #1	% Recovered	131*	86	N.A.
Spike Recovery #2	% Recovered	154*	N.A.	N.A.

N.A. - Not available
* - Indicates that the reported value is not within specified QC limits.

recovered value was within the 95% confidence interval for the reference standard, and therefore, it is considered acceptable. All other QC criteria for the water samples were met.

For the sediment samples obtained from the first sampling event, the preparation blank contained 50 mg/kg of oil and grease. This indicates that some contamination may have been introduced in the laboratory that would positively bias the analytical results for the sediment. Consequently, the oil and grease concentrations for the first sampling event sediments should be used cautiously. No oil and grease was found in the field blanks, which suggests that this contamination was not occurring the in the field. The recovery of the reference standard was low; however, this recovery was within the 95% confidence levels for this reference standard and is acceptable. The recoveries of the spiked samples exceeded the upper QC limit of 110% for the sediment samples, providing further evidence that a positive bias may have been introduced.

For the second sampling event, the results in Table 3-8 suggest that the oil and grease analyses were in control. Again, the reference standard recovery for the water samples was high, but was within the 95% confidence interval. Also, as was the case for the first sampling event samples, the preparation blank for the sediment contained oil and grease, but at an insignificant quantity when compared to the sediment sample concentrations. All other QC criteria were met for the samples from the second sampling event samples.

The results of the third sampling event samples also show that the oil and grease analyses were in control. Although the reference standard and calibration verification standard recoveries for the water samples were slightly high, they were within the 95% confidence interval. Additionally, as was the case with analyses from previous sampling events, the preparation blank for the sediment samples did contain oil and grease, but this concentration (24 mg/kg) was negligible when compared to the sediment sample concentrations. Therefore, no significant positive bias from the blank contamination was introduced in

the analyses of the samples. All other QC criteria were met for the samples collected from the third sampling event.

3.4.3 Volatile Organic Compound QA/QC

The ground-water, surface water, and sediment samples from both the base landfill area and the oil separator pit were analyzed for the presence of volatile organic compounds (VOCs). Each sample was spiked with surrogate compounds, and each sample batch was accompanied by a blank, check standards, a matrix spike (MS), and a matrix spike duplicate (MSD). The surrogate recoveries for the water samples and the sediment samples are presented in Tables 3-9 and 3-10, respectively. The matrix spike and matrix spike duplicate results are presented in Table 3-11.

For the samples collected from the first sampling event, all tuning, system performance check, and continuing calibration check requirements were met, and all samples were analyzed within prescribed holding times during a 12-hour period following daily calibration. A field blank was also analyzed and it did not contain any VOCs. The laboratory blanks for both the waters and sediment contained acetone (8 μg/L for water and 8 μg/kg for sediment) and methylene chloride (3 μg/L for water and 3μg/kg for sediment). Therefore, the analytical results for actual samples that yielded detectable levels of these compounds were flagged with a "B" to indicate that these parameters were found in the laboratory blanks and should be used with caution. The results in Tables 3-9 through 3-11 indicate that all QC criteria for surrogate recoveries, MS/MSD recoveries, and MS/MSD RPDs were met, and therefore, the analyses are considered acceptable for both the water and sediment samples.

The results in Table 3-9 through 3-11 indicate that the analyses for the samples from the second sampling event were also acceptable. The MS and MSD recoveries for chlorobenzene in water were below the lower QC limit of 75%. However, the sample concentration was more than five times the spike concentration, so the QC limits for recovery do not apply. All other QC criteria, including adherence to holding times, were met. The

TABLE 3-9. SURROGATE COMPOUND RECOVERIES FOR VOLATILE ORGANIC ANALYSES OF GROUNDWATER AND SURFACE WATER SAMPLES

Sample No.	Sample Description	Volatile Organic Surrogate % Recovery		
		Toluene-d8 (88 - 110)	Bromofluoro-Benzene (86 - 115)	1,2-Dichloro-Ethane-d4 (76 - 114)
21151	1GW-1, Round 1	99	97	96
21153	1GW-4, Round 1	100	93	96
21155	1GW-3, Round 1	98	100	102
21157	1GW-5, Round 1	100	96	97
21159	1GW-2, Round 1	97	97	98
21161	1SW-1, Round 1	98	97	97
21163	1SW-2, Round 1	97	99	97
21165	2GW-1, Round 1	98	97	98
21169	2GW-3, Round 1	100	96	97
21173	2GW-2, Round 1	98	97	98
21177	2GW-4, Round 1	101	96	99
21181	2GW-5, Round 1	98	98	97
21185	2SW-1, Round 1	100	96	96
21189	2SW-2, Round 1	98	96	97
21193	2SW-3, Round 1	101	98	98
21197	Field Blank, Round 1	99	98	99
21197MS	Matrix Spike, Round 1	96	100	99
21197MSD	Matrix Spike Duplicate, Round 1	98	100	99
35445	2GW-1, Round 2	96	96	90
35449	2GW-2, Round 2	96	95	91
35453	2GW-3, Round 2	96	96	89
35457	2GW-4, Round 2	95	95	88
35461	2GW-5, Round 2	96	95	87
35465	2SW-1, Round 2	94	87	95
35469	2SW-2, Round 2	94	95	86
35473	2SW-3, Round 2	94	94	85
35477	Field Blank, Round 2	96	95	84
35482	1GW-1, Round 2	94	95	83
35484	1GW-2, Round 2	98	98	97
35487	1GW-3, Round 2	100	104	98
35487MS	Matrix Spike, Round 2	101	109	89
35487MSD	Matrix Spike Duplicate, Round 2	101	109	92
35488	1GW-4, Round 2	101	97	99
35490	1GW-5, Round 2	97	100	99
35492	1SW-1, Round 2	100	98	98
35494	1SW-2, Round 2	99	99	99
33009	2GW-1, Round 3	98	94	96
33013	2GW-2, Round 3	101	93	98
33017	2GW-3, Round 3	97	93	98
33021	2GW-4, Round 3	99	101	101
33025	2GW-5, Round 3	99	101	100
33029	2SW-1, Round 3	100	102	103
33033	2SW-2, Round 3	100	100	102
33037	2SW-3, Round 3	98	100	103
33058	1GW-1, Round 3	97	97	104
33060	1GW-2, Round 3	100	99	106
33062	1GW-3, Round 3	99	113	105
33064	1GW-4, Round 3	99	101	105
33066	1GW-5, Round 3	100	107	105
33066MS	Matrix Spike, Round 3	97	99	98
33066MSD	Matrix Spike Duplicate, Round 3	96	98	95
33068	1SW-1, Round 3	100	99	104
33070	1SW-2, Round 3	101	102	103

TABLE 3-10. SURROGATE COMPOUND RECOVERIES FOR VOLATILE ORGANIC ANALYSES OF STREAM SEDIMENT SAMPLES

Sample No.	Sample Description	Volatile Organic Surrogate % Recovery		
		Toluene-d8 (81 - 117)	Bromofluoro-Benzene (74 - 121)	1,2-Dichloro-Ethane-d4 (70 - 121)
21202	1SED-1, Round 1	94	93	95
21204	1SED-2, Round 1	95	96	94
21204MS	Matrix Spike, Round 1	95	95	97
21204MSD	Matrix Spike Duplicate, Round 1	94	93	95
21206	2SED-1, Round 1	95	94	95
21210	2SED-2, Round 1	108	78	98
21214	2SED-3, Round 1	98	92	93
21222	1SED-1, Round 2	97	89	95
21222MS	Matrix Spike, Round 2	95	91	91
21222MSD	Matrix Spike Duplicate, Round 2	98	91	95
21224	1SED-2, Round 2	94	89	94
21226	2SED-1, Round 2	96	87	94
21230	2SED-2, Round 2	89	77	94
21234	2SED-3, Round 2	89	92	75
33046	2SED-1, Round 3	101	102	121
33050	2SED-2, Round 3	88	86	83
33054	2SED-3, Round 3	97	92	84
33076	1SED-1, Round 3	94	91	81
33078	1SED-2, Round 3	95	94	97
33078MS	Matrix Spike, Round 3	97	95	83
33078MSD	Matrix Spike Duplicate, Round 3	94	94	81

TABLE 3-11. MATRIX SPIKE QC SUMMARY FOR VOLATILE ORGANIC ANALYSES

QC Sample	Volatile Organic Spiking Compounds				
	1,1-Dichloroethene	Trichloroethene	Chlorobenzene	Toluene	Benzene
Field Blank, Round 1 (Sample No. 21197)					
MS Recovery (%)	118	102	102	108	106
MSD Recovery (%)	124	108	106	114	110
RPD (%)	5	6	4	5	4
QC Recovery Limits	61 - 145	71 - 120	75 - 130	76 - 125	76 - 127
QC RPD Limits	0 - 14	0 - 14	0 - 13	0 - 13	0 - 11
1SED-2, Round 1 (Sample No. 21204)					
MS Recovery (%)	124	108	106	108	108
MSD Recovery (%)	120	104	100	102	104
RPD (%)	3	4	6	6	4
QC Recovery Limits	59 - 172	62 - 137	60 - 133	59 - 139	66 - 142
QC RPD Limits	0 - 22	0 - 24	0 - 21	0 - 21	0 - 21
1GW-3, Round 2 (Sample No. 35487)					
MS Recovery (%)	94	86	68*	82	80
MSD Recovery (%)	92	84	58*	82	82
RPD (%)	2	2	4	0	2
QC Recovery Limits	61 - 145	71 - 120	75 - 130	76 - 125	76 - 127
QC RPD Limits	0 - 14	0 - 14	0 - 13	0 - 13	0 - 11
1SED-1, Round 2 (Sample No. 21222)					
MS Recovery (%)	120	100	106	114	110
MSD Recovery (%)	116	96	97	103	104
RPD (%)	3	4	8	11	6
QC Recovery Limits	59 - 172	62 - 137	60 - 133	59 - 139	66 - 142
QC RPD Limits	0 - 22	0 - 24	0 - 21	0 - 21	0 - 21
1GW-5, Round 3 (Sample No. 33066)					
MS Recovery (%)	120	104	104	110	114
MSD Recovery (%)	112	102	102	106	108
RPD (%)	7	2	2	4	5
QC Recovery Limits	61 - 145	71 - 120	75 - 130	76 - 125	76 - 127
QC RPD Limits	0 - 14	0 - 14	0 - 13	0 - 13	0 - 11
1SED-2, Round 3 (Sample No. 33078)					
MS Recovery (%)	146	114	114	118	124
MSD Recovery (%)	130	102	102	106	112
RPD (%)	15	11	11	11	10
QC Recovery Limits	59 - 172	62 - 137	60 - 133	59 - 139	66 - 142
QC RPD Limits	0 - 22	0 - 24	0 - 21	0 - 21	0 - 21

MS - Matrix Spike
MSD - Matrix Spike Duplicate
RPD - Relative Percent Difference
* - Indicates that the reported value is not within specified QC limits.

field blank contained toluene (1 μg/L), methylene chloride (2 μg/L), chloroform (2 μg/L), and 1,1,2-trichlorotrifluoroethane (10 μg/L), and the laboratory blanks for both the water and sediment contained acetone (13 μg/L for water and 11 μg/kg for sediment), methylene chloride (9 μg/L for water and 8 μg/kg for sediment), and 1,1,2-trichlorotrifluoroethane (18 μg/L for water and 6 μg/kg for sediment). Therefore, the analytical results for these compounds were flagged with a "B", and should be used with caution.

The analytical results for the third sampling event samples also indicate that the analyses were in control. The samples were analyzed within prescribed holding times, and all QC criteria were met. A field blank was not collected during the third round of sampling, but laboratory blanks were analyzed. The water laboratory blank contained methylene chloride (6 μg/L) and hexamethylcyclo-trisiloxane (3 μg/L), and the sediment blank contained acetone (3 μg/kg) and hexamethylcyclotrisiloxane (3 μg/kg). The positive results for these compounds were flagged with a "B", indicating that these compounds were found in blanks, and data should be used with caution.

3.4.4 Pesticide and PCB QA/QC

The ground-water, surface water, and sediment samples from the base landfill area were analyzed for organochlorine pesticides, and the samples from the oil separator pit were analyzed for PCBs. Each sample was spiked with a surrogate compound (dibutylchlorendate), which is the same for both the pesticide and PCB analyses, and each sample batch included a blank, standard mixtures, a matrix spike (MS), and a matrix spike duplicate (MSD). The surrogate recoveries for the water samples and the sediment samples are presented in Tables 3-12 and 3-13, respectively. The matrix spike and matrix spike duplicate results are presented in Tables 3-14 and 3-15 for the pesticides and PCBs, respectively.

For samples obtained from the first sampling event in March 1988, all calibration standards, linearity checks, degradation checks, and DBC

TABLE 3-12. SURROGATE RECOVERY FOR PESTICIDE AND PCB ANALYSES OF GROUNDWATER AND SURFACE WATER SAMPLES

Sample No.	Sample Description	Surrogate % Recovery (1) Dibutylchlorendate (24 - 154)
21152	1GW-1, Round 1 (Pesticides)	37
21154	1GW-4, Round 1 (Pesticides)	68
21156	1GW-3, Round 1 (Pesticides)	28
21158	1GW-5, Round 1 (Pesticides)	33
21158MS	Matrix Spike, Round 1 (Pesticides)	65
21158MSD	Matrix Spike Duplicate, Round 1 (Pesticides)	65
21160	1GW-2, Round 1 (Pesticides)	23*
21162	1SW-1, Round 1 (Pesticides)	93
21164	1SW-2, Round 1 (Pesticides)	96
21198	Field Blank, Round 1 (Pesticides)	86
21166	2GW-1, Round 1 (PCBs)	67
21170	2GW-3, Round 1 (PCBs)	60
21174	2GW-2, Round 1 (PCBs)	96
21178	2GW-4, Round 1 (PCBs)	97
21182	2GW-5, Round 1 (PCBs)	129
21186	2SW-1, Round 1 (PCBs)	56
21190	2SW-2, Round 1 (PCBs)	94
21194	2SW-3, Round 1 (PCBs)	98
21199	Field Blank, Round 1 (PCBs)	99
21199MS	Matrix Spike, Round 1 (PCBs)	98
21199MSD	Matrix Spike Duplicate, Round 1 (PCBs)	106
35478	Field Blank, Round 2 (Pesticides)	75
35483	1GW-1, Round 2 (Pesticides)	73
35485	1GW-2, Round 2 (Pesticides)	56
35486	1GW-3, Round 2 (Pesticides)	41
35486MS	Matrix Spike, Round 2 (Pesticides)	46
35486MSD	Matrix Spike Duplicate, Round 2 (Pesticides)	37
35489	1GW-4, Round 2 (Pesticides)	85
35491	1GW-5, Round 2 (Pesticides)	53
35493	1SW-1, Round 2 (Pesticides)	83
35496	1SW-2, Round 2 (Pesticides)	79
35446	2GW-1, Round 2 (PCBs)	N.A.
35450	2GW-2, Round 2 (PCBs)	N.A.
35454	2GW-3, Round 2 (PCBs)	N.A.
35454MS	Matrix Spike, Round 2 (PCBs)	N.A.
35454MSD	Matrix Spike Duplicate, Round 2 (PCBs)	N.A.
35458	2GW-4, Round 2 (PCBs)	N.A.
35462	2GW-5, Round 2 (PCBs)	N.A.
35466	2SW-1, Round 2 (PCBs)	N.A.
35470	2SW-2, Round 2 (PCBs)	N.A.
35474	2SW-3, Round 2 (PCBs)	N.A.
35479	Field Blank, Round 2 (PCBs)	N.A.
33010	2GW-1, Round 3 (PCBs)	381*
33014	2GW-2, Round 3 (PCBs)	161*
33018	2GW-3, Round 3 (PCBs)	112
33022	2GW-4, Round 3 (PCBs)	235*
33026	2GW-5, Round 3 (PCBs)	195*
33030	2SW-1, Round 3 (PCBs)	279*
33034	2SW-2, Round 3 (PCBs)	156*
33038	2SW-3, Round 3 (PCBs)	401*
33059	1GW-1, Round 3 (Pesticides)	571*
33061	1GW-2, Round 3 (Pesticides)	644*
33063	1GW-3, Round 3 (Pesticides)	342*
33063MS	Matrix Spike, Round 3 (Pesticides)	292*
33063MSD	Matrix Spike Duplicate, Round 3 (Pesticides)	356*
33065	1GW-4, Round 3 (Pesticides)	383*
33067	1GW-5, Round 3 (Pesticides)	675*
33069	1SW-1, Round 3 (Pesticides)	168*
33075	1SW-2, Round 3 (Pesticides)	514*

(1) - Dibutylchlorendate is used as the surrogate compound for both the pesticide (landfill samples) and PCB (oil separator pit area samples) fractions.

N.A. - Not available; surrogate compound was removed by acid cleaning step.

* - Indicates that the reported value is not within specified QC limits.

TABLE 3-13. SURROGATE RECOVERY FOR PESTICIDE AND PCB ANALYSES OF STREAM SEDIMENT SAMPLES

Sample No.	Sample Description	Pesticide/PCB Surrogate % Recovery (1) Dibutylchlorendate (20 - 150)
21203	1SED-1, Round 1 (Pesticides)	103
21205	1SED-2, Round 1 (Pesticides)	100
21205MS	Matrix Spike, Round 1 (Pesticides)	98
21205MSD	Matrix Spike Duplicate, Round 1 (Pesticides)	96
21207	2SED-1, Round 1 (PCBs)	N.A.
21207MS	Matrix Spike, Round 1 (PCBs)	N.A.
21207MSD	Matrix Spike Duplicate, Round 1 (PCBs)	N.A.
21211	2SED-2, Round 1 (PCBs)	N.A.
21215	2SED-3, Round 1 (PCBs)	N.A.
21223	1SED-1, Round 2 (Pesticides)	92
21225	1SED-2, Round 2 (Pesticides)	110
21225MS	Matrix Spike, Round 2 (Pesticides)	92
21225MSD	Matrix Spike Duplicate, Round 2 (Pesticides)	96
21227	2SED-1, Round 2 (PCBs)	N.A.
21227MS	Matrix Spike, Round 2 (PCBs)	N.A.
21227MSD	Matrix Spike Duplicate, Round 2 (PCBs)	N.A.
21231	2SED-2, Round 2 (PCBs)	N.A.
21231MS	Matrix Spike, Round 2 (PCBs)	N.A.
21231MSD	Matrix Spike Duplicate, Round 2 (PCBs)	N.A.
21235	2SED-3, Round 2 (PCBs)	N.A.
33047	2SED-1, Round 3 (PCBs)	120
33051	2SED-2, Round 3 (PCBs)	366*
33055	2SED-3, Round 3 (PCBs)	102
33077	1SED-1, Round 3 (Pesticides)	122
33077MS	Matrix Spike, Round 3 (Pesticides)	130
33077MSD	Matrix Spike Duplicate, Round 3 (Pesticides)	108
33080	1SED-2, Round 3 (Pesticides)	103

(1) - Dibutylchlorendate is used as the surrogate compound for both the pesticide (landfill samples) and PCB (oil separator pit area samples) fractions.
N.A. - Not available: surrogate compound was removed by acid cleaning step.
* - Indicates that the reported value is not within specified QC limits.

TABLE 3-14. MATRIX SPIKE QC SUMMARY FOR PESTICIDE ANALYSES

QC Sample	Pesticide Spiking Compounds					
	Lindane	Heptachlor	Aldrin	Dieldrin	Endrin	4,4'-DDT
1GW-5, Round 1 (Sample No. 21158)						
MS Recovery (%)	95	100	85	84	84	76
MSD Recovery (%)	110	120	90	86	88	128*
RPD (%)	15	18	6	2	5	49*
QC Recovery Limits	56 - 123	40 - 131	40 - 120	52 - 126	56 - 121	38 - 127
QC RPD Limits	0 - 15	0 - 20	0 - 22	0 - 18	0 - 21	0 - 27
1SED-2, Round 1 (Sample No. 21205)						
MS Recovery (%)	99	118	96	83	93	70
MSD Recovery (%)	104	117	96	86	97	89
RPD (%)	5	1	0	4	4	24
QC Recovery Limits	46 - 127	35 - 130	34 - 132	31 - 134	42 - 139	23 - 134
QC RPD Limits	0 - 50	0 - 31	0 - 43	0 - 38	0 - 45	0 - 50
1GW-3, Round 2 (Sample No. 35486)						
MS Recovery (%)	100	80	70	84	86	54
MSD Recovery (%)	100	75	65	82	84	44
RPD (%)	0	6	7	2	2	20
QC Recovery Limits	56 - 123	40 - 131	40 - 120	52 - 126	56 - 121	38 - 127
QC RPD Limits	0 - 15	0 - 20	0 - 22	0 - 18	0 - 21	0 - 27
1SED-2, Round 2 (Sample No. 21225)						
MS Recovery (%)	111	118	103	111	99	102
MSD Recovery (%)	117	119	109	117	104	119
RPD (%)	5	1	6	5	5	50
QC Recovery Limits	46 - 127	35 - 130	34 - 132	31 - 134	42 - 139	23 - 134
QC RPD Limits	0 - 50	0 - 31	0 - 43	0 - 38	0 - 45	0 - 50
1GW-3, Round 3 (Sample No. 33063)						
MS Recovery (%)	283*	283*	238*	222*	234*	263*
MSD Recovery (%)	335*	338*	290*	263*	271*	279*
RPD (%)	17*	18	20	17	15	16
QC Recovery Limits	56 - 123	40 - 131	40 - 120	52 - 126	56 - 121	38 - 127
QC RPD Limits	0 - 15	0 - 20	0 - 22	0 - 18	0 - 21	0 - 27
1SED-1, Round 3 (Sample No. 33077)						
MS Recovery (%)	96	100	122	110	132	202*
MSD Recovery (%)	94	82	113	101	126	112
RPD (%)	2	9	8	9	5	57*
QC Recovery Limits	46 - 127	35 - 130	34 - 132	31 - 134	42 - 139	23 - 134
QC RPD Limits	0 - 50	0 - 31	0 - 43	0 - 38	0 - 45	0 - 50

MS - Matrix Spike
MSD - Matrix Spike Duplicate
RPD - Relative Percent Difference
* - Indicates that the reported value is not within specified QC limits.

TABLE 3-15. MATRIX SPIKE QC SUMMARY FOR PCB ANALYSES

QC Sample	PCB Spiking Compound Aroclor-1242
Field Blank, Round 1 (Sample No. 21199)	
MS Recovery (%)	91
MSD Recovery (%)	94
RPD (%)	3
QC Recovery Limits	80 - 120
QC RPD Limits	0 - 20
2SED-1, Round 1 (Sample No. 21207)	
MS Recovery (%)	96
MSD Recovery (%)	108
RPD (%)	12
QC Recovery Limits	80 - 120
QC RPD Limits	0 - 20
2GW-3, Round 2 (Sample No. 35454)	
MS Recovery (%)	118
MSD Recovery (%)	121*
RPD (%)	3
QC Recovery Limits	80 - 120
QC RPD Limits	0 - 20
2SED-1, Round 2 (Sample No. 21227)	
MS Recovery (%)	165*
MSD Recovery (%)	151*
RPD (%)	9
QC Recovery Limits	80 - 120
QC RPD Limits	0 - 20
2SED-2, Round 2 (Sample No. 21231)	
MS Recovery (%)	298*
MSD Recovery (%)	316*
RPD (%)	6
QC Recovery Limits	80 - 120
QC RPD Limits	0 - 20

MS - Matrix Spike
MSD - Matrix Spike Duplicate
RPD - Relative Percent Difference
* - Indicates that the reported value is not within specified QC limits.

retention time requirements were met, and all samples were extracted and analyzed within the prescribed holding time. A field blank and laboratory blank for both the waters and sediment were analyzed and did not contain any pesticides or PCBs. The results in Table 3-12 indicate that the surrogate recoveries were within the advisory limits for all the water samples, with one exception. Similarly, the results in Table 3-13 show that the surrogate recoveries for the sediment samples were within the advisory QC limits for all samples. The surrogate recoveries for the PCB analyses of the first sampling event sediment samples are not available because these samples were acid cleaned because of matrix interferences. This acid-cleaning procedure eliminated the matrix interferences, but it also removed the surrogate. The MS/MSD recoveries and MS/MSD RPDs results in Tables 3-14 and 3-15 were acceptable for all samples, with the exception of the 4,4'-DDT recovery and RPD in the first sampling event water sample. However, this high recovery of 4,4'-DDT in the MSD sample, which led to the high RPD, indicates that the analytical results for this compound may be positively biased, but no 4,4'-DDT was detected in any water samples. Therefore, both the pesticide and PCB analyses are considered acceptable for the water and sediment samples for the first sampling event.

For samples collected from the second sampling event, results illustrated in Table 3-12 through 3-15 suggest that the analyses were again in control. The surrogate recoveries for the pesticides were within the advisory limits for the water and sediment samples. Surrogate recoveries were not available for the analyses of PCBs in water or sediment because the acid-cleaning procedures was required for these samples due to matrix interferences. As was the case with the first sampling event, no pesticides or PCBs were detected in either the field blank or the laboratory blanks. The MS and MSD recoveries and RPDs for the pesticides were also all within QC limits, but the recoveries for the PCB MS and MSD samples exceeded the upper QC limit of 120%. This suggests that the reported PCB concentrations for the water and sediment samples would exhibit a positive bias. However, since no PCBs were

detected in any of the samples from the second sampling event, these high recoveries are not indicative of any analytical problem. It is unclear whether these high recoveries were the result of spiking errors or final adjustment errors. All other QC criteria, including adherence to holding times, were met for these sample analyses.

The results for samples analyzed from the third sampling event also show that the analyses were in control. The samples were analyzed within prescribed holding times, and all preliminary QC criteria were met. A field blank was not collected during the third round of sampling, but laboratory blanks were analyzed and did not contain any pesticides or PCBs. As in in the analysis of samples from the previous sampling event, the surrogate and MS/MSD recoveries for several water and sediment samples exceeded the QC limits for both the pesticides and PCBs. These high recoveries are indicative of a spiking or final adjustment error, but they do not compromise the data quality since the results would be biased high and no pesticides or PCBs were detected in any of the samples. The MS/MSD precision was very good with only two values slightly outside of the QC limits.

4.0 DATA EVALUATION AND CONCLUSIONS

Results discussed in Section 3.0 were evaluated with respect to various criteria and standards set forth by the U.S. Environmental Protection Agency (EPA). The data was compared to criteria and standards to assess the degree of contamination and potential hazards to human health and/or the environment. The following section details our evaluation and summarizes our findings and conclusions. Results of EPA's Hazard Ranking System (HRS) assessment of the Bainbridge NTC facility are also presented in this section.

4.1 Applicable or Relevant and Appropriate Requirements (ARARs)

In July 1987, the EPA Office of Solid Waste and Emergency Response issued interim guidance on compliance with Applicable or Relevant and Appropriate Requirements as they pertain to remedial actions under CERCLA (Superfund)(EPA, 1987d). The NTC Bainbridge facility is not a CERCLA facility, nonetheless, data collected as part of this investigation has been evaluated with respect to available ARARs to assess the extent and environmental impact of any detected contaminants.

ARARs are EPA, state or federal guidelines, action levels, standards, or health-based quality criteria that are either applicable at a given site or relevant and appropriate to a given site. These may include, but are not limited to, Federal Drinking Water Standards (Maximum Contaminant Levels [MCLs]), Clean Water Act Federal Water Quality Criteria Maximum Contaminant Level Goals (MCLGs), and Clean Water Act Freshwater Acute (or Chronic) Toxicity Criteria. Where applicable, or relevant and appropriate, these criteria are presented with reference to analytical results obtained during this investigation. The most stringent ARAR that is available is used for each detected constituent. Additionally, for the purpose of determining "acceptable" target levels in water and sediment, EPA's Draft RCRA Facility Investigation (RFI) Guidance Manual (EPA, 1987c) which contains health-based criteria for a large number of environmental toxicants in air, soil, and water is also used. These health-based criteria, subject to change by EPA, have been

formulated from chronic health levels and are used at RCRA sites as a means to determine when corrective action may be required.

4.2 Base Landfill

As noted earlier, ground-water, surface water, and sediment samples were collected and analyzed from wells and drainage ditch sampling points established at the NTC Bainbridge base landfill. During three separate sampling events conducted in March, May, and July 1988, all samples collected were analyzed for the presence of volatile organic compounds (VOCs) and organochlorine pesticides. Tables 4-1a and 4-1b presents the maximum concentration of individual constituents detected in surface water, ground water, and stream sediment samples collected from the vicinity of the base landfill over the three sampling events. Also listed in Tables 4-1a and 4-1b are the designated ARARs used to evaluate the detected constituents with established quality standards.

When available, EPA's Maximum Contaminant Levels (MCLs) promulgated under the Safe Drinking Water Act and routinely referred to as the Federal Primary Drinking Water Standards, have been listed as the ARAR. These presently exist for only a small number of environmental toxicants. [EPA has also proposed MCLGs, or Maximum Contaminant Level Goals (formerly referred to as RMCLs), which are health-based guidelines for some constituents that are recommended but not Federally enforceable for drinking water quality. When available for a detected compound in water at the base landfill and when no MCL exists, MCLGs are listed as the ARAR.] Health based criteria for Systematic Toxicants as defined by EPA in the Draft RCRA Facility Investigation (RFI) Guidance (EPA, 1987c) are used as ARARs when no MCLs or MCLGs are available. With respect to sediment quality ARARs, criteria for the detected pesticides are presented in Table 4-1 from three separate sources; EPA's Draft RFI Guidance Manual (EPA, 1987c); Elaborization of Sediment Normalization Theory for Nonpolar Organic Chemicals (EPA, 1986a) and National Perspective on Sediment Quality (EPA, 1985). Lastly, Clean Water Act Freshwater Acute Criteria for Aquatic Life are presented as the ARAR when

TABLE 4-1a
Maximum Concentrations of Detected Contaminants from Ground-Water and Surface Water Samples Collected During the NTC Bainbridge Base Landfill Investigation, and the ARARs Used in Evaluation

Detected Compound	Maximum Detected Concentration (μg/l)	Sampling Point/ Sampling Event	ARAR (μg/l)
Ground Water (μg/L)			
VOC's			
Acetone	18	1GW-4/Event 3	NA
Trans-1,2-Dichloroethene	11	1GW-5/Event 3	70[c]
Chloroform	1	1GW-2/Event 3	400[b]; 100[a,d]
Trichloroethene	2	1GW-5/Event 3	5[a]
Benzene	3	1GW-3/Event 3	5[a]
Toluene	2	1GW-3/Event 3	2,000[c]
1,2-Dichlorobenzene	16	1GW-4/Event 3	620[c]
Chlorobenzene	350	1GW-3/Event 2	1,000[b]; 60[c]
1,4-Dichlorobenzene	3.8	1GW-3/Event 3	75[a]
Surface Water (μg/L)			
VOC's			
Acetone	15	1SW-1/Event 3	NA
Toluene	5	1SW-2/Event 3	2,000[c]
Trichlorofluoromethene	4	1SW-2/Event 3	10,000[b]
Pesticides			
Heptachlor epoxide	0.20	1SW-1/Event 3	1[b]
Alpha chlordane	0.35	1SW-1/Event 3	2[b]
Gamma chlordane	0.22	1SW-1/Event 3	2[b]

NA - Non Available
[a] - Federal Register, 1987. National Primary Drinking Water Regulations Synthetic Organic Chemicals, Vol. 52, No. 130, July 8, 1987.
[b] - Health Based Criteria for Systematic Toxicants in Table 8-7 Draft RCRA Facility Investigation Manual, Office of Solid Waste, EPA 530/SW-87-001, July 1987
[c] - Safe Drinking Water Act, Proposed Maximum Contaminant Level Goals (MCLG) [Formerly Recommended MCLs or RMCLs], Federal Register Vol 50, No. 219, Nov. 13, 1985
[d] - MCL is designated for trichloromethanes, of which chloroform is one.

TABLE 4-1b
Maximum Concentrations of Detected Contaminants from Sediment Samples Collected During the NTC Bainbridge Base Landfill Investigation, and the ARARs Used in Evaluation

Detected Compound	Maximum Detected Concentration (μg/l)	Sampling Point/ Sampling Event	ARAR (μg/l)
Sediment (μg.kg)			
Pesticides			
Heptachlor	97	1SED-1/Event 2	20[b]; 600[a]; 604[c]
4,4'-DDE	180	1SED-1/Event 2	28,000[b]; 460,000[c]; 600[a]
4,4'-DDD	77	1SED-1/Event 3	600[a]; 13,000[b]; 111,000[c]
4,4'-DDT	360	1SED-1/Event 2	600[a]; 6[b]; 18,500[c]
Alpha chlordane	190	1SED-1/Event 2	
Gamma chlordane	350	1SED-1/Event 2	60[a]; 20[b]; 334[c]

NA - Non Available
[a] - Health Based Criteria for Systematic Toxicants in Table 8-7 Draft RCRA Facility Investigation Manual, Office of Solid Waste, EPA 530/SW-87-001, July 1987
[b] - Toxicant threshold contamination concentrations based upon organic cargon-water partition coefficients. U.S. Environmental Protection Agency, 1985. National Perspective on Sediment Quality. Prepared by Batelle for U.S. EPA Criteria and Standards Division Under Contract No. 68-01-6986, May 10, 1985.
[c] - Permissible sediment contaminant concentrations based on octanol-water partition coefficients and Clean Water Act Acute Water Water Quality Criteria. U.S. Environmental Protection Agency, 1986a. Elaborization of Sediment Normalization Theory for Nonpolar Hydrophobia Organic Chemicals. Prepared by Envirosphere Co. for U.S. EPA Criteria and Standards Division, January 1986.

none of the previously stated ARARs are available for a particular constituent.

At the base landfill no pesticides were detected in ground-water samples, however, some volatile organic compounds were detected. As shown on Table 4-1a, all of the maximum concentrations for the constituents detected fall below the ARAR with the exception of chlorobenzene (also, referred to as monochlorobenzene). No ARAR is available for acetone. The maximum concentration of acetone detected was 18 μg/L. This low level is likely attributable to laboratory contamination. Acetone is a common laboratory chemical and is also a common laboratory contaminant. Typically, values of acetone at these low concentrations are used with reservation since they are known to be ubiquitous laboratory contaminants. In short, the levels of acetone detected do not suggest that water quality has been adversely impacted from the presence of this compound in some samples.

Chlorobenzene was detected in monitoring well 1GW-3 during each of the three sampling events, with a maximum concentration of 350 μg/L from the second event. This maximum concentration is below the 1,000 μg/L ARAR established for water by EPA in the EPA Draft RFI Guidance Manual for "acceptable" levels at RCRA sites (i.e., levels below which corrective action will likely not be required). However, under the Safe Drinking Water Act a maximum contaminant level goal [MCLG] (non-enforceable for drinking water) has been proposed for chlorobenzene by EPA at a concentration of 60 μg/L for drinking water. As such, the maximum detected concentrations of chlorobenzene in well 1GW-3, as well as well 1GW-5, exceed the MCLG. It should be noted that these two wells do not serve as potable supply wells and the closest well downgradient from the landfill that is used for domestic supply exists in the town of Port Deposit, approximately 1/2 mile to the south. From this investigation it cannot be determined if chlorobenzene has migrated in ground water to a point outside of the base boundaries at a concentration level in excess of the MCLG. Furthermore, MCLGs are recommended levels

for drinking water and in most instances to date, EPA has established a final MCL that is not as stringent as the MCLG. No MCL for chlorobenzene has yet been proposed or promulgated by EPA. Due to the complex nature of ground-water flow via bedrock fractures in the Port Deposit Formation it is difficult to assess the liklihood that chlorobenzene may have already or will potentially migrate in ground-water to receptor points outside of facility boundaries. It's presence primarily in well 1GW-3 and to a lesser extent in well 1GW-5 may suggest a more localized source.

Wells 1GW-3 and 1GW-5 are located in proximity to the City of Port Deposit's potable water supply tank reservoir. This aboveground storage supply is not in any way impacted by contaminated ground water that may exist beneath it. This storage tank is entirely supplied by Susquehanna River surface water that is pumped from an intake port located in the river upstream of the town of Port Deposit.

In the vicinity of the base landfill, two surface water stations were established to monitor water quality around the landfill (see Figure 2-1). These samples were analyzed for the presence of volatile organic compounds and organochlorine pesticides. As shown in Table 4-1, low concentrations of three volatile organic compounds and three pesticides were detected in samples. The values shown in Table 4-1 represent the maximum levels of those constituents detected across the three sampling events. The maximum concentrations of all the detected compounds were all detected during the third sampling event. This is consistent with the very low flow conditions at the base landfill surface water sampling points during this time of year (July). During higher flow conditions, these compounds were not detected at all.

Toluene and trichlorofluoromethane were quantified in surface water samples all below the available ARARs. Acetone, for which there exists no available ARAR, quantified at a maximum concentration of 15 μg/L and this detection is likely the result of laboratory contamination. The three pesticides, only detected in sampling event three, were all from the upgradient sampling location and all were quantified below

0.5 μg/L. These levels are below the listed ARAR, as described in the EPA Draft RFI guidance manual health-based criteria for water quality (EPA, 1987c).

Stream sediments were collected at the same locations as surface water samples during each of the three sampling events at the base landfill. No volatile organic compounds were detected in any of the sediments samples during any of the monitoring events. Six organochlorine pesticides were detected from sampling location 1SED-1 as shown on Table 4-1. The highest concentrations were generally encountered during the second sampling event. The pesticides 4,4'-DDT and gamma chlordane were the two most prominent compounds detected in sediments from 1SED-1. To evaluate the level of contamination of these pesticides, ARARs were obtained from the EPA Draft RFI Guidance Manual for environmental toxicants in soils (EPA, 1987c), the National Perspective on Sediment Quality (EPA, 1985), and Elaborization of Sediment Normalization Theory for Nonpolar Hydrophobic Organic Chemicals, (EPA, 1986a). No EPA enforcement criteria has been promulgated specifically for levels of contaminants in stream sediments. Total chlordane, heptachlor, and 4,4-DDT were detected in sediments in concentrations in excess of the most stringent ARAR listed in Table 4-1b.

Total chlordane in the sediment samples from 1SED-1 obtained from the second sampling event (540 μg/L) exceeded each of the three ARARs present for soil which are established at 60 μg/kg, 20 μg/kg, and 334 μg/kg (Table 4-1). The maximum heptachlor concentration detected in sediments (0.97 μg/kg) exceeded the Toxicant threshold contamination concentrations set forth in the U.S. EPA National Perspective on Sediment Quality (20 μg/kg) [U.S. EPA, 1985]. Likewise, the maximum detected concentration of 4,4-DDT (360 μg/kg) exceeded the threshold contaminant concentration established for that compound (6 μg/kg) in the same document. These threshold concentrations were derived from organic carbon-water partition coefficients.

The presence of these pesticides in stream sediments at location 1SED-1 indicates that transport via surface runoff or ground water has taken place from the upgradient area of the landfill. As the aqueous solubilities of these compounds are quite low, transport by ground-water is considered minimal, and the most likely mode of transport is believed to be pesticide-bound fine-grained sediments that are transported to the drainage via surface runoff.

In evaluating the degree of environmental impact from the presence of these pesticides in the eastern drainage of the landfill, the DDT metabolites (4,4'-DDE, 4,4'-DDT, and 4,4'-DDD), the two chlordane isomers (alpha and gamma), and heptachlor, it is important to consider a number of fate and transport factors. Sediment pesticide concentrations should be reviewed alongside the aqueous concentrations detected from the identical sampling points. In this comparison, it can be seen that during typical base flow conditions, like those encountered during the first two sampling events, no detectable levels of these compounds are found in the surface water as a result of the low aqueous solubilities of the compounds and the level of dilution. Again, no pesticides were detected in the downstream surface water sample during any of the sampling events. The other means of downstream migration of pesticides is via sediment transport within the drainage. Chlordane nor heptachlor was not detected in any of the samples collected from the downstream sediment location at the southeastern end of the NTC Bainbridge property (1SED-2), although low concentrations of DDT metabolites were detected in samples from 1SED-2, particularly during the first sampling event. This result confirms that pesticides bound to particulates will, and have, moved downgradient in the eastern drainage at the base landfill. Nonetheless, the sediment pesticide levels downgradient are all below the ARAR for soils/sediments. It should be noted that EPA Region III has used ARARs for DDT as high as 300 mg/kg for soil cleanup at some Superfund sites (Mr. Bruce Molholt, U.S. EPA Region III, personal communication, September 20, 1988). The levels detected here are well below 1 mg/kg.

It is probable that pesticides will continue to be transported along this eastern landfill drainage route via both sediment and to a lesser degree, surface water. However, it appears to be unlikely that water quality will be impacted to the point where pesticide concentrations in water will exceed any EPA water quality criteria due to both the low sediment pesticide concentrations (< 1 ppm) and the low aqueous solubilities of the pesticides detected. A significant unknown regarding continued landfill releases of pesticides does exist. We cannot ascertain whether the majority of the pesticide source continues to remain at the landfill, has been flushed from the soils since the dumping in the late 1970's, or resides in the subsurface at an intermediate point between the landfill and local drainage routes. This difficulty is principally due to the unknown state of the pesticide source and the variability of the bedrock fracture system that controls ground-water flow. Since no pesticides were detected in any of the downgradient ground water monitoring wells, the most likely scenario is that sediment-bound concentrations of pesticides in the eastern drainage and landfill soils, represent the majority of the remaining pesticide source. Therefore, due to the low solubilities and relatively low sediment concentrations, measured surface water concentrations of pesticides are either very low or non-detectable.

4.3 Oil Separator Pit

Ground-water, surface water, and sediment samples were collected during three separate sampling events, in March, May, and July 1988, and analyzed for oil and grease content, lead, volatile organic compound (VOCs) and polychlorinated biphenyls (PCBs). Tables 4-2a and 4-2b present the maximum concentration of individual constituents detected in surface water, ground-water, and stream sediment samples collected from the vicinity of the oil separator pit over the three sampling events. Also listed in Tables 4-2a and 4-2b are the designated ARARs used to compare the detected constituents with established quality standards. When available, EPA's Maximum Contaminated Levels (MCLs) promulgated

TABLE 4-2a
Maximum Concentrations of Detected Contaminants from Ground-Water and Surface Water Samples Collected During the NTC Bainbridge Oil Separator Pit Investigation, and the ARARs Used in Evaluation

Detected Compound	Maximum Detected Concentration	Sampling Point/ Sampling Event	ARAR (μg/L)
Ground-Water (μg/L)			
VOCs			
Acetone	16	2GW-3/Event 3	NA
Carbon Disulfide	1	2GW-4/Event 3	4,000[b]
Trans-1,2-Dichloroethene	10	2GW-4/Event 3	70[d]
Trichloroethene	7	2GW-2/Event 2 2GW-4/Event 2	5[a]
1,1,2,2-Tetrachloroethane	1	2GW-4/Event 3	2,400[c]
Trichlorofluoromethane	5	2GW-4/Event 2	4,000[b]
Lead	5.8	2GW-4/Event 3	50[e]
Oil & Grease (mg/L)	1.69	2GW-3/Event 1	5.0 (mg/L)[f]
Surface Water (μg/L)			
VOCs			
Acetone	14	2SW-3/Event 3	NA
Lead	39	2SW-2/Event 2	50[a]
Oil & Grease (mg/L)	3.19	2SW-2/Event 3	5.0 (mg/L)[f] 15 (mg/L)[g]

NA - Non Available
[a] - Federal Register, 1987. National Primary Drinking Water Regulations-Synthetic Organic Chemicals, Vol. 52, No. 130, July 8, 1987.
[b] - Health Based Criteria for Systematic Toxicants in Table 8-7 Draft RCRA Facility Investigation Manual, Office of Solid Waste, EPA 530/SW-87-001, July 1987.
[c] - Clean Water Act, Fresh Water Acute Criteria for Aquatic Life, Table 8-8 in Investigation Manual, Office of Solid Waste, EPA 530/SW-87-001, July 1987.
[d] - Safe Drinking Water Act, Proposed Maximum Contaminant Level Goals (MCLG) [Formerly Recommended MCLs or RMCLs], Federal Register Vol 50, No. 219, Nov. 13, 1985.
[e] - Federal Register, 1985. Final MCLs for Inorganic Chemicals and MCLGs for Organic Chemicals, Vol. 50, No. 219, November 13, 1985.
[f] - Water Quality Standards, Florida Department of Environmental Regulation, State Code 17-3.061(3)K1, September 12, 1985.
[g] - Federal Register, NPDES Effluent Limitations for Contaminant Runoff, 40 CFR 419.12(e)1, July 1, 1987.

TABLE 4-2b
Maximum Concentrations of Detected Contaminants from Sediment Samples Collected During the NTC Bainbridge Oil Separator Pit Investigation, and the ARARs Used in Evaluation

Detected Compound	Maximum Detected Concentration	Sampling Point/ Sampling Event	ARAR (μg/L)
Sediment (μg/kg)			
VOCs			
Toluene	4	2SED-2/Event 2	400[a]
1-Ethyl-3-Methyl Benzene	1	2SED-1/Event 3	NA
Lead	147	2SED-2/Event 2	NA
Oil & Grease (mg/L)	123,000	2SED-2/Event 1	NA

NA - Non Available
[a] - Health Based Criteria for Systematic Toxicants, Table 8-7 Draft RCRA Facility Investigation Manual, Office of Solid Waste, EPA 530/SW-87-001, July 1987.

under the Safe Drinking Water Act and routinely referred to as the Federal Primary Drinking Water Standards, have been listed as the ARAR. These presently exist for only a small number of environmental toxicants. EPA has also proposed MCLGs or Maximum Contaminant Level Goals (formerly referred to as RMCLs) which are health-based guidelines for some constituents that are recommended by EPA but not Federally enforceable for drinking water supply. When available for a detected compound in water at the oil separator pit, and when no MCL exists, MCLGs are listed as the ARAR. Health-based criteria for Systematic Toxicants as defined by EPA in the Draft RCRA Facility Investigation (RFI) Guidance (EPA, 1987c) are used as ARARs when no MCLs or MCLGs are available. Clean Water Act Freshwater Acute Criteria for Aquatic Life are presented as the ARAR when none of the previously stated ARARs are available for a particular constituent.

At the oil separator pit, no polychlorinated biphenyls (PCBs) were detected in any sampling event in either ground-water, surface water, or sediment samples.

In ground-water samples collected from the five monitoring wells installed around the oil separator pit, several volatile organic compounds (VOCs) were detected at low concentrations, all below 20 μg/L. The only VOC that exceeded an ARAR is trichloroethene (TCE). TCE was quantified in monitoring wells 2GW-2 and 2GW-4 at a concentration of 7 μg/L during the second sampling event. This just exceeds the MCL established for drinking water of 5 μg/L. Nonetheless, since water from these 2 wells is not used for potable water supply and the fact that TCE levels slightly exceeded the ARAR in only one of 3 sampling events, suggests that ground-water is only minimally impacted by VOCs emanating from the oil separator pit via ground-water.

Oil and grease content, as well as lead concentrations were determined from ground-water samples. Oil and grease content in ground-water did not show any discernable variations across all wells and sampling events, including the background monitoring well 2GW-1. This

fact, along with low VOC concentrations, indicates that ground-water in the vicinity of the oil separator pit does not presently contain any significant amounts of petroleum products that may have been released from the unlined separator pit. EPA has not promulgated any ARARs for oil and grease content in water samples, nor has the State of Maryland. The ARAR used to evaluate oil and grease content in ground water is the water quality standard promulgated by the Florida Department of Environmental Regulation (DER) for surface water quality. The Florida DER enforceable oil and grease content ceiling is 5.0 mg/L. None of the ground-water samples taken from the wells installed at the oil separator pit yielded oil and grease content greater than 1.7 mg/L.

Lead was detected in two of the ground-water monitoring wells, 2GW-2 and 2GW-4 during the third sampling event. As illustrated on Table 4-2, the concentrations detected (5.5 μg/L and 5.8 μg/L, respectively) are below the MCL of 50 μg/L established for drinking water quality.

Surface water samples were collected from three locations around the oil separator pit during each of the 3 sampling events. No VOCs were detected in any samples, with the single exception of 14 μg/L acetone from station 2SW-3 during the third event. As noted earlier, acetone is a common laboratory contaminant and its detection at this low level in the sample is likely related to laboratory introduction. No PCBs were detected in any surface water sample. Lead was quantified from sampling station 2SW-2 at 39 μg/L during the second sampling event. This is below the MCL of 50 μg/L used as the ARAR in this evaluation.

Sampling location 2SW-2 receives drainage directly from the oil separator pit and would be expected to contain the highest concentrations of the three oil separator pit surface water stations of any petroleum constituents released. This surface water station did yield the highest oil and grease content, 3.19 mg/L during the third (low flow conditions) sampling event. It is likely that various petroleum constituents not present in the VOC fraction (i.e., PAHs - polynuclear aromatic hydrocarbons), are present in the water sample in low concentrations

which accounts for this higher oil and grease content. Sampling station 2SW-2 is located approximately 50 feet downgradient from the oil separator pit drainage outflow pipe. The ARAR used to evaluate oil and grease content in surface water is the water quality standard promulgated by the Florida DER. The Florida DER enforceable oil and grease content ceiling for surface waters is 5.0 mg/L. None of the surface water samples collected in the vicinity of the oil separator pit exceeded this ARAR. The State of Maryland has not established water quality criteria for oil and grease content in surface waters. EPA, under NPDES permit requirements, has established an effluent limitation of contaminated runoff of 15 mg/L for oil and grease (40 CFR 419.12(e)1). The oil and grease content determined in water samples from location 2SW-2, which receives direct discharge from the oil separator pit, were far below the NPDES discharge limitation for contaminated runoff.

Stream sediments were obtained from two locations along Happy Valley Creek (1SED-1 and 1SED-3) and one from the drainage ditch leading directly from the oil separator pit to Happy Valley Creek (1SED-2). These sediment sampling locations coincide with the three surface water sampling locations at the oil separator pit. Two VOCs were detected in sediment samples, toluene and 1-ethyl-3-methyl benzene at concentrations below 5 μg/L (Table 4-2b). Toluene is below the listed ARAR and 1-ethyl-3-methyl benzene is a tentatively identified VOC (i.e., it's not a routinely monitored constituent) with an estimated concentration of 1 μg/L from the upgradient sediment location, 1SED-1. No State or Federal ARAR was identified for this compound, nonetheless its presence just above detection limits suggests minimal contamination.

Lead and oil and grease content were notably high in the sediment sample from sampling location 2SED-2. Lead was quantified at 147 mg/kg in the second sampling event, and oil and grease content was measured at 123 mg/kg during the first sampling event. Again, sampling location 2SED-2 lies along the drainage leading from the oil separator pit to Happy Valley Creek (see Figure 2-8). As such, it would be expected to

yield the highest levels of these indicators of petroleum releases. Concentrations of lead and oil and grease were substantially lower in 2SED-3, located in Happy Valley Creek a few hundred feet downgradient of the confluence of the drainage ditch and the Creek. The sediments from the drainage ditch did have a dark oily appearance during sampling whereas, sediment samples from the other two sediment sampling locations did not have this color. It is likely that petroleum products were once released to this drainage ditch from the oil separator pit during facility operations. Nonetheless, the fact that present day surface water quality has been only slightly impacted from previous releases suggests that remaining oil fractions (i.e., semivolatile constituents) may be present in sediments along the drainage ditch and account for the relatively high oil and grease content. These heavier organic compounds are not particularly volatile, soluble, or mobile in the environment and their presence in sediments should not pose any imminent environmental risks. Ultimately, most of those compounds will undergo in situ biodegradation.

In summary, results of the sampling and analysis investigation at the oil separator pit indicates only minor releases of potentially hazardous constituents at levels in most cases below acceptable ARARs. The beginning of the drainage ditch leading from the oil separator pit to Happy Valley Creek appears to be the most impacted area, although even here only minimal contamination was quantified. Ground water and surface water do not appear to be adversely affected from the presence of the oil separator pit.

4.4 Hazard Ranking Score

Appendix C contains a Hazard Ranking Score (HRS) for NTC Bainbridge. The HRS evaluates the environmental hazard potential for the landfill area as a result of observed local ground-water and surface water contamination resulting from pesticide burial at the landfill. The oil separator pit area was not evaluated under the HRS because no significant contamination was detected to be migrating from the area, and

the only known waste product disposed at the pit was fuel oil, which is not scoreable under current HRS guidelines.

The migration pathways of concern at the base landfill are ground water and surface water, which both produced a score in the HRS model due to observed releases of contaminants and the proximity of drinking water wells and a surface water intake (within a 3-mile radius) to the landfill. Air contamination, fire and explosion potential, and risk of direct human contact with hazardous materials are not of concern at this particular site. The overall HRS score for the NTC Bainbridge is 35.03, a significant score relative to the cutoff value of 28.5 for placement on the National Priorities List. However, several factors may affect the accuracy of this score.

The primary migration pathway of concern, ground water, contributed to the high score due to observed contamination in monitoring wells 1GW-3 and 1GW-5. However, there is no present data which indicates that contaminants have migrated further downgradient to the populated area of Port Deposit. Furthermore, all residents of Port Deposit and the Job Corps Center are presently served by a public water supply, and no wells within the city limits (downgradient from landfill) are currently used for drinking water purposes. The proximity of a residential drinking water well (approximately 600 feet) to the landfill also contributed to the high ground-water score based on the considerations of the HRS model. However, this well is located side-gradient to the landfill, across State Route 276, and does not appear to be along the ground-water flow path exiting the landfill. In addition, the vast majority of the total population served by ground-water within a 3-mile radius from the landfill (4,283 persons estimated) reside and use domestic supply wells located upgradient from the landfill.

The second pathway of concern, surface water, also contributed to the high overall score due, in part, to observed contamination in the sediments of the drainage stream located along the eastern portion of the landfill study area. As with the ground-water route, however, no data

presently exists which suggests that contaminants have migrated to populated areas. A second contributing factor to the surface water score is the location of a surface water (potable water supply) intake within a 3-mile radius from the landfill. The intake is located in the Susquehanna River at a point approximately 0.9 miles downgradient from the landfill, and provides drinking water for the residents of Port Deposit and the Job Corps Center. However, the intake is located upstream from the town of Port Deposit and the NTC Bainbridge facility. No evidence suggests that contaminants emanating from the base landfill have reached the Susquehanna River.

Appendix C includes all calculations and assumptions used for developing the HRS, including all references cited.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This section outlines the primary conclusions drawn from the hydrogeologic and chemical investigations at the two former disposal sites at the NTC Bainbridge facility. The two sites are referred to as the base landfill and the firefighting training area/oil separator pit. For this investigation comprehensive monitoring systems were established at each site to assess the degree of contamination in ground water, surface water, and stream sediments. At the base landfill, five ground-water monitoring wells were installed and two surface water/sediment sampling stations were established. At the oil separator pit five ground-water monitoring wells were installed and three surface water/sediment sampling stations were established. Sampling and analyses of each well/station for each of the two NTC Bainbridge sites took place over three independent sampling events in March, May, and July 1988, respectively. The following outlines Versar's principal findings and recommendations from the hydrogeologic investigation and sampling/analysis activities at the base landfill and oil separator pit at NTC Bainbridge.

5.1 Base Landfill

Conclusions

- The five ground-water monitoring wells installed at the base landfill adequately monitor the upper fractured zone of the bedrock aquifer in the vicinity of the landfill.

- Ground-water flow is towards the south-southeast at the base landfill.

- Monitoring well 1GW-3 along the western boundary of the landfill yielded the highest level of contamination of all the monitoring wells. This is principally due to the presence of chlorobenzene. Chlorobenzene concentrations exceeded the most stringent ARAR, the maximum contaminant level goal (MCLG) established under the Safe Drinking Water Act.

- Low levels of a number of volatile organic compounds (VOCs) were detected in ground-water samples from downgradient monitoring Wells 1GW-3, 1GW-5, and 1GW-4. With the exception of chlorobenzene, all were below established ARARs.

- No organochlorine pesticides were detected in any ground-water samples.

- Low concentrations of a few pesticides were detected in surface water samples. All the pesticides detected were quantified below 1 $\mu g/L$ from a single sample during the third sampling event only. No pesticides were detected in any downgradient samples. This coincides with low base flow conditions in the intermittent drainage during the third sampling event in July. During the prior sampling events when base flow was greater, no pesticides were detected at either surface water station.

- No volatile organic compounds were detected in any stream sediment sample.

- Three pesticides were quantified in sediment samples from upgradient station 1SED-1: heptachlor, DDT, and chlordane. More specifically, the three DDT metabolites [4,4'-DDE; 4,4'-DDT; 4,4'-DDD] were all detected as were the two chlordane isomers, alpha and gamma. Only total chlordane exceeded the ARAR for soils established by EPA for their Draft RCRA RFI Guidance of soil concentrations above which corrective action may be required.

- Although concentrations of total DDT and total chlordane were elevated in sediments from location 1SED-1, aqueous concentrations in surface water were either non-detectable or below 0.5 $\mu g/L$. This suggests that the partitioning of pesticides from soil to water is minimal. Sediments downgradient did not contain significant concentrations of pesticides, that is, only the DDT metabolites were detected at location 1SED-2. Transport of pesticides appears to be controlled by pesticide-bound particulates and exposure risks are limited.

Recommendations

- Periodic ground-water and surface water quality monitoring for pesticides and volatile organic compounds to determine if levels of contamination are changing over time.

- Installation and sampling of additional ground-water monitoring wells (approximately 3) to determine if off-site migration of detected contaminants via ground-water has occurred.

5.2 Oil Separator Pit

Conclusions

- The five ground-water monitoring wells installed at the oil separator pit adequately monitor the upper fractured zone of the bedrock aquifer in the vicinity of the oil separator pit.

- Monitoring well 2GW-3, installed adjacent to the red barn, (Building 53), appears to lie in a former drainage channel that was filled with alluvial sediments. Bedrock was not encountered during the drilling of this well.

- No significant contamination was detected in any monitoring well at the oil separator pit. That is, no constituent exceeded drinking water standards or the available ARAR with the exception of trichloroethene (TCE) which was quantified at 7 ppb, thereby exceeding the MCL by 2 ppb. This level of TCE occurred in only a single sampling event.

- No polychlorinated biphenyl's (PCBs) were detected in any ground-water, surface water, or sediment sample collected at the oil separator pit.

- Lead concentrations did not exceed Federal drinking water standards (MCLs) in any ground-water or surface water sample. The MCL was the ARAR used in data evaluation.

- Volatile organic compound (VOC) levels in surface water samples and stream sediment samples were very low, in all cases below the ARAR.

- Sediment sample 2SED-2 yielded substantially high oil and grease concentrations. This sample location is situated along a drainage ditch leading directly from the oil separator pit to Happy Valley Creek. This drainage ditch continues to receive outflow from the pit. Since levels of VOCs were low in the 2SED-2 sample, it is hypothesized that the oil and grease content reflects the presence of non-volatile organic compounds, specifically PAHs (polynuclear aromatic hydrocarbons) not analyzed during this investigation.

Recommendations

- Due to the high oil and grease content in the drainage ditch connecting the oil separator pit with Happy Valley Creek (2SED-2), any remedial activities associated with the oil pit should include this drainage as well.

- Ground water and surface water in the vicinity of the oil separator pit should be tested for the presence of PAHs (polynuclear aromatic hydrocarbons) to confirm that these relatively insoluble compounds are not adversely effecting water quality.

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(continued)

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APPENDIX A

WELL LOGS, WELL NARRATIVES, AND STATE OF MARYLAND WELL COMPLETION REPORTS

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 1GW-1
Date: February 1 - 3, 1988
Observer: Jeff Flanzenbaum, hydrogeologist

Monitoring well 1GW1 was installed topographically and hydraulically upgradient of the Bainbridge NTC base landfill (Figure 2-1). The original agreed upon well position, approximately 200 feet south of the final location of 1GW-1, was moved prior to drilling because it was felt that this original location was too close to the periphery of the landfill. As such, this well location was moved further upgradient to assure background hydrological and chemical conditions for the ground-water around the landfill. This new location was agreed to by the EIC.

Monitoring well 1GW-1 was drilled to a depth of 24 feet before auger refusal occurred. Split-spoon samples were collected at 5-foot intervals in these unconsolidated sediments. Auger flights removed and air hammer drilling through the open borehole proceeded to 45 feet below land surface. Ground-water was encountered in the fine-grained silty and micaceous saprolite at 37 feet. To facilitate drilling at this hole, 8 oz of the drilling surfactant, Quik-Foam (N.L. Bariod), was added to remove cuttings. [After careful review of product specifications, the use of Quik-Foam was proposed as a means to assist the drilling operations in removing cuttings. Quik-Foam has been environmentally tested by the manufacturer and shown to contain only one compound (in low concentrations) that could potentially impact Priority Pollutant analyses, polyacrylamide. This compound was not anticipated to be of concern at this location.] At a depth of 48 feet, the borehole was purged, by air, for approximately 50 minutes to clear out sediments and remove residual Quik-Foam. The hole would still undergo development after the well was installed.

A 4-inch ID Schedule 40 PVC monitoring well was installed at this location. A 10-foot screen zone (.010-inch slotted) was set from 36.5-46.5 below ground surface and was attached (flush-threaded) to 38 feet of 4-inch ID Schedule 40 PVC riser pipe. Sand (No. 2) was placed in the annulus around the screen to approximately two feet above the screen. A 2.5 foot 1/4-inch bentonite pellet seal was emplaced above the sand pack. Using a tremie-tube, a 5% bentonite/cement slurry was placed in the remaining annulus to three feet below ground surface.

After the grout and seal was allowed to set, a 5-foot long 6-inch by 6-inch locking protector casing was cemented in over the well and was surrounded by a 5-foot by 5-foot square concrete pad with a steel bumper post at each corner. The well casing, protector casing, and concrete pad were surveyed relative to sea level on March 4, 1988 using a U.S.G.S. bench mark as a reference point. To facilitate identification, the well protector casing was painted international orange and a State of Maryland well permit tag [permit number CE-81-3607] was affixed to the protector casing.

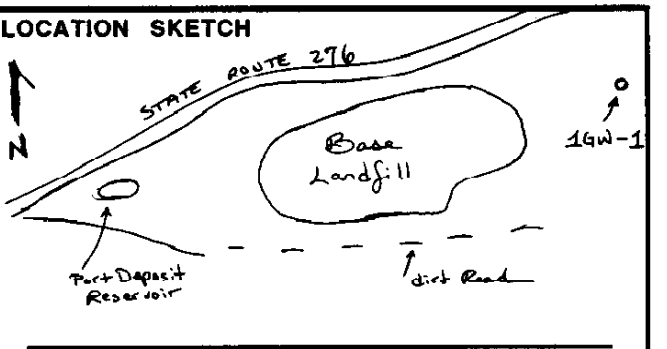
On March 1, 1988, the well was developed by pumping and surging with a submersible pump. Approximately 400 gallons of water was purged from the well and discharged a minimum of 25 feet downgradient of the well. In situ measurements of pH, specific conductance, and temperature were monitored and recorded periodically. Development continued until there in situ parameters had stabilized, and water clarity remained constant.

Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Bainbridge NTC
JOB NUMBER: 5065.3.6
LOCATION: Base Landfill
WELL NUMBER: 1GW-1
GROUND ELEVATION: (Concrete Pad) 295.20
DATE INSTALLED: 2-3-88
WELL CASING ELEVATION: 296.37
FIELD REPRESENTATIVE: Jeff Flanzenbaum
PROTECTOR CASING ELEVATION: 296.77
DRILLING CONTRACTOR: Hardin / Huber
DRILLER: Nate Lazaro LICENSE NO. 336
DRILLING METHOD: Hollow Stem Auger / Air Hammer
RIG TYPE: Mobile B61
CONDITION OF GROUND SURFACE: sloping / grassy
FORMATION SCREENED: Saprolite / bedrock

LOCATION SKETCH



City of Port Deposit, Cecil County, Md.

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
Auger	8" / 12"	24	—
Hammer	7 5/8"	48	Air

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH (feet)	TOP *	BOTTOM *
Schedule 40 PVC riser	4"	38.35	+1.90	36.45
Schedule 40 PVC screen	4"	10.0	36.45	46.45
(0.010 machine slotted)				
Schedule 40 PVC Bottom cap	4"	0.17	46.45	46.62
Protector Casing	6" x 6"	5.07	2.07	-3

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP *	BOTTOM *
#2 Sand Pack	-34'	-47.17'
Bentonite Pellet (1/4") seal	-31.5'	-34'
5% Bentonite / cement grout	-3	-31.5'
Portland cement grout (Type 1)	0'	-3
Concrete Apron (5' x 5')	+0.5'	0'

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	2/1	1545	1700
	2/2	0930	1700
	2/3	0850	1050
CASING	2/3	1150	1210
FILTER PACK	2/3	1210	1225
SEAL	2/3	1225	1245
GROUT	2/3	1330	1500
DEVELOPMENT	3/1	1350	1550
SURVEY	3/4/88	—	—
OTHER 1st Sampling	3/16/88	0725	0750

GROUND WATER LEVELS

DURING DRILLING:

2/3/88 : 37 Ft. below ground surface

3/16/88 : 35.87 feet below top of casing

WELL DEVELOPMENT

Well developed w/ submersible pump. Approx. 400 gallons pumped from 1GW-1

Final in-situ parameter measurements:
pH = 5.68
Temp = 13.3 °C
Sp. Cond. = not determined meter malfunction

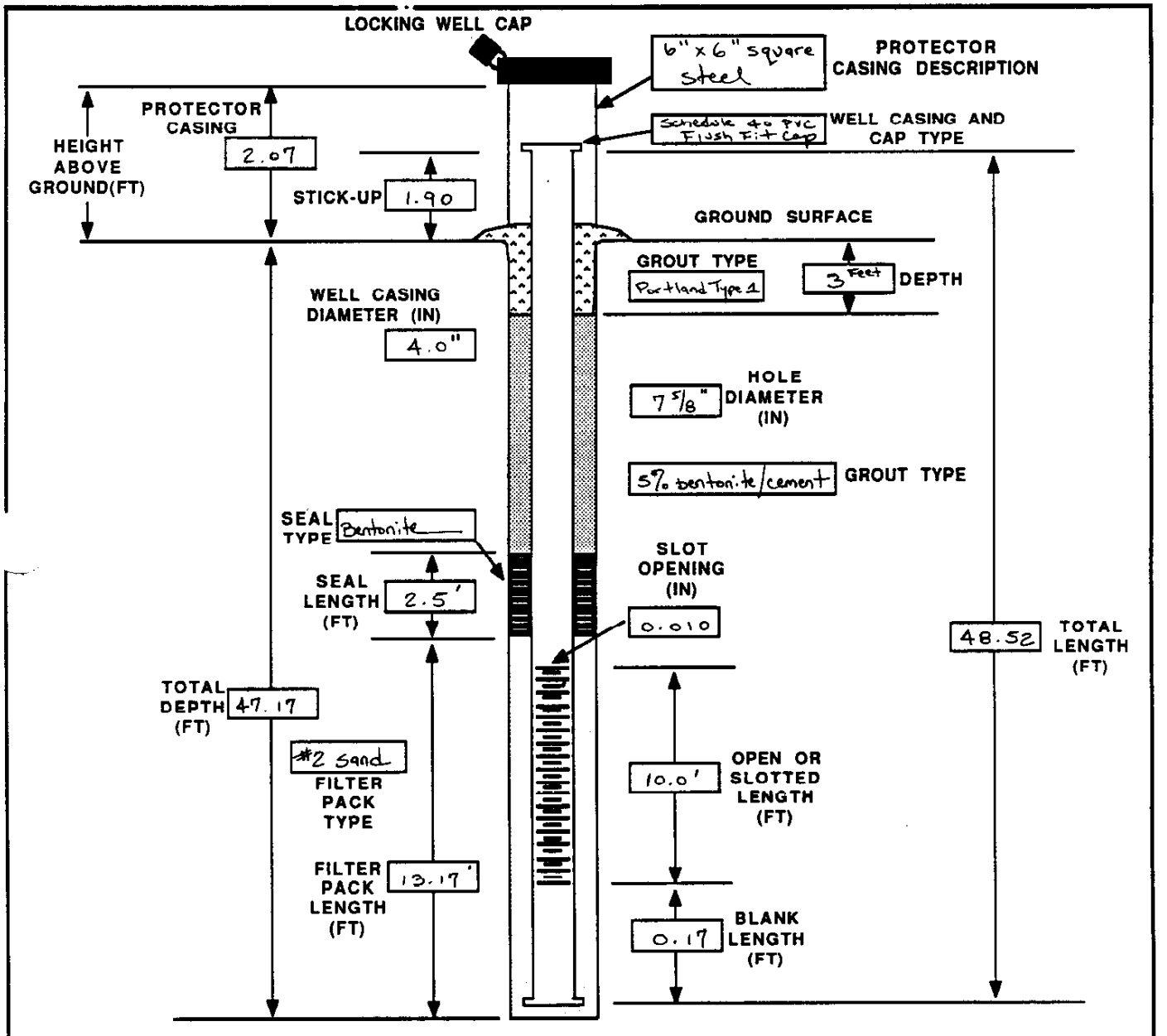
* DEPTH FROM GROUND SURFACE (Feet)

COMMENTS: 4 Guard posts installed around protector casing. Protector casing and guard posts painted international orange

Versar INC.

WELL CONSTRUCTION DIAGRAM

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: Base Landfill
WELL NUMBER: 1GW-1 ELEVATION: 296.61
DATE INSTALLED: 2-3-88 ☐ GROUND ☑ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☑ ABOVE MEAN SEA LEVEL



COMMENTS: Background monitoring well at Bainbridge NTC base landfill. Well protector casing painted international orange, and surrounded by 4 protector pipes. Maryland State Permit #: CE-81-3607
[Concrete pad thickness = 0.5 Feet]

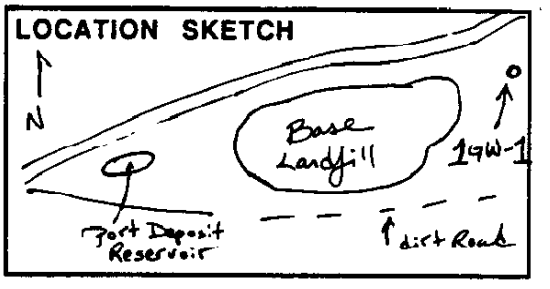
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: Bainbridge NTC
LOCATION: Base Landfill
BOREHOLE NUMBER: 14W-1
DATE DRILLED: 2/1/88 — 2/3/88
FIELD REPRESENTATIVE: Jeff Flanzenbaum
DRILLING CONTRACTOR: Hardin / Huber
DRILLER: Nate Lazaro
DRILLING METHOD: Hollow Stem Auger / Air Hammer
HOLE DIAMETER: 12" to 24' // 7 5/8" to 48' bls
GROUND ELEVATION: (Concrete Pad) 266.37
CONDITION OF GROUND SURFACE: Grassy / sloped

LOCATION SKETCH



COMMENTS: City of Port Deposit, Cecil County, Md.

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)	
		Grab				moderate yellow brown fine sand, with some very fine sand, well sorted, mostly quartz, some mica, subangular, some organic staining. (likely fill from building removal in 1960's) no odor, some clay, dry	HNu = 0 ppm
5	1	SS	2'/2'	5 9 12 12		grayish orange fine to very fine sand, saprolite (weathered bedrock of Port Deposit Gneiss) dry, poorly sorted mostly quartz, some mica, some silt and medium sand grains, subangular, no odor, gneissic laminations	HNu = 0 ppm
10	2	SS	8"/8"	50 50/2"		Same as above, increasing % of very fine sand, pale yellowish orange color. very dry saprolite w/ gneissic laminations	HNu = 0 ppm
15	3	SS	8"/8"	50 50/2"		same as above, silty very fine sand, saprolite, dry w/ gneissic laminations	HNu = 0 ppm
20	4	SS	7"/7"	50 50/1"		same as above, highly indurated very fine sand (saprolite) still dry	HNu = 0 ppm
		Grab				Very pale orange very fine sandy silt w/ some mica and mafics, mostly quartz, well-sorted, dry stiff weathered bedrock — saprolite, (Auger refusal at 24 feet)	
25		Grab				same as above, dry saprolite	HNu = 0 ppm

Jeffrey Flanzenbaum
GEOLOGIST'S SIGNATURE

Versar INC. GEOLOGIC LOG

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: Base Landfill
BOREHOLE/WELL NUMBER: 1GW-1
DATE LOGGED: 2/1/88 – 2/3/88

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
25		Grab				same as above, dry saprolite, very fine sandy silt, mostly quartz w/ some mica and mafics
30		Grab				same as above, dry saprolite HNu=0 ppm
35		Grab				same as above, partially moist, w/ some rock fragments (5%) weathered, gneissic laminations
40		Grab			▽	greenish grey coarse sand and pebbles in very fine sand matrix (bimodal), subangular, moderately well sorted within each modal class, pebbles have distinct gneissic laminations, mostly quartz w/ ≈10% mica and feldspars, moist, contact of fractured bedrock and saprolite at 40-41 feet bls. incomplete weathering HNu=0ppm Water seam at approximately 41 feet bls.
45		Grab				Increasing rock fragments (1/8" – 1/2"), greenish-grey gneissic, subangular, qtz, mica, Port Deposit Gneiss, poorly sorted, estimated top of unweathered bedrock at 46' bls.
50						— — — — — — T.D. @ 48' bls — — — — — — — 4" monitoring well 1GW-1 set. screen zone 36.5 – 46.5 bls.

Jeffrey Flanagan
GEOLOGIST'S SIGNATURE

(OEP USE ONLY)
1 2 3 6
THIS NUMBER IS TO BE PUNCHED
(COLS. 3-6 ON ALL CARDS)

WELL COMPLETION REPORT

FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER Test Well-Bainbridge

DATE Received ____ 13

DATE WELL COMPLETED 0 2 0 3 8 8 (15–20)

Depth of Well 22 4 7 26 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL" C E - 8 1 - 3 6 0 3 (28–37)

OWNER Arnold (last name) Paul (first name)

S OR RFD Base Closure Force TOWN Port Deposit

VISION ____ SECTION ____ LOT ____

WELL LOG

Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
urface soil moderate yellow brown fine sand ell sorted, subangular	0'	5'	
aprolite pale yellowish orange, very ine sand neissic laminations ell-sorted	5'	40'	✓
Port Deposit ss sic laminations actured angular asts w/quartz mica, felds par	40'	47'	✓

CIRCLE APPROPRIATE LETTER

A A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

E ELECTRIC LOG OBTAINED

P TEST WELL CONVERTED TO PRODUCTION WELL

EREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN CORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" D IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

RILLERS IDENT. NO. 174

[signature]

S SIGNATURE
(MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman ponsible for sitework if different from permittee)

GROUTING RECORD

WELL HAS BEEN GROUTED (Circle Appropriate Box) yes Y 44 no N 44

TYPE OF GROUTING MATERIAL

CEMENT C M 45 46 BENTONITE CLAY B C 45 46

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER ____

DEPTH OF GROUT SEAL (to nearest foot)

from 0 ft. (48 TOP 52) to 3 4 ft. (54 BOTTOM 58)

(enter 0 if from surface)

CASING RECORD

casing types insert appropriate code below

S T STEEL C O CONCRETE PVC P L PLASTIC O T OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
60 61	63 64 4	66 70 3 6

OTHER CASING (if used)

EACH CASING	diameter inch	depth (feet) from	to

SCREEN RECORD

screen type or open hole insert appropriate code below

S T STEEL B R BRASS BRONZE H O OPEN HOLE PVC P L PLASTIC O T OTHER

C 2 (1 2)

EACH SCREEN	DEPTH (nearest ft.)		
1	8 9	11 15 3 6	17 21 4 6
2	23 24	26 30	32 36
3	38 39	41 45	47 51

SLOT SIZE 1 0 2 0 3 1

DIAMETER OF SCREEN 56 4 60 (NEAREST INCH)

GRAVEL PACK from -34 to -47

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68 68

OEP USE ONLY
(NOT TO BE FILLED IN BY DRILLER)

T 70 TELESCOPE CASING

(E.R.O.S.) 72 LOG INDICATOR

W Q 74 75 76 OTHER DATA

C 3 (1 2)

PUMPING TEST

HOURS PUMPED (nearest hour) 8 9

PUMPING RATE (gal. per min. to nearest gal.) 11 15

METHOD USED TO MEASURE PUMPING RATE ____

WATER LEVEL (distance from land surface)

BEFORE PUMPING 17 20

WHEN PUMPING 22 25

TYPE OF PUMP USED (for test)

A air 27 P piston 27 T turbine 27

C centrifugal 27 R rotary 27 O other (describe below) 27

J jet 27 S submersible 27

MONITORING

PUMP INSTALLED

DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO) YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX-SEE ABOVE: 29

CAPACITY: GALLONS PER MINUTE (to nearest gallon) 31 36

PUMP HORSE POWER 37 41

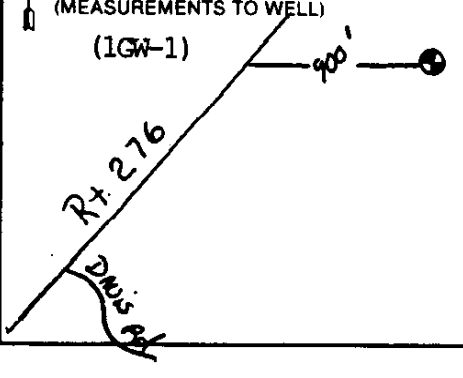
PUMP COLUMN LENGTH (nearest ft.) 43 47

CASING HEIGHT (circle appropriate box and enter casing height)

+ above 49 / − below 49 LAND SURFACE 2 (nearest foot) 50 51

LOCATION OF WELL ON LOT

SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 1GW-2
Date: February 8 - 10, 1988
Observer: Timothy J. Baker, Hydrogeologist

Monitoring well 1GW-2 was installed along the northwest perimeter of the landfill as shown in Figure 2-1. Access to the location is through Gate No. 9 along State Route 276. The well is located approximately 30 feet inside the locked gate. The well was drilled by advancing 8" hollow-stem augers until refusal occurred in saprolite at 20 feet. Split spoon samples were collected at five foot intervals in the overburden. Saturated conditions were encountered at 13.5 feet while augering in silts and sands. This probably represents a perched water table above the saprolite zone, which was very dry and first occurred at approximately 16 feet. Following auger refusal at 20 feet, the hole was advanced to 20.3 feet with a 3-7/8" tri-cone bit. Saprolite and bedrock were cored from 20.3 feet to 28 feet using a 3-inch diamond core bit while circulating fresh water. Competent bedrock was first encountered at 23.2 feet and core recovery in the saprolite was very poor. Bedrock consisted of the Port Deposit Gneiss and contained significant water-bearing fractures with heavy staining at 23.2 feet, 25.1 feet, and 27.0 feet. Twelve-inch augers were emplaced to 20 feet and the borehole was reamed to a depth of 31 feet with a 7-5/8" air hammer bit.

The well was subsequently constructed by placement of a 10 foot length of 4-inch ID PVC schedule 40 (.010 slotted) well screen from 30.7 feet to 20.7 feet. This screen interval was chosen to monitor water-bearing zones at the top of the bedrock surface and in bedrock fractures. Twenty-three feet of 4-inch ID PVC schedule 40 well casing was installed above the screen. Gravel pack, consisting of No. 2 sand, was tremied into place around the screen. The top of the gravel pack was brought to 19 feet, about 1.7 feet above the top of the screen. A 2.2 foot seal was installed above the sand pack using 1/4-inch bentonite pellets. The remaining annulus was then tremie grouted to the surface using a 5% bentonite-cement slurry.

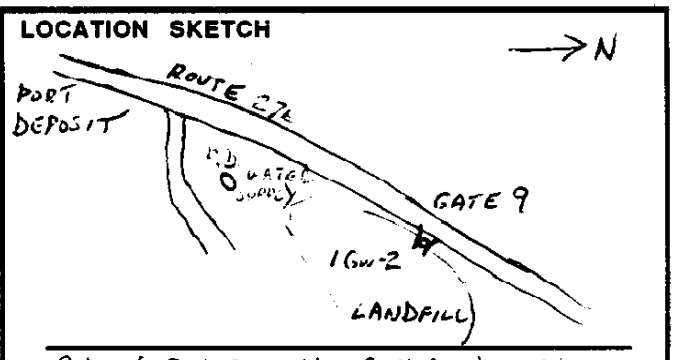
Following completion of the well, a 6 inch by 6 inch square, 5 foot steel protector casing with a locking cap was cemented in place over the well and was surrounded by a 5 foot by 5-foot concrete pad and four steel bumper posts. The well was developed using a submersible pump. Pumping continued until development water remained clean and until in situ parameters, pH, and specific conductance stabilized. Development water, approximately 560 gallons, discharged a minimum distance of 25 feet topographically down slope from the well location. The well, protector casing and concrete pad, were subsequently surveyed relative to a USGS bench mark. A State of Maryland Permit tag [No. CE-81-3607] was affixed to the protector casing. The bumper posts and protector casing were painted international orange.

Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: BAINBRIDGE NTC
JOB NUMBER: 5065.3.6
LOCATION: LANDFILL
WELL NUMBER: 1GW-2
GROUND ELEVATION: (PAD) 242.98
DATE INSTALLED: 2/8 TO 2/10/88
WELL CASING ELEVATION: 244.78
FIELD REPRESENTATIVE: TIM BAKER
PROTECTOR CASING ELEVATION: 244.74
DRILLING CONTRACTOR: HARDIN-HUBER
DRILLER: N. LAZARO LICENSE NO. 336
DRILLING METHOD: HSA, DIAMOND CORE, AIR
RIG TYPE: MOBILE B61
CONDITION OF GROUND SURFACE: FILL
FORMATION SCREENED: SAPROLITE/BEDROCK

LOCATION SKETCH



City of Port Deposit, Cecil County, Md.

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
AUGER	8"/12"	20'	—
TRI-CONE	3 7/8"	20'-20.3'	FRESH WATER
DIAMOND CORE	3"	20.3'-28'	FRESH WATER
HAMMER	7 5/8"	20'-31'	AIR

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP*	BOTTOM*
PROTECTOR CASING	6"x6"	5'	+2.26	2.74
PVC SCH.40 CASING	4"ID	23'	+2.3	20.7
PVC SCH.40 SCREEN	4"ID	10'	20.7	30.7
(.010) MACHINE SLOTTED				

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP*	BOTTOM*
PORTLAND CEMENT	0'	2.5'
BENTONITE/CEMENT GROUT	2.5'	16.8'
SEAL - 1/4" BENTONITE PELLETS	16.8'	19'
#2 SAND PACK	19'	31'
Concrete Apron (5'x5')	+0.5'	0'

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	2/8/88	1545	1700
	2/9/88	0930	1045
CASING	2/10/88	0900	1500
	2/10/88	1510	1520
FILTER PACK	2/10/88	1520	1610
SEAL	2/10/88	1610	1620
GROUT	2/10/88	1630	1700
DEVELOPMENT	3/1/88	1320	1350
SURVEY	3/4/88		
OTHER 1ST SAMPLING	3/16/88	1230	—
DIAMOND CORE	2/9/88	1100	1500

GROUND WATER LEVELS

DURING DRILLING:
2/10/88 0900 13.5' BELOW GROUND
3/10/88 15.17' BELOW WELL CASING
3/15/88 15.12' BELOW WELL CASING

WELL DEVELOPMENT

WELL DEVELOPMENT WITH SUBMERSIBLE PUMP
PURGED APPROXIMATELY 560 GALLONS

FINAL IN-SITU PARAMETER MEASUREMENTS:
TEMP: 12.8°C
SPEC. COND: 475 umhos
pH: 6.84

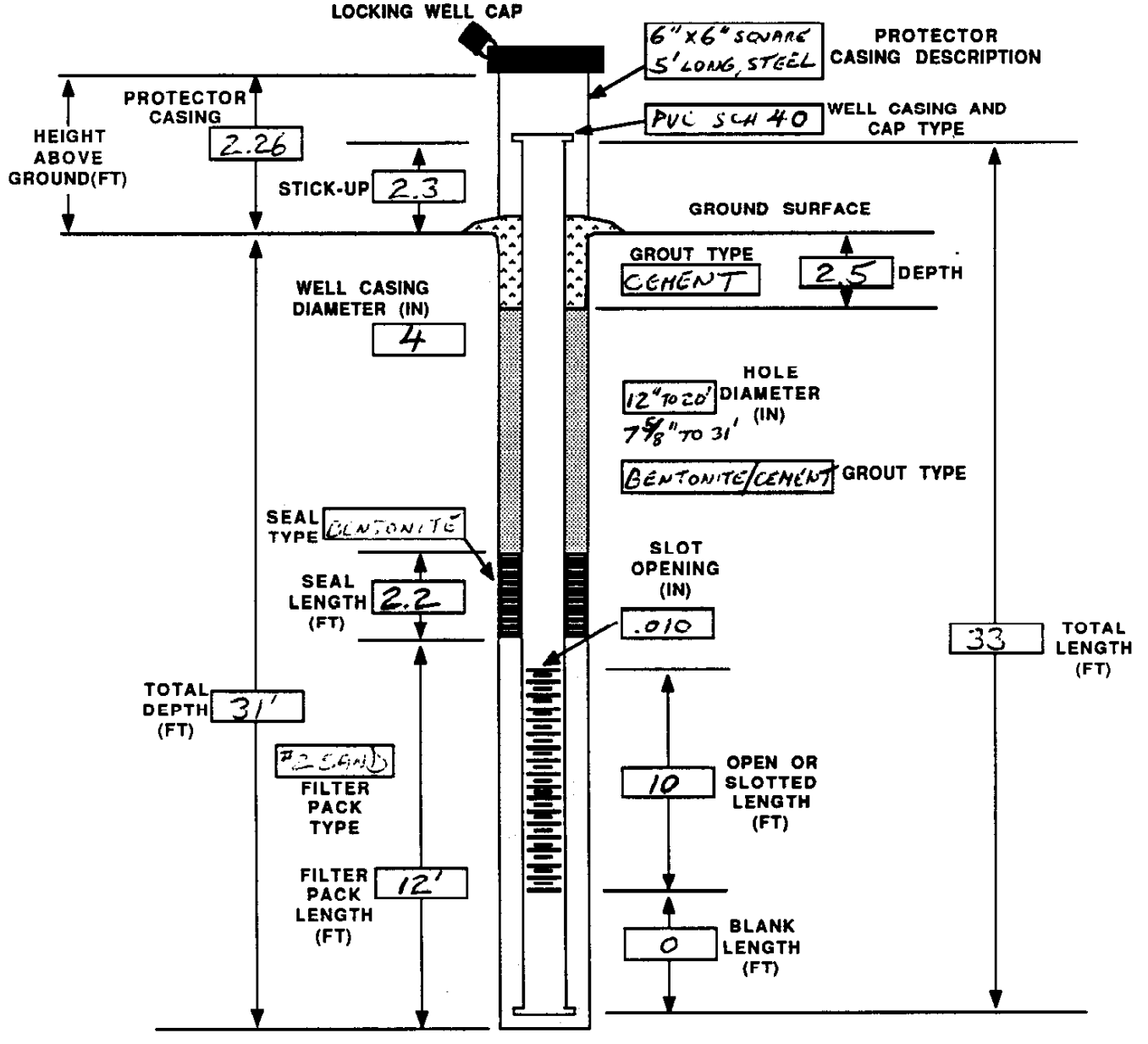
* DEPTH FROM GROUND SURFACE

COMMENTS: 4 GUARD POSTS INSTALLED AROUND PROTECTOR CASING. PROTECTOR CASING AND GUARD POSTS PAINTED INTERNATIONAL ORANGE.

Versar INC.

WELL CONSTRUCTION DIAGRAM

PROJECT: BRINGBRIDGE NTC JOB NUMBER: 5065.3.6
LOCATION: LANDFILL
WELL NUMBER: 16W-2 ELEVATION: 244.78
DATE INSTALLED: 2/10/88 ☐ GROUND ☒ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☐ ABOVE MEAN SEA LEVEL



COMMENTS: PERCHED WATER ZONE ENCOUNTERED ABOVE SAPROLITE FROM 13.5' TO 15.5'; SEALED OFF. BEDROCK YIELDED SIGNIFICANT WATER VOLUMES WHILE AIR HAMMERING. FRACTURES LOCATED AT 23.2', 25.1' AND 27.0' IN THE BEDROCK CORE.

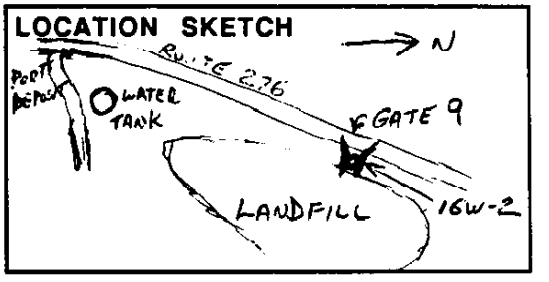
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: BAINBRIDGE NTC
LOCATION: LANDFILL
BOREHOLE NUMBER: 16W-2
DATE DRILLED: 2/8 TO 2/10/88
FIELD REPRESENTATIVE: TIM BAKER
DRILLING CONTRACTOR: HARDIN HUBER, INC.
DRILLER: NATE LAZARD
DRILLING METHOD: AUGER (20') AIR HAMMER
HOLE DIAMETER: 5" OD, 12" OD, 7 5/8"
GROUND ELEVATION: (PAD) 242.98
CONDITION OF GROUND SURFACE: GRAVEL FILL

LOCATION SKETCH



COMMENTS: City of Port Deposit, Cecil Co.

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
						OLD ROAD BED ENCOUNTERED @ 2'-4'; ASPHALT + CINDER BLOCKS, DIFFICULT AUGERING
5	1	SS	2'/1.6'	5 6 22 9		FILL MATERIAL: SAND, SILT, CLAY, SOME PEBBLES, GRAY, BLACK, DARK BROWNISH ORANGE, VERY FINE - COARSE GRAINED, SOME GLASS AND WOOD FRAGMENTS, SLAG FROM ROAD CONSTRUCTION
10	2	SS	2'/1.3'	2 2 7 5		.2' SILT: BROWNISH BLACK, MOIST, SOME PEBBLES .9' WEATHERED BOULDER: MODERATE RED, SILTY MICACEOUS, BEDROCK TEXTURE, VERY FINE GRAINED, DRY .2' SILT AND PEBBLES: BROWNISH BLACK, POORLY SORTED, ORGANIC RICH, SATURATED, SHARP CONTACT WITH ABOVE LAYER
					▽	WATER LEVEL ENCOUNTERED WHILE DRILLING (13.5')
15	3	SS	2'/1.7'	14 24 32 51		.4' SILT: MODERATE RED, GRAYISH RED, SOME CLAY, MICA, SATURATED .4' SAND: DARK YELLOWISH ORANGE, VERY FINE, SILTY, WELL SORTED, SUBANGULAR, MOIST .9' SAPROLITE: YELLOWISH GRAY WITH BLACK MAFIC LAYERING, SOME DARK YELLOWISH ORANGE, VERY SILTY, HEAVILY WEATHERED, FINE GRAINED, VERY DRY
20						AUGER TO 20' - REFUSAL IN SAPROLITE; ATTEMPT SS SAMPLE - NO PENETRATION REAM TO 20.3' WITH 3 7/8" ROLLER BIT H W X 0 PPM
	4	DIAMOND CORE	3.7'/.9'			CORE 20.3' TO 24': INTERVAL FROM 20.3' TO 23.1' WAS SAPROLITE - NO RECOVERY INTERVAL FROM 23.1' TO 24': .1' WEATHERED GNEISS .8' BEDROCK (PORT DEPOSIT GNEISS): VERY PALE ORANGE - GRAYISH ORANGE, MAFIC FOLIATIONS, FINE GRAINED, DENSE, VERY COMPETENT, FRACTURE W/BROWN STAINING AT 23.2'
25						TOP UNWEATHERED BEDROCK - 23.2'

Timothy J. Baker
GEOLOGIST'S SIGNATURE

Versar INC. GEOLOGIC LOG

PROJECT: BAINBRIDGE NTC JOB NUMBER: 5065.3.6
LOCATION: LANDFILL
BOREHOLE/WELL NUMBER: 1 GW-2
DATE LOGGED: 2/9/88, 2/10/88

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
25	5	DIAMOND CORE	4'/33'			CORE 24'-28' PORT DEPOSIT GNEISS: VERY PALE ORANGE TO GRAYISH ORANGE, MAFIC LAYERING, FINE GRAINED, VERY DENSE + COMPETENT FRACTURES W/HEAVY DARK BROWN STAINING @ 25.1' AND 27.0'
30						AIR HAMMER IN BEDROCK TO 31' WITH 7 5/8" BIT; WELL MADE SIGNIFICANT AMOUNTS OF WATER WHILE AIR HAMMERING
						T.D. = 31 FEET

Timothy J. Baker
GEOLOGIST'S SIGNATURE

PAGE 4 OF 4

01 6122 (OEP USE ONLY)
(THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

STATE OF MARYLAND
WELL COMPLETION REPORT
FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER: Test Well Bainbridge

DATE Received:

DATE WELL COMPLETED: 02 10 88

Depth of Well: 31 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL": CE-81-3604

OWNER: Arnold (last name) Paul (first name)

OR RFD: Base Closure Force TOWN: Port Deposit

SUBDIVISION: SECTION: LOT:

WELL LOG
Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
ill and surface soil and, silt, clay /glass, wood road slag asphalt (2' - 4') ark brownish orange	0'	10'	
aprolite dark yellowish orange silty icaceous gneissic laminations	10'	23'	✓
Port Deposit Gneiss (Bedrock) ale orange mafic laminations fracture at 23' uartz, mica elds par	23'	31'	✓

CIRCLE APPROPRIATE LETTER
- A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED
- L ELECTRIC LOG OBTAINED
- P TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 174

DRILLER SIGNATURE (MUST MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

GROUTING RECORD
WELL HAS BEEN GROUTED (Circle Appropriate Box): yes [Y] no [N]

TYPE OF GROUTING MATERIAL: CEMENT [CM] BENTONITE CLAY [BC]

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER

DEPTH OF GROUT SEAL (to nearest foot): from 0 ft. (TOP) to 19 ft. (BOTTOM) (enter 0 if from surface)

CASING RECORD
casing types — insert appropriate code below

[ST] STEEL [CO] CONCRETE [PL] PVC PLASTIC [OT] OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
	4	21

OTHER CASING (if used) — EACH CASING

diameter inch	depth (feet) from	to

SCREEN RECORD
screen type or open hole — insert appropriate code below

[ST] STEEL [BR] BRASS BRONZE [HO] OPEN HOLE [PL] PVC PLASTIC [OT] OTHER

C2

EACH SCREEN		DEPTH (nearest ft.)	
1	PL	21	31
2			
3			

SLOT SIZE 1 0 2 0 3 1

DIAMETER OF SCREEN 4 (NEAREST INCH)

GRAVEL PACK from 19 to 31

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68

OEP USE ONLY (NOT TO BE FILLED IN BY DRILLER)

T (TELESCOPE CASING) (E.R.O.S.) (LOG INDICATOR) W Q (OTHER DATA)

C3

PUMPING TEST
HOURS PUMPED (nearest hour)

PUMPING RATE (gal. per min. to nearest gal.)

METHOD USED TO MEASURE PUMPING RATE

WATER LEVEL (distance from land surface)

BEFORE PUMPING

WHEN PUMPING

TYPE OF PUMP USED (for test): [A] air [P] piston [T] turbine [C] centrifugal [R] rotary [O] other (describe below) [J] jet [S] submersible

MONITORING

PUMP INSTALLED
DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO): YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE:

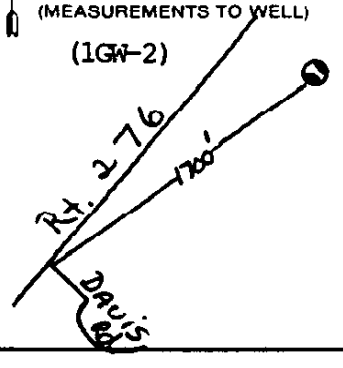
CAPACITY: GALLONS PER MINUTE (to nearest gallon)

PUMP HORSE POWER

PUMP COLUMN LENGTH (nearest ft.)

CASING HEIGHT (circle appropriate box and enter casing height): [+] above [−] below LAND SURFACE [Z] (nearest foot)

LOCATION OF WELL ON LOT
SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 1GW-3 (Maryland State Permit #CE-81-3605)
Date: February 19 and 25, 1988
Observer: Dennis Papa, Hydrogeologist

Monitoring well 1GW-3 was installed approximately 800 feet north of the Port Deposit Reservoir and 100 feet east of State Route 276 as shown in Figure 2-1. Access to the location is via a dirt path cutting across the southern border of the landfill. The path is accessible from a dirt road which parallels the drainage ditch along the eastern border of the landfill and exits the landfill area near well 1GW-1. The well was drilled by advancing an 8-inch diameter hollow-stem auger until refusal occurred at a depth of 20 feet, the top of competent bedrock. Split spoon samples were collected at 5-foot intervals in the saprolite overburden. The saprolite was composed of green and white, very micaceous, weathered gneiss and schist. After reaching bedrock, drilling continued with a 7-5/8-inch diameter air hammer bit to a final depth of 29.5 feet. Bedrock consisted of the Port Deposit Gneiss and contained several water-bearing fractures beginning at a depth of 21 feet. The fractures did not yield water until approximately 4 ounces of Quik-Foam was added to the air stream. Quik-Foam, a drilling surfactant used to increase the hole cleaning capability of the air stream, helped to remove drill cuttings which were clogging water-bearing structures. After adding the Quik-Foam, the borehole began producing small amounts of silty and turbid water. The borehole was purged with air for approximately twenty minutes to induce water flow into the well and remove residual Quik-Foam.

Following purging, the well was constructed with a 10-foot length of 4-inch diameter schedule 40 PVC screen with a slot size of 0.010 inches. The screen was set at a depth from 29.0 feet to 19.0 feet to monitor water-bearing zones in the upper fractured portion of the Port Deposit Gneiss. A 21.55 foot section of 4-inch diameter schedule 40 PVC well casing was installed above the screen, with a stick-up length of 2.55 feet

above ground surface. A gravel pack of No. 2 silica sand was then placed around the screen and was extended to approximately 2.5 feet above the screen. The sand pack was sealed with a 2-foot thick seal formed with 3/8-inch bentonite pellets, and the remaining annulus grouted with a 5% bentonite and cement slurry. The grout was added by tremie pipe and was brought to a depth of 3 feet below ground surface. A 5-foot long, 6-inch by 6-inch square steel protector casing with a locking cap was cemented over the well casing and surrounded by a 5-foot by 5-foot square, 6-inch thick concrete pad with a steel bumper post at each corner. The well casing, protector casing and concrete pad were surveyed relative to sea level on March 5, 1988 using a USGS bench mark as an initial reference point. To facilitate identification, the well protector casing was painted international orange and labeled with a well tag bearing the Maryland State Permit Number CE-81-3605.

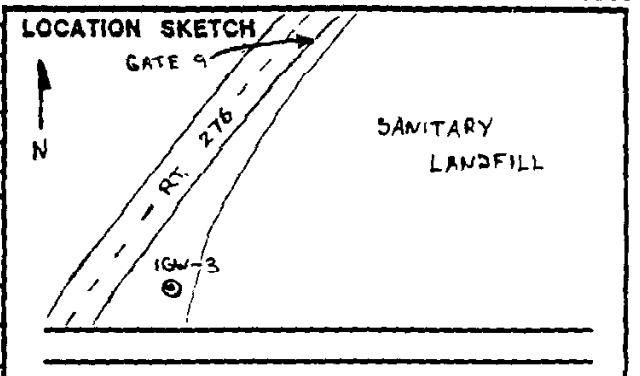
On March 1 and 2, 1988 the well was developed by bailing and by pumping and surging with a submersible pump. Approximately 140 gallons of water were purged from the well. Development water was discharged a minimum of 25 feet downgradient from the well. In-situ measurements of pH, specific conductance, and temperature were recorded periodically. Development continued until in-situ parameters had stabilized and water clarity remained constant. Final depth to water in the well, measured on March 16, 1988, was 23.21 feet below the well casing.

Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Bainbridge NTC
JOB NUMBER: 5065.3.6
LOCATION: southwest of landfill
WELL NUMBER: IGW-3
GROUND ELEVATION: 227.43 (pad)
DATE INSTALLED: 2-25-88
WELL CASING ELEVATION: 229.48' above MSL
FIELD REPRESENTATIVE: Dennis Papa
PROTECTOR CASING ELEVATION: 229.30'
DRILLING CONTRACTOR: Hardin Huber
DRILLER: N. Lazaro LICENSE NO. 336
DRILLING METHOD: hollow auger + air rotary
RIG TYPE: mobile B61
CONDITION OF GROUND SURFACE: muddy clay
FORMATION SCREENED: Port Deposit Gneiss and saprolite

LOCATION SKETCH



BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
hollow auger	8"	20	—
hammer	7 5/8"	29.5	air

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP*	BOTTOM*
protector casing	6 x 6	5'	+2.37	2.63
PVC Sch 40 casing	4" ID	21.55	+2.35	19.0'
PVC Sch 40 screen -	4" ID	10'	19.0	29.0
0.010 slot size				

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP*	BOTTOM*
portland cement	0	3
bentonite + cement grout	3	15'
bentonite seal (3/8" pellets)	15'	17'
#2 sand pack	17'	29.5

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	2-19-88	1100	1235
	2-25-88	1100	1420
CASING	2-25-88	1425	1430
FILTER PACK	2-25-88	1430	1440
SEAL	2-25-88	1440	1445
GROUT	2-25-88	1530	1620
DEVELOPMENT	3-1-88	1710	1745
SURVEY	3-2-88	1000	1330
	3-5-88		
OTHER 1st sampling	3-16-88	0850	

GROUND WATER LEVELS

DURING DRILLING:

2-25-88 1330 — 21' below surface

3-16-88 0850 — 23.21' below well casing

WELL DEVELOPMENT

3-1-88; 3-2-88 — bailed 25 gal to remove excessive silt, then pumped approx. 115 gal (well volume = 5 gal) water turbid

Final field parameters:

Temp. = 14.0 °C
Conductivity = 900 umhos
pH = 6.51

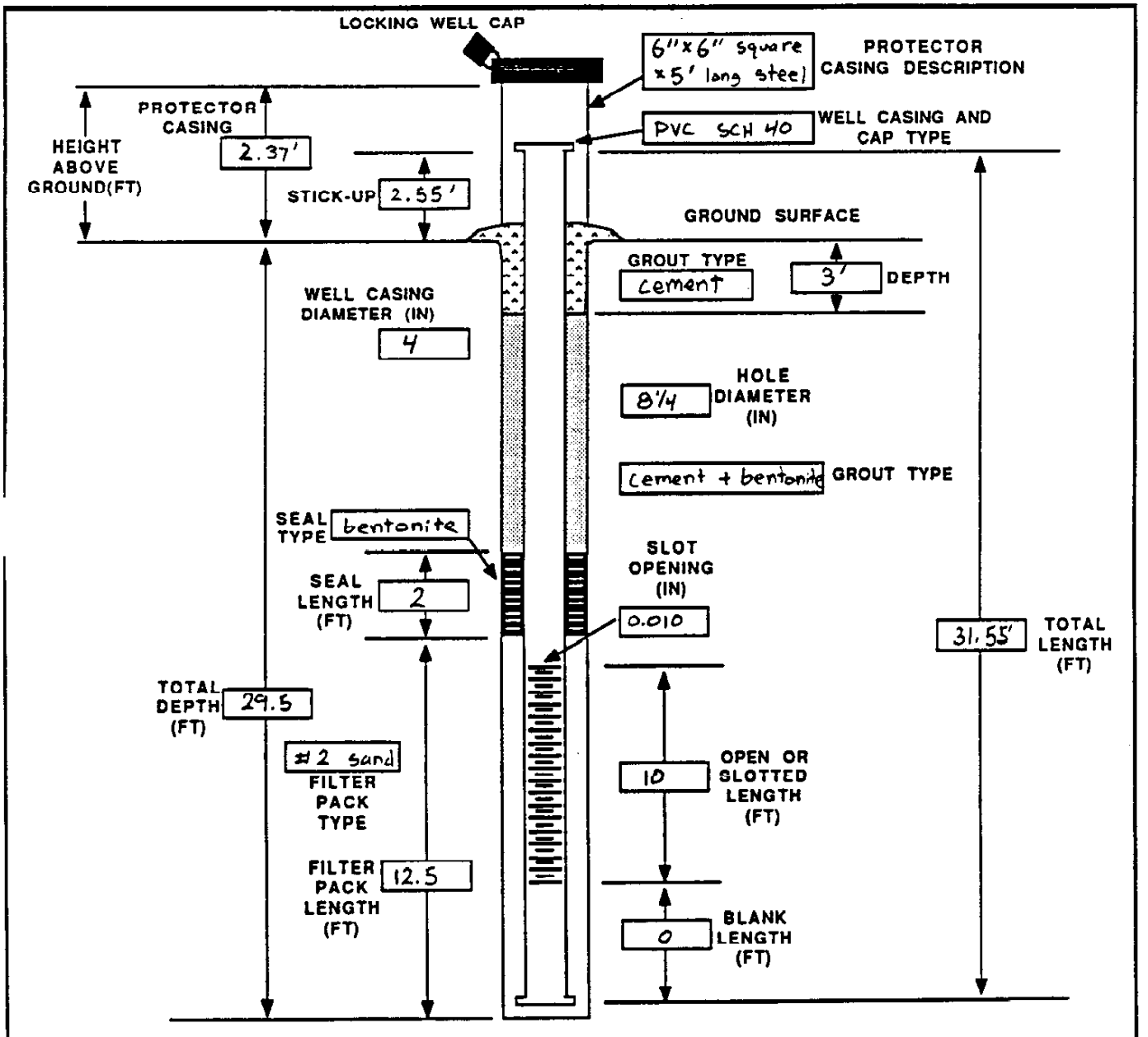
* DEPTH FROM GROUND SURFACE

COMMENTS:

Versar INC.

WELL CONSTRUCTION DIAGRAM

OJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
CATION: Southwest of landfill
WELL NUMBER: IGW-3 ELEVATION: 229.48'
DATE INSTALLED: 2-25-88 ☐ GROUND ☒ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☒ ABOVE MEAN SEA LEVEL



COMMENTS: Protector casing painted orange. Concrete pad is 5'x5' square x 0.5' thick with a guard post at each corner. Maryland state permit # CE-81-3605.

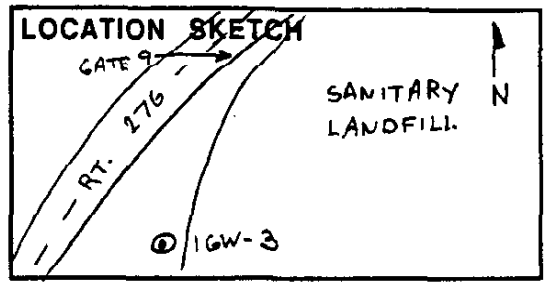
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: Bainbridge NTC
LOCATION: southwest of landfill
BOREHOLE NUMBER: IGW-3
DATE DRILLED: 2-19-88 and 2-25-88
FIELD REPRESENTATIVE: Dennis Papa
DRILLING CONTRACTOR: Harlin Huber
DRILLER: Nate Lazaro
DRILLING METHOD: hollow auger + air hammer
HOLE DIAMETER: 8 1/4" to ~20' ; 7 5/8" to 29.5
GROUND ELEVATION: 227.43 (pad)
CONDITION OF GROUND SURFACE: muddy clay

LOCATION SKETCH



COMMENTS: Port Deposit, Cecil Co., MD

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
		grab				surface soil - dark yellowish orange, silty, micaceous clay; plastic, w/ roots, pebbles, twigs and weathered saprolite fragments Port Deposit Gneiss HNu = 0 ppm
5	1	S.S.	2.0'/2.0'			saprolite - dusky yellow, indurated, pelitic, fine-grain qtz and feldspar matrix w/ 0.25 mm to 2.0 mm biotite & muscovite mica flakes (~30%) alternating light & dark gneissic banding; dry HNu = 0 ppm
10	2	S.S.	0.75'/0.75'	38 50/3"		Saprolite - yellowish gray w/ black and greenish gray schistose banding of 0.25 mm to 2.0 mm flakes of biotite, muscovite and chlorite - oriented vertical; very dense yet indurated; schistosity very apparent on fresh surface; dry, no odor
15	3	S.S.	1"/1"	51/1"		saprolite - yellowish gray qtz + feldspar matrix w/ black and moderate brown gneissic banding of biotite + muscovite, scattered v. fine mica throughout; pelitic, very dense, dry.
20		S.S.	4"/4"	51/4"	▽	saprolite - same as above w/ greater biotite (~15%) and reappearance of schistosity.
						Top of bedrock @ 20 feet - auger refusal. Begin air hammer with 7 5/8" bit
		grab				schist - greenish black shist layer of Port Deposit formation; v. fine to fine grains + flakes of mafics w/ 10-15% qtz. mod well sorted, friable, weathered zone to ~24 feet; saturated HNu = 0 ppm
25						

Dennis Papa
GEOLOGIST'S SIGNATURE

Versar INC.

GEOLOGIC LOG

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: Southwest of landfill
BOREHOLE/WELL NUMBER: 1GW-3
DATE LOGGED: 2-19-88 and 2-25-88

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
29		grab				- same as above, except less weathered and more heavily fractured; fractures stained with orange, iron oxides/- yielding brownish orange, very turbid water. low yield (< 2 GPM)
						T.D. = 29.5 feet Monitoring well 1GW-3 screened in saprolite & bedrock from 19-29 feet.

Dennis Papa
GEOLOGIST'S SIGNATURE

C1 9770 (OEP USE ONLY)

IS NUMBER IS TO BE PUNCHED (COLS. 3-6 ON ALL CARDS)

STATE OF MARYLAND
WELL COMPLETION REPORT
FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER: TEST WELL BAINBRIDGE

DATE Received: 13

DATE WELL COMPLETED: 0 2 2 5 8 8 (15–20)

Depth of Well: 2 9 (22–26) (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL": C E - 8 1 - 3 6 0 5 (28–37)

OWNER: ARNOLD (last name) PAUL (first name)

S OR RFD: Base Closure Force TOWN: Port Deposit

SUBDIVISION: SECTION: LOT:

WELL LOG
Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
Surface soil silt w/roots weathered rock fragments	0'	5'	
Saprolite well-soiled fine-grained sand	5'	20'	
Port Deposit Gneiss (Bedrock) Shistose fabric fractured with quartz par fragments (angular)	20'	29'	✓

CIRCLE APPROPRIATE LETTER
- A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED
- ELECTRIC LOG OBTAINED
- TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 674

[signature]

DRILLER'S SIGNATURE (MUST MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

GROUTING RECORD
WELL HAS BEEN GROUTED (Circle Appropriate Box): yes Y (44) no N (44)

TYPE OF GROUTING MATERIAL: CEMENT C M (45–46) BENTONITE CLAY B C (45–46)

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER ____

DEPTH OF GROUT SEAL (to nearest foot): from 0 ft. (48–52) to 1 7 ft. (54–58) (enter 0 if from surface)

CASING RECORD
casing types insert appropriate code below: ST STEEL, CO CONCRETE, PVC PL PLASTIC, OT OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
	4	1 9

EACH CASING — OTHER CASING (if used): diameter inch, depth (feet) from, to

SCREEN RECORD
screen type or open hole insert appropriate code below: ST STEEL, BR BRASS BRONZE, HO OPEN HOLE, PVC PL PLASTIC, OT OTHER

C 2

EACH SCREEN — DEPTH (nearest ft.)

1		1 9	2 9
2			
3			

SLOT SIZE 1 0 2 0 3 1

DIAMETER OF SCREEN: 4 (56–60) (NEAREST INCH)

GRAVEL PACK from 17 to 29

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68 (68)

OEP USE ONLY (NOT TO BE FILLED IN BY DRILLER)

T (70) TELESCOPE CASING; (E.R.O.S.) (72) LOG INDICATOR; W Q (74–76) OTHER DATA

C 3

PUMPING TEST
HOURS PUMPED (nearest hour): (8–9)

PUMPING RATE (gal. per min. to nearest gal.): (11–15)

METHOD USED TO MEASURE PUMPING RATE ____

WATER LEVEL (distance from land surface)

BEFORE PUMPING: (17–20)

WHEN PUMPING: (22–25)

TYPE OF PUMP USED (for test): A air, P piston, T turbine, C centrifugal, R rotary, O other (describe below), J jet, S submersible (27)

Monitoring

PUMP INSTALLED
DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO): YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE: (29)

CAPACITY: GALLONS PER MINUTE (to nearest gallon): (31–35)

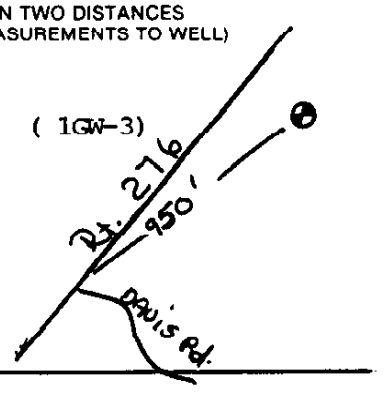
PUMP HORSE POWER: (37–41)

PUMP COLUMN LENGTH (nearest ft.): (43–47)

CASING HEIGHT (circle appropriate box and enter casing height): + above (49), − below (49) LAND SURFACE 2 (50–51) (nearest foot)

LOCATION OF WELL ON LOT

SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 1GW-4 (Maryland State Permit #CE-81-3606)
Date: February 4 - 8, 1988
Observer: Dennis Papa, Hydrogeologist

Monitoring well 1GW-4 was installed approximately 1200 feet northeast of the Port Deposit Reservoir and adjacent to a drainage ditch as shown in Figure 2-1. Access to the location is via the service road at Bainbridge NTC Gate 7, which joins a dirt path leading past well 1GW-4 and exiting the landfill area near well 1GW-1. The well was drilled by advancing an 8-inch diameter hollow-stem auger until refusal occurred in a zone of very dense saprolite at a depth of 27 feet. Split-spoon samples were collected at 5-foot intervals in the saprolite overburden. The saprolite was composed of white weathered gneiss with black and orange banding. Split-spoon sample collection was attempted at the dense layer at 27 feet, however the spoon could not be advanced. Drilling then resumed with a 7-5/8-inch air hammer bit through the saprolite overburden to a final depth of 45 feet. Solid bedrock, consisting of grey and orange gneiss with black banding, was encountered at a depth of 35.5 feet. A major fracture was encountered at this depth, however the fracture did not yield water until approximately 12 ounces of Quik-Foam was added to the air stream. The Quik-Foam, a drilling surfactant used to increase the hole cleaning capability of the air stream, helped to remove drill cuttings which were clogging water-bearing structures. After adding the Quik-Foam, the borehole began producing a large amount of slightly orange-colored water. The borehole was purged with air for approximately one hour to induce water flow into the well and remove residual Quik-Foam.

Following purging, the borehole became unstable and collapsed to a depth of 36 feet. Due to the large amount of water in the borehole (water level had risen to 24 feet below the surface) and to avoid further collapse, the well was installed above the cave-in.

The well was constructed with a 10-foot length of 4-inch diameter schedule 40 PVC screen with a slot size of 0.010 inches. The screen was set at a depth of 35.63 feet to 25.63 feet. A 27.43 foot section of 4-inch diameter schedule 40 PVC well casing was installed above the screen, with a stick-up length of 1.80 feet above ground surface. A gravel pack of No. 2 silica sand was then placed around the screen and was extended to approximately 3 feet above the well screen. The sand pack was sealed with a 3-foot thick seal formed with 1/4-inch bentonite pellets, and the remaining annulus grouted with a 5% bentonite and cement slurry. The grout slurry was added by tremie pipe, and was brought to a depth of 4 feet below ground surface. A 5-foot long, 6-inch by 6-inch square steel protector casing with a locking cap was cemented over the well casing and surrounded by a 5-foot by 5-foot square, 6-inch thick concrete pad with a steel bumper post at each corner. The well casing, protector casing, and concrete pad were surveyed relative to sea level on March 5, 1988 using a USGS bench mark as an initial reference point. To facilitate identification, the well protector casing was painted international orange and labeled with a well tag bearing the Maryland State Permit Number CE-81-3606.

On March 2, 1988, the well was developed by pumping and surging with a submersible pump. Approximately 400 gallons of water was purged from the well. Development water was discharged a minimum of 25 feet downgradient from the well. In-situ measurements of pH, specific conductance, and temperature were recorded periodically. Development continued until in-situ parameters had stabilized and water clarity remained constant. Final depth to water in the well, measured on March 16, 1988, was 25.0 feet below the well casing.

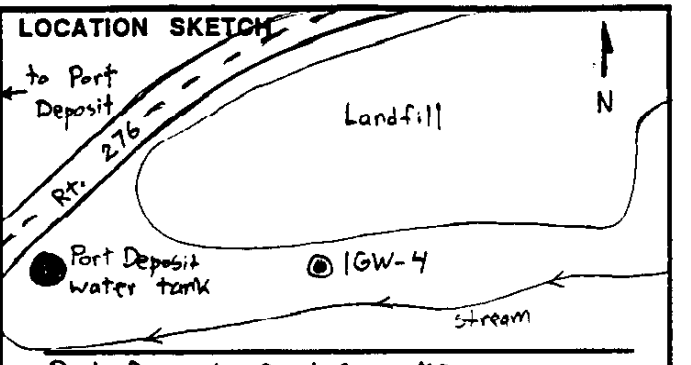
Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Bainbridge NTC
JOB NUMBER: 5065. 3.6
LOCATION: South of landfill
WELL NUMBER: IGW-4
GROUND ELEVATION: 249.48' (pad)
DATE INSTALLED: 2-8-88
WELL CASING ELEVATION: 250.78' above MSL
FIELD REPRESENTATIVE: Dennis Papa
PROTECTOR CASING ELEVATION: 250.92'
DRILLING CONTRACTOR: Hardin-Huber
DRILLER: N. Lazaro LICENSE NO. 336
DRILLING METHOD: hollow auger, air hammer
RIG TYPE: Mobile B61
CONDITION OF GROUND SURFACE: mud
FORMATION SCREENED: Port Deposit Gneiss and saprolite

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
auger	8" OD	27	—
air hammer	7 5/8"	27-36	air

LOCATION SKETCH



Port Deposit, Cecil Co., MD

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP*	BOTTOM*
protector casing	6 x 6	5'	+1.94	3.06
PVC SCH 40 casing	4" ID	27.43	+1.80	25.63'
PVC SCH 40, 0.010	4" ID	10'	25.63	35.63'
slotted screen				

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	2-4-88	1430	1630
	2-5-88	0830	1715
	2-8-88	1015	1230
CASING	2-5-88	1610	1620
FILTER PACK	2-5-88	1620	1700
SEAL	2-5-88	1700	1705
GROUT	2-8-88	1030	1140
DEVELOPMENT	3-2-88	0955	1130
SURVEY	3-5-88		
OTHER 1st sampling	3-16-88	0930	

GROUND WATER LEVELS

DURING DRILLING:
2-5-88 1520 — 24' 2" below surface
3-16-88 0930 — 25.0' below well casing

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP*	BOTTOM*
portland cement	0	4'
bentonite + cement grout	4'	20'
bentonite seal (1/4" pellets)	20'	23'
#2 silica sand pack	23'	36'

WELL DEVELOPMENT

3-2-88 - purged approx. 400 gal (well volume = 7.8 gal) water slightly turbid
Final field parameters:
Temp. = 12.2° C
Conductivity = 420 µmhos
pH = 6.15

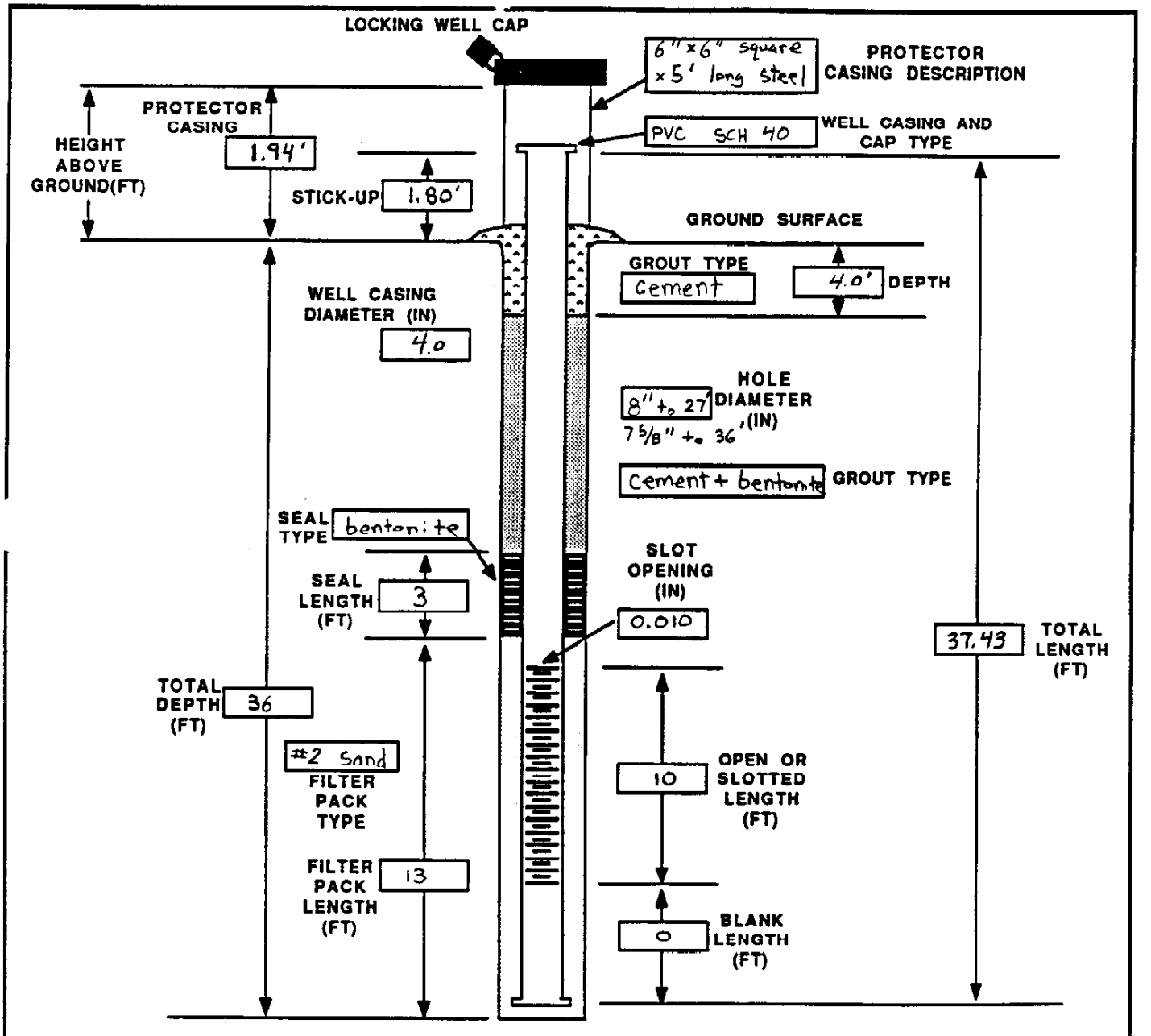
* DEPTH FROM GROUND SURFACE

COMMENTS:

Versar INC.

WELL CONSTRUCTION DIAGRAM

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: South of landfill
WELL NUMBER: LGW-4 ELEVATION: 250.78 feet
DATE INSTALLED: 2-8-88 ☐ GROUND ☒ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☒ ABOVE MEAN SEA LEVEL



COMMENTS: Hole originally drilled to 43' but was unstable and caved to 36'. Hole diameter not uniform. Protector casing painted orange. Concrete pad is 5'x5' square x 0.5' thick with a guard post at each corner. Maryland state permit # CE-81-3606.

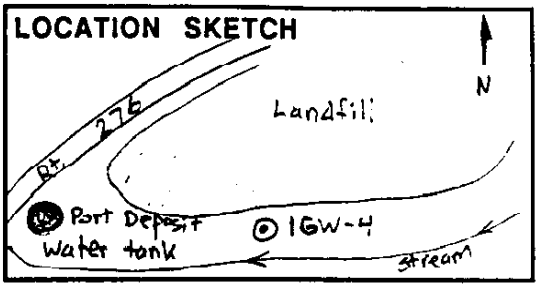
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.5

PROJECT: Bainbridge NTC
LOCATION: south of landfill
BOREHOLE NUMBER: IGW-4
DATE DRILLED: 2-4-88 to 2-8-88
FIELD REPRESENTATIVE: Dennis Papa
DRILLING CONTRACTOR: Hardin Huber
DRILLER: Nate Lazaro
DRILLING METHOD: hollow auger & air hammer
HOLE DIAMETER: 8" to 27'; 7 5/8" to 36'
GROUND ELEVATION: 249.48 (pad)
CONDITION OF GROUND SURFACE: muddy clay

LOCATION SKETCH



COMMENTS: Port Deposit Cecil Co., MD

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
		grab				surface soil - moderate yellowish brown silty micaceous clay; very plastic w/ roots, leaves and pebbles
5	1	S.S.	2'/0.3'	4 9 11 14		sand - dark yellowish orange, fine-grain, pelitic and micaceous (biotite + muscovite), dry, no odor; some rounded pebbles
10	2	S.S.	2'/1.5'	11 11 18 22		saprolite - white w/ black & dark yellowish orange gneissic banding; fine to very fine, well sorted, sub-angular grains, pelitic w/ biotite + muscovite; no odor; very dry and weathered.
15	3	S.S.	7"/7"	20/51		saprolite - same as above
20	4	S.S.	1.6'/1.6'	14 24 32 51		saprolite - as above, but denser & more compacted; gneissic banding better defined.
25	5	S.S.	7"/7"	26/51		saprolite - same as above
						auger refusal in saprolite @ 27' - attempt S.S. sample, but no penetration. HNu at background

Dennis Papa
GEOLOGIST'S SIGNATURE

Versar INC.

GEOLOGIC LOG

PROJECT: Bainbridge NTC **JOB NUMBER:** 5065.3.6
LOCATION: south of landfill
BOREHOLE/WELL NUMBER: IGW-4
DATE LOGGED: 2-4-88 to 2-5-88

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
27		grab				air hammer (7 5/8" bit) through dense saprolite to top of bedrock @ 35.5' – air cuttings yellowish gray, pelitic, silty; slightly moist HNv = background, no odor
35		grab			▽	Port Deposit Gneiss – bedrock @ 35.5', white to grayish orange w/ black banding, fractured; w/ some angular qtz clasts first occurrence of water @ 35.5' – large water seam; water level rose to 24' below surface * continued air hammering to 45', however extensive caving occurred, so well set at 36' – set on 9 feet of cave-in material (saprolite & pebbles) T.D. = 36' Port Deposit bedrock, same as above, continuous to 45'

Dennis Papa
GEOLOGIST'S SIGNATURE

[illegible] 3771 (OEP USE ONLY)
(THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

STATE OF MARYLAND
WELL COMPLETION REPORT
FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER: TEST WELL BAINBRIDGE

DATE Received: [ ]

DATE WELL COMPLETED: 020888

Depth of Well: 36 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL": CE-81-3606

OWNER: ARNOLD (last name) PAUL (first name)

STREET R RFD: BASE CLOSURE FORCE TOWN: PORT DEPOSIT

SUBDIVISION: SECTION: LOT:

WELL LOG
Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
Surface soil silty clay w roots, pebbles m a gravels	0'	4'	
Sand layer d k yellowish orange, fine - grained micaceous	4'	5'	
Saprolite dark yellowish o nge, gneissic l inations well-sorted very f ained s	5'	35.5'	
Port Deposit G iss (Bedrock) angular clasts l inations	35.5'	36'	✓

CIRCLE APPROPRIATE LETTER
A — A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED
E — ELECTRIC LOG OBTAINED
P — TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 174

[signature]
DRILLER SIGNATURE
(MUST MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

GROUTING RECORD
WELL HAS BEEN GROUTED (Circle Appropriate Box) yes Y / no N

TYPE OF GROUTING MATERIAL
CEMENT CM — BENTONITE CLAY BC

NO. OF BAGS ____ NO. OF POUNDS ____
GALLONS OF WATER ____
DEPTH OF GROUT SEAL (to nearest foot)
from 0 ft. (TOP) to 23 ft. (BOTTOM)
(enter 0 if from surface)

CASING RECORD
casing types insert appropriate code below
ST STEEL — CO CONCRETE — PVC PL PLASTIC — OT OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
	4	26

OTHER CASING (if used)

EACH CASING	diameter inch	depth (feet) from	to

SCREEN RECORD
screen type or open hole insert appropriate code below
ST STEEL — BR BRASS BRONZE — HO OPEN HOLE — PVC PL PLASTIC — OT OTHER

C2

EACH SCREEN	DEPTH (nearest ft.)		
1		26	36
2			
3			

SLOT SIZE 1 0 2 0 3 1

DIAMETER OF SCREEN 4 (NEAREST INCH)

GRAVEL PACK from 23 to 36
IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68

OEP USE ONLY
(NOT TO BE FILLED IN BY DRILLER)
T — TELESCOPE CASING
(E.R.O.S.) — LOG INDICATOR
WQ — OTHER DATA

C3

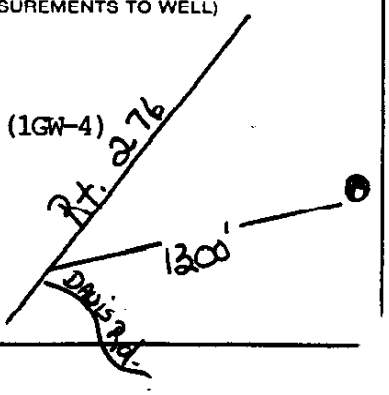
PUMPING TEST
HOURS PUMPED (nearest hour)
PUMPING RATE (gal. per min. to nearest gal.)
METHOD USED TO MEASURE PUMPING RATE
WATER LEVEL (distance from land surface)
BEFORE PUMPING
WHEN PUMPING

TYPE OF PUMP USED (for test)
A air — P piston — T turbine
C centrifugal — R rotary — O other (describe below)
J jet — S submersible

Monitoring

PUMP INSTALLED
DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO) YES NO
IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE
TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE:
CAPACITY: GALLONS PER MINUTE (to nearest gallon)
PUMP HORSE POWER
PUMP COLUMN LENGTH (nearest ft.)
CASING HEIGHT (circle appropriate box and enter casing height)
+ above / − below — LAND SURFACE 2 (nearest foot)

LOCATION OF WELL ON LOT
SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 1GW-5 (Maryland State Permit #CE-81-3607)
Date: February 26, 1988
Observer: Dennis Papa, Hydrogeologist

Monitoring well 1GW-5 was installed approximately 100 feet northeast of the Port Deposit Reservoir as shown in Figure 2-1. Access to the location is via the service road at Gate 7 along State Route 276. The well was drilled by first advancing a 12-inch diameter hollow-stem auger flight to a depth of 4 feet to act as a temporary surface casing. Drilling then resumed with a 3-7/8-inch rotary bit advanced by the air rotary method to the top of bedrock, which was encountered at a depth of 23 feet. Split-spoon samples were collected at 5-foot intervals in the saprolite overburden. The saprolite was composed of orange, pelitic weathered gneiss with green and black schistose banding. After reaching bedrock, the borehole was reamed with a 7-5/8-inch air hammer bit and continued into bedrock to a final depth of 33 feet. Bedrock consisted of a green schist member of the Port Deposit Gneiss formation, cut sharply by a milky quartz vein beginning at a depth of 28 feet and continuing through the remainder of the borehole. The quartz vein was highly fractured and yielded a significant amount of very clear water.

The borehole was subsequently purged with air for approximately 15 minutes prior to well installation. The well was constructed with a 10-foot length of 4-inch diameter schedule 40 PVC screen with a slot size of 0.010 inches. The screen was set at a depth from 32.25 feet to 22.25 feet to monitor water-bearing zones in the upper fractured portion of the Port Deposit Gneiss. A 24.75 foot section of 4-inch diameter schedule 40 PVC well casing was installed above the screen with a stick-up length of 2.50 feet above ground surface. A gravel pack of No. 2 silica sand was then placed around the screen and was extended to approximately 3 feet above the screen. The sand pack was sealed with a 3.5 foot thick

seal formed with 1/4-inch bentonite pellets and the remaining annulus grouted by tremie pipe to the ground surface with a 5% bentonite and cement slurry. A 5-foot long, 6-inch by 6-inch square steel protector casing with a locking cap was cemented over the well casing and surrounded by a 5-foot by 5-foot square, 6-inch thick concrete pad with a steel bumper post at each corner. The well casing, protector casing and concrete pad were surveyed relative to sea level using a local USGS bench mark as an initial reference point. To facilitate identification, the well protector casing was painted international orange and labeled with a well tag bearing the Maryland State Permit Number CE-81-3607.

On March 1, 1988, the well was developed by pumping and surging with a submersible pump. Approximately 100 gallons of water was purged from the well. Development water was discharged a minimum of 25 feet downgradient from the well. In-situ measurements of pH, specific conductance, and temperature were recorded periodically. Development continued until in-situ parameters had stabilized and water clarity remained constant. Final depth to water in the well, measured on March 15, 1988, was 16.58 feet below the well casing.

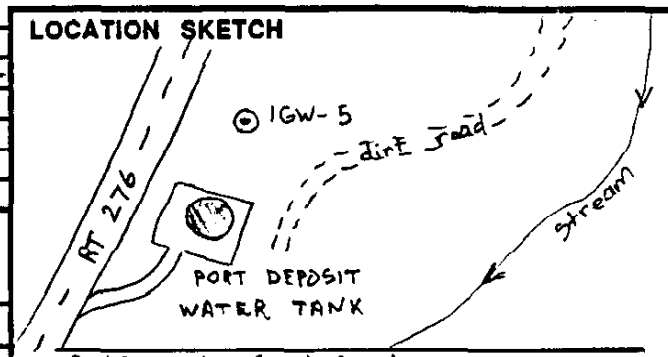
Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Bainbridge NTC
JOB NUMBER: 5065.3.6
LOCATION: southwest of landfill
WELL NUMBER: IGW-5
GROUND ELEVATION: 196.46 (pad)
DATE INSTALLED: 2-26-88
WELL CASING ELEVATION: 198.46 ' above MSL
FIELD REPRESENTATIVE: Dennis Popa
PROTECTOR CASING ELEVATION: 198.23
DRILLING CONTRACTOR: Nardin Huber
DRILLER: N. Lazaro LICENSE NO. 336
DRILLING METHOD: auger / air rotary & hammer
RIG TYPE: mobile B61
CONDITION OF GROUND SURFACE: grassy topsoil
FORMATION SCREENED: Port Deposit

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
hollow auger	8 1/4 ID	4	——
tri-cone	3 7/8 "	23'	air
hammer	7 5/8 "	4 - 33'	air

LOCATION SKETCH



Port Deposit, Cecil County, MD

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP *	BOTTOM *
protector casing	6"x6"	5'	+2.27	2.73
PVC SCH 40 casing	4	24.75	+2.50	22.25
PVC SCH 40 screen -	4	10'	22.25	32.25
0.010 slot				

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	2-26-88	1115	1625
CASING	2-26-88	1645	1650
FILTER PACK	2-26-88	1650	1655
SEAL	2-26-88	1655	1700
GROUT	2-26-88	1710	1730
DEVELOPMENT	3-1-88	1610	1645
SURVEY	3-5-88		
OTHER 1st sampling	3-16-88	1105	

GROUND WATER LEVELS

DURING DRILLING:

2-26-88 1615 - water seam at 28'
1730 - water up to 16.5' in completed well
3-15-88 1415 - 16.68' from well casing

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP *	BOTTOM *
portland cement	0	3'
bentonite + cement grout	3'	16.5'
bentonite seal	16.5'	20'
# 2 sand pack	20'	33'

WELL DEVELOPMENT

3-1-88 - Purged approx. 100 gal (well volume = 12 gal) water very clear

Final field parameters:

Temp. = 11.6°C
Conductivity = 500 umhos
pH = 6.17

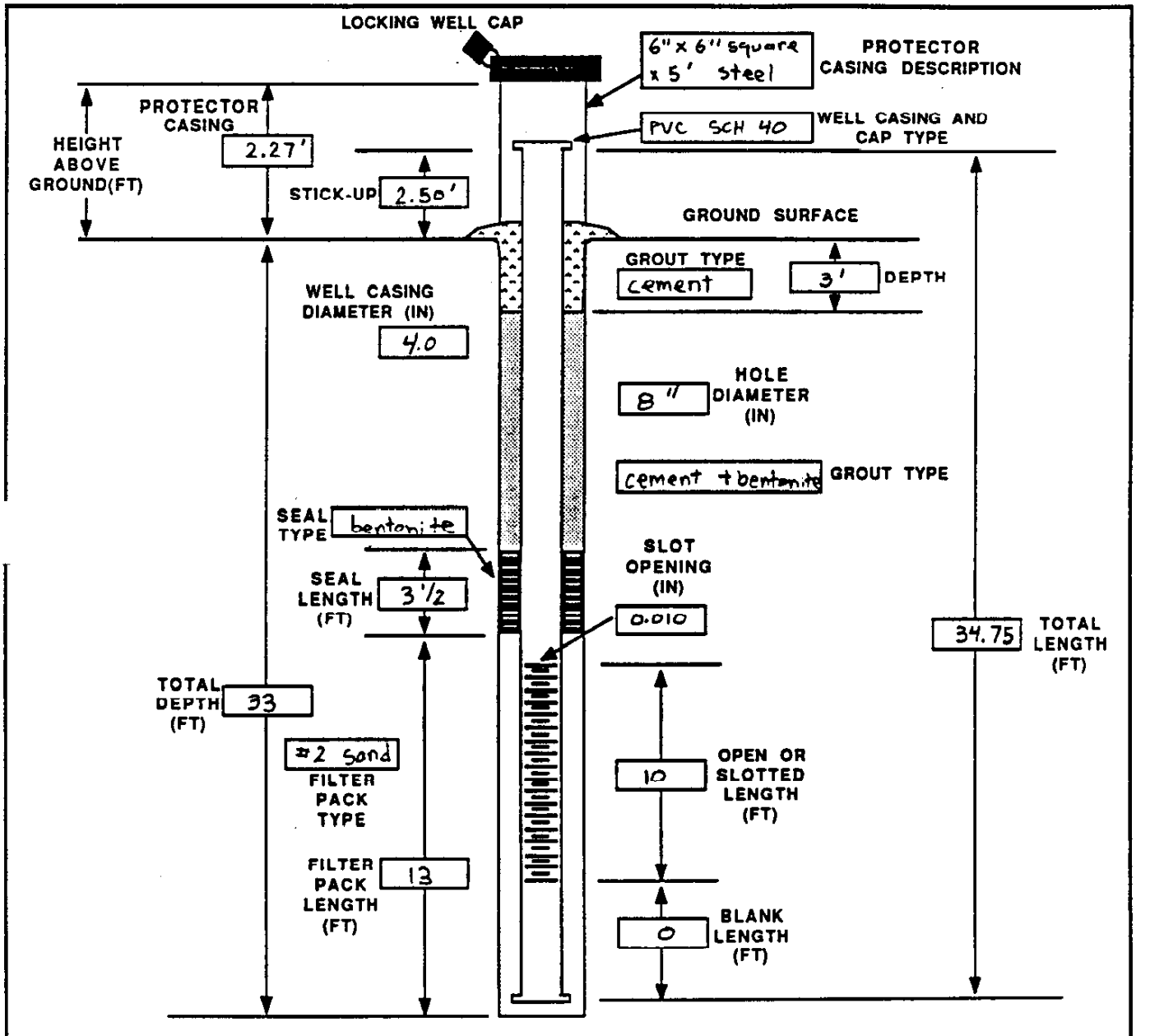
* DEPTH FROM GROUND SURFACE

COMMENTS:

Versar INC.

WELL CONSTRUCTION DIAGRAM

PROJECT: Bainbridge NTC JOB NUMBER: 5065. 3.6
LOCATION: South west of landfill
WELL NUMBER: IGW-5 ELEVATION: 198.46'
DATE INSTALLED: 2-26-88 ☐ GROUND ☒ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☒ ABOVE MEAN SEA LEVEL



COMMENTS: Large amount of very clear water encountered in fractured quartz at depth of 28 feet. Protector casing painted orange. Concrete pad is 5' x 5' square x 0.5' thick with a guard post at each corner. Maryland state permit # CE-81-3607.

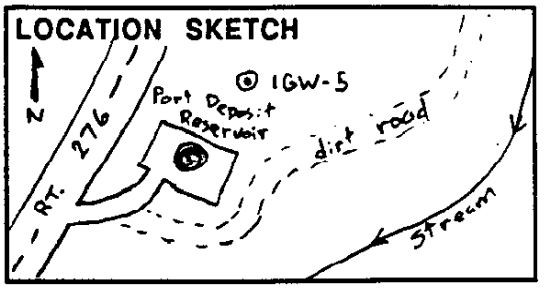
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: Bainbridge NTC
LOCATION: southwest of landfill
BOREHOLE NUMBER: IGW-5
DATE DRILLED: 2-26-88
FIELD REPRESENTATIVE: Dennis Papa
DRILLING CONTRACTOR: Hardin Huber
DRILLER: Nate Lazaro
DRILLING METHOD: auger / air rotary + hammer
HOLE DIAMETER: 7 5/8"
GROUND ELEVATION: 196.46 (pad)
CONDITION OF GROUND SURFACE: grassy topsoil

LOCATION SKETCH



COMMENTS: Port Deposit, Cecil Co., MD

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
		grab				surface soil - light brown, silty, micaceous clay; very plastic with roots, pebbles and saprolite fragments from Port Deposit.
5	1	S.S.	2.0/2.0	7 10 11 15		saprolite - dark yellowish orange, indurated, fine-grain pelitic and micaceous (biotite + muscovite) black + green (chlorite ?) banding; very dry, no odor. Hnu = 0 ppm
8	2	S.S.	2.0/2.0	7 8 14 15		saprolite - same as above, with 2 vertical fracture cavities [1-2 mm] of dusky brown staining; saprolite becoming denser
13	3	S.S.	2.0/2.0	16 28 32 51		saprolite - dense, compacted, dark yellowish orange with greenish gray schistose banding containing v. fine flakes of chlorite and mica schist - oriented vertical; dry Hnu = 0 ppm
18	4	S.S.	2.0/2.0	20 20 22 23		saprolite - same as above, with greater biotite mica content [~20%]
23	5		0/0	51/0		Top of bedrock @ 23 feet (auger refusal - no penetration with split spoon) Begin air hammer w/ 7 5/8" bit schist - greenish black schist layer of Port Deposit formation, v. fine to fine grains + flakes of mafic minerals w/ 10-15% quartz, mod. well sorted, friable, weathered; dry 5 feet thick - cut by quartz vein at 28 feet
		grab				

Dennis Papa
GEOLOGIST'S SIGNATURE

Versar INC.

GEOLOGIC LOG

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: Southwest of landfill
BOREHOLE/WELL NUMBER: 1GW-5
DATE LOGGED: 2-26-88

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
28		grab			◁	quartz - milky, amorphous, highly fractured quartz vein in sharp contact w/ overlying schist. Some mica flakes (aventurine) fractures stained with green and yellowish orange from chlorite & possibly iron. yielding significant amount of very clear water T.D. = 33 feet Monitoring well 1GW-5 screened in bedrock from 23-33 feet.

Dennis Papy
GEOLOGIST'S SIGNATURE

(OEP USE ONLY)
THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

WELL COMPLETION REPORT

FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER Test Well Bainbridge

DATE Received

DATE WELL COMPLETED 022688

Depth of Well 33 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL" CE-81-3607

OWNER Arnold (last name) Paul (first name)

T OR RFD Base Closure Force TOWN Port Deposit

VISION SECTION LOT

WELL LOG

Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
urface soil silty w/roots ebbles, saprolite ragments	0'	5'	
aprolite ery fine sand gneissic aminations ell-sorted	5'	23'	
ort Deposit neiss (Bedrock) Shistose fabric ured w/ z, mica felds par angular fragments	23'	33'	✓

CIRCLE APPROPRIATE LETTER

A A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

E ELECTRIC LOG OBTAINED

P TEST WELL CONVERTED TO PRODUCTION WELL

EREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN CORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST MY KNOWLEDGE

RILLERS IDENT. NO. 174

S SIGNATURE
(MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman sponsible for sitework if different from permittee)

GROUTING RECORD

WELL HAS BEEN GROUTED (Circle Appropriate Box) yes Y / no N

TYPE OF GROUTING MATERIAL

CEMENT CM BENTONITE CLAY BC

NO. OF BAGS NO. OF POUNDS

GALLONS OF WATER

DEPTH OF GROUT SEAL (to nearest foot)

from 0 ft. (TOP) to 17 ft. (BOTTOM)
(enter 0 if from surface)

CASING RECORD

casing types insert appropriate code below

ST STEEL CO CONCRETE
PVC PL PLASTIC OT OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
	4	22

OTHER CASING (if used)

EACH CASING	diameter inch	depth (feet) from	to

SCREEN RECORD

screen type or open hole insert appropriate code below

ST STEEL BR BRASS BRONZE HO OPEN HOLE
PVC PL PLASTIC OT OTHER

C 2

EACH SCREEN		DEPTH (nearest ft.)	
1		22	32
2			
3			

SLOT SIZE 1 0 2 0 3 1

DIAMETER OF SCREEN 4 (NEAREST INCH)

GRAVEL PACK from 20 to 33

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68

OEP USE ONLY
(NOT TO BE FILLED IN BY DRILLER)

T TELESCOPE CASING (E.R.O.S.) LOG INDICATOR W Q OTHER DATA

C 3

PUMPING TEST

HOURS PUMPED (nearest hour)

PUMPING RATE (gal. per min. to nearest gal.)

METHOD USED TO MEASURE PUMPING RATE

WATER LEVEL (distance from land surface)

BEFORE PUMPING

WHEN PUMPING

TYPE OF PUMP USED (for test)

A air P piston T turbine
C centrifugal R rotary O other (describe below)
J jet S submersible

MONITORING

PUMP INSTALLED

DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO) YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE:

CAPACITY: GALLONS PER MINUTE (to nearest gallon)

PUMP HORSE POWER

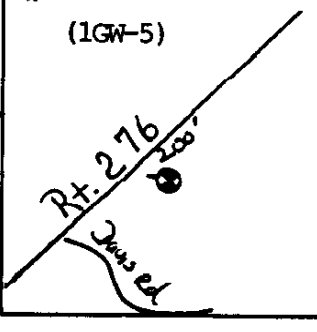
PUMP COLUMN LENGTH (nearest ft.)

CASING HEIGHT (circle appropriate box and enter casing height)
+ above
− below
LAND SURFACE 2 (nearest foot)

LOCATION OF WELL ON LOT

SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)

(1GW-5)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 2GW-1
Date: January 19 - 22, 1988
Observers: Timothy J. Baker, hydrogeologist;
Jeff Flanzenbaum, hydrogeologist

Monitoring well 2GW-1 was installed adjacent to the east corner of the concrete pad at the firefighters training area, 10 feet north of abandoned borehole 2GW-1A as shown on Figure 2-8. The well is hydraulically upgradient of the oil separator pit. The well was installed by augering to refusal on bedrock at 31 feet. Augering was accomplished using 8-inch diameter auger followed by borehole reaming with 12-inch diameter augers. No split spoon soil samples were collected, since sampling was conducted while drilling adjacent borehole 2GW-1A. A casing seat was drilled 3.26 feet into the bedrock surface using a 7-5/8" air hammer bit. Six inch I.D. PVC, schedule 40 conductor casing constructed with couplings was then installed into the bedrock and secured with a one foot bentonite seal followed by a bentonite/cement grout. After the grout set, air hammering continued into bedrock to a total depth of 42.26 feet. The bedrock yielded significant volumes of water through fracture systems while air drilling, especially at 37 feet. Additional casing or screens were not necessary since the bedrock hole from 34.26 feet to 42.26 feet remained open after drilling. A static water level of approximately 7 feet below ground was measured after installation.

Following completion, the well was developed using a 3-7/8-inch diameter stainless steel submersible pump attached to drinking-water grade polyethylene tubing. Pumping continued until development water remained clear and until pH and specific conductance stabilized. Development water was discharged a minimum distance of 25 feet topographically down slope from the well location. The well casing is protected by a 6" diameter steel locking protector casing surrounded by a 5'x5' concrete pad and four steel bumper posts. The well was subsequently surveyed relative to a U.S.G.S. bench mark and painted international orange. A State of Maryland well identification tag [permit number CE-81-3608] is affixed to the protector casing.

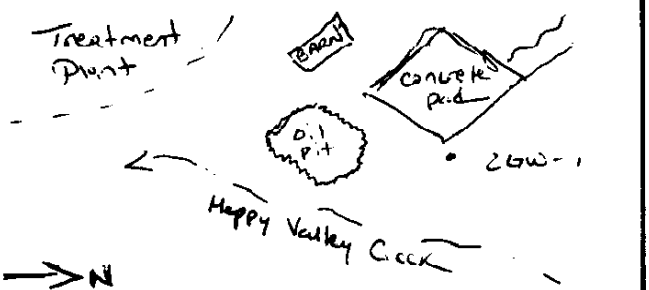
Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Brunbridge NTC
JOB NUMBER: 5065.3.6
LOCATION: Oil Separator Pit
WELL NUMBER: 2GW-1 (Background)
GROUND ELEVATION: 265.13 (PAD)
DATE INSTALLED: 1/20/88 - 1/22/88
WELL CASING ELEVATION: 266.37
FIELD REPRESENTATIVE: Baker / Franzenbaum
PROTECTOR CASING ELEVATION: 266.56
DRILLING CONTRACTOR: Hardin-Hobe Inc.
DRILLER: Nate Lazaro
LICENSE NO. MD. 336
DRILLING METHOD: Auger / Air hammer
RIG TYPE: Mobile B61
CONDITION OF GROUND SURFACE: clear (muddy)
FORMATION SCREENED: upper bedrock unit
Port Deposit Gneiss

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
Auger	8 inch	31	—
Auger	12 inch	31	—
HAMMER	7 5/8 inch	31 - 34	Air
Hammer	5 7/8 inch	34 - 42	Air

LOCATION SKETCH



2GW-1 Approx 10' North of original
2GW-1A which was grouted.

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP *	BOTTOM *
Schedule 40 PVC (WITH COUPLINGS)				
conductor casing	6"	36	+1.74	34.26
open hole (Rock)	5 7/8	8	34.26	42.26
PROTECTOR-CASING	8"	5'	+1.93	3.07

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	1/19/88	1030	1620
CASING	1/20/88	0900	1720
	1/22/88	1540	1700
FILTER PACK	1/20/88	1530	1630
SEAL	N/A	N/A	N/A
GROUT	1/20/88	1525	1530
DEVELOPMENT	1/21/88	0820	1100
SURVEY	3/1/88	1040	1103
OTHER 1ST SAMPLING	3/4/88		
PROTECTOR	3/15/88	0730	0910
	2/9/88	1530	1600

GROUND WATER LEVELS

DURING DRILLING:

- First encountered H_2O @ 14' during drilling
- After augering static water at 7'
- WATER ENCOUNTERED @ 37' WHILE AIR HAMMERING BEDROCK

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP *	BOTTOM *
Bentonite pellet seal	33	34
5% bentonite grout	2.5	33
CEMENT	0	2.5
CONCRETE APRON (5'x5')	+0.5	0.0

WELL DEVELOPMENT

WELL DEVELOPMENT WITH SUBMERSIBLE PUMP
3/1/88 PURGE A TOTAL OF 295 GALLONS

FINAL PARAMETER MEASUREMENTS:
- TEMP: 12.4°C
- COND: 105 umhos
- pH: 5.90

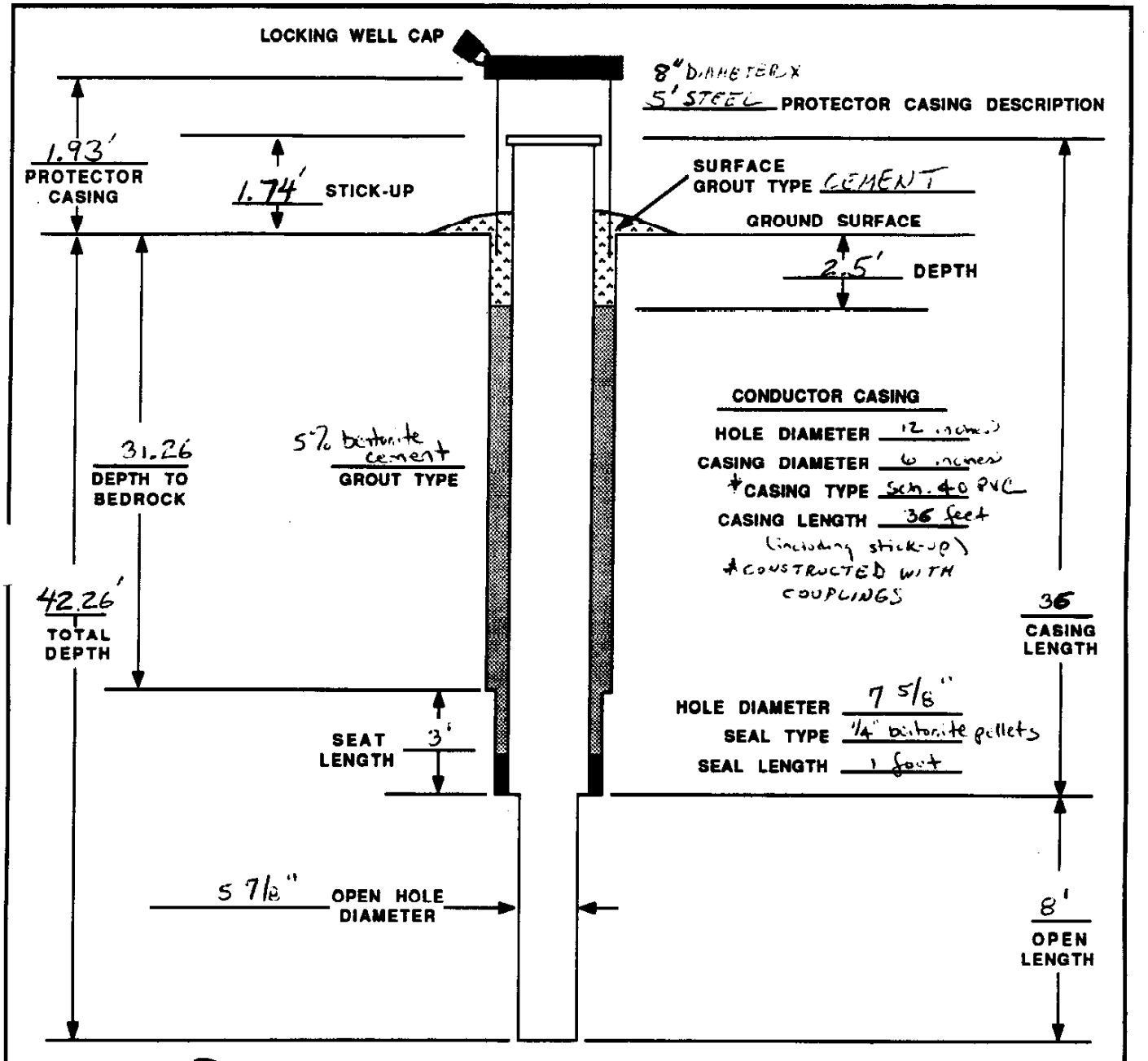
* DEPTH FROM GROUND SURFACE

COMMENTS: REPLACEMENT WELL FOR 2GW-1A, 4 GUARD POSTS INSTALLED AROUND WELL; PROTECTOR + POSTS PAINTED INTERNATIONAL ORANGE.

Versar INC.

WELL CONSTRUCTION DIAGRAM

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: Oil Separator Pit
WELL NUMBER: 29W-1 (Background well) ELEVATION: 266.37
DATE INSTALLED: 1/20/87 / 1/22/87 ☐ GROUND ☒ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☒ ABOVE MEAN SEA LEVEL



COMMENTS: Perched water encountered above bedrock, and sealed off. Drilling of open hole using air hammer technique yielded water at approximately 37 feet below grade. Bedrock hole (5 7/8") remains open after drilling. No well casing into rock set.

PAGE 2 OF 3

State of Maryland well permit No. CE-81-3608.

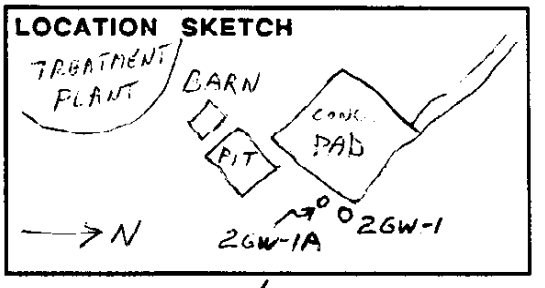
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: BAINBRIDGE NTC
LOCATION: CECIL COUNTY, MARYLAND
BOREHOLE NUMBER: 2GW-1
DATE DRILLED: 1-19-88
FIELD REPRESENTATIVE: TIM BAKER
DRILLING CONTRACTOR: HARDIN-HUBER, INC.
DRILLER: NATE LAZARO
DRILLING METHOD: AUGER, AIR HAMMER
HOLE DIAMETER: 8" OD, 12" OD, 5 7/8"
GROUND ELEVATION: (PAD) 265.13
CONDITION OF GROUND SURFACE: SOIL

LOCATION SKETCH



COMMENTS: 10' NORTH OF 2GW-1

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
						NOTE: SEE "GEOLOGIC LOG" FOR BOREHOLE 2GW-1A FOR SAMPLE DESCRIPTIONS TO 25'
30	1	SS	3"/3"	101		SAPROLITE: VERY PALE ORANGE TO GRAYISH ORANGE, VERY FINE TO MEDIUM GRAINED, POORLY SORTED, MICACEOUS, MAFIC STREAKS, WEATHERED GNEISS, DENSE, CLAYEY, SILTY, VERY DRY
						BEDROCK @ 31' BY AUGER REFUSAL
35						Fractured bedrock to 42' using air hammer drilling. Significant water zone at approximately 37'. Bedrock is Port Deposit Gneiss.
40						T.D. = 42 feet { 6" PVC to 34' / open hole (5) to 42'
45						

Timothy J. Baker
GEOLOGIST'S SIGNATURE

SEQUENCE NO. (OEP USE ONLY): 6126

(THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

STATE OF MARYLAND
WELL COMPLETION REPORT

FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER: Test Well Bainbridge

DATE Received: [ ]

DATE WELL COMPLETED: 0 1 2 2 8 8

Depth of Well: 4 2 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL": C E - 8 1 - 3 6 0 8

OWNER: ARNOLD (last name) PAUL (first name)

STREET OR RFD: Base Arnold TOWN: Port Deposit

SUBDIVISION: SECTION: LOT:

WELL LOG

Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
Surface soil dark yellowish orange silt cobbles, clay roots, fine sand	0'	12'	
Saprolite silty gneissic laminations, pale yellowish orange, micaceous w/mafics well sorted	12'	31'	✓
Port Deposit (Bedrock) pale orange fractured clasts fine-grained granitic gneissic laminations, quartz mafics, mica felds par	31'	42'	✓

CIRCLE APPROPRIATE LETTER

A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

E ELECTRIC LOG OBTAINED

T TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 174

DRILLERS SIGNATURE (MUST MATCH SIGNATURE ON APPLICATION)

TITLE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

GROUTING RECORD

WELL HAS BEEN GROUTED (Circle Appropriate Box): yes Y / no N

TYPE OF GROUTING MATERIAL

CEMENT CM BENTONITE CLAY BC

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER ____

DEPTH OF GROUT SEAL (to nearest foot)

from 0 ft. (TOP) to 3 4 ft. (BOTTOM) (enter 0 if from surface)

CASING RECORD

casing types insert appropriate code below

ST STEEL CO CONCRETE PVC PL PLASTIC OT OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
	6	3 4

OTHER CASING (if used)

EACH CASING	diameter inch	depth (feet) from	to
1			
2			

SCREEN RECORD

screen type or open hole insert appropriate code below

ST STEEL BR BRASS BRONZE HO OPEN HOLE PL PLASTIC OT OTHER

C 2

EACH SCREEN		DEPTH (nearest ft.)	
1		3 4	4 2
2			
3			

SLOT SIZE 1 ____ 2 ____ 3 ____

DIAMETER OF SCREEN ____ (NEAREST INCH)

GRAVEL PACK from ____ to ____

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68

OEP USE ONLY (NOT TO BE FILLED IN BY DRILLER)

T: TELESCOPE CASING

(E.R.O.S.): LOG INDICATOR

W Q: OTHER DATA

C 3

PUMPING TEST

HOURS PUMPED (nearest hour)

PUMPING RATE (gal. per min. to nearest gal.)

METHOD USED TO MEASURE PUMPING RATE

WATER LEVEL (distance from land surface)

BEFORE PUMPING

WHEN PUMPING

TYPE OF PUMP USED (for test)

A air, P piston, T turbine, C centrifugal, R rotary, O other (describe below), J jet, S submersible

Monitoring

PUMP INSTALLED

DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO): YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE:

CAPACITY: GALLONS PER MINUTE (to nearest gallon)

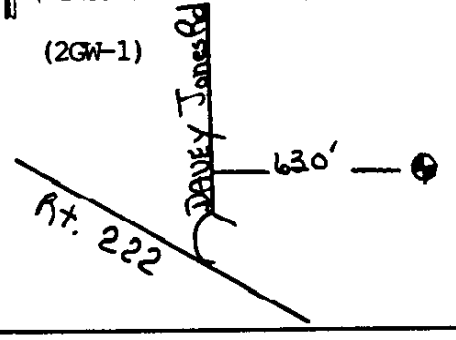
PUMP HORSE POWER

PUMP COLUMN LENGTH (nearest ft.)

CASING HEIGHT (circle appropriate box and enter casing height): + above / − below LAND SURFACE 2 (nearest foot)

LOCATION OF WELL ON LOT

SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 2GW-1A (Grouted)
Date: January 15 - 18, 1988
Observer: Timothy J. Baker, hydrogeologist

Borehole 2GW-1A was positioned adjacent to the east corner of the concrete pad at the fire training area as shown on Figure 2-8. Six split spoon samples were obtained at five foot intervals while augering. Saturated sediments were encountered while drilling at 14 feet below surface. This represents a perched water zone above the saprolite which was encountered at 15 feet. The saprolite zone was dense and very dry. This borehole was intended to serve as the upgradient monitoring well for the site. However, the 7" OD hollow-stem auger broke while drilling at a depth of 26.5 feet. Approximately 10 feet of augers remained in the bottom of the borehole and were not returnable. As a result, it was necessary to plug the borehole with a bentonite/cement slurry.

This was the first borehole drilled during the well installation operations at NTC. As a result of the auger string failure while drilling this borehole, the drilling contractor decided to utilize a heavier, 8" OD auger string for all subsequently drilled wells. No other auger string failures occurred during the well installation program.

A replacement well, 2GW-1, was installed approximately 10 feet north (upgradient) of the abandoned borehole to serve as the upgradient sampling point for the oil separator pit site. The well was completed in the bedrock aquifer using an open hole completion (see well completion records for 2GW-1).

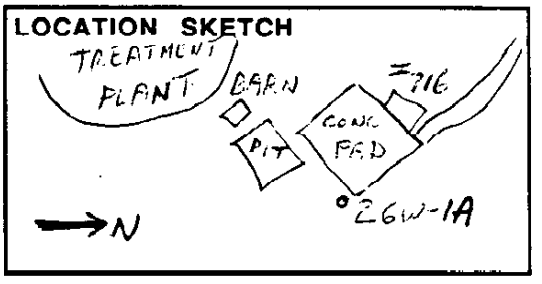
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: BAINBRIDGE NTC
LOCATION: CECIL COUNTY, MARYLAND
BOREHOLE NUMBER: 26W-1A
DATE DRILLED: 1-15-88, 1-19-88
FIELD REPRESENTATIVE: BAKER, FLANZENBAUM
DRILLING CONTRACTOR: HARDING-HUBER, INC.
DRILLER: NATE LAZARO
DRILLING METHOD: HOLLOW STEM AUGER
HOLE DIAMETER: 7" OD / 3½" ID
GROUND ELEVATION: 265'
CONDITION OF GROUND SURFACE: SOIL + SNOW

LOCATION SKETCH



COMMENTS: UPGRADIENT WELL

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
	1	SURFACE				SILT: DARK YELLOWISH ORANGE, ORGANIC RICH, SOME COBBLES, CLAY, ROOTS, HOMOGENEOUS, DRY
5	2	SS	2'/1.75'	5 10 8 9	▽	SILT: MODERATE YELLOWISH BROWN, CLAY, SOME PEBBLES, BECOMING COARSER W/SOME FINE SAND, DRY (WATER LEVEL MEASUREMENT TAKEN IN AUGERS WHILE AT TOTAL DEPTH - 7' BELOW GROUND LEVEL)
10	3	SS	2'/1.75'	7 4 7 7		SILT: MODERATE YELLOWISH BROWN, SOME CLAY AND PEBBLES, INCREASING SAND CONTENT (FINE), DRY
					▽	(WATER ENCOUNTERED WHILE DRILLING)
15	4	SS	2'/1'	7 11 17 22		SAPROLITE: WEATHERED, SATURATED, SILTY, GNEISSIC LAMINATIONS, CLAY, MICACEOUS, MAFIC MINERALS SM. FINE-MEDIUM SAND, MODERATELY SORTED, SUBANGULAR Hmw (OPEN AUGERS) ≈ 2PPM
20	5	SS	2'/1.5'	30 14 23 32		SAPROLITE: PALE YELLOWISH ORANGE, WEATHERED, GNEISSIC LAYERING, MICACEOUS, SILTY, CLAYEY, MAFIC STREAKS, MEDIUM GRAINED, MODERATELY SORTED, BEDROCK TEXTURE
25	6	SS	5'/.5'	101		SAPROLITE: PALE YELLOWISH BROWN, FINE-MEDIUM GRAINED, WEATHERED GNEISS AS ABOVE, BECOMING MORE COMPETENT, DENSE, VERY DRY
						T.D. @ 26.5' ABANDON DUE TO 10' OF BROKEN AUGERS IN HOLE, PLUG HOLE WITH BENTONITE/CEMENT GROUT

OVA = 0.0ppm

SS ≈ INDICATES SPLIT SPOON SAMPLE

Timothy J. Baker
GEOLOGIST'S SIGNATURE

PAGE 1 OF 1

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 2GW-2
Date: January 25, 1988; February 17, 23 - 24, 1988
Observers: Timothy J. Baker, Hydrogeologist;
Jeff Flanzenbaum, Hydrogeologist

Monitoring well 2GW-2 was installed about 50 feet east of the oil separator pit as shown on Figure 2-8. The well was drilled using hollow stem augers until refusal occurred in saprolite at 19.36 feet. Split spoon samples of soils were collected at five foot intervals until auger refusal. Saturated soils were encountered at 5.5 feet. This indicates the presence of a perched water table above the saprolite contact, encountered at 6 feet. The saprolite appeared to be moist but was not saturated. Following the use of 8-inch diameter augers to refusal, the borehole was further reamed using 12-inch diameter augers. The borehole was advanced into bedrock to a depth of 22.5 feet using the air hammer method with a 7-5/8-inch diameter bit. Competent bedrock was first encountered at 21.5 feet. Six inch stainless steel type 304 casing was then installed to 22.36 feet with a one foot bentonite seal followed by a bentonite/cement slurry for the remaining annulus. Stainless steel casing was utilized because of the possible presence of organic contaminants in soil or ground-water that may degrade PVC or other types of casing material. After allowing the grout to set, air hammering continued through the conductor casing into competent bedrock to a total depth of 27.36 feet using a 5-7/8-inch diameter hammer bit. Significant volumes of water were encountered while air hammering in bedrock especially through a fracture located at 23.5 feet. The bedrock hole from 22.36 feet to 27.36 feet remained open and additional casing and screening was not necessary.

Following completion, the well was developed using a 3-7/8-inch diameter stainless steel submersible pump attached to drinking-water grade polyethylene tubing. Pumping continued until development water remained clear and until pH and specific conductance stabilized. Development water was discharged a minimum distance of 25 feet topographically down slope

from the well location. A locking protector casing was installed, surrounded by a 5'x5' concrete pad and four steel bumper posts. The well was subsequently surveyed relative to a U.S.G.S. bench mark and painted international orange. A State of Maryland identification tag [permit number CE-81-36] is affixed to the protector casing.

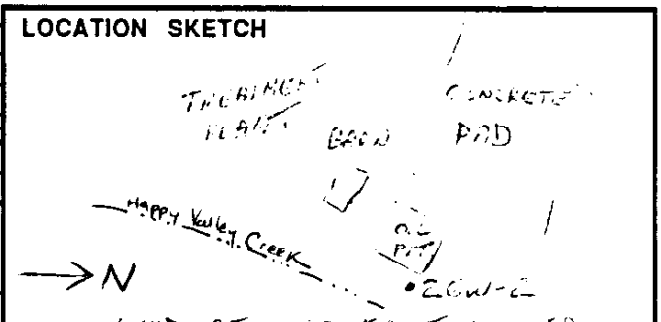
Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: BA VBRIDGE NTC
JOB NUMBER: 5065.3.6
LOCATION: OIL SEPARATOR PIT
WELL NUMBER: 2GW-2
GROUND ELEVATION: (PAD) 249.76
DATE INSTALLED: 2/23, 2/24/88
WELL CASING ELEVATION: 251.90
FIELD REPRESENTATIVE: FLANZENBAUM, BAKER
PROTECTOR CASING ELEVATION: 252.28
DRILLING CONTRACTOR: HARDIN HOBER, INC.
DRILLER: TAYLOR, LAZARO LICENSE NO. MO. 336
DRILLING METHOD: AUGER, AIR HAMMER
RIG TYPE: MOBILE C61
CONDITION OF GROUND SURFACE: MUDDY, CLEARED
FORMATION SCREENED: BEDROCK - PORT DEPOSIT GNEISS

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
AUGER	8'	17.5	—
AUGER	12"	19.5	—
HAMMER	5 7/8	22.5	A.R.
HAMMER	5 7/8	27.5	A.R.

LOCATION SKETCH



LOCATED AT NORTHEAST CORNER OF OIL PIT

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP *	BOTTOM *
PROTECTOR CASING	8	5'	+3.02	1.98
STAINLESS STEEL	6" ID	25'	+2.64	22.36
CASING (TYPE 304)				
OPEN HOLE	5 7/8"	5'	22.36	27.36

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	1/25/88	1140	1415
	2/16/88	1300	1430
CASING	2/17/88	0800	1200
	2/24/88	1600	1145
FILTER PACK	2/23/88	1300	1310
SEAL	2/23/88	1255	1300
GROUT	2/23/88	1330	1515
DEVELOPMENT	2/29/88	1650	1744
SURVEY	3/4/88		
OTHER 1ST SAMPLING	3/15/88	1255	—
PROTECTOR	2/24/88	1345	1400

GROUND WATER LEVELS

DURING DRILLING:
PERCHED WATER ENCOUNTERED @ 5.5'
3/10/88 : 9.27' BELOW WELL CASING
3/15/88 : 9.17' BELOW WELL CASING

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP *	BOTTOM *
PORTLAND CEMENT	0'	2.5'
BENTONITE/CEMENT GROUT	2.5'	21.5
SEAL - 1/2 BENTONITE PELLETS	21.5'	22.5'
CONCRETE APRON (5'x5')	+0.5'	0.0

WELL DEVELOPMENT

WELL DEVELOPMENT WITH SUBMERSIBLE PUMP
PURGED APPROXIMATELY 608 GALLONS
WELL DRY AFTER 528 GALLONS; ALLOWED TO RECOVER
FINAL IN-SITU PARAMETER MEASUREMENTS
TEMP: 11.6°C
SPEC. COND: 155 umhos
pH : 5.82

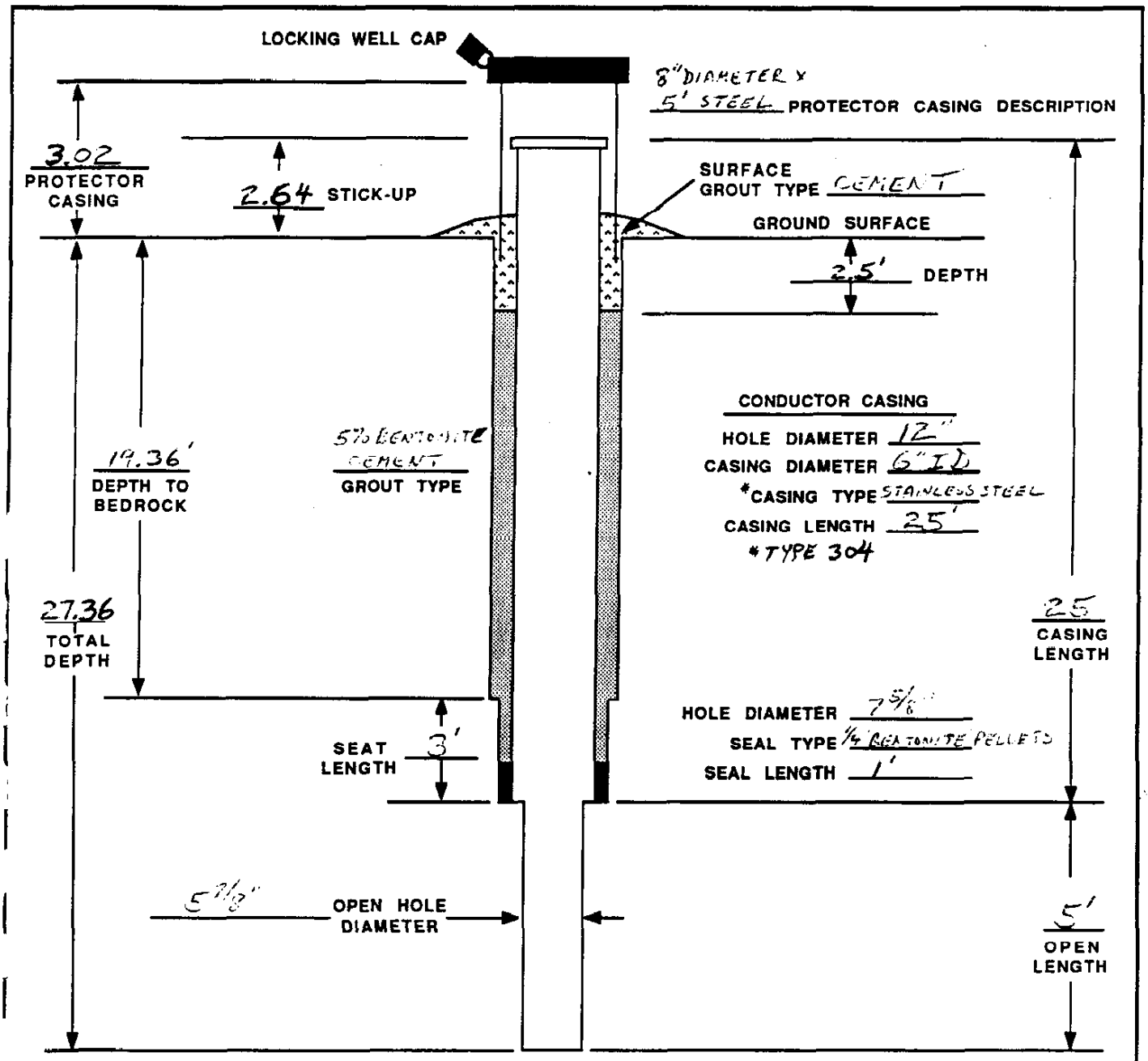
* DEPTH FROM GROUND SURFACE

COMMENTS: 4 GUARD POSTS INSTALLED AROUND PROTECTOR CASING.
PROTECTOR CASING AND GUARD POSTS PAINTED INTERNATIONAL ORANGE

Versar INC.

WELL CONSTRUCTION DIAGRAM

PROJECT: BAINBRIDGE JOB NUMBER: 5065.3.6
CATION: OIL SEPARATOR PIT
LL NUMBER: 26W-2 ELEVATION: 251.90
DATE INSTALLED: 2/22, 2/24/88 ☐ GROUND ☒ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☒ ABOVE MEAN SEA LEVEL



COMMENTS: PERCHED WATER ZONE ENCOUNTERED AT 5.5' AND SEALED OFF. WELL COMPLETION BY OPEN HOLE TECHNIQUE IN BEDROCK FROM 22.5' TO 27.5'. SIGNIFICANT AMOUNT OF CLEAN WATER WAS PRODUCED THROUGH FRACTURES, ESPECIALLY AT 23.5'.

State of Maryland Well Permit No. CE-81-3609 PAGE 2 OF 3

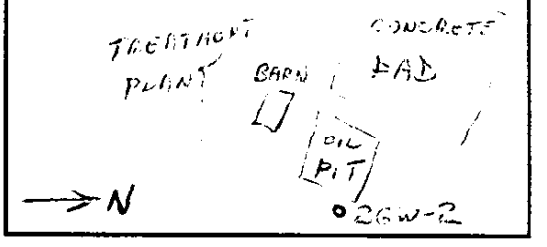
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: BAINBRIDGE NTC
LOCATION: OIL SEPARATOR PIT
BOREHOLE NUMBER: 2GW-2
DATE DRILLED: 1/25/88, 2/17/88, 2/24/88
FIELD REPRESENTATIVE: FLANZENBAUM, BAKER
DRILLING CONTRACTOR: HARDIN-HUBER INC.
DRILLER: DAVE TAYLOR, NATE LAZARO
DRILLING METHOD: AUGER, AIR HAMMER
HOLE DIAMETER: 12" OD 5 7/8"
GROUND ELEVATION: (PAD) 249.76
CONDITION OF GROUND SURFACE: MUDDY, CLEARED

LOCATION SKETCH



COMMENTS:

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
	1	SURFACE GRAB				SAND: MODERATE BROWN, VERY FINE, SOME COARSE, SUBROUNDED, MOD. WELL SORTED, SOME SILT + PEBBLES, COHESIVE, MOIST, NO ODOR, ORGANIC STAINING, PLASTIC, ROOTS, HOMOGENEOUS. GRAVEL ENCOUNTERED AT 2' (FLUVIAL)
5	2	SS	2'/1.75'	5 6 17 20	▽	SAND: DARK YELLOWISH BROWN, VERY FINE, INCREASING MAFIC FRACTION, ORGANIC STAINING, ROOTS, SUBANGULAR, POORLY SORTED, SOME COARSE SAND, PEBBLES, SILT, NO ODOR, MOIST. SAPROLITE CONTACT @ 6': WEATHERED BEDROCK, YELLOWISH GRAY, INDURATED, VERY FINE SAND/SILT MATRIX, SM. COARSE SAND, PEBBLES, MOSTLY QUARTZ, GNEISSIC LAMINATIONS, MICACEOUS, POORLY SORTED, SUBANGULAR, DRY. PERCHED WATER ZONE ENCOUNTERED ABOVE SAPROLITE
10	3	SS	2'/1.75'	5 17 21 15		SAPROLITE: WEATHERED BEDROCK, GREENISH GRAY, MOSTLY QUARTZ, VERY FINE SAND, SOME FINE SAND AND SILT, SUBROUNDED, WELL SORTED, GNEISSIC LAMINATIONS, MAFIC MINERALS, MOIST, NO ODOR, POORLY COHESIVE
15	4	SS	1.5'/1.2'	37 67 75		SAPROLITE: AS ABOVE, MORE INDURATED
20						AUGER REFUSAL AT 19.5' IN SAPROLITE. AIR HAMMER (7 5/8" BIT) TO 22.5', SET 6" ID STAINLESS STEEL CASING @ 22.5'. FRACTURED SAPROLITE ENCOUNTERED FROM 19.5'-21.5'. SOLID BEDROCK FROM 21.5'-22.5', MAJOR WATER SEAM AT 21.0'
25						AIR HAMMER (5 7/8" BIT) FROM 22.5' TO 27.5' - OPEN HOLE. FRACTURED BEDROCK ≈ PORT DEPOSIT GNEISS. ENCOUNTER LARGE FRACTURE @ 23.5': WELL PRODUCING SIGNIFICANT AMOUNTS OF CLEAN, CLEAR WATER. T.D. ≈ 27.5'

SS ≈ INDICATES SPLIT SPOON SAMPLE

Flanzenbaum / Timothy J. Baker
GEOLOGIST'S SIGNATURE

(OEP USE ONLY)
THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

WELL COMPLETION REPORT

FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER Test Well Bainbridge

DATE Received

DATE WELL COMPLETED 022488

Depth of Well 28 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL" CE-81-3609

OWNER Arnold Paul (last name, first name)

STREET OR RFD Base Closure Force TOWN Port Deposit

SUBDIVISION SECTION LOT

WELL LOG

Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
Surface soil moderate brown very fine sand well-sorted	0'	6'	
Saprolite yellowish grey very fine sand gneissic laminations micaceous	6'	19.5'	✓
Fractured bedrock Port Deposit Gneiss	19.5'	21.5'	✓
Port Deposit Gneiss (solid bedrock) angular clasts gneissic laminations quartz, mafics, mica felds par	21.5'	27.5'	✓

GROUTING RECORD

WELL HAS BEEN GROUTED (Circle Appropriate Box) yes Y 44 no N 44

TYPE OF GROUTING MATERIAL

CEMENT CM 45 46 BENTONITE CLAY BC 45 46

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER ____

DEPTH OF GROUT SEAL (to nearest foot)

from 0 ft. (TOP 48–52) to 23 ft. (BOTTOM 54–58)

(enter 0 if from surface)

CASING RECORD

casing types insert appropriate code below

Stainless ST STEEL CO CONCRETE PL PLASTIC OT OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
	6	23

OTHER CASING (if used)

EACH CASING	diameter inch	depth (feet) from	to

SCREEN RECORD

screen type or open hole insert appropriate code below

ST STEEL BR BRASS BRONZE HO OPEN HOLE PL PLASTIC OT OTHER

C2

EACH SCREEN		DEPTH (nearest ft.)	
1		23	28
2			
3			

SLOT SIZE 1____ 2____ 3____

DIAMETER OF SCREEN ____ (NEAREST INCH)

GRAVEL PACK from ____ to ____

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68

C3

PUMPING TEST

HOURS PUMPED (nearest hour)

PUMPING RATE (gal. per min. to nearest gal.)

METHOD USED TO MEASURE PUMPING RATE

WATER LEVEL (distance from land surface)

BEFORE PUMPING

WHEN PUMPING

TYPE OF PUMP USED (for test)

A air, P piston, T turbine, C centrifugal, R rotary, O other (describe below), J jet, S submersible

Monitoring

PUMP INSTALLED

DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO) YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE:

CAPACITY: GALLONS PER MINUTE (to nearest gallon)

PUMP HORSE POWER

PUMP COLUMN LENGTH (nearest ft.)

CASING HEIGHT (circle appropriate box and enter casing height) + above / − below LAND SURFACE 2 (nearest foot)

CIRCLE APPROPRIATE LETTER

A A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

E ELECTRIC LOG OBTAINED

P TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 174

DRILLER SIGNATURE (MUST MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

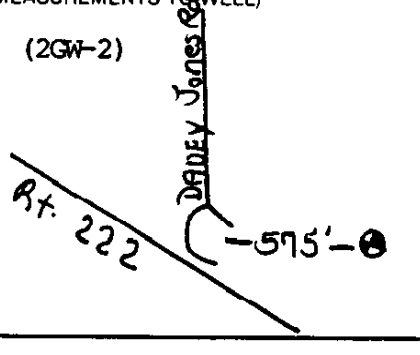
OEP USE ONLY (NOT TO BE FILLED IN BY DRILLER)

T (E.R.O.S.) W Q

TELESCOPE CASING LOG INDICATOR OTHER DATA

LOCATION OF WELL ON LOT

SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 2GW-3
Date: January 27, 1988; February 1 and 11, 1988
Observers: Jeff Flanzenbaum, hydrogeologist

Monitoring well 2GW-3 was installed approximately 25 feet from the west berm of the oil separator pit adjacent to the red storage barn (Building 53) on the Bainbridge NTC property (Figure 2-8). The well was drilled using hollow-stem augers (8-inch diameter followed by 12-inch diameter) until refusal occurred at 21 feet below grade. Split-spoon samples were collected at five foot intervals until auger refusal. Saturated soils were encountered at approximately 9 feet during augering and appeared to be perched on the low permeability saprolite. Silty fine sands (saprolite) with gneissic laminations were encountered until auger refusal at 21 feet. Pneumatic hammer drilling with a 7-5/8-inch hammer bit proceeded through the 12-inch diameter augers to 30 feet below grade. Competent bedrock was not encountered at 2GW-3. From 21 feet to 30 feet below grade, pebbles, gravels, and cobbles of what appeared to be fluvial origin were encountered. These sediments were saturated and yielded substantial quantities of water during hammer drilling.

Versar decided to screen this well in the gravel and cobble zone from approximately 17.4 to 27.4 feet below grade. Since the water emanating from the borehole during hammer drilling contained an oily bifrefringence and a slight petroleum odor was noted at the borehole, a four-inch diameter stainless steel well was installed at this location.

A possible hypothesis for this scenario where fluvial gravels are found beneath a saprolite zone is that the site of 2GW-3 represents a cut-bank deposit. That is, a stream at one time cut through the saprolite and in some locations actually undercut some of the saprolite along the stream. In this manner, as the stream migrated, deposition of fluvial sediments would have occurred beneath the cut bank of the saprolite. This

hypothesis is plausible since aerial photographs of the site from 1937, 1949, and 1952 show a surface drainage along the eastern side of the barn. Alternative hypothesis include the presence of "float" rock above fluvial sediments that has weathered in place, or sediment filled fractures at the well site.

The 4-inch diameter screened stainless steel well at 2GW-3 was completed with number 2 sand to approximately two feet above the screen, followed by a two-foot bentonite pellet seal and a bentonite/cement slurry that was tremied into the annulus to 3 feet below the ground surface. A 6-inch diameter protector casing was subsequently cemented into the remaining annulus.

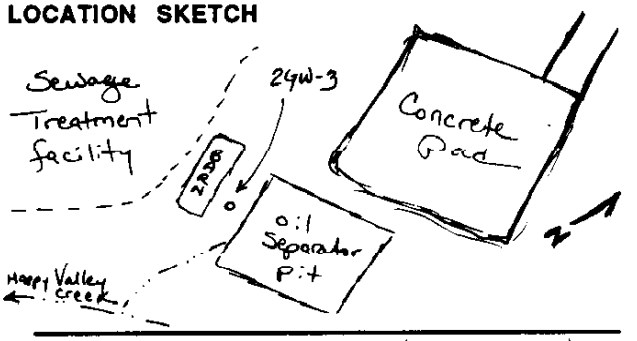
Following completion, the well was developed using a 3-7/8-inch diameter submersible pump attached to drinking-water grade polyethylene tubing. Pumping continued until development water remained clear and until pH and specific conductance stabilized. Development water was discharged a minimum distance of 25 feet topographically down slope from the well location. A locking protector casing was installed surrounded by a 5'x5' concrete pad and four steel bumper posts. The well was subsequently surveyed relative to a U.S.C.S. bench mark and painted international orange. A State of Maryland identification tag [permit number CE-81-3610] is affixed to the protector casing.

Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Bainbridge NTC
JOB NUMBER: 5065.36
LOCATION: Oil Separator Pit
WELL NUMBER: 2GW-3
GROUND ELEVATION: (pad) 254.77
DATE INSTALLED: 2-11-88
WELL CASING ELEVATION: 257.05
FIELD REPRESENTATIVE: J. Flanzenbaum
PROTECTOR CASING ELEVATION: 257.02
DRILLING CONTRACTOR: Hardin / Huber
DRILLER: Nate Lazaro LICENSE NO. 336 (MD)
DRILLING METHOD: Hollow Stem Auger / Air Hammer
RIG TYPE: Mobile B61
CONDITION OF GROUND SURFACE: Mud
FORMATION SCREENED: saprolitic / gravels (fluvial?)

LOCATION SKETCH



City of Port Deposit, Cecil County, Maryland

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
Auger	8"	21	—
Auger	12"	19.5	—
Hammer	7 5/8"	30	Air

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	1/27	1100	1645
	2/11	1115	1200
CASING	2/11	1100	1145
	2/11	1330	1400
FILTER PACK	2/11	1400	1500
SEAL	2/11	1500	1530
GROUT	2/11	1530	1700
DEVELOPMENT	3/1	0800	1010
SURVEY	3/4	—	—
OTHER 1st Sampling	3/15	1040	1135

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP *	BOTTOM *
Sched. 40 Type 304 Stainless steel Riser	4"	20.15	+2.78	-17.37
Sched. 40 Type 304 Stainless steel (0.010 slotted) Screen	4"	10.0	-17.37	-27.37
Sched 40 Type 304 Stainless bottom cap	4"	0.5	-27.37	-27.87
Protector (steel)	6" x 6"	5'	+2	-3

GROUND WATER LEVELS

DURING DRILLING:

1/27/88 : 9' below ground surface

3/15/88 : 10.17 feet below well casing

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP *	BOTTOM *
#2 sand pack	-16	-30
Bentonite Pellet (1/4") seal	-14.3	-16
5% bentonite cement grout	-3	-14.3
Portland Cement Grout (Type 1)	0'	-3
Concrete Apron (5' x 5')	+0.5'	0'

WELL DEVELOPMENT

well development with submersible pump
Approx 152 gallons pumped from 2GW-3

Final in-situ parameter measurements:
Temp: 11.4°C
pH: 6.13
Spec. Cond = 120 µmhos

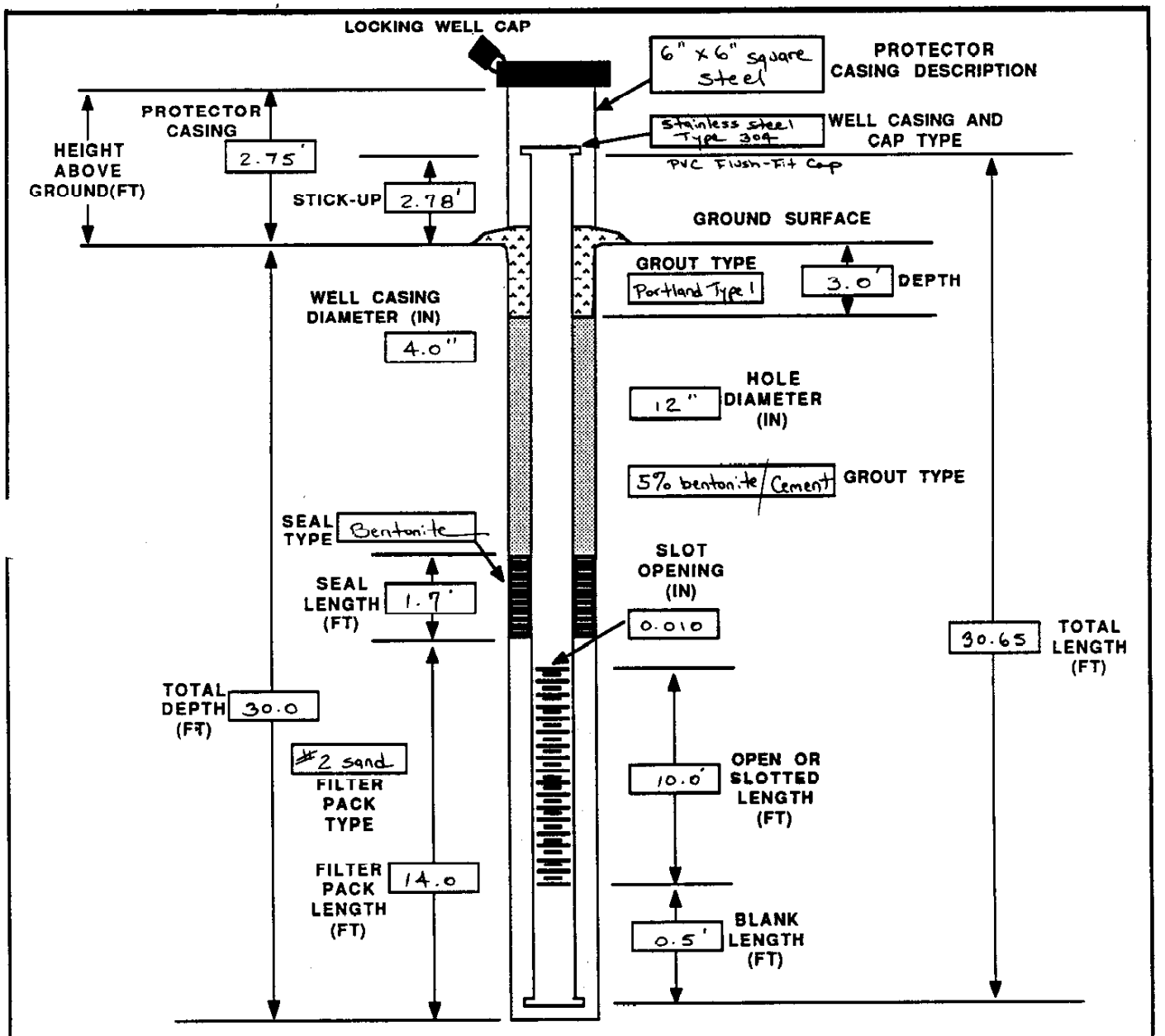
* DEPTH FROM GROUND SURFACE

COMMENTS: 4 guard posts installed around protector casing
Protector casing and guard posts painted international orange.

Versar INC.

WELL CONSTRUCTION DIAGRAM

OJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
CATION: Oil Separator Pit
WELL NUMBER: 26W-3 ELEVATION: 257.05
DATE INSTALLED: 2-11-88 ☐ GROUND ☑ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☑ ABOVE MEAN SEA LEVEL



COMMENTS: 4" stainless steel Type 304 (Johnson Environmental). Well adjacent to wooden barn (circa 1890). Well protector casing painted international orange and surrounded by 4 protector pipes. Maryland state permit #: CE-81-3610. [Concrete pad thickness = 0.5 feet]

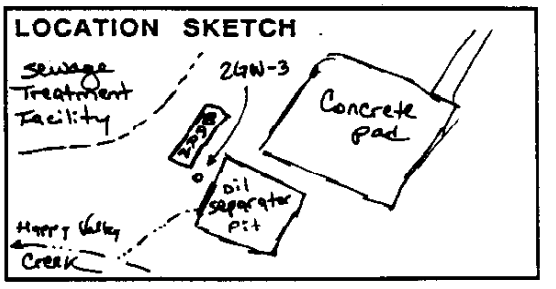
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: Bainbridge NTC
LOCATION: Oil Separator Pit
BOREHOLE NUMBER: 2GW-3
DATE DRILLED: 1/27/88; 2/1/88; 2/11/88
FIELD REPRESENTATIVE: J. Flanzenbaum
DRILLING CONTRACTOR: Hardin/Huber Inc
DRILLER: Nate Lazaro
DRILLING METHOD: Hollow Stem Auger/Air Hammer
HOLE DIAMETER: 7 5/8" — 12"
GROUND ELEVATION: (Pad) 254.77
CONDITION OF GROUND SURFACE: sloping/muddy

LOCATION SKETCH



COMMENTS: Port Deposit, Cecil Co., Md.

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)	
		Grab				moderate yellowish brown silt w/ some fine sand and clay. Roots and organic staining, mostly quartz w/ and mica. Subangular, poorly sorted, moist, cohesive No odor.	HNu = 0 ppm
5	1	SS	2'/2'	5 6 6 9		Dark yellowish orange fine sand, subrounded, moderately well sorted, cohesive, moist, with some silt and clay. Organic staining, mostly quartz, no odor	HNu = 2 ppm (borehole)
					▽	perched (?) H_2O on saprolite	
10	2	SS	0.5'/0.5'	41 52/0"		light brownish grey fine sand, with some medium & coarse sand, pebbles, poorly sorted, subrounded, mostly quartz, some mafics and mica, indurated and dry. Contact of weathered saprolite of the Port Deposit Gneiss. Slight petroleum odor around borehole	HNu = 5 ppm (borehole)
15	3	SS	0.7'/0.7'	21 51/2"		Yellowish grey silty fine sand (saprolite), gneissic laminations mostly quartz with some mafics and 10-15% mica. some coarse sand and very fine sand and pebbles, friable, moderately well-sorted, indurated, subrounded grains, dry. Slight petroleum odor around borehole.	HNu = 2 ppm (borehole)
20	4	SS	0.5'/0.5'	37 51/0"		Same as above. Highly indurated and friable saprolite of the Port Deposit Gneiss. Gneissic laminations. Some light greenish-grey cobbles (1" diameter) of gneiss and quartz. Cobbles are subrounded (fluvial?). Slight petroleum odor in borehole area. (Auger refusal @ 21')	HNu = 2 ppm
25		Grab				Mostly cobbles and pebbles, subrounded (fluvial?) of quartz and Port Deposit Gneiss. Some fine sand variable color, some iron staining. wet. slight petroleum odor	

Jeffrey Flanzenbaum
GEOLOGIST'S SIGNATURE

Versar INC.

GEOLOGIC LOG

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: Oil Separator Pit
BOREHOLE/WELL NUMBER: 2GW-3
DATE LOGGED: 1/27/88; 2/1/88; 2/11/88

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
25						
		Grab				still cobbles and pebbles, rounded, (appears fluvial?) mostly quartz and gneiss, some iron-stained pebbles, poorly sorted, some fine grained sand (saprolite). Slight petroleum odor. HNu = 0ppm
30						saturated.
						--- T.D. @ 31' b.l.s. Competent bedrock of the Port Deposit Gneiss not encountered.
						★ Monitoring well 2GW-3 screened in gravel zone 28' bls — 18' bls. Stainless steel Type 304 construction.

Need a hole down near Barn that accomplishes this!

Jeffrey Sharpenberg
GEOLOGIST'S SIGNATURE

(OEP USE ONLY)

THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

WELL COMPLETION REPORT

FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER: Test Well Bainbridge

DATE Received:

DATE WELL COMPLETED: 02 11 88

Depth of Well: 30 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL": CE-81-3610

OWNER: Arnold (last name) Paul (first name)

STREET OR RFD: Base Closure Force TOWN: Port Deposit

SUBDIVISION: SECTION: LOT:

WELL LOG

Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
Surface soil fine sand dark yellowish orange w/silt, clay	0'	10'	
Saprolite Gneissic laminations well-sorted, very fine grained silty sand yellowish gray	10'	21'	✓
Fine to coarse and gravel subrounded gneiss, quartz granite fragments	21'	30'	✓

CIRCLE APPROPRIATE LETTER
A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

E ELECTRIC LOG OBTAINED

D TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 174

SIGNATURE
(MUST MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

GROUTING RECORD

WELL HAS BEEN GROUTED (Circle Appropriate Box): yes Y / no N

TYPE OF GROUTING MATERIAL

CEMENT CM BENTONITE CLAY BC

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER ____

DEPTH OF GROUT SEAL (to nearest foot)

from 0 ft. (TOP) to 16 ft. (BOTTOM)
(enter 0 if from surface)

CASING RECORD

casing types insert appropriate code below

Stainless ST STEEL CO CONCRETE PL PLASTIC OT OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
ST	4	17

OTHER CASING (if used)

EACH CASING	diameter inch	depth (feet) from	to

SCREEN RECORD

screen type or open hole insert appropriate code below

ST STEEL BR BRASS BRONZE HO OPEN HOLE Stainless PL PLASTIC OT OTHER

C2

EACH SCREEN		DEPTH (nearest ft.)	
1	ST	17	27
2			
3			

SLOT SIZE 1 0 2 0 3 1

DIAMETER OF SCREEN 4 (NEAREST INCH)

GRAVEL PACK from -30 to -16

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68

OEP USE ONLY
(NOT TO BE FILLED IN BY DRILLER)

T TELESCOPE CASING | (E.R.O.S.) LOG INDICATOR | WQ OTHER DATA

C3

PUMPING TEST

HOURS PUMPED (nearest hour)

PUMPING RATE (gal. per min. to nearest gal.)

METHOD USED TO MEASURE PUMPING RATE

WATER LEVEL (distance from land surface)

BEFORE PUMPING

WHEN PUMPING

TYPE OF PUMP USED (for test)

A air, P piston, T turbine, C centrifugal, R rotary, O other (describe below), J jet, S submersible

Monitoring

PUMP INSTALLED

DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO): YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE:

CAPACITY: GALLONS PER MINUTE (to nearest gallon)

PUMP HORSE POWER

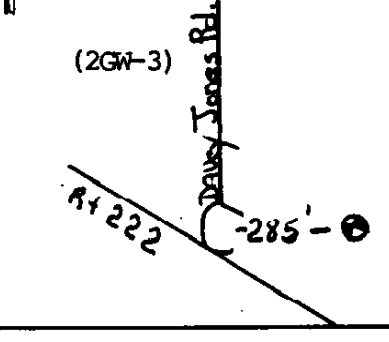
PUMP COLUMN LENGTH (nearest ft.)

CASING HEIGHT (circle appropriate box and enter casing height)

+ above / − below LAND SURFACE (nearest foot)

LOCATION OF WELL ON LOT

SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 2GW-4
Date: January 28, 1988; February 12, and 15-18, 1988
Observers: Timothy J. Baker, Hydrogeologist;
Jeff Flanzenbaum, Hydrogeologist;
Dennis Papa, Hydrogeologist

Monitoring well 2GW-4 was installed on February 18, 1988 approximately 150 feet south of a former oil separator pit and 700 feet north of State Route 222 as shown on Figure 2-8. Access to the location is via a dirt path which runs adjacent to Building 53 and exits at Davey Road near the Sewage Treatment Plant. The well was drilled by advancing an 8-inch diameter hollow stem auger until refusal occurred at the top of bedrock at a depth of 22.5 feet. Split spoon samples were collected at 5-foot intervals in the saprolite overburden. The saprolite was composed of yellow-grey and dark yellowish-orange weathered gneiss with black and green gneissic banding. Saturated conditions were encountered at a perched zone at a depth of 6 to 9 feet. This perched zone occurs in sandy clay and silts immediately overlying the dry saprolite.

Bedrock was cored from a depth of 23.0 feet to 25.0 feet using a 3-inch diameter diamond core bit while circulating fresh water. Bedrock consisted of dark yellowish-orange Port Deposit Gneiss with distinct water-bearing fractures at depths of 23.8 feet and 24.3 feet. The fractures were lined with orange iron oxides and yielded a significant amount of orange-stained water. Following coring, the borehole was reamed to bedrock with 12-inch diameter augers. Drilling then resumed with a 7-5/8-inch diameter air hammer bit down to 24 feet, to provide a 1.5-foot section of bedrock into which was seated a conductor casing to seal off the perched water zone. This conductor casing was constructed of a 25.46-foot length of 6-inch diameter schedule 40, type 304 stainless steel with a stick-up length of 1.46 feet above ground surface. The casing was seated into bedrock with a 1.5-foot thick seal formed with 1/4-inch

bentonite pellets, and the remaining annulus grouted with a 5% bentonite and cement slurry. The grout was added by tremie pipe and was brought to a depth of 3 feet below ground surface. Once the seal and grout had set, drilling resumed with a 5-7/8-inch air hammer bit through the bentonite seal and down to a final depth of 29 feet. The interval from 24 feet to 29 feet remains as an open borehole in competent, fractured bedrock. The borehole was purged with air for 40 minutes to induce water flow into the well and to remove suspended sediments. The well water cleared considerably after purging.

A 5-foot long, 8-inch diameter steel protector casing with a locking cap was cemented over the well casing and surrounded by a 5-foot by 5-foot square, 6-inch thick concrete pad with a steel bumper post at each corner. The well casing, protector casing and concrete pad were surveyed relative to sea level on March 4, 1988 using a USGS bench mark as an initial reference point. To facilitate identification, the well protector casing was painted international orange and labeled with a well tag bearing the Maryland State Permit Number CE-81-3611.

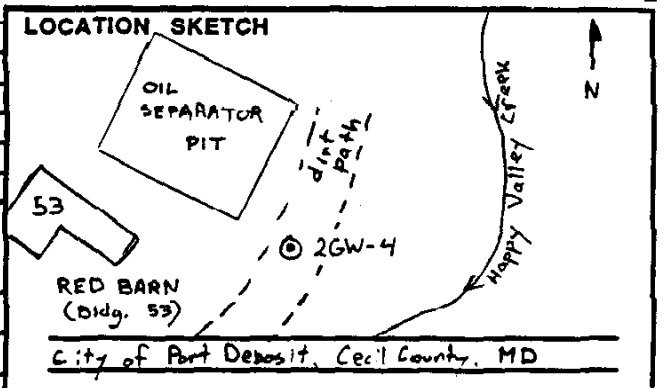
On February 29, 1988 the well was developed by pumping and surging with a submersible pump. Approximately 390 gallons of water was purged from the well. Development water was discharged a minimum of 25 feet downgradient from the well. In-situ measurements of pH, specific conductance, and temperature were recorded periodically. Development continued until in-situ parameters had stabilized and water clarity remained constant. Final depth to water in the well, measured on March 15, 1988, was 7.83 feet below the well casing.

Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Bainbridge NTC
JOB NUMBER: 5065.3.6
LOCATION: South of oil separator pit
WELL NUMBER: 2GW-4
GROUND ELEVATION: 247.06 (pad)
DATE INSTALLED: 2-18-88
WELL CASING ELEVATION: 248.02' above MSL
FIELD REPRESENTATIVE: Dennis Papa
PROTECTOR CASING ELEVATION: 248.32
DRILLING CONTRACTOR: Hardin Huber
DRILLER: N. Lazaro LICENSE NO. 336
DRILLING METHOD: hollow auger & air hammer
RIG TYPE: mobile B61
CONDITION OF GROUND SURFACE: muddy clay
FORMATION SCREENED: Port Deposit bedrock

LOCATION SKETCH



BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
hollow auger	12.00/8 1/4 ID	22.5	—
hammer	7 5/8	24	air
hammer	5 7/8	29	air
diamond core	3.0	23-25	water

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP *	BOTTOM *
protector casing	8	5'	+1.76	3.24
S.S. SCH 40 casing	6 ID	25.46'	+1.46'	24'
open borehole	5 7/8	5'	24'	29'

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP *	BOTTOM *
portland cement	0	3'
bentonite + cement grout	3'	22.5'
bentonite seal	22.5'	24'
concrete apron (5' x 5')	0.5'	0'

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	1-28-88	1430	1700
	2-12-88	0900	1400
CASING	2-18-88	0900	0945
	2-16-88	0815	0900
FILTER PACK	—	—	—
SEAL	2-16-88	0830	0845
GROUT	2-16-88	1000	1100
DEVELOPMENT	2-29-88	1450	1600
SURVEY	3-5-88		
OTHER 1st sampling	3-15-88	1415	

GROUND WATER LEVELS

DURING DRILLING:

2-18-88 1550 - 8' 11" below well casing

3-15-88 1415 - 7.83' below well casing

WELL DEVELOPMENT

2-29-88 Purged total of approx 390 gal (well volume 33.5 gal). water clear

Final field parameters:

Temp = 11.7 °C

Conductivity = 200 umhos

pH = 6.13

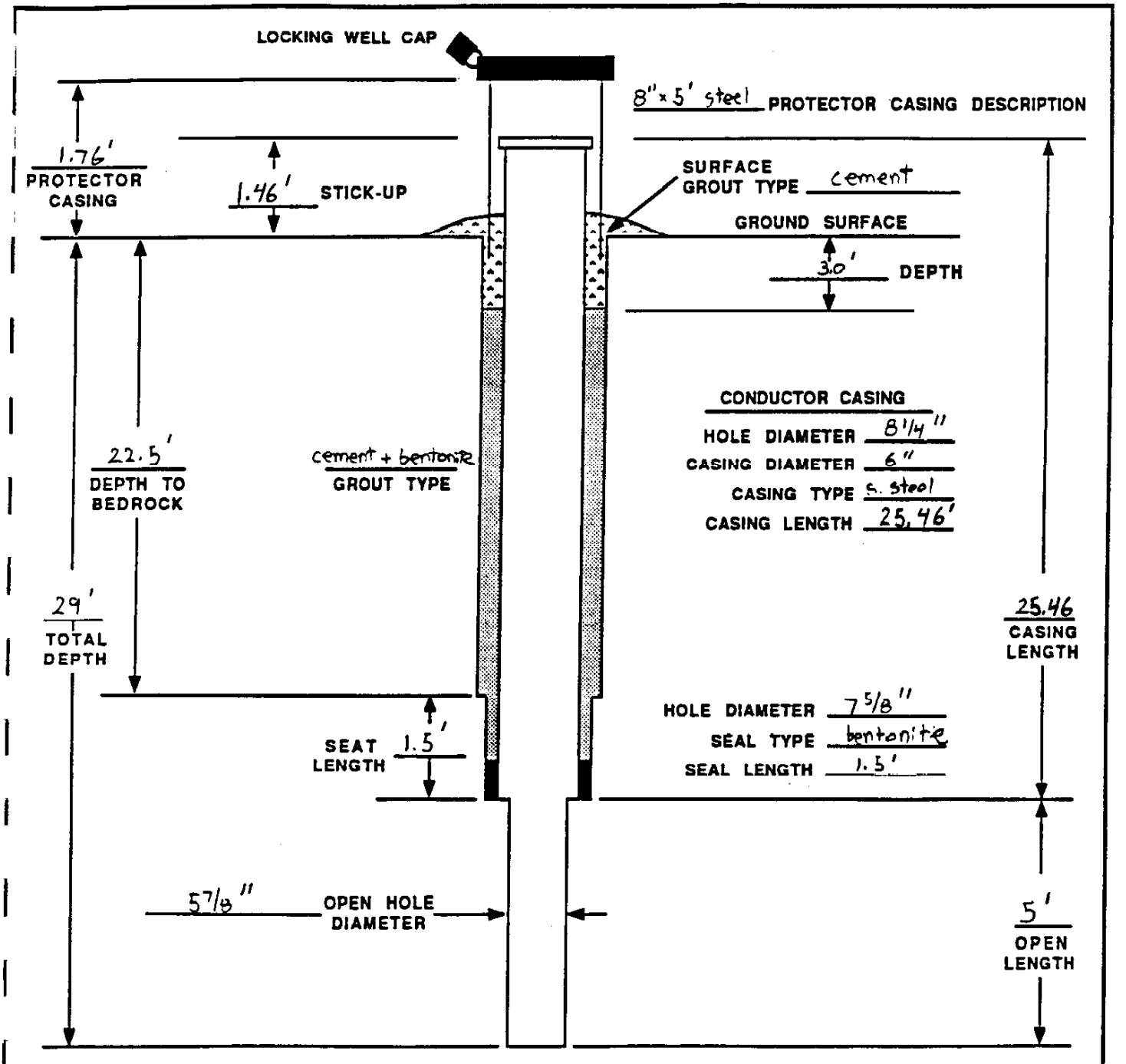
* DEPTH FROM GROUND SURFACE

COMMENTS: Stainless steel casing is Type 304.

Versar INC

WELL CONSTRUCTION DIAGRAM

PROJECT: Bainbridge NTC
JOB NUMBER: 5065.3.6
LOCATION: south of oil separator pit
L NUMBER: 2GW-4
ELEVATION: 248.02'
E INSTALLED: 2-18-88
☐ GROUND ☒ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☒ ABOVE MEAN SEA LEVEL



COMMENTS: Perched water zone encountered at 6 feet and sealed off. Well completed as open hole in fractured bedrock from 24 to 29 feet. Significant amount of orange-stained water yielded beginning at depth of 19.5 feet. Protector casing painted orange. Concrete pad is 5 feet x 5 feet x 0.5 feet thick w/ guard post at each corner. Maryland

state permit # CE-81-3611.

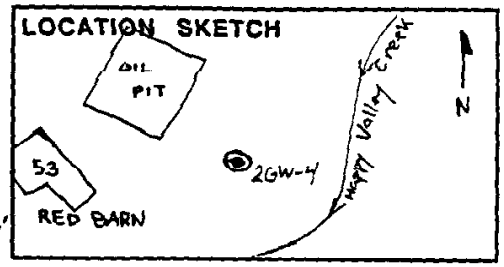
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5063.3.6

PROJECT: Bainbridge NTC
LOCATION: South of oil separator pit
BOREHOLE NUMBER: 2GW-4
DATE DRILLED: 1-28-88 ; 2-12-88 — 2-18-88
FIELD REPRESENTATIVE: Dennis Papa
DRILLING CONTRACTOR: Hardin Huber
DRILLER: Nate Lazaro
DRILLING METHOD: hollow auger & air hammer
HOLE DIAMETER: 8 1/4" to 22.5' 7 5/8" to 24, 5 7/8" - 29'
GROUND ELEVATION: 247.06' (pad)
CONDITION OF GROUND SURFACE: muddy clay

LOCATION SKETCH



COMMENTS: Port Deposit, Cecil Co. MD

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
		grab				Surface soil - moderate yellowish brown silty clay w/ fine to med. sand; moderately plastic w/ roots & organic material
5	1	S.S.	1.5'/1.5'	12 11 51/4"	▽	Sandy clay - yellowish gray to mod. yellowish brown medium to very fine, poorly sorted w/ angular quartz grains and biotite and muscovite flakes, moderately plastic unsaturated to 6 feet. HNu reading background.
						perched water seen at 6-7 feet
						cobbles (4-5") of angular gneiss at 8 feet; yellow gray saprolite, dry, first encountered at 9 feet.
10	2	S.S.	2.0'/1.5'	12 11 12 13		saprolite - yellow-gray w/ black and green gneissic banding, angular, mod. well sorted grains of quartz, feldspar with biotite & muscovite; moist but not saturated
15	3	S.S.	2"/2"	51/2"		saprolite - dark yellowish orange w/ evidence of iron staining, very dense and compacted, silty clay matrix w/ angular quartz and feldspar; moist but not saturated
19.5	4	S.S.	0.5'/0.5'	101	▽	gneiss - weathered fragments of Port Deposit Formation, saturated, dark yellowish orange (dry color), very angular grains and pebbles. Weathered zone 3 feet thick; water zone tapped @ 19.5 feet. (C horizon) top of Port Deposit bedrock at 22.5 feet
		core	2.0'/1.8			- Top of Port Deposit bedrock @ 22.5 feet — air hammer from 22.5 feet to 23 feet - fractured Port Deposit gneiss, dark yellowish orange w/ matic banding; quartz, plagioclase and aventurine (quartz + mica) ang. fragments. Very good water yield - water dark orange and very silty
						diamond core from 23.0 to 25.0 feet - fractures at 23'10" and 24'4"
29						T.D. = 29 feet; well completed as 5 7/8" dia open hole 24'-29'

Dennis Papa
GEOLOGIST'S SIGNATURE

C1 6129 SEQUENCE NO. (OEP USE ONLY)

(THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

STATE OF MARYLAND
WELL COMPLETION REPORT

FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

45 DAYS AFTER WELL IS COMPLETED.

COUNTY NUMBER: Test Well Bainbridge

DATE Received:

DATE WELL COMPLETED: 02 18 88

Depth of Well: 29 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL": CE-81-3611

OWNER: Arnold (last name) Paul (first name)

STREET OR RFD: ~~Base Closure Force~~ TOWN: ~~Port Deposit~~

SUBDIVISION: SECTION: LOT:

WELL LOG
Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
Surface soil moderate yellowish brown silty clay w/roots, sand	0'	8'	
Saprolite Gneissic laminations well-sorted very fine-grained sand dark yellowish brown rock fragments at 5'	8'	22.5'	✓
Port Deposit Gneiss laminations fractured angular clasts w/mica, quartz felds par	22.5'	29'	✓

CIRCLE APPROPRIATE LETTER
A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

E ELECTRIC LOG OBTAINED

T TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 174

DRILLER'S SIGNATURE (MUST MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

GROUTING RECORD
WELL HAS BEEN GROUTED (Circle Appropriate Box): yes Y / no N

TYPE OF GROUTING MATERIAL

CEMENT CM BENTONITE CLAY BC

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER ____

DEPTH OF GROUT SEAL (to nearest foot)

from 0 ft. (TOP) to 23 ft. (BOTTOM) (enter 0 if from surface)

CASING RECORD
casing types insert appropriate code below

Stainless STEEL ST; CONCRETE CO; PLASTIC PL; OTHER OT

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
	6	25

OTHER CASING (if used) — EACH CASING

diameter inch	depth (feet) from	to

SCREEN RECORD
screen type or open hole insert appropriate code below

STEEL ST; BRASS BRONZE BR; OPEN HOLE HO; PLASTIC PL; OTHER OT

C2

EACH SCREEN — DEPTH (nearest ft.)

1	24	29
2		
3		

SLOT SIZE 1 ____ 2 ____ 3 ____

DIAMETER OF SCREEN ____ (NEAREST INCH)

GRAVEL PACK from ____ to ____

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68

OEP USE ONLY (NOT TO BE FILLED IN BY DRILLER)

T: TELESCOPE CASING; (E.R.O.S.): LOG INDICATOR; WQ: OTHER DATA

C3

PUMPING TEST
HOURS PUMPED (nearest hour)

PUMPING RATE (gal. per min. to nearest gal.)

METHOD USED TO MEASURE PUMPING RATE

WATER LEVEL (distance from land surface)

BEFORE PUMPING

WHEN PUMPING

TYPE OF PUMP USED (for test)

A air; P piston; T turbine; C centrifugal; R rotary; O other (describe below); J jet; S submersible

MONITORING

PUMP INSTALLED
DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO): YES / NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE:

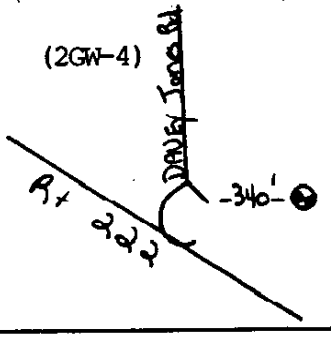
CAPACITY: GALLONS PER MINUTE (to nearest gallon)

PUMP HORSE POWER

PUMP COLUMN LENGTH (nearest ft.)

CASING HEIGHT (circle appropriate box and enter casing height): + above / − below LAND SURFACE (nearest foot)

LOCATION OF WELL ON LOT
SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

Well Installation Narrative

Project: Bainbridge Naval Training Center (NTC)
Well: 2GW-5
Date: January 21 - 22, 1988, January 26, 1988
Observers: Jeff Flanzenbaum, hydrogeologist

Monitoring well 2GW-5 was installed on January 26, 1988 alongside Happy Valley Creek hydraulically downgradient of the oil separator pit (Figure 2-8). This well represented the furthest downgradient monitoring well emplaced at the oil separator pit site. The well location is approximately 10 feet west of the creek alongside a former sewage treatment facility roadway. The well was drilled by advancing an 8-inch diameter hollow-stem auger until refusal occurred at the top of bedrock at a depth of 12.5 feet. Split spoon samples were collected at depths of 5 and 10 feet. A gravel zone was encountered from 11.5 feet to 12.5 feet, and ground-water was present within the saprolite at approximately 5 feet below ground surface during drilling.

Air rotary drilling within 7-5/8-inch diameter rotary bit proceeded to 15 feet below grade, approximately 2.5 feet into competent bedrock. A 6-inch diameter PVC conductor casing was set into the bedrock at 15 feet. One foot of bentonite pellets was placed at the bottom of the hole prior to insertion of the conductor casing. The remaining annulus was grouted by tremie pipe with a 5% bentonite/cement slurry to 3.5 feet below ground surface. Once the seal and grout had set drilling resumed with a 5-7/8-inch hammer bit through the bentonite seal and down to a final depth of 23 feet. The interval from 15 to 23 feet below ground surface remains as an open borehole in competent, fractured bedrock.

A 5-foot long, 8-inch diameter steel protector casing with a locking cap was cemented over the well casing and surrounded by a 5-foot by 5-foot square, 6-inch thick concrete pad with a steel bumper post at each corner. The well casing, protector casing, and concrete pad were surveyed relative to sea level on March 4, 1988 using a U.S.G.S. bench mark as an

initial reference point. To facilitate identification, the well protector casing was painted international orange, and a State of Maryland well tag [permit number CE-81-3612] was affixed to the protector casing.

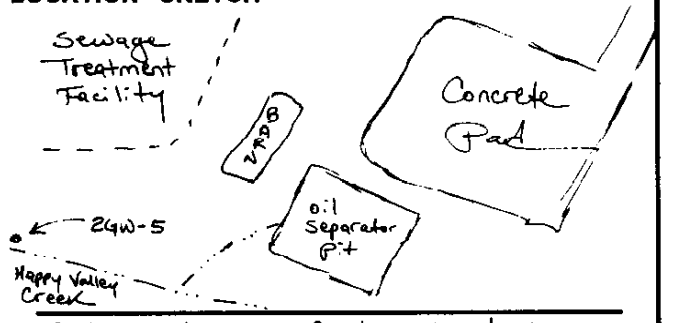
On February 29, 1988, the well was developed by pumping and surging with a submersible pump. Approximately 265 gallons of water were purged from the well and discharged a minimum of 25 feet downgradient of the well. In situ measurements of pH, specific conductance, and temperature were monitored and recorded periodically. Development continued until in situ parameters had stabilized, and water clarity remained constant.

Versar INC.

WELL CONSTRUCTION RECORD

PROJECT: Bainbridge NTC
JOB NUMBER: 5065.3.6
LOCATION: Oil Separator Pit
WELL NUMBER: 24W-5
GROUND ELEVATION: (Pad) 243.01
DATE INSTALLED: 1/22/88 - 1/26/88
WELL CASING ELEVATION: 243.93
FIELD REPRESENTATIVE: J. Flanzenbaum
PROTECTOR CASING ELEVATION: 244.33
DRILLING CONTRACTOR: Hardin / Huber Inc.
DRILLER: Nate Lazaro LICENSE NO. 336
DRILLING METHOD: Hollow Stem Auger / Air Hammer
RIG TYPE: Mobile B61
CONDITION OF GROUND SURFACE: Grass / Mud
FORMATION SCREENED: Port Deposit Gneiss

LOCATION SKETCH



Port Deposit, Cecil County, Maryland

BIT TYPE	HOLE DIA. (IN.)	END DEPTH* (FT.)	FLUID TYPE
Auger	8"	12.5	—
Auger	12"	12.5	—
Tri-Cone	7 5/8"	15	Air
Hammer	5 7/8"	23.0	Air

PROTECTOR, CASING & SCREEN RECORD

DESCRIPTION	DIA. (IN.)	TOTAL LENGTH	TOP *	BOTTOM *
Schedule 40 PVC Conductor	6"	16.42	+1.42'	-15
Open Hole (Rock)	5 7/8"	8.03	-15	-23.03
Protector (steel)	8"	5	+1.83	-3.17

COMPLETION MATERIALS RECORD

DESCRIPTION	TOP *	BOTTOM *
Bentonite Pellet (1/4") seal	-14	-15
5% bentonite cement grout	-3.5	-14
Portland Cement Grout (Type 1)	0.0	-3.5
Concrete Apron (5' x 5')	+0.5	0.0

TIME LOG

ACTIVITY	DATE	START	END
DRILLING	1/21	1300	1730
	1/22	0830	1100
	1/26	1345	1700
CASING	1/22	1100	1130
FILTER PACK	N/A	N/A	N/A
SEAL	1/22	1130	1140
GROUT	1/22	1200	1330
DEVELOPMENT	2/29	0800	1325
SURVEY	3/4	—	—
OTHER 1st sampling	3/15	1430	1535

GROUND WATER LEVELS

DURING DRILLING:

1/21/88 : 5.5' below ground surface

3/15/88 : 7.05 below well casing

WELL DEVELOPMENT

well development with submersible pump
Approximately 265 gallons pumped from 24W-5

Final in-situ parameter measurements
- Temp: 10.5°C
- pH : 6.42
- Spec. Cond. 305 µmhos

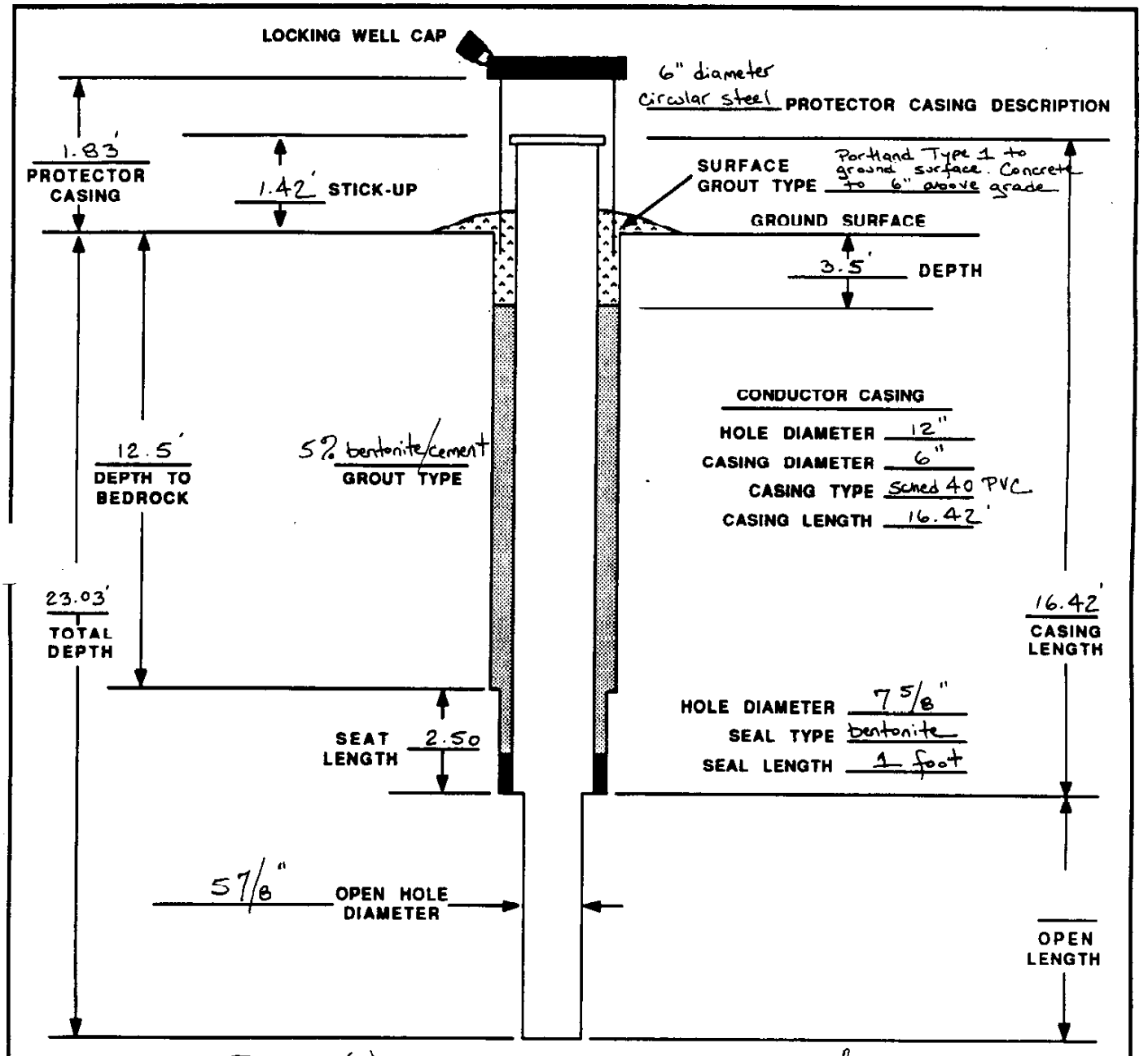
* DEPTH FROM GROUND SURFACE

COMMENTS: 4 guard posts installed around protector casing. Protector casing and guard posts painted international orange

Versar INC.

WELL CONSTRUCTION DIAGRAM

PROJECT: Bainbridge NTC JOB NUMBER: 5065.3.6
LOCATION: Oil Separator Pit
WELL NUMBER: 29W-5 ELEVATION: 243.93
DATE INSTALLED: 1-26-88 ☐ GROUND ☑ CASING ☐ PROTECTOR CASING
☐ ABOVE GROUND LEVEL ☑ ABOVE MEAN SEA LEVEL



COMMENTS: Perched (?) water encountered above bedrock & sealed off. Drilling of open hole using air hammer technique yielded significant quantities of water at ≈ 19.5' below grade. No casing or screen set into open rock hole to 23.03'. 4 protector pipes installed around well set into 5'x5' concrete apron (6" thick). Maryland state Permit #: CE-81-3612.

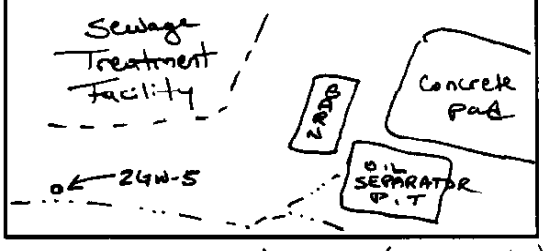
Versar INC.

GEOLOGIC LOG

JOB NUMBER: 5065.3.6

PROJECT: Bainbridge NTC
LOCATION: Oil Separator Pit
BOREHOLE NUMBER: 2GW-5
DATE DRILLED: 1/21/88; 1/22/88; 1/26/88
FIELD REPRESENTATIVE: J. Flanzenbaum
DRILLING CONTRACTOR: Hardin/Huber, Inc.
DRILLER: Nate Lazaro
DRILLING METHOD: Hollow Stem Auger / Air Hammer
HOLE DIAMETER: 12" → 5 7/8"
GROUND ELEVATION: (MSL) 243.01
CONDITION OF GROUND SURFACE: grass

LOCATION SKETCH



COMMENTS: 15' west of (Happy Valley) creek. Port Deposit, Cecil Co. Md.

DEPTH	NUMBER	INTERVAL AND TYPE	ADVANCED/ RECOVERED	BLOW COUNTS PER 6 INCHES	WATER TABLE	SAMPLE DESCRIPTION (SOIL OR ROCK TYPE, COLOR, GRAIN SIZE, SORTING, ROUNDNESS, PLASTICITY, MOISTURE CONTENT, TRACE MATERIALS, ODOR, STAINING, TRACE GAS READINGS)
		Grab				dark yellowish orange clayey silt with some fine sand, roots, organic rich, slightly cohesive, moderately well-sorted, homogeneous, some pebbles of gneiss. Quartz-rich with mica (muscovite ?). Fine sand is subangular. No odor, moist. HNU = 0ppm
5	1	SS	2'/1'	2 2 2 2	▼	moist, cohesive silty clay, moderate yellow brown color, plastic with increasing % of pebbles and cobbles of quartz and gneiss weathered. Angular grains (friable); quartz w/ some mafics and mica. poorly sorted, saturated, no odor HNU = 0ppm
10	2	SS	2'/1'	5 8 44 56		Very fine grained silty sand (saprolite of the Port Deposit Gneiss) (in SS), friable, gneissic laminations, moderately well sorted, mostly quartz w/some feldspar, mica and mafics, no odor HNU = 0 ppm
						Fractured bedrock from 11.5' → 12.5'
						- @ 12.5' auger refusal = contact of Port Deposit Gneiss Bedrock Surface
15						- Tri-cone roller bit to 15' bls into competent rock (7 5/8")
						- Air Hammer (5 7/8") to 23' in Port Deposit Gneiss
20						Cuttings yield fractured pieces of Port Deposit Gneiss Qtz, some mica, feldspar, and mafics, laminations, wet. No odor. Water seam encountered in the fractured bedrock at approx. 19.5 feet bls HNU = 0 ppm
						- - - T.D. = 23.0' below land surface
25						Monitoring well 2GW-5 installed. 6" PVC conductor set into competent rock to 15' Open Hole to 23.0 feet bls.

Jeffrey Flanzenbaum
GEOLOGIST'S SIGNATURE

(THIS NUMBER IS TO BE PUNCHED IN COLS. 3-6 ON ALL CARDS)

WELL COMPLETION REPORT

FILL IN THIS FORM COMPLETELY
PLEASE PRINT OR TYPE

COUNTY NUMBER: Test Well Bainbridge

DATE Received:

DATE WELL COMPLETED: 0 1 2 6 8 8

Depth of Well: 2 3 (TO NEAREST FOOT)

PERMIT NO. FROM "PERMIT TO DRILL WELL": C E - 8 1 - 3 6 1 2

OWNER: Arnold (last name) Paul (first name)

CONTRACTOR OR RFD: Base Closure Force TOWN: Port Deposit

DIVISION: SECTION: LOT:

WELL LOG

Not required for driven wells

STATE THE KIND OF FORMATIONS PENETRATED, THEIR COLOR, DEPTH, THICKNESS AND IF WATER BEARING

DESCRIPTION (Use additional sheets if needed)	FEET FROM	FEET TO	Check if water bearing
Surface soil dark yellowish orange clayey silt, well-sorted w/sand	0'	8'	
Saprolite gneissic laminations well-sorted very fine-grained sand dark yellowish brown fractured rock 11.5 - 12.5	8'	12.5'	✓
Deposit Gneiss gneiss laminations fractured angular clasts /mica, quartz feldspar	12.5'	23'	✓

CIRCLE APPROPRIATE LETTER

A — A WELL WAS ABANDONED AND SEALED WHEN THIS WELL WAS COMPLETED

E — ELECTRIC LOG OBTAINED

P — TEST WELL CONVERTED TO PRODUCTION WELL

I HEREBY CERTIFY THAT THIS WELL HAS BEEN CONSTRUCTED IN ACCORDANCE WITH COMAR 10.17.13 "WELL CONSTRUCTION" AND IN CONFORMANCE WITH ALL CONDITIONS STATED IN THE ABOVE CAPTIONED PERMIT, AND THAT THE INFORMATION PRESENTED HEREIN IS ACCURATE AND COMPLETE TO THE BEST OF MY KNOWLEDGE.

DRILLERS IDENT. NO. 174

DRILLER'S SIGNATURE (MATCH SIGNATURE ON APPLICATION)

SITE SUPERVISOR (sign. of driller or journeyman responsible for sitework if different from permittee)

GROUTING RECORD

WELL HAS BEEN GROUTED (Circle Appropriate Box): yes Y (44) no N (44)

TYPE OF GROUTING MATERIAL

CEMENT CM (45 46) BENTONITE CLAY BC (45 46)

NO. OF BAGS ____ NO. OF POUNDS ____

GALLONS OF WATER ____

DEPTH OF GROUT SEAL (to nearest foot)

from 0 ft. (48 TOP 52) to 14 ft. (54 BOTTOM 58)

(enter 0 if from surface)

CASING RECORD

casing types insert appropriate code below

ST STEEL, CO CONCRETE, PVC PL PLASTIC, OT OTHER

MAIN CASING TYPE	Nominal diameter top (main) casing (nearest inch)	Total depth of main casing (nearest foot)
(60 61)	6 (63 64)	16 (66 70)

EACH CASING — OTHER CASING (if used)

diameter inch	depth (feet) from	to

SCREEN RECORD

screen type or open hole insert appropriate code below

ST STEEL, BR BRASS BRONZE, HO OPEN HOLE, PL PLASTIC, OT OTHER

C 2 (1 2)

EACH SCREEN — DEPTH (nearest ft.)

1	15 (11 15)	23 (17 21)
2		
3		

SLOT SIZE 1 ____ 2 ____ 3 ____

DIAMETER OF SCREEN ____ (56 60) (NEAREST INCH)

GRAVEL PACK from ____ to ____

IF WELL DRILLED WAS FLOWING WELL INSERT F IN BOX 68 (68)

OEP USE ONLY (NOT TO BE FILLED IN BY DRILLER)

T (70) TELESCOPE CASING; (E.R.O.S.) (72) LOG INDICATOR; WQ (74 75 76) OTHER DATA

C 3 (1 2)

PUMPING TEST

HOURS PUMPED (nearest hour) ____ (8 9)

PUMPING RATE (gal. per min. to nearest gal.) ____ (11 15)

METHOD USED TO MEASURE PUMPING RATE ____

WATER LEVEL (distance from land surface)

BEFORE PUMPING ____ (17 20)

WHEN PUMPING ____ (22 25)

TYPE OF PUMP USED (for test)

A air (27), P piston (27), T turbine (27), C centrifugal (27), R rotary (27), O other (describe below) (27), J jet (27), S submersible (27)

MONITORING

PUMP INSTALLED

DRILLER WILL INSTALL PUMP (CIRCLE) (YES or NO): YES NO

IF DRILLER INSTALLS PUMP, THIS SECTION MUST BE COMPLETED FOR ALL WELLS EXCEPT HOME USE

TYPE OF PUMP INSTALLED PLACE (A,C,J,P,R,S,T,O) IN BOX - SEE ABOVE: ____ (29)

CAPACITY: GALLONS PER MINUTE (to nearest gallon) ____ (31 35)

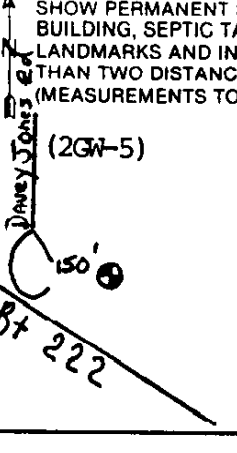
PUMP HORSE POWER ____ (37 41)

PUMP COLUMN LENGTH (nearest ft.) ____ (43 47)

CASING HEIGHT (circle appropriate box and enter casing height): + above (49), − below (49) LAND SURFACE ____ (50 51) (nearest foot)

LOCATION OF WELL ON LOT

SHOW PERMANENT STRUCTURE SUCH AS BUILDING, SEPTIC TANKS, AND/OR LANDMARKS AND INDICATE NOT LESS THAN TWO DISTANCES (MEASUREMENTS TO WELL)



ORIGINAL

APPENDIX B

MONITORING WELL SURVEYING DATA

Frederick Ward Associates Inc. Engineers • Architects • Surveyors
P.O. Box 310 • 5 South Main Street, Bel Air, Maryland 21014 • (301) 838-7900 • 879-2090

ELEVATIONS FOR MONITORING WELLS
BAINBRIDGE NAVAL TRAINING CENTER, CECIL CO.

WELL NO.	ELEVATION	DESCRIPTIONS
1 GW 1	296.61	Inner Casing @ Notch
	296.77	Outer Casing @ Notch
	295.20	□ -Cut @ Conc. Base
1 GW 2	244.78	Inner Casing @ Notch
	244.74	Outer Casing @ Notch
	242.98	□ -Cut @ Conc. Base
1 GW 3	229.48	Inner Casing @ Notch
	229.30	Outer Casing @ Notch
	227.43	□ -Cut @ Conc. Base
1 GW 4	250.78	Inner Casing @ Notch
	250.92	Outer Casing @ Notch
	249.48	□ -Cut @ Conc. Base
1 GW 5	198.46	Inner Casing @ Notch
	198.23	Outer Casing @ Notch
	196.46	X -Cut @ Conc. Base

Frederick Ward Associates Inc. Engineers • Architects • Surveyors
P.O. Box 310 • 5 South Main Street, Bel Air, Maryland 21014 • (301) 838-7900 • 879-2090

ELEVATIONS FOR MONITORING WELLS
BAINBRIDGE NAVAL TRAINING CENTER, CECIL CO.

WELL NO.	ELEVATIONS	DESCRIPTIONS
2 GW 1	266.37	Inner Casing @ Notch
	266.56	Outer Casing @ Notch
	265.13	□ -Cut @ Conc. Base
2 GW 2	251.90	Inner Casing @ Notch
	252.28	Outer Casing @ Notch
	249.76	□ -Cut @ Conc. Base
2 GW 3	257.05	Inner Casing @ Notch
	257.02	Outer Casing @ Notch
	254.77	□ -Cut @ Conc. Base
2 GW 4	248.02	Inner Casing @ Notch
	248.32	Outer Casing @ Notch
	247.06	□ -Cut @ Conc. Base
2 GW 5	243.93	Inner Casing @ Notch
	244.33	Outer Casing @ Notch
	243.01	□ -Cut @ Conc. Base

APPENDIX C

HAZARD RANKING SCORE

HRS COVER SHEET

Facility Name: Bainbridge Naval Training Center (NTC)

Location: Route 222, Port Deposit, Cecil County,, Maryland

EPA Region: III

Person(s) in Charge of Facility: Mr. John Kresky
Atlantic Division
Naval Facilities Engineering Command
Norfolk, Virginia 23511

Name of Reviewer: Dennis Papa - Versar, Inc.

Date: 10/26/88

General Description of the Facility:

The Bainbridge NTC is a former U.S. Naval training center located on a 1,200-acre tract near Port Deposit, Maryland, on the northern bank of the Susquehanna River. The facility is bounded on the north and east by rural residential area, on the west by State Route 276, on the southeast by U.S. Route 222, and on the south by the Town of Port Deposit and the Susquehanna River.

The Bainbridge NTC was constructed in 1941 as a training facility for World War II Navymen. The facility was partially deactivated shortly after World War II and maintained minimal activity until finally closing in the early 70s. A portion of the facility currently houses a Department of Labor-sponsored youth job training program (RCA Job Corps) of approximately 300 students and 200 staff.

In 1987, Versar, Inc. (Versar) was contracted by the U.S. Navy to initiate an Installation Restoration Program (IRP) at two locations at the facility suspected of having environmental contamination resulting from past Naval operations. The two locations are a former on-base sanitary landfill and an oil separator pit. The landfill accepted sanitary wastes generated by the facility and was also used to dispose of building debris and unused pesticides. The oil separator pit is an unlined catchment basin used to contain waste oil runoff from past firefighting training operations. Versar investigated ground water, air, soil, and surface water at both locations and discovered evidence of pesticide runoff in the ground water and surface water at the landfill area. No significant contamination was discovered at the oil separator pit location except for evidence of oil residue in a small drain ditch next to the pit.

General Description of the Facility (continued):

Because fuel oil or waste oil is not scoreable under the HRS, and sampling and analysis conducted during Versar's investigation, did not reveal contaminants in the ground water or surface water at the oil separator pit location, this HRS Scoring evaluates the landfill area only.

The contamination routes of concern at the landfill area are ground water and surface water. Observed releases were noted in both routes. Ground water is used for drinking water by approximately 4,283 persons residing within a 3-mile radius of the landfill. The majority of these residents are located upgradient from the landfill. There are no known wells located directly downgradient from the landfill which are currently used for drinking water. Surface water contamination was noted in a drainage stream flowing near the landfill, however the drainage stream is not used for drinking water or other purposes. A surface water intake which provides drinking water for approximately 1,167 persons is located on the Susquehanna River approximately 0.9 miles from the landfill.

Scores: $S_M = 35.03$ ($S_{gw} = 41.84$, $S_{sw} = 43.85$, $S_a = 0$)

S_{FE} = N/A

$S_{DC} = 0$

Ground Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	3.1
If observed release is given a score of 45, proceed to line 4. If observed release is given a score of 0, proceed to line 2.					
2 Route Characteristics					3.2
Depth to Aquifer of Concern	0 1 2 3	2		6	
Net Precipitation	0 1 2 3	1		3	
Permeability of the Unsaturated Zone	0 1 2 3	1		3	
Physical State	0 1 2 3	1		3	
	Total Route Characteristics Score		N/A	15	
3 Containment	0 1 2 3	1	N/A	3	3.3
4 Waste Characteristics					3.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	12	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	1	8	
	Total Waste Characteristics Score		13	26	
5 Targets					3.5
Ground Water Use	0 1 2 3	3	6	9	
Distance to Nearest Well/Population Served	0 4 6 8 10 12 16 18 20 24 30 32 35 40	1	35	40	
	Total Targets Score		41	49	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			23,985	57,330	
7 Divide line 6 by 57,330 and multiply by 100		S_{gw} = 41.84			

FIGURE 2
GROUND WATER ROUTE WORK SHEET

Surface Water Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	0 45	1	45	45	4.1
If observed release is given a value of 45, proceed to line 4. If observed release is given a value of 0, proceed to line 2.					
2 Route Characteristics					4.2
Facility Slope and Intervening Terrain	0 1 2 3	1		3	
1-yr. 24-hr. Rainfall	0 1 2 3	1		3	
Distance to Nearest Surface Water	0 1 2 3	2		6	
Physical State	0 1 2 3	1		3	
	Total Route Characteristics Score		N/A	15	
3 Containment	0 1 2 3	1	N/A	3	4.3
4 Waste Characteristics					4.4
Toxicity/Persistence	0 3 6 9 12 15 18	1	18	18	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1	1	8	
	Total Waste Characteristics Score		19	26	
5 Targets					4.5
Surface Water Use	0 1 2 3	3	9	9	
Distance to a Sensitive Environment	0 1 2 3	2	0	6	
Population Served/Distance to Water Intake Downstream	0 4 6 8 10 / 12 16 18 20 / 24 30 32 35 40	1	24	40	
	Total Targets Score		33	55	
6 If line 1 is 45, multiply 1 x 4 x 5 / If line 1 is 0, multiply 2 x 3 x 4 x 5			28,215	64,350	
7 Divide line 6 by 64,350 and multiply by 100		S_{sw} = 43.85			

FIGURE 7
SURFACE WATER ROUTE WORK SHEET

Air Route Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Release	(0) 45	1	0	45	5.1
Date and Location:					
Sampling Protocol:					
If line 1 is 0, the S_a = 0. Enter on line 5. If line 1 is 45, then proceed to line 2.					
2 Waste Characteristics					5.2
Reactivity and Incompatibility	0 1 2 3	1		3	
Toxicity	0 1 2 3	3		9	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
	Total Waste Characteristics Score		N/A	20	
3 Targets					5.3
Population Within 4-Mile Radius	0 9 12 15 18 21 24 27 30	1		30	
Distance to Sensitive Environment	0 1 2 3	2		6	
Land Use	0 1 2 3	1		3	
	Total Targets Score		N/A	39	
4 Multiply 1 x 2 x 3			N/A	35,100	
5 Divide line 4 by 35,100 and multiply by 100		S_a = 0			

FIGURE 9
AIR ROUTE WORK SHEET

	S	S^2
Groundwater Route Score (S_{gw})	41.84	1,750.59
Surface Water Route Score (S_{sw})	43.85	1,922.82
Air Route Score (S_a)	0	0
$S_{gw}^2 + S_{sw}^2 + S_a^2$		3,673.41
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2}$		60.61
$\sqrt{S_{gw}^2 + S_{sw}^2 + S_a^2} / 1.73 = S_M =$		35.03

WORKSHEET FOR COMPUTING S_M

Fire and Explosion Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Containment	1 3	1	N/A	3	7.1
2 Waste Characteristics					7.2
Direct Evidence	0 3	1		3	
Ignitability	0 1 2 3	1		3	
Reactivity	0 1 2 3	1		3	
Incompatibility	0 1 2 3	1		3	
Hazardous Waste Quantity	0 1 2 3 4 5 6 7 8	1		8	
Total Waste Characteristics Score			N/A	20	
3 Targets					7.3
Distance to Nearest Population	0 1 2 3 4 5	1		5	
Distance to Nearest Building	0 1 2 3	1		3	
Distance to Sensitive Environment	0 1 2 3	1		3	
Land Use	0 1 2 3	1		3	
Population Within 2-Mile Radius	0 1 2 3 4 5	1		5	
Buildings Within 2-Mile Radius	0 1 2 3 4 5	1		5	
Total Targets Score			N/A	24	
4 Multiply 1 x 2 x 3			N/A	1,440	
5 Divide line 4 by 1,440 and multiply by 100		S_{FE} = N/A			

FIGURE 11
FIRE AND EXPLOSION WORK SHEET

Direct Contact Work Sheet					
Rating Factor	Assigned Value (Circle One)	Multi-plier	Score	Max. Score	Ref. (Section)
1 Observed Incident	(0) 45	1	0	45	8.1
If line 1 is 45, proceed to line 4 If line 1 is 0, proceed to line 2					
2 Accessibility	(0) 1 2 3	1	0	3	8.2
3 Containment	0 (15)	1	15	15	8.3
4 Waste Characteristics Toxicity	0 1 2 (3)	5	15	15	8.4
5 Targets					8.5
Population Within a 1-Mile Radius	(0) 1 2 3 4 5	4	0	20	
Distance to a Critical Habitat	(0) 1 2 3	4	0	12	
Total Targets Score			0	32	
6 If line 1 is 45, multiply 1 x 4 x 5 If line 1 is 0, multiply 2 x 3 x 4 x 5			0	21,600	
7 Divide line 6 by 21,600 and multiply by 100	S_{DC} = 0				

FIGURE 12
DIRECT CONTACT WORK SHEET

DOCUMENTATION RECORDS
FOR
HAZARD RANKING SYSTEM

INSTRUCTIONS: The purpose of these records is to provide a convenient way to prepare an auditable record of the data and documentation used to apply the Hazard Ranking System to a given facility. As briefly as possible summarize the information you used to assign the score for each factor (e.g., "Waste quantity = 4,230 drums plus 800 cubic yards of sludges"). The source of information should be provided for each entry and should be a bibliographic-type reference that will make the document used for a given data point easier to find. Include the location of the document and consider appending a copy of the relevant page(s) for ease in review.

FACILITY NAME: Bainbridge Naval Training Center

LOCATION: Port Deposit, Cecil County, Maryland

GROUND WATER ROUTE

1 OBSERVED RELEASE

Contaminants detected (5 maximum):

Chlorobenzene
Trans-1,2-Dichloroethene
Reference 1

Rationale for attributing the contaminants to the facility:

The above contaminants have been detected in two of the five on-site monitoring wells installed around the base landfill area during three consecutive sampling events as part of Versar's remedial investigation at Bainbridge NTC (Reference 1). (Five monitoring wells were also installed around the oil separator pit location, however analysis of water samples from these five wells did not reveal any identifiable contamination. The only substance identified to have been disposed at the oil separator pit is fuel oil, which is not scoreable under the HRS - see Reference 16.) The two landfill wells that showed contamination, 1GW-3 and 1GW-5, are located directly downgradient from the landfill. As the table on the next page indicates, chlorobenzene was detected in well 1GW-3 (located less than 1,000 feet directly downgradient from the landfill) and well 1GW-5 (approximately 1,600 feet downgradient from the landfill), while trans-1,2-dichloroethene was detected in well 1GW-5 only. No contaminants were detected in a background well (1GW-1) located several hundred feet upgradient of the landfill. Well locations are depicted in Figure 2-1 of Reference 1.

The contaminants detected in these wells are suspected to have entered the local ground water as a result of past dumping of pesticides at the base landfill (Reference 1). The following pesticides (liquid and solid form) are suspected to have been poured into pits or buried at the landfill (References 1 and 9: Reference 2, page 9):

Aramite 15-@ (Mitricide)	60 lbs
BHC 11% E.C.	150 gal
Black Leaf 40 (Nicotine Sulphate)	60 gal
Captan 50 W.P.	110 lbs
Copper Sulphate	20 lbs
DDT 25% E.C.	350 gal
DDT 20% O.S.	350 gal
DDT 5% O.S.	100 gal
Ferbam	20 lbs

Karathane	80 lbs
Red Squill	15 lbs
Ryania	60 lbs

Contaminant Concentrations Detected in Landfill Monitoring Wells

Sampling Round/ Date	Contaminant	1GW-3 1GW-3	1GW-5	1GW-1 (upgradient)
1 (3/16/88)	chlorobenzene	270	82	<5
	trans-1,2-dichloroethene	<10	5	<5
2 (5/17/88)	chlorobenzene	350	82	<5
	trans-1,2-dichloroethene	<20	5	<5
3 (7/26/88)	chlorobenzene	290	160	<5
	trans-1,2-dichloroethene	<5	11	<5

Concentrations in $\mu g/l$

A value of 45 was assigned (References 1, 2, and 9)

* * *

2 ROUTE CHARACTERISTICS

Depth to Aquifer of Concern

Name/description of aquifers(s) of concern:

Ground water at the study area occurs in the fractures and joints of the Port Deposit Gneiss, which underlies the entire Bainbridge NTC facility (References 1, 14, and 16).

Depth(s) from the ground surface to the highest seasonal level of the saturated zone [water table(s)] of the aquifer of concern:

N/A*

Depth from the ground surface to the lowest point of waste disposal/ storage:

N/A

*NA = Not Applicable .

Net Precipitation

Mean annual or seasonal precipitation (list months for seasonal):

N/A

Mean annual lake or seasonal evaporation (list months for seasonal):

N/A

Net precipitation (subtract the above figures):

N/A

Permeability of Unsaturated Zone

Soil type in unsaturated zone:

N/A

Permeability associated with soil type:

N/A

Physical State

Physical state of substances at time of disposal (or at present time for generated gases):

N/A

* * *

3 CONTAINMENT

Containment

Method(s) of waste or leachate containment evaluated:

N/A

Method with highest score:

N/A

* * *

4 WASTE CHARACTERISTICS

Toxicity and Persistence

Compound(s) evaluated:

1) Chlorobenzene

Toxicity	Persistence	Matrix Value
2 (Ref 3; Ref 10, 47FR31229)	2 (Ref 3; Ref 10, 47FR31229)	12 (Ref 3; Ref 10, 47FR31229)

2) trans-1,2-dichloroethene

Toxicity	Persistence	Matrix Value
1 (Ref 3 - p. 945)	2 (Ref 3; Ref 10, 47FR31229)	9 (Ref 3; Ref 10, 47FR31229)

Compound with highest score:

Chlorobenzene has a matrix score of 12 (Ref 10, 47FR31229)

Hazardous Waste Quantity

Total quantity of hazardous substances at the facility, excluding those with a containment score of 0 (Give a reasonable estimate even if quantity is above maximum):

The total quantity of pesticides dumped at the landfill is not known, however Navy records (References 2 and 9) indicate that at least 365 pounds of dry pesticides and 1,010 gallons of liquid pesticides were dumped at the landfill around 1968. The score was then based on the following mass conversions (47FR31229):

1 ton = 2,000 pounds = 4 drums
1 drum = 50 gallons

therefore:

365 pounds	=	0.73 drums
1,010 gallons	=	20.2 drums
Total		20.93 drums = 21 drums

A value of 1 was assigned (47FR31229)

Basis of estimating and/or computing waste quantity:

Waste quantities were estimated based on the quantity of pesticides and chemicals known to have been dumped at the landfill, as reported in References 2 and 9.

* * *

5 TARGETS

Ground Water Use

Use(s) of aquifer(s) of concern within a 3-mile radius of the facility:

Within a 3-mile radius of the facility the aquifer of concern is used as a potable water source by all residents using private wells (Reference 4). The nearest alternative supply for water is the Port Deposit Water Tank Reservoir on Route 276 in Port Deposit (Reference 1, Section 1.3.2; Reference 5). Residents within the city limits of Port Deposit and the RCA Job Corps obtain drinking water from this source.

A value of 2 was assigned.

Distance to Nearest Well

Location of nearest well drawing from aquifer of concern or occupied building not served by a public water supply:

The nearest occupied building not western - SNH served by a public water supply is a farm house located on the eastern side of State Route 276, to the ~~east~~ West of the base landfill disposal area (References 5 and 6).

Distance to above well or building:

The distance between the nearest occupied building and the base landfill disposal area is approximately 600 feet (Reference 6).

A value of 4 was assigned for distance to nearest well.

Population Served by Ground Water Wells Within a 3-Mile Radius

Identified water-supply well(s) drawing from aquifer(s) of concern within a 3-mile radius and populations served by each:

Within the 3-mile radius study area, 1,127 homes have been identified which use the aquifer of concern as a potable water supply (Reference 6). The population served by ground water is:

1,127 homes x 3.8 persons per home = 4,283

Computation of land area irrigated by supply well(s) drawing from aquifer(s) of concern] within a 3-mile radius, and conversion to population (1.5 people per acre):

Ground water is not used for irrigation within the 3-mile radius area (Reference 4).

Total population served by ground water within a 3-mile radius:

4,283 persons

A value of 4 was assigned for population served.

A matrix value of 35 was assigned.

SURFACE WATER ROUTE

1 OBSERVED RELEASE

Contaminants detected in surface water at the facility or downhill from it (5 maximum):

Heptachlor
alpha-chlordane
gamma-chlordane
4,4'-DDT
4,4-'DDE

Rationale for attributing the contaminants to the facility:

The above contaminants have been detected in stream sediment samples collected from two locations in a drainage stream flowing in a downgradient (south) direction east of the landfill area (Reference 1, Sections 2.1.4 and Figure 2-1). The samples were collected and analyzed on 3 occasions in conjunction with Versar's remedial investigation (Reference 1). Sample 1SED-1 was collected at a point in the stream approximately 800 feet southeast of the suspected pesticide disposal area in the landfill. Sample 1SED-2 was collected further downstream at the point where the stream crosses State Route 276, approximately 2,000 feet directly downgradient from the pesticide disposal area. Water samples were also collected at these same locations. Water sample 1SW-1, corresponding to sediment location 1SED-1, contained low levels of some pesticides during the third (most recent) round of sampling, while water sample 1SW-2 (from 1SED-2 location) did not show any contamination. Specific contaminant concentrations for water and sediment samples, collected on July 25, 1988 (latest round of sampling) from the landfill area stream are shown below (Reference 1).

	Location			
	Surface Water		Sediment	
Contaminant	1SW-1	1SW-2	1SED-1	1SED-2
Heptachlor	0.20	<0.05	38	<17
alpha-chlordane	0.35	<0.10	180	<34
gamma-chlordane	0.22	<0.10	260	<34
4,4'-DDT	ND	ND	170	<34
4,4'-DDE	ND	ND	95	<34

Concentrations in μg/l for water and μg/kg for sediments.
ND = not detected.

A value of 45 was assigned.

* * *

2 ROUTE CHARACTERISTICS

Facility Slope and Intervening Terrain

Average slope of facility in percent:

N/A

Name/description of nearest downslope surface water:

N/A

Average slope of terrain between facility and above-cited surface water body in percent:

N/A

Is the facility located either totally or partially in surface water?

N/A

Is the facility completely surrounded by areas of higher elevation?

N/A

1-Year 24-Hour Rainfall in Inches

N/A

Distance to Nearest Downslope Surface Water

N/A

Physical State of Waste

N/A

* * *

3 CONTAINMENT

Containment

Method(s) of waste or leachate containment evaluated:

N/A

Method with highest score:

N/A

* * *

4 WASTE CHARACTERISTICS

Toxicity and Persistence

Compound(s) evaluated:

	Toxicity (Ref 3; Ref 10, 47FR31236)	Persistence (Ref 3; Ref 10, 47FR31236)	Matrix Value (Ref 10, 47FR31236)
Heptachlor	3	3	18
alpha-chlordane	3	3	18
gamma chlordane	3	3	18
4,4'-DDT	3	3	18
4,4'-DDE	3	3	18

Compound with highest score:

All five compounds evaluated have matrix values of 18 (Ref 10, 47FR31236).

A matrix value of 18 was assigned.

Hazardous Waste Quantity

Total quantity of hazardous substances at the facility, excluding those with a containment score of 0 (Give a reasonable estimate even if quantity is above maximum):

The total quantity of pesticides dumped at the landfill is not known, however Navy records (References 2 and 9) indicate that at

least 365 pounds of dry pesticides and 1,010 gallons of liquid pesticides were dumped at the landfill around 1968. The total known waste quantity was calculated to be equal to 21 drums (see "Ground Water Route," Section 4, page 4).

A value of 1 was assigned.

Basis of estimating and/or computing waste quantity:

Waste quantities were estimated based on the quantity of pesticides and chemicals known to have been dumped at the landfill, as reported in References 2 and 9.

* * *

5 TARGETS

Surface Water Use

Use(s) of surface water within 3 miles downstream of the hazardous substance:

The Town of Port Deposit has a surface water intake on the Susquehanna River that supplies drinking water for the Town of Port Deposit and the Bainbridge NTC (used by the Job Corps Center)(Reference 5). The Susquehanna is used for boating and sport fishing (Reference 12).

A value of 3 was assigned.

Is there tidal influence?

The gauging station at the Conowingo Dam (4.5 miles upstream from Port Deposit) indicates the Susquehanna River is tidal downstream from the dam (Reference 12).

Distance to a Sensitive Environment

Distance to 5-acre (minimum) coastal wetland, if 2 miles or less:

The topographic maps (References 6, 7, 8 and 8a) do not indicate a coastal wetland larger than 5 acres.

Distance to 5-acre (minimum) fresh-water wetland, if 1 mile or less:

The topographic maps (References 6, 7, 8, and 8a) do not indicate a fresh-water wetland larger than 5 acres.

Distance to critical habitat of an endangered species or national wildlife refuge, if 1 mile or less:

There are no critical habitats within 1 mile of the landfill disposal area. The bald eagle (Haliaeetus leucocephalus) may be a transient visitor to the area.

A value of 0 was assigned for distance to a sensitive environment.

Population Served by Surface Water

Location(s) of water-supply intake(s) within 3-miles (free-flowing bodies) or 1 mile (static water bodies) downstream of the hazardous substance and population served by each intake:

A Town of Port Deposit public water supply intake is located on the Susquehanna River upstream from Port Deposit. The 667 residents of Port Deposit and the 500 residents of the Job Corps Center within the Bainbridge NTC obtain their drinking water from this source.

Computation of land area irrigated by above-cited intake(s) and conversion to population (1.5 people per acre):

No land is irrigated with water from the above-cited intakes (Reference 17).

Total population served:

1,167 people

Name/description of nearest of above water bodies:

Susquehanna River (Reference 6).

Distance to above-cited intakes, measured in stream miles.

Approximately 0.9 miles (Reference 6).

A matrix value of 24 was assigned for population served/distance to water intake.

AIR ROUTE

1 OBSERVED RELEASE

Contaminants detected:

No airborne contamination has been detected at the site. Air quality readings taken throughout the site during the remedial investigation with an HNu photoionization detector and an OVA flame ionization detector were at background levels (Reference 1).

$S_a = 0$

Date and location of detection of contaminants:

N/A

Methods used to detect the contaminants:

Air quality was monitored at various locations throughout the site during the remedial investigation using both an HNu photoionization detector and an OVA flame ionization detector. Readings remained at background levels (Reference 1).

Rationale for attributing the contaminants to the site:

N/A

* * *

2 WASTE CHARACTERISTICS

<u>Reactivity and Incompatibility</u>

Most reactive compound:

N/A

Most incompatible pair of compounds:

N/A

Toxicity

Most toxic compound:

N/A

Hazardous Waste Quantity

Total quantity of hazardous waste:

N/A

Basis of estimating and/or computing waste quantity:

N/A

* * *

3 TARGETS

Population Within 4-Mile Radius

Circle radius used, give population, and indicate how determined:

0 to 4 mi 0 to 1 mi 0 to 1/2 mi 0 to 1/4 mi

N/A

Distance to a Sensitive Environment

Distance to 5-acre (minimum) coastal wetland, if 2 miles or less:

N/A

Distance to 5-acre (minimum) fresh-water wetland, if 1 mile or less:

N/A

Distance to critical habitat of an endangered species, if 1 mile or less:

N/A

Land Use

Distance to commercial/industrial area, if 1 mile or less:

N/A

Distance to national or state park, forest, or wildlife reserve, if 2 miles or less:

N/A

Distance to residential area, if 2 miles or less:

N/A

Distance to agricultural land in production within past 5 years, if 1 mile or less:

N/A

Distance to prime agricultural land in production within past 5 years, if 2 miles or less:

N/A

Is a historic or landmark site (National Register or Historic Places and National Natural Landmarks) within the view of the site?

The Tomes School, a structure listed on the National Register, is located within the borders of NTC Bainbridge, approximately one-half mile south of the landfill.

FIRE AND EXPLOSION

1 CONTAINMENT

Hazardous substances present:

No evidence suggests the threat of fire and explosion.

Type of containment, if applicable:

N/A

* * *

2 WASTE CHARACTERISTICS

Direct Evidence

Type of instrument and measurements:

N/A

Ignitability

Compound used:

N/A

Reactivity

Most reactive compound:

N/A

Incompatibility

Most incompatible pair of compounds:

N/A

Hazardous Waste Quantity

Total quantity of hazardous substances at the facility:

N/A

Basis of estimating and/or computing waste quantity:

N/A

* * *

3 TARGETS

Distance to Nearest Population

N/A

Distance to Nearest Building

N/A

Distance to Sensitive Environment

Distance to wetlands:

N/A

Distance to critical habitat:

N/A

Land Use

Distance to commercial/industrial area, if 1 mile or less:

N/A

Distance to national or state park, forest, or wildlife reserve, if 2 miles or less:

N/A

Distance to residential area, if 2 miles or less:

N/A

Distance to agricultural land in production within past 5 years, if 1 mile or less:

N/A

Distance to prime agricultural land in production within past 5 years, if 2 miles or less:

N/A

Is a historic or landmark site (National Register or Historic Places and National Natural Landmarks) within the view of the site?

N/A

Population Within 2-Mile Radius

N/A

Buildings Within 2-Mile Radius

N/A

DIRECT CONTACT

1 OBSERVED INCIDENT

Date, location, and pertinent details of incident:

N/A

* * *

2 ACCESSIBILITY

Describe type of barrier(s):

The Bainbridge NTC is completely enclosed by a fence, and the main gate is guarded by security personnel. The general public does not have access to the facility. Residents of the Job Corps Center are restricted to their assigned work areas, which are away from zones of contamination (Reference 1).

A value of 0 was assigned.

* * *

3 CONTAINMENT

Type of containment, if applicable:

Pesticides have migrated into the ground water and surface water at the landfill disposal area as a result of dumping and burying (References 1 and 2).

A value of 15 was assigned.

* * *

4 WASTE CHARACTERISTICS

<u>Toxicity</u>

Compounds evaluated:

Chlorobenzene	2	4,4'-DDT	3
trans-1,2-dichloroethene	1	Chlordane	3
Heptachlor	3		

Compound with highest score:

Three compounds evaluated, heptachlor, 4,4'-DDT, and chlordane, have toxicity values of 3 (Reference 10, 47FR31241).

A value of 3 was assigned.

* * *

5 TARGETS

Population within one-mile radius

Not applicable because of restricted site access (Reference 1).

A value of 0 was assigned.

Distance to critical habitat (of endangered species)

N/A (Reference 13)

A value of 0 was assigned.

HRS DOCUMENTATION LOG SHEET

REFERENCE NUMBER	DESCRIPTION OF THE REFERENCE
1	Versar, Inc., 1988. Hydrogeological Investigations of Waste Disposal Sites at the Former Naval Training Center. November, 1988.
2	Atlantic Division Naval Facilities Engineering Command, 1968. Memo to Commander of Bainbridge NTC re: pest control program at Bainbridge (with pesticide inventory and recommendations for landfill disposal). December 19, 1968.
3	Sax, Irving N. Dangerous Properties of Industrial Materials. Van Nostrand Reinhold Co., New York, NY. 6th Ed., 1984.
4	Telephone conversation with Chuck Smyser of Cecil County Health Department regarding ground water use and irrigation near the Bainbridge NTC. September 29, 1988.
5	Telephone conversation with Nancy Peters, Town Clerk for Port Deposit, regarding water use in the Town of Port Deposit. September 14, 1988.
6	U.S. Geological Survey. Havre de Grace, MD Quadrangle, 7.5 minute series topographic map, 1953. Photo revised 1985.
7	U.S Geological Survey. Aberdeen, MD Quadrangle, 7.5 minute series topographic map, 1953. Photo revised 1985.
8	U.S. Geological Survey. Rising Sun, MD Quadrangle, 7.5 minute series topographic map, 1953. Photo revised 1985.
8a	U.S. Geological Survey. Conowingo Dam, MD Quadrangle, 7.5 minute series topographic map, 1953. Photo revised 1970.
9	U.S. Navy. File memo regarding review of property records to predict degree of contamination at the Bainbridge NTC. January 29, 1981.
10	Federal Register, July 16, 1982.

HRS DOCUMENTATION LOG SHEET

REFERENCE NUMBER	DESCRIPTION OF THE REFERENCE
11	U.S. Department of Agriculture. Soil Survey of Cecil County, Maryland. 1973.
12	Telephone conversation with Linda Zynjuk of Maryland Geological Survey regarding uses and tidal influence of the Susquehanna River. September 30, 1988.
13	Telephone conversation with District Wildlife Administration, Maryland Department of Natural Resources, regarding critical habitats near Bainbridge. October 3, 1988.
14	Nutter, L. J. and E. G. Otton. Ground-Water Occurrence in the Maryland Piedmont. Maryland Geological Survey Report of Investigations No. 10. 1969.
15	Higgins, Michael W. Geology of the Crystalline Rocks of Cecil County, Maryland. U.S. Geological Survey. 1986.
16	Telephone conversation with Michele Mrozek of Mitre Corporation regarding scoring of waste fuel oil. October 4, 1988.
17	Telephone conversation with Eric Webberking of Cecil County Soil Conservation service regarding irrigation of farmland near the Bainbridge area. October 4, 1988.

REFERENCE 1

DRAFT

Hydrogeological Investigation of Waste Disposal Sites at the Former Naval Training Center Bainbridge, Port Deposit, Cecil County, Maryland

U.S. Navy Contract No: N62470-87-8-8901

Prepared for:

Mr. John Kresky, Code 1143
Atlantic Division
Naval Facilities Engineering Command
Norfolk, Virginia 23511-6287

Prepared by:

Versar, Inc.
6850 Versar Center
Springfield, Virginia 22151

December 7, 1988

REFERENCE 2

444-7121
AUTOVON 444-7121

1CA:LCS:pb
6250

19 DEC 1968

From: Commander, Atlantic Division, Naval Facilities Engineering Command
To: Commander, Naval Training Center, Bainbridge, Maryland

Subj: Review of the pest control program; report on

Ref: (a) SECNAVINST 3430.3[illegible] of 27 Dec 1961
(b) NAVFACINST 6250.3[illegible] of 1 Oct 1964

Encl: (1) Report on the review of the pest control program at Naval Training Center, Bainbridge, Maryland

1. In accordance with references (a) and (b), enclosure (1) is transmitted.

2. Should clarification of the content of enclosure (1) or technical assistance in connection with future applied biology problems be required, it is requested that the Commander, Atlantic Division, Naval Facilities Engineering Command be advised.

E. T. DiBERTO
By direction

Copy to:
NAVFAC (1:132)
NAVPVNTMEDU TWO
10
1CA (LCS)

Stover
12-17-68

REVIEW OF THE PEST CONTROL PROGRAM
AT THE
NAVAL TRAINING CENTER
BAINBRIDGE, MARYLAND

Ref: (a) SECNAVINST 5430.54 of 27 Dec 1961
(b) NAVFACINST 6250.3A of 1 Oct 1964
(c) NAVFACINST 6250.5 of 24 May 1966

I. AUTHORITY

A. In accordance with references (a), (b) and (c), Mr. L. C. Stover, Entomologist, Atlantic Division, Naval Facilities Engineering Command, visited the Naval Training Center, Bainbridge, Maryland, 2 - 6 December 1968, to review and discuss the activity pest control program.

B. The pest control program was discussed with the following persons:

CDR J. E. Ford	Public Works Officer
LCDR W. G. Ripley	Assistant Public Works Officer
CWO-4 F. E. Sullivan	Sanitation Officer
Mr. P. E. Orr	Director, Shops Division
Mr. A. Roth	Maintenance Control Director
Mrs. M. Scharf	Housing Manager
Mr. C. Carrick	Assistant Housing Manager
Mr. H. Stikes	Foreman, Transportation
Mr. C. L. Martin	Foreman, Pest Control Equipment Operator
Mr. J. R. Linzy	Pest Control Equipment Operator
Mr. W. L. Parker	Pest Control Equipment Operator
Mr. W. L. Brooks	Pest Control Equipment Operator

II. PURPOSE

The review was made to determine:

1. The types of pest control problems present.

2. The extent of damage by pests.

3. The measures necessary to eliminate these pests.

4. Progress made in pest abatement.

III. DETERMINATION

Pest control problems were encountered in household pest control, structural pest control, vector pest control and materials. Minor problems were encountered in vegetation pest control and weed control.

IV. SCOPE OF REVIEW AND RELATED COMMENTS

A. Household Pest Control

1. Cockroaches are considered to be the principal household pest at the Naval Training Center. These insects present an arduous task to the pest control operator and are especially difficult to control in food handling establishments. Inspection made at the various clubs and other food service areas showed the degree of control to be adequate. Discussions with personnel at these areas also showed the service rendered by the pest control shop to be on a scheduled basis, which is the only effective way to deal with these pests.

2. In controlling cockroach populations in housing areas, however, a problem does exist. At present, roach control in family housing is based on the premise that residual treatment of shelf spaces in kitchens, bathrooms and closets will be done only if the tenant so desires. This is resulting in only partial treatment of some units of apartment buildings, which greatly reduces the effectiveness of roach control operations in these areas. Accordingly, it is recommended that occupants of family housing at the Naval Training Center be required to prepare shelves in the above mentioned areas for treatment. This will result in a much more effective control program and reduce the number of service calls.

3. Cockroach control chemicals used at NTC BAIN are 0.5 - 1.0% diazinon, kepone bait and chlordane (for American roaches). These chemicals are adequate and no recommendations of alternate insecticides are given at this time.

B. Structural Pest Control

1. Subterranean termites are present at the Naval Training Center and are especially prevalent in the Manor Heights housing area. An Engineering Service Request (LANTDIV Project No. 1036-20505), which was answered by LANTDIV previous to this review, offered suggestions for the control of termites. The termites present in the Manor Heights area will, if not controlled, cause more extensive damage.

2. A special project is being submitted by the housing office at the Naval Training Center, and when funded will greatly reduce the chance of further damage. This work, as mentioned in the ESR, is within the capability of the pest control shop, and can be completed by station forces.

3. In the area of structural pest control, another problem is the lack of an adequate utility pole inspection program. The large number of poles at the training center (approximately 1,500) represents a large investment and a proper inspection and treatment program can protect this investment.

4. Wooden utility poles, as any other wood structure, are subject to attack and deterioration from wood-destroying fungi and other wood-destroying organisms. At present, there are no utility pole inspections performed at the Training Center and it is recommended that a pole inspection program be initiated to protect the large investment present in wooden poles.

5. To aid in the establishment of a pole inspection program, LANTDIV has available a sonic pole tester that provides an accurate method for testing in-place poles. It is suggested that the Naval Training Center submit an ESR to LANTDIV for training in the use of this instrument and for guidance in establishing a pole inspection program. After personnel have been trained in the use of the instrument, it will be made available upon request for future inspections.

C. Vegetation Pest Control

1. Bagworms (Thyridopteryx ephemeraeformis) have caused a considerable amount of damage to evergreen trees. This insect is particularly destructive to evergreen trees since populations of this pest build up rapidly and trees attacked are commonly completely defoliated. Control measures are effective, however, if applied correctly and if particular attention is given to timing of treatments. The insecticide of choice for bagworm control is carbaryl (sevin) applied as a 0.14% suspension (1.5 pounds of 80% carbaryl W.P./100 gallons of water). This spray must be applied in late spring (approximately 1 May) when the overwintering eggs hatch and the resulting larvae are exposed. Several sprayings may be necessary to control the populations present. Lead arsenate, another insecticide, may also be used for control, but only until the larvae are half grown. After this growth stage is reached, hand picking of bags is the only practical method of control.

2. The large sycamore (Plantus occidentalis) trees present in the Tome area of the Naval Training Center were reported and observed to be in poor health. Inspection made of the trees, due to the season of the year, revealed very little and no conclusions could be drawn. It is suggested that the pest control shop observe the trees this spring and submit any unhealthy foliage or twigs to the State Forestry Office or the U. S. Department of Agriculture Laboratory in Beltsville, Maryland, for determination of the disease agent and recommendations for control.

D. Weed Control

1. The only problem reported was control of plantain (Plantago spp.) in lawns. This species of weed can be readily controlled by applying 2,4-D at the rate of 2 pounds per acre applied in 50 to 100 gallons of water. This material should be applied in the early spring to the foliage of the plants for the most effective results.

2. Should other weed species become a problem or technical advice on chemical weed control be needed, it is suggested that the Natural Resources Management Staff (Code 07B), LANTDIV be contacted.

E. Rodent Control

Other than occasional and seasonal problems with field mice, no rodent control problems were reported or observed. The station pest control shop maintains a scheduled baiting and trapping program and no recommendations are offered in the phase of pest control operations.

F. Vector Pest Control

1. Flies are a problem at the Training Center throughout the summer months. This is due, in part, to the agarian nature of the area surrounding the base. Control efforts are based on residual spraying and aerosol applications; and the proper insecticides are being utilized.

2. A suitable bait for flies that can be utilized in conjunction with the above treatments is diazinon. This material can be prepared in two bait formulations, which are given below:

a. Dry diazinon bait (1%)

1.0 oz of 50% diazinon W.P. + 3 lb of sugar

b. Wet diazinon bait (0.38%)

1.0 fluid oz of 48% diazinon E.C. + 1 lb of sugar + 1 gallon of water

The dry bait should be applied at the rate of 3 - 4 ounces per 1,000 square feet. The wet bait should be applied at the rate of 1 - 3 gallons per 1,000 square feet around garbage containers, loading platforms, etc.

3. Ticks are also a problem at the Naval Training Center and a threat to the physical well-being of Center personnel. Ticks are vectors of Rocky Mountain spotted fever, a rickettsial disease. In the five year period 1960 - 1964, there were 65 cases of spotted fever in the state, making Maryland the third highest state in spotted fever incidence.

4. These pests are especially prevalent in base housing areas and every effort should be taken to continue control operations for these areas. Control chemicals and application rates being used are correct and no recommendations are given in this area.

5. Mosquitoes are not a serious pest at the Naval Training Center and no control problems were reported. Control of mosquitoes, however, like control of many pests, require that population surveys be made. During the past mosquito season, no adult surveys were made by the station medical department. The medical department is responsible for conducting surveys for pests of medical importance, as stated in SECNAVINST 5430.54 of 27 December 1961. Accordingly, it is recommended that the medical department initiate a mosquito survey program. Mosquitoes collected (both larva and adult) may be forwarded to Preventive Medicine Unit Two, U. S. Naval Base, Norfolk, Virginia, 23511, for identification. COMFIVEINST 6250.2A contains information on the use and reporting of mosquito surveys and should be used for additional reference.

F. Miscellaneous Pests

The only miscellaneous pest of importance found during the review was filter flies (Psychoda spp.). These flies are common pests at sewage plants throughout the Fifth Naval District and can be controlled with malathion. To provide a longer residual effect, it is suggested that a 2.5% malathion suspension be used in lieu of the current solution formulation. In the event the recommended malathion formulation does not reduce the population, it is suggested that the Special Assistant for Applied Biology (Code 10A) LANTDIV be contacted for further recommendations.

V. EQUIPMENT, MATERIALS AND FACILITIES

A. Equipment

1. A review of power driven pest control equipment showed that sufficient equipment to perform the necessary pest control operations is on hand. One sprayer (USN #54-02538), however, is rapidly becoming worn to such a degree that replacement will be needed in a relatively short time. It is therefore recommended that a new NAVFAC equipment code type 5421-10 sprayer be ordered on the FY 1970 engineering support equipment list, to replace the 1951 model sprayer. This piece of equipment is listed in enclosure (2) of NAVFACINST 11200.12D.

2. Other pest control equipment such as hand sprayers and safety equipment was inspected and found to be adequate.

B. Materials

1. An inventory of materials showed the following to be on hand:

Material	Quanity
ACP Grass Killer (Sodium TCA)	30 lbs
*Aramite 15-W (Miticide)	60 lbs
*BHC 11% E. C.	150 gal
*Black Leaf 40 (Nicotine Sulphate)	60 gal
*Captan 50 W. P.	110 lbs
Chlordane 72% E. C.	55 gal
*Copper Sulphate	20 lbs
Creosote	90 gal
*DDT 25% E. C.	350 gal
*DDT 20% O. S.	350 gal
*DDT 5% O. S.	100 gal
DDT 75% W. P.	120 lbs
Diazinon 0.5% O. S.	25 gal
Diazinon 47.5% O. S.	15 gal
*Ferbam	20 lbs
Indoor fogging SLN	80 gal
*Karathane	80 lbs
Kepone (pelleted)	15 lbs
Lead Arsenate	180 lbs
Lethane	3 gal
Malathion 57% E. C.	90 gal

Malathion 25% E. C.	300 gal
MH-40	50 gal
Pentachlorophenol 5% O. S.	150 gal
Pival	2 lbs
Poly-bor chlorate	150 lbs
*Red Squill	15 lbs
*Ryania	60 lbs
Sevin 50% W. P.	50 lbs
Sulfur	80 lbs
Telvar-W	450 lbs
Warfarin (0.5%)	15 lbs
Zinc Phosphide	2 lbs
2,4-D + 2,4,5-T Mixture	10 gal

2. Those materials marked with an asterisk, due to age, are no longer useful. The toxic ingredients of these pesticides have crystalized or have been otherwise chemically altered, rendering them ineffective for use. However, these materials are still toxic to a degree and must be disposed of in the proper manner so as not to pollute the environment. It is therefore recommended that these pesticides be disposed of as soon as possible and in the following manner:

a. Bury all dry pesticides at a depth of 36 inches in the sanitary land fill.

b. Pour all liquid concentrates into a pit dug to a depth of 30 inches in the sanitary fill.

c. Bury all empty containers, after chopping holes in them to prevent reuse, at least 18 inches deep at the sanitary land fill.

C. Facilities

The storage and mixing facilities for pesticides at the Naval Training Center were inspected and found to be adequate.

VI. SCHEDULING OF OPERATIONS

Pest control operations at the Naval Training Center are accomplished on a scheduled basis and no recommendations are necessary. Job orders covering pest control were also reviewed and found to be adequate.

VII. STAFFING AND CERTIFICATION

A. Staffing

The pest control shop at the Naval Training Center is staffed with a pest control supervisor, three certified pest control equipment operators and one exterminator. This is an adequate number of personnel to complete the workload in pest control operations, and no additional personnel are required.

B. Certification

1. Pest control training conferences are held biennially as required by NAVFACINST 6250.5. Attaining a passing grade on the examination given at the conference partially fulfills the requirements for certification of pest control operators. The next conference will be held at Norfolk during the first two weeks of February, the first week being directed toward supervisory personnel and personnel previously certified, and the second week is to be a more basic type of training for exterminators and other personnel who have not been previously certified.

2. Since all pest control personnel at the Naval Training Center are required to be certified, it is recommended that they be sent to the upcoming certification conference in Norfolk. It is also suggested that Mr. Stewart, the exterminator in the pest control shop, be sent to the second weeks course.

3. A LANTDIV Notice concerning the course, room accomodations and other information pertinent to the conference will be forthcoming.

VIII. RECOMMENDATIONS

A. That occupants of family housing be required to prepare shelves in the kitchen, bathroom and other areas to allow a more effective treatment for roach control.

B. That a utility pole inspection program be initiated to protect the large investment in wooden utility poles.

C. That the station Medical Department initiate a msoquito survey program.

D. That a new 5421-10 sprayer be ordered on the FY 1970 engineering support equipment list to replace a 1951 model sprayer (USN #54-02538) currently on hand.

E. That the insecticides that are described in the report be disposed of.

F. That pest control personnel be sent to Norfolk to attend the upcoming training conference so they can be recertified.

G. That a sufficient amount of 50% diazinon wettable powder be procured for use in fly control if dry baits are to be used.

REFERENCE 3

Dangerous Properties of Industrial Materials

Sixth Edition

N. IRVING SAX

Assisted by:

Benjamin Feiner/Joseph J. Fitzgerald/Thomas J. Haley/Elizabeth K. Weisburger

VAN NOSTRAND REINHOLD COMPANY
NEW YORK CINCINNATI TORONTO LONDON MELBOURNE

ihl-mus TC:55 ppm/43W-I:ETA	JTEHD6 4,15,78
ihl-hmn TCLo:25 ppm:SYS	CHINAG 11,463,76
·at LD50:200 mg/kg	DCTODJ 1,63,77
it LCLo:10000 ppm/24H	EXMPA6 20,187,74
·mus LC50:98 ppm/22H	JTEHD6 3(5-6),913,77
orl-dog LDLo:5750 mg/kg	QJPPAL 7,205,34
ivn-dog LDLo:225 mg/kg	QJPPAL 7,205,34
scu-rbt LDLo:3700 mg/kg	QJPPAL 7,205,34

Aquatic Toxicity Rating: TLm96:1000-100 ppm WQCHM* 3,-,74. Carcinogenic Determination: Animal Positive IARC** 19,439,79.

TLV: Air: 10 ppm DTLVS* 4,432,80. *Toxicology Review:* CTOXAO 8,633,75; CMTVAS 10(3),49,73; NTIS** ORNL/TIRC-77/3. Occupational Exposure to Vinyl Halides recm std: Air: TWA 1 ppm; CL 5 ppm/15M NTIS**. NTP Carcinogenesis Bioassay Completed as of December 1980. "NIOSH Manual of Analytical Methods" VOL 4 266*. NIOSH Current Intelligence Bulletin 28, 1978. Reported in EPA TSCA Inventory, 1980. EPA TSCA 8(a) Preliminary Assessment Information Proposed Rule FERREAC 45,13646,80.

THR: An exper MUT, ETA, NEO, CARC. HIGH acute orl, ihl. See also vinyl chloride.

Fire Hazard: Highly dangerous, when exposed to heat or flame.

Explosion Hazard: Mod, in the form of gas, when exposed to heat or flame. Also can explode spontaneously; reacts violently with chlorosulfonic acid, HNO_3, oleum.

Disaster Hazard: Highly dangerous; see chlorides; can react vigorously with oxidizing materials.

To Fight Fire: Alcohol foam, CO_2, dry chemical.

Incomp: Air; chlorotri-fluoroethylene; ozone; perchloryl fluoride.

cis-DICHLOROETHYLENE

CAS RN: 156592 NIOSH #: KV 9420000
mf: $C_2H_2Cl_2$; mw: 96.94

Colorless liquid, pleasant odor. mp: −80.5°, bp: 59°, lel = 9.7%, uel = 12.8%, flash p: 39°F, d: 1.2743 @ 25°/4°, vap. press: 400 mm @ 41.0°, vap. d: 3.34.

SYNS:
1,2-DICHLOROETHYLENE ACETYLENE DICHLORIDE

TOXICITY DATA: 1	CODEN:
ihl-mus LCLo:65000 mg/m3/2H	AHBAAM 116,131,36
ihl-cat LCLo:20000 mg/m3/6H	AHBAAM 116,131,36

Reported in EPA TSCA Inventory, 1980.

THR: LOW via oral route. In high conc it is irr and narcotic. Has produced liver and kidney injury in exper animals.

Fire Hazard: Dangerous, when exposed to heat or flame. Reacts violently with N_2O_4, KOH, Na, NaOH.

Spontaneous Heating: No.

Explosion Hazard: Mod, in the form of vapor when exposed to flame.

Disaster Hazard: Dangerous; see chlorides; can react vigorously with oxidizing materials.

To Fight Fire: Water spray, foam, CO_2, dry chemical.

cis, 1,2-DICHLOROETHYLENE

mf: $C_2H_2Cl_2$; mw: 96.94

Flash p: 42.8°F; lel = 3.3%; uel = 15%.

trans-1,2-DICHLOROETHYLENE

mf: $C_2H_2Cl_2$; mw: 96.94

Flash p: 35.6°F; lel = 9.7%; uel = 12.8%.
Can cause fire hazard.

Incomp: Alkalies; difluoromethylene dihypofluorite; nitrogen tetraoxide.

1,2-DICHLOROETHYLENE CARBONATE

CAS RN: 3967553 NIOSH #: JH 7400000
mf: $C_3H_2Cl_2O_3$; mw: 156.95

TOXICITY DATA: 3	CODEN:
scu-mus TDLo:648 mg/kg/54W-I:ETA	JNCIAM 48,1431,72

THR: An exper ETA.

Disaster Hazard: When heated to decomp it emits tox fumes of Cl^-.

DICHLORO(ETHYLENEDIAMMINE)-PLATINUM(II)

CAS RN: 14096516 NIOSH #: TP 2497100
mf: $C_2H_8Cl_2N_2Pt$; mw: 326.11

TOXICITY DATA: 3	CODEN:
mmo-sat 2 ug/plate	MUREAV 77,45,80
mma-sat 2 ug/plate	MUREAV 77,45,80
ipr-mus LDLo:14 mg/kg	BICHBX 2,187,73

THR: MUT data. HIGH ipr. See also platinum compounds.

Disaster Hazard: When heated to decomp it emits very tox fumes of Cl^- and NO_x.

DI-2-CHLOROETHYL MALEATE

CAS RN: 63917066 NIOSH #: ON 1050000
mf: $C_8H_{10}Cl_2O_4$; mw: 241.08

TOXICITY DATA: 3	CODEN:
orl-rat LD50:71 mg/kg	TXAPA9 28,313,74
skn-rbt LD50:140 mg/kg	TXAPA9 28,313,74

THR: HIGH orl, skn.

Disaster Hazard: When heated to decomp it emits tox fumes of Cl^-.

2,3-DICHLORO-N-ETHYLMALEINIMIDE

CAS RN: 20198770 NIOSH #: ON 5175000
mf: $C_6H_5Cl_2NO_2$; mw: 194.02

SYN: N-ETHYL-DICHLOROMALEINIMIDE

TOXICITY DATA: 3	CODEN:
ipr-mus TDLo:6200 ug/kg/(9D preg):TER	ARTODN 37,15,76
ipr-mus LD50:15 mg/kg	ARTODN 37,15,76
ivn-mus LD50:5600 ug/kg	CSLNX* NX#03694

CHLORCYCLIZINE DIHYDROCHLORIDE

CAS RN: 129715 NIOSH #: TL 2100000
$C_{18}H_{21}ClN_2 \cdot 2ClH$; mw: 373.78

SYNS:

1-(4-CHLOROBENZHYDRYL)-4-METHYLPIPERAZINE DIHYDROCHLORIDE
DI-PARALENE-2-HYDROCHLORIDE
N-METHYL-N'-(4-CHLOROBENZHYDRYL)PIPERAZINE DIHYDROCHLORIDE
PERAZIL DIHYDROCHLORIDE

TOXICITY DATA: 3	CODEN:
ipr-rat LD50:100 mg/kg	AIPTAK 80,378,49
orl-mus LDLo:150 mg/kg	AIPTAK 80,378,49
ipr-mus LD50:137 mg/kg	JPETAB 96,388,49
scu-mus LDLo:150 mg/kg	AIPTAK 80,378,49
ivn-mus LD50:35 mg/kg	AIPTAK 80,378,49
ipr-dog LDLo:100 mg/kg	AIPTAK 80,378,49
ipr-cat LD50:75 mg/kg	AIPTAK 80,378,49
ipr-gpg LD50:100 mg/kg	AIPTAK 80,378,49

THR: HIGH ipr, orl, scu.
Disaster Hazard: When heated to decomp it emits very tox fumes of Cl^-, NO_x and HCl.

CHLORCYCLIZINE HYDROCHLORIDE

CAS RN: 14362313 NIOSH #: TL 2200000
mf: $C_{18}H_{21}ClN_2 \cdot 7ClH$; mw: 556.08

SYNS:

CHLORCYCLIZINIUM CHLORIDE
1-(P-CHLOROBENZHYDRYL)-4-METHYLPIPERAZINE HYDROCHLORIDE
DIPARALENE HYDROCHLORIDE

TOXICITY DATA: 3	CODEN:
orl-rat TDLo:240 mg/kg (12-15D preg) TER	TJADAB 18,199,78
orl-rat TDLo:100 mg/kg (12-15D preg) TER	JPETAB 147,391,65
ipr-rat LD50:100 mg/kg	CLDND*
orl-mus LD50:300 mg/kg	CLDND*
ipr-mus LD50:100 mg/kg	CLDND*
scu-mus LD50:200 mg/kg	CLDND*
ivn-mus LD50:35 mg/kg	CLDND*
ipr-dog LD50:125 mg/kg	CLDND*
ipr-cat LD50:100 mg/kg	CLDND*
ipr-gpg LD50:100 mg/kg	CLDND*

THR: An exper TER. HIGH ipr, orl, scu.
Disaster Hazard: When heated to decomp it emits very tox fumes of HCl and NO_x.

CHLORCYCLIZINE HYDROCHLORIDE A

CAS RN: 894564 NIOSH #: TL 2275000
mf: $C_{18}H_{21}ClN_2 \cdot ClH$; mw: 337.32

SYNS:

CHLOROCYCLIZINE HYDROCHLORIDE
1-(P-CHLORO-ALPHA-PHENYLBENZYL)-4-METHYLPIPERAZINE HYDROCHLORIDE

TOXICITY DATA: 3	CODEN:
unk-mus TDLo:800 mg/kg (11-14D preg)TER	AJOGAH 95,109,66
orl-rat TDLo:500 mg/kg (6-15D preg)	TXCYAC 8,87,77
hmn TDLo:360 ug/kg:CNS	12VXA5 7,236,60
rat LD50:100 mg/kg	27ZQAG -,213,72
orl-mus LD50:300 mg/kg	27ZQAG -,213,72
ipr-mus LD50:137 mg/kg	JPETAB 96,388,49
scu-mus LD50:200 mg/kg	27ZQAG -,213,72
ipr-dog LD50:125 mg/kg	27ZQAG -,213,72
ipr-cat LD50:75 mg/kg	27ZQAG -,213,72
ipr-gpg LD50:100 mg/kg	27ZQAG -,213,72

THR: An exper TER also a hmn CNS. HIGH ipr, orl, scu.
Disaster Hazard: When heated to decomp it emits very tox fumes of HCl and NO_x.

CHLORDANE

CAS RN: 57749 NIOSH #: PB 9800000
mf: $C_{10}H_6Cl_8$; mw: 409.76

Colorless to amber, odorless, viscous liquid. bp: 175°, d: 1.57-1.63 @ 15.5°/15.5°.

SYNS:

BELT
CHLOORDAAN (DUTCH)
GAMMA-CHLORDAN
CHLORODANE
CLORDAN (ITALIAN)
ENT 9,932
ENT 25,552-X
NCI-C00099
OCTACHLOR
OCTACHLORODIHYDRODICYCLOPENTADIENE
1,2,4,5,6,7,8,8-OCTACHLORO-2,3,3A,4,7,7A-HEXAHYDRO-4,7-METHANOINDENE
1,2,4,5,6,7,8,8-OCTACHLORO-2,3,3A,4,7,7A-HEXAHYDRO-4,7-METHANO-1H-INDENE
1,2,4,5,6,7,8,8-OCTACHLORO-3A,4,7,7A-HEXAHYDRO-4,7-METHYLENE INDANE
OCTACHLORO-4,7-METHANOHYDROINDANE
OCTACHLORO-4,7-METHANOTETRAHYDROINDANE
1,2,4,5,6,7,8,8-OCTACHLORO-4,7-METHANO-3A,4,7,7A-TETRAHYDROINDANE
1,2,4,5,6,7,8,8-OCTACHLOOR-3A,4,7,7A-TETRAHYDRO-4,7-ENDO-METHANO-INDAAN (DUTCH)
1,2,4,5,6,7,8,8-OCTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-METHANOINDANE
1,2,4,5,6,7,8,8-OCTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-METHANOINDANE
1,2,4,5,6,7,10,10-OCTACHLORO-4,7,8,9-TETRAHYDRO-4,7-METHYLENEINDANE
1,2,4,5,6,7,8,8-OCTACHLOR-3A,4,7,7A-TETRAHYDRO-4,7-ENDO-METHANO-INDAN (GERMAN)
1,2,4,5,6,7,8,8-OTTOCHLORO-3A,4,7,7A-TETRAIDRO-4,7-ENDO-METANO-INDANO (ITALIAN)

TOXICITY DATA: 3	CODEN:
unk-mus TDLo:168 mg/kg (1-21D preg)	APTOD9 19,A18,80
unk-mus TDLo:168 mg/kg (1-21D preg)	TJADAB 19,23A,79
orl-mus LD50:430 mg/kg	DTLVS* 4,78,80
scu-mus LD50:153 mg/kg	AIPTAK 241,79,79
orl-mus TDLo:3360 ug/kg (1-21D preg)	JEPTDQ 2,357,78
dns-hmn:fbr 1 umol/L	MUREAV 42,161,77
orl-mus TDLo:2020 mg/kg/80W-C:CAR	NCITR* NCI-CG-TR-8,77
orl-mus TD:3780 mg/kg/80W-C:CAR	NCITR* NIC-CG-TR-8,77
orl-hmn LDLo:40 mg/kg	CMEP** -,1,56
unk-man LDLo:118 mg/kg	85DCAI 2,73,70
skn-rat LD50:700 mg/kg	PHJOAV 185,361,60
ipr-rat LD50:343 mg/kg	TXAPA9 32,443,75
ipr,mus LDLo:240 mg/kg	TXAPA9 23,288,72
ivn-mus LD50:100 mg/kg	CSLNX* NX#04876
ihl-cat LC50:100 mg/m3/4H	GTPZAB 8(4),30,64
orl-rat LD50:100 mg/kg	PCOC** -,226,66
skn-rbt LD50:780 mg/kg	85DPAN -,-,71/76
ivn-rbt LDLo:10 mg/kg	AIHOAX 1,13,50
orl-ham LD50:1720 mg/kg	JETOAS 7,159,74
orl-ckn LD50:220 mg/kg	PCOC** -,266,66

Carcinogenic Determination: Animal Positive IARC* 20,45,79.

TLV: Air: 0.5 mg/m3 (skin) DTLVS* 4,78,80. *Toxicology Review* CNDQA8 10(3),43,75; RREVAH 56,107,75; BNYMAM 54,413,78; CTOXAO 13,231,78. OSHA Standard Air: TWA 500 ug/m3 (skin) (SCP-S) FEREAC 39,23540,74. DOT: Combustible Liquid, Label: None. FEREAC 41,57018,76. NCI Carcinogenesis Bioassay Completed; Results Positive: Mouse (NCITR* NCI-CG-TR-8,77). NCI Carcinogenesis Bioassay Completed; Results negative: Rat (NCITR* NCI-CG-TR-8,77).

THR: MUT data. An exper CARC. HIGH hmn orl, unk. HIGH orl, ivn, ihl, ipr. MOD skn, orl. Implicated in aplastic anemia. An insecticide. Must be considered quite toxic. Chlordane is readily absorbed through the skin as well as through other portals. It is a CNS stimulant whose exact mode of action is unknown, but it may involve microsomal enzyme stimulation. Animals poisoned by this and related compounds show an extremely marked loss of appetite and neurological symptoms. The fatal dose to man is unknown. It has been estimated to be between 6 to 60 g(1/5 to 2 oz.). One person receiving an accidental skin application of 25% solution (amounting to something over 30 g of technical chlordane) developed symptoms within about 40 min and died before medical attention was obtained. In two patients, death followed exposure to low oral doses of chlordane (2-4 g); on microscopic examination both patients showed severe chronic fatty degeneration of the liver, characteristic of chronic alcoholism. Although these two fatalities cannot be attributed exclusively to chlordane, they are entirely consistent with previous observations that the toxicity of other chlorinated hydrocarbons is much enhanced in the presence of chronic liver damage. The dangerous chronic dose in man is unknown.

One person poisoned by chlordane developed convulsions within 40 min of gross skin contamination and died, apparently of respiratory failure, before medical aid could be obtained.

Acutely poisoned exper animals show similar signs. Exper animals exposed to repeated small doses exhibit hyperexcitability, tremors, and convulsions, and those which survive long enough show marked anorexia and loss of weight. Symptoms in animals frequently occur within an hour of the administration of a large dose, but death often is delayed for several days depending on the dosage and route of administration. In any event, symptoms are of longer duration with chlordane than with DDT under similar conditions.

Laboratory findings are essentially normal, except that the insecticide may be demonstrated in tissues of poisoned animals by means of bioassay. A method for specific, quantitative chemical analysis for chlordane is now available using small amounts of subcutaneous fat. Chronically poisoned animals show degenerative changes in the liver and kidney tubules.

Treatment and Antidotes: Removal of the poison from the skin or the alimentary tract should be attempted. Oil laxatives should be avoided. The nervous symptoms may best be combatted with pentobarbital or phenobarbital.

Disaster Hazard: When heated to decomp it emits tox fumes of Cl^-.

For further information see Vol. 1, No. 2 and Vol. 3, No. 5 of *DPIM Report.*

CHLORENDIC ACID

CAS RN: 115286 NIOSH #: RB 9000000

SYNS:

1,4,5,6,7,7-HEXACHLORO-5-NORBORNENE-2,3-DICARBOXYLIC ACID
KYSELINA 3,6-ENDOMETHYLEN-3,4,5,6,7,7-HEXACHLOR-DELTA(SUP 4)-TETRAHYDROFTALOVA (CZECH)
KYSELINA HET (CZECH)
NCI-C55072

TOXICITY DATA: 2 CODEN:
orl-rat LD50:1770 mg/kg 28ZPAK -,92,72

Currently Tested by NTP for Carcinogenesis by Standard Bioassay Protocol as of December 1980. Reported in EPA TSCA Inventory, 1980. EPA TSCA 8(a) Preliminary Assessment Information Proposed Rule FERREAC 45,13646,80.

THR: MOD orl.

Disaster Hazard: When heated to decomp it emits tox fumes of Cl^-.

CHLORETHYLBENZMETHOXAZONE

CAS RN: 132898 NIOSH #: DM 3675000
mf: $C_{10}H_{10}ClNO_2$; mw: 211.66

SYNS:

2-(2-CHLOROETHYL)-3-AZA-4-CHROMANONE
2-(2-CHLOROETHYL)-2,3-DIHYDRO-4H-1,3-BENZOXAZIN-4-ONE
2-(2-CHLOROETHYL)-2,3-DIHYDRO-4-OXO-1,3-BENZOXAZINE
2-(BETA-CHLOROETHYL)-2,3-DIHYDRO-4-OXO(BENZO-1,3-OXAZINE)
4-OXO-2-(BETA-CHLOROETHYL)-2,3-DIHYDROBENZO-1,3-OXAZINE

TOXICITY DATA: 2-1 CODEN:
ipr-rat LD50:730 mg/kg BMJOAE 1,36,60
orl-rat LD50:10 gm/kg ARZNAD 7,651,57

THR: MOD ipr; LOW orl.

Disaster Hazard: When heated to decomp it emits very tox fumes of Cl^- and NO_x.

CHLORFENSULFIDE

CAS RN: 2274740 NIOSH #: IL 8842000
mf: $C_{12}H_6Cl_4N_2S$; mw: 352.06

SYNS:

CHLORFENSULFID (GERMAN)
4-CHLOROPHENYL-2,4,5-TRICHLOROPHENYLAZOSULFIDE
2,4,5-TRICHLOROPHENYLAZO-4'-CHLOROPHENYL-SULFIDE

TOXICITY DATA: 2 CODEN:
orl-rat LD50:4000 mg/kg 85DPAN -,-,71/76
unk-mus LD50:3000 mg/kg 30ZDA9 -,281,71

THR: An exper ETA.
Disaster Hazard: When heated to decomp it emits acrid smoke and fumes.

.MICHOLINIUM-3-DIBROMIDE

CAS RN: 312458 NIOSH #: QF 2450000
mf: $C_{24}H_{34}N_2O_4 \cdot 2Br$; mw: 574.42

SYNS:

2,2'-(1,1'-BIPHENYL-4,4'-DIYLBIS(20HYDROXY-4,4-DIMETHYL-MORPHOLINIUM DIBROMIDE
HEMICHOLINIUM BROMIDE
HEMICHOLINIUM-3-BROMIDE
HEMICHOLINIUM DIBROMIDE

TOXICITY DATA: 3	CODEN:
ipr-rat LD50:160 ug/kg	EJPHAZ 33,145,75
ipr-mus LD50:46 ug/kg	EJPHAZ 33,145,75
ipr-rat LD50:212 ug/kg	EJPHAZ 50,393,78
ipr-mus LD50:120 ug/kg	JPPMAB 22,20,70
ivn-mus LD50:80 ug/kg	TXAPA9 27,666,74

Reported in EPA TSCA Inventory, 1980.
THR: HIGH ipr, ivn. See also bromides.
Disaster Hazard: When heated to decomp it emits very tox fumes of NO_x and Br^-.

HEPARIN

CAS RN: 9005496 NIOSH #: MI 0700000

SYNS:

HED-HEPARIN
HEPARINATE
ˆUAEMIN SODIUM
SODIUM HEPARIN
THROMBOLIQUINE

)XICITY DATA: 2	CODEN:
dni-esc 1 mg/L	NNBYA7 232,143,71
dni-omi 14 mg/L	NNBYA7 232,143,71
dns-rat:lvr 20 ug	BBACAQ 479,391,77
scu-man TDLo:7 mg/kg/4D	JAMAAP 244,1831,80
dnd-ham:ovr 200 mg/L	BBACAQ 517,486,78
ipr-rat LDLo:420 mg/kg	TXAPA9 1,156,59
ivn-mus LD50:1500 mg/kg	AJMSA9 216,234,48

Toxicology Review: AEMBAP 52,375,75; JPMSAE 62,517,73.
THR: MOD ivn, ipr. MUT data.

HEPTACHLOR

CAS RN: 76448 NIOSH #: 0700000
mf: $C_{10}H_5Cl_7$; mw: 373.30

Crystals, nearly insol in water; sol in organic solvents. mp: 96°.

SYNS:

1,4,5,6,7,8,8A-HEPTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-METHANOINDANE
3-CHLOROCHLORDENE
NCI-C00180
ENT 15,152
EPTACLORO (ITALIAN)
HEPTACHLOOR (DUTCH)
1,4,5,6,7,8,8-HEPTACHLOOR-3A,4,7,7A-TETRAHYDRO-4,7-ENDO-METHANO-INDEEN DUTCH)
HEPTACHLOR
HEPTACHLORE (FRENCH)
3,4,5,6,7,8,8-HEPTACHLORODICYCLOPENTADIENE
3,4,5,6,7,8,8A-HEPTACHLORODICYCLOPENTADIENE
1,4,5,6,7,8,8-HEPTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-ENDOMETHANOINDENE
1,4,5,6,7,8,8-HEPTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-METHANOINDENE
1(3A),4,5,6,7,8,8-HEPTACHLORO-3A(1),4,7,7A-TETRAHYDRO-4,7-METHANOINDENE
3A,4,5,6,7,8,8-HEPTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-METHANOINDENE
1,4,5,6,7,8,8-HEPTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-METHANOL-1H-INDENE
1,4,5,6,7,8,8-HEPTACHLORO-3A,4,7,7A-TETRAHYDRO-4,7-METHYLENE INDENE
1,4,5,6,7,10,10-HEPTACHLORO-4,7,8,9-TETRAHYDRO-4,7-METHYLENEINDENE
1,4,5,6,7,10,10-HEPTACHLORO-4,7,8,9-TETRAHYDRO-4,7-ENDOMETHYLENEINDENE

TOXICITY DATA 3	CODEN:
cyt-rat-orl 60 ug/kg	34LXAP -,555,76
dlt-rat-orl 60 ug/kg	34LXAP -,555,76
cyt-mus-ipr 5200 ug/kg	SOGEBZ 2(1),80,66
ipr-mus LD50:130 mg/kg	SOGEBZ 2(1),80,66
mma-hmn:fbr 100 umol/L	MUREAV 42,161,77
orl-mus TDLo:403 mg/kg/80W-C:CARC	NCITR* NCI-CG-TR-9,77
orl-mus TD:930 mg/kg/80W-C:CARC	NCITR* NCI-CG-TR-9,77
orl-rat LD50:40 mg/kg	PHJOAV 185,361,60
skn-rat LD50:119 mg/kg	SPEADM 74-1,-,74
ipr-rat LD50:27 mg/kg	FCTXAV 11,63,73
orl-mus LD50:68 mg/kg	SPEADM 74-1,-,74
ivn-mus LDLo:20 mg/kg	JPETAB 107,266,53
skn-rbt LD50:2000 mg/kg	AFDOAQ 16,3,52
orl-gpg LD50:116 mg/kg	PCOC** -,576,66
orl-ham LD50:100 mg/kg	JETOAS 7,159,74
orl-ckn LD50:62 mg/kg	TXAPA9 3,521,61
unk-mam LD50:60 mg/kg	30ZDA9 -,59,71

Aquatic Toxicity Rating: TLm96:under 1 ppm WQCHM* 3,-,74.
Carcinogenic determination: Animal positive IARC** 20,129,79; Indefinite IARC** 5,173,74.
TLV: Air: 0.5 mg/m3 (skin) DTLVS* 4,209,80. *Toxicology Review:* 31ZNAA 1(1),93,71; CNDQA8 10(3), 43,75; RREVAH 56,107,75; BNYMAM 54,413,78; CTOXAO 13,231,78; 85CVA2 5,250,70; 27ZTAP 3,74,69. OSHA Standard-air: TWA 500 ug/m3 (skn) (SCP-T) FEREAC 39,23540,74. NCI Carcinogenesis Bioassay completed; results positive: Mouse (NCITR* NCI-CG-TR-9,77); Results negative: Rat (NCITR* NCI-CG-TR-9,77). "NIOSH Manual of Analytical Methods" Vol 5 S287#.
THR: MUT data. An exper CARC. HIGH orl, skn, ipr, ivn, unk. MOD skn. Acute exposure causes liver damage. Chronic doses have caused liver damage in exper animals. See closely related chlordane. In man, a dose of 1-3 g can cause serious symptoms, especially where liver impairment is the case. Acute symptoms include tremors, convulsions, kidney damage, respiratory collapse and death.
Disaster Hazard: Dangerous; when heated to decomp, it emits highly tox fumes of Cl^-.
NOTE: The EPA has cancelled registration of pesticides containing this with the exception of its use through subsurface ground insertion for termite control.
For further information see Vol. 1, No. 8 of *DPIM Report.*

HEPTACHLOR (technical grade)

NIOSH #: PC 0750000

73% heptachlor, 22% trans-chlordane, and 5% nonachlor (NCITR* NCI-CG-TR-9)

TOXICITY DATA: 2	CODEN:
ihl-rat LCLo:520 mg/m3/4H	HYSAAV 31,383,66
unk-rat LDLo:452 mg/kg	HYSAAV 31,383,66
[illegible]-mus LDLo:580 mg/kg	HYSAAV 31,383,66

R: MOD ihl, unk. See also esters.

Disaster Hazard: When heated to decomp it emits tox fumes of Cl^-.

DDT

CAS RN: 50293 NIOSH #: KJ 3325000

mf: $C_{14}H_9Cl_5$; mw: 354.48

Colorless crystals or white to slightly off-white powder. Odorless or with slight aromatic odor. mp: 108.5°-109°.

SYNS:

ALPHA,ALPHA-BIS(P-CHLOROPHENYL)-BETA,BETA,BETA-TRICHLORETHANE
2,2-BIS(P-CHLOROPHENYL)-1,1,1-TRICHLOROETHANE
CHLOROPHENOTHANE
P,P'-DDT
P,P'-DICHLORODIPHENYLTRICHLOROETHANE
4,4'-DICHLORODIPHENYLTRICHLOROETHANE
DIPHENYLTRICHLOROETHANE
ENT 1,506
NCI-C00464
1,1,1-TRICHLOOR-2,2-BIS(4-CHLOOR FENYL)-ETHAAN (DUTCH)
1,1,1-TRICHLOR-2,2-BIS(4-CHLOR-PHENYL)-AETHAN (GERMAN)
1,1,1-TRICHLORO-2,2-DI(4-CHLOROPHENYL)-ETHANE
1,1,1-TRICLORO-2,2-BIS(4-CLORO-FENIL)-ETANO (ITALIAN)

TOXICITY DATA: 3	CODEN:
cyt-hmn:lym 200 ug/1/72H	MUREAV 40,131,76
dlt-rat-orl 100 mg/kg	FCTXAV 11,53,73
[illegible]-rat-orl 1 gm/kg/2D-I	BECTA6 14,171,75
[illegible]mus-ipr 50 ppm	CNJGA8 16,491,74
[illegible]-mus-unk 50 mg/kg	PHTHDT 6,147,79
dlt-mus-orl 100 mg/kg	PHTHDT 6,147,79
dlt-mus-unk 200 mg/kg/10W-I	PHTHDT 6,147,79
orl-rat TDLo:19 gm/kg/2Y-C:NEO	IJCNAW 19,179,77
orl-mus TDLo:73 mg/kg/26W-C:CAR	FCTXAV 7,215,69
scu-mus TDLo:370 mg/kg/80W-I:NEO	IJCNAW 19,725,77
orl-mus TD:11 gm/kg/78W-C:ETA	NCITR* NCI-CG-TR-131,78
orl-mus TD:7560 mg/kg/90W-C:NEO	FCTXAV 11,433,73
orl-mus TD:5600 mg/kg/80W-I:NEO	IJCNAW 19,725,77
orl-rat TD:8100 mg/kg/2Y-C:ETA	TXAPA9 11,88,67
orl-inf LDLo:150 mg/kg	BMJOAE 2,845,45
orl-hmn TDLo:6 mg/kg:CNS	DTLVS* 3,68,71
unk-man LDLo:221 mg/kg	85DCAI 2,73,70
orl-rat LD50:113 mg/kg	TXAPA9 2,88,60
skn-rat LD50:1931 mg/kg	SPEADM 74-1,-,74
ipr-rat LD50:74 mg/kg	ANTBAL 14,316,69
scu-rat LD50:1500 mg/kg	BMJOAE 1,865,45
ivn-rat LDLo:30 mg/kg	JPETAB 86,213,46
ivn-rat LD50:68 mg/kg	ANTBAL 14,316,69
orl-mus LD50:135 mg/kg	FEPRA7 12,368,53
ipr-mus LD50:77 mg/kg	ANTBAL 14,316,69
ivn-mus LD50:68500 ug/kg	ANTBAL 14,316,69
orl-dog LDLo:300 mg/kg	MEMOAQ 4,25,50
ivn-dog LDLo:75 mg/kg	JPETAB 86,213,46
orl-mky LD50:200 mg/kg	AVPCAQ 12,31,75
ivn-mky LDLo:50 mg/kg	JPETAB 86,213,46
orl-cat LDLo:250 mg/kg	JPETAB 86,213,46
ivn-cat LDLo:40 mg/kg	JPETAB 86,213,46
[illegible]-rbt LD50:250 mg/kg	PCOC** -,347,66
[illegible]-rbt LD50:300 mg/kg	BMJOAE 1,865,45
[illegible]-rbt LD50:250 mg/kg	BMJOAE 1,865,45
ivn-rbt LDLo:50 mg/kg	JPETAB 86,213,46
orl-gpg LD50:150 mg/kg	JETOAS 7,159,74
skn-gpg LD50:1000 mg/kg	BMJOAE 1,865,45
scu-gpg LD50:900 mg/kg	BMJOAE 1,865,45
orl-ckn LDLo:300 mg/kg	MEMOAQ 4,25,50
orl-frg LD50:7600 ug/kg	ENVPAF 20,45,79
scu-frg LD50:35 mg/kg	AIPTAK 74,343,47
orl-dom LDLo:300 mg/kg	MEMOAQ 4,25,50
dlt-oln-orl 200 ppm	ETEAAT 12,221,69
cyt-hmn:lym 200 ug/L/72H	MUREAV 40,131,76
cyt-rat:oth 10 ug/L	34LXAP -,555,76
orl-rat TDLo:390 mg/kg (1-20D preg)	GISAAA 45(6),14,80
ipr-rat TDLo:60 mg/kg (3D pre)	TXAPA9 18,348,71
scu-mus TDLo:418 mg/kg (6-14D preg)	NTIS** PB223-160
unk-mus TDLo:3 mg/kg (10-17D preg)	TXAPA9 22,327,72
orl-dog TDLo:3540 mg/kg (MGN)	AECTCV 6,83,77
orl-rbt TDLo:150 mg/kg (7-9D preg)	AIPTAK 192,286,71
orl-mus TDLo:3408 mg/kg (MGN) TFX:NEO	IJCNAW 11,688,73

Aquatic Toxicity Rating: TLm96:under 1 ppm WQCHM* 2,-,74. Carcinogenic Determination: Animal Suspected IARC** 5,83,74. *TLV:* Air: 1 mg/m3 DTLVS* 4,117,80; *Toxicology Review:* JSIRAC 34,462,75; AABIAV 35,505,48; ATXKA8 29,1,72; ADCSAJ 1,160,50; ENVRAL 7(2),243,74; RREVAH 48,141,73; RREVAH 59,119,75; ADCSAJ 1,160,50; RREVAH 61,37,75; NOALA4 41(217),271,75; MZUZA8 (8),90,73; CNDQA8 10(3),43,75; ECMAAI 14(3),141,73; DTTIAF 80(20),485,73; RREVAH 56,107,75; AJDDAL 20,331,53; AJMEAZ 38,409,65; ETOXAC 7,1,76; IRGGAJ 24,193,68; BISNAS 20,958,70; 85CVA2 5,250,70; PTPAD4 7,513,79; CTOXAO 13,231,78; EESADV 1,89,77; EESADV 1,503,78; BNYMAM 54,413,78; 27ZTAP 3,45,69. OSHA Standard: Air: TWA 1 mg/m3 (skin) (SCP-S) FEREAC 39,23540,74. DOT: ORM-A, Label: None FEREAC 41,57018,76. NCI Carcinogenesis Bioassay Completed; Results Negative (NCITR* NCI-CG-TR-131,78). "NIOSH Manual of Analytical Methods" VOL 3 S274. Reported in EPA TSCA Inventory, 1980. EPA TSCA 8(a) Preliminary Assessment Information Proposed Rule FERREAC 45,13646,80.

THR: HIGH via oral and dermal routes. Used as a food additive permitted in the food and drinking water of animals and/or for the treatment of food-producing animals. Also a food additive permitted in food for human consumption. *Note:* DDT is a common air contaminant.

DDT is readily absorbed from the intestinal tract and, if it occurs in the air in the form of an aerosol or dust, it may be taken into the lung and readily absorbed. DDT is not, however, absorbed from the skin unless it is in solution. Solutions are absorbed from the skin and, by the same token, emulsions are absorbed to some extent. Likewise, fats and oils from whatever source increase the absorption of DDT from the intestine. DDT acts on the CNS, but the exact mechanism of this action either in man or in animals has not been elucidated. DDT is an exper MUT, CARC, ETA, NEO. See chlorinated hydrocarbons. Large doses of DDT also induce nausea and/or diarrhea in man; how-

ever, whether this is a central or local action is not yet clear. Chronically, DDT produces microscopic changes in the liver and kidneys in some exper animals. This has not been demonstrated in man. DDT is secreted in the milk and, as an acid derivative is excreted in the urine of rabbits, dogs and man. DDT and certain of its degradation products, particularly DDE, are stored in fat. Such storage results either from a single large dose or from repeated small doses. DDT stored in the fat is at least largely inactive since a greater total dose may be stored in an exper animal than is sufficient as a lethal dose for that same animal if given at one time. A study based on 75 human cases reported an average of 5.3 ppm of DDT stored in the fat. A higher content of DDT and its derivatives (up to 434 ppm of DDE and 648 ppm of DDT) was found in workers who had very extensive exposure. Without exception, the samples were taken from persons who were either asymptomatic or suffering from some disease completely unrelated to DDT. Careful hospital examination of workers, who had been very extensively exposed and who had volunteered for examination revealed no abnormality which could be attributed to DDT. Much higher levels than have been found in man have been observed in the fat of exper animals which were apparently asymptomatic. DDT stored in the fat is eliminated only very gradually when further dosage is discontinued. After a single dose, the secretion of DDT in the milk and its excretion in the urine reach their height within a day or two and continue at a lower level thereafter.

Dangerous Acute Dose in Man: A dose of 20 g has proved highly dangerous though not fatal to man. This dose was taken by 5 persons who vomited an unknown portion of the material and even so recovered only incompletely after 5 weeks. Smaller doses produced less important symptoms with relatively rapid recovery. Exper ingestion of 1.5 g resulted in great discomfort and moderate neurological changes including paraesthesia, tremor, moderate ataxia, exaggeration of part of the reflexes, headache, and fatigue. Vomiting followed only after 11 hours. Recovery was complete on the following day. The fatal dose of DDT for man is not known. Judging from the literature, no one has ever been killed by DDT in the absence of other insecticides and/or a variety of toxic solvents. However, these common solvent formulations are highly fatal when taken in small doses, partly because of the toxicity of the solvent, and perhaps because of the increased absorbability of the DDT; several fatal cases in man have been reported. Acute oral toxicity for man = 250 mg/kg. Acute oral LD_{50} (rat) = 113 mg/kg (tech grade). Federal fruit and vegetable tolerance = 7 ppm.

Dangerous Chronic Dose in Man: Even less is known of the hazard of chronic DDT poisoning. It is known that certain exper animals fed diets containing one part of DDT per million store the compound in their fat. The storage of DDT in man has been mentioned above. The exact significance of these findings is not known and their further investigation is of the greatest importance. Human volunteers have ingested up to 35 mg/day for 21 months with no ill effects.

Signs and Symptoms of Poisoning in Man: In patients who ate substantial doses of DDT in flour, the symptoms observed were vomiting, numbness and partial paralysis of the extremities, mild convulsions, loss of proprioception and vibratory sensation of the extremities, and hyperactive knee jerk reflexes. Symptoms appeared in 30 to 60 min after eating the DDT. The paralysis and numbness were most evident in the most distal portions of the extremities, and their intensity was directly proportional to the amount of DDT ingested. All the patients were apprehensive and excited; respiration was moderately rapid; pulse remained slow to normal. The immediate protective mechanism in man, following substantial doses, is vomiting. With smaller doses, nausea and vomiting are less prominent, but diarrhea has been observed. Signs and symptoms of chronic poisoning in man are unknown, although, judging from the observed microscopic changes in exper animals, liver and kidney dysfunctions should be looked for. The primary irr of DDT is practically nil, and it has little or no tendency to produce allergy. Dermatitis induced by DDT has occasionally been reported, but these reports are unconfirmed; nevertheless the phenomenon should be expected to occur in rare instances.

Laboratory Findings: Laboratory findings are essentially negative except for the presence of DDT which may be quantitatively measured in stomach contents, urine, or tissues.

Treatment of Poisoning: Depending on the condition of the patient, attention should first be given to the sedation or to the removal of poison which may have been taken internally. Stomach lavage and saline laxatives may be used. Oil laxatives should be avoided; they promote absorption of DDT and of many organic solvents, The five drugs of choice, arranged roughly in order of their effectiveness, are phenobarbital, pentobarbital, paraldehyde, urethane, and calcium gluconate. Phenobarbital, which has been used in doses up to 0.7 g per day in epilepsy, and pentobarbital (0.25 to 0.5 g) are the barbiturates known to control convulsions of central origin. Paraldehyde (average dosage 15 cc orally, 1 cc undiluted intravenously, 35 cc rectally in normal saline) controls the convulsions of DDT-poisoned animals. Urethane (human dosage 1 to 4 g) has proved very effective in rats, but it should be remembered that the hypnotic and narcotic effects of urethane are not correspondingly high in man. Urethane has an added advantage, however, of being tolerated in the young and the aged. The object of sedation is not to induce sleep but to restore a relative calm; however, the proper dosage in the presence of poisoning may be so large that it would induce anesthesia if poisoning were not present.

Calcium gluconate has been used less than the other antidotes, but it is reported to control DDT-induced convulsions in several animals. Since its mechanism

of action is entirely different, it may be used in addition to sedatives. Epinephrine is contraindicated.
For further information see Vol. 1, No. 3 of *DPIM Report.*

ACETYLCEPHALOTHIN SODIUM SALT

NIOSH #: XI 0383500
mf: $C_{14}H_{13}N_2O_5S_2 \cdot Na$; mw: 376.40

SYN: DESACETYLCEPHALOTHIN SODIUM

TOXICITY DATA:	1	CODEN:
ipr-rat LD50:8877 mg/kg		JJANAX 28,81,75
ivn-rat LD50:6116 mg/kg		JJANAX 28,81,75
ipr-mus LD50:8754 mg/kg		JJANAX 28,81,75
ivn-mus LD50:6600 mg/kg		JJANAX 28,81,75

THR: LOW ipr, ivn.
Disaster Hazard: When heated to decomp it emits very tox fumes of SO_x and NO_x.

DEACETYL-HT-2 TOXIN

CAS RN: 34114-98-2 NIOSH #: YD 0105000
mf: $C_{19}H_{30}O_7$; mw: 370.49

SYNS:
12,13-EPOXY-3-ALPHA,4-BETA,8-ALPHA,15-TETRAHYDROXY TRICHOTHEC-9-ENE-8-ISOVALERATE
3-ALPHA,4-BETA,15-TRIHYDROXY-8-ALPHA (3-METHYLBUTYRYLOXY)-12,13-EPOXY-TRICHOTHEC-9-ENE

TOXICITY DATA:	3	CODEN:
orl-ckn LD50:30180 ug/kg		AEMIDF 35,636,78

THR: HIGH orl.
Disaster Hazard: When heated to decomp it emits acrid smoke and fumes.

DEACETYLMULDAMINE

CAS RN: 36069462 NIOSH #: QG 1360000
mf: $C_{27}H_{46}NO_2$; mw: 416.74

TOXICITY DATA:	3	CODEN:
orl-ham TDLo:150 mg/kg (7D preg)		JAFCAU 26,561,78

THR: HIGH orl.
Disaster Hazard: When heated to decomp it emits tox fumes of NO_x.

2-DEAMINOACTINOMYCIN D

CAS RN: 10118328 NIOSH #: AU 1595000
mf: $C_{62}H_{85}N_{11}O_{16}$; mw: 1240.0

TOXICITY DATA:	CODEN:
dnd-mam:lym 5200 nmol/L	JMCMAR 20,1055,77

THR: MUT data.
Disaster Hazard: When heated to decomp it emits tox fumes of NO_x.

7-DEAZAINOSINE

CAS RN: 2862160 NIOSH #: UY 9450000
$C_{11}H_{13}N_3O_5$; mw: 267.27

TOXICITY DATA:	3	CODEN:
orl-rat LD50:26 mg/kg		CNREA8 29,116,69
ipr-rat LD50:25 mg/kg		CNREA8 29,116,69
scu-rat LD50:24 mg/kg		CNREA8 29,116,69
ipr-mus LD50:30 mg/kg		CNREA8 29,116,69
orl-dog LDLo:48 mg/kg		CNREA8 29,116,69
ivn-dog LDLo:48 mg/kg		CNREA8 29,116,69

THR: HIGH orl, ipr, scu, ivn.
Disaster Hazard: When heated to decomp it emits tox fumes of NO_x.

DECABORANE(14)

CAS RN: 17702419 NIOSH #: HD 1400000
mf: $B_{10}H_{14}$; mw: 122.24

Colorless needles. mp: 99.7°, d: 0.94. (solid), d: 0.78 (liquid @ 100°), vap. press: 19 mm @ 100°.

SYN:
DECABORANE (DOT)
BORON HYDRIDE

TOXICITY DATA:	3-2	CODEN:
orl-rat LD50:64 mg/kg		MLSR** No.8,51
ihl-rat LC50:46 ppm/4H		AMIHAB 17,362,58
skn-rat LD50:740 mg/kg		AMIHAB 11,132,55
ipr-rat LD50:23 mg/kg		AMIHBC 8,335,53
orl-mus LD50:40 mg/kg		AMIHAB 11,132,55
ihl-mus LC50:12 ppm/4H		NTIS** AD224-006
ipr-mus LD50:32 mg/kg		AMIHAB 11,132,55
ipr-dog LDLo:10 mg/kg		AMRL** TR-65-49
skn-rbt LD50:71 mg/kg		AMIHAB 11,132,55
ipr-rbt LD50:28 mg/kg		AMIHBC 8,335,53

TLV: Air: 0.05 ppm DTLVS* 4,118,80. OSHA Standard: Air: TWA 300 ug/m3 (skin) (SCP-Q) FEREAC 39,23540,74. DOT: Flammable Solid, Label: Flammable Solid and Poison FEREAC 41,57018,76. Reported in EPA TSCA Inventory, 1980. EPA TSCA 8(a) Preliminary Assessment Information Proposed Rule FEREAC 45,13646,80. AIHQA5 16,280,55.
THR: HIGH orl, ihl, ipr, skn. MOD skn. See also boron compounds and boron hydrides. Self-ignites in O_2.
Disaster Hazard: When heated to decomp it emits tox fumes of B oxides.
Incomp: ethers, halocarbons; O_2 @ 100°; dimethyl sulfoxide.
For further information see Vol. 1, No. 8 of *DPIM Report.*

1,1a,3,3a,4,5,5a,5b,6-DECACHLOROOCTAHYDRO-2-HYDROXY-1,3,4-METHENO-1H-CYCLOBUTA(c,d)-PENTALENE-2-LEVULINIC ACID, ETHYL ESTER

CAS RN: 4234791 NIOSH #: PC 8400000
mf: $C_{17}H_{12}Cl_{10}O_4$; mw: 634.79

SYNS:
GC-9160
KELEVAN

TOXICITY DATA:	3	CODEN:
orl-rat LD50:255 mg/kg		BESAAT 15,96,69
orl-dog LD50:400 mg/kg		BESAAT 15,96,69
skn-rbt LD50:188 mg/kg		BESAAT 15,96,69

Toxicology Review: RREVAH 63,45,76.

REFERENCE 4

FILE MEMO

Name: Dennis Papa - Versar
Date: 9/29/88
Time: 10:00 AM
File No. 5065.5.9
Subject: groundwater use within a 3-mile radius of Bainbridge NTC landfill.

Persons Contacted:

Name	Chuck Smyser	Name	
Company	Cecil County Health Dept.	Company	
Phone	(301) 398-5160	Phone	

Comments:

Chuck Smyser indicated that residences outside the Town of Port Deposit and the Bainbridge NTC obtain drinking water from private wells. Most homes have their own well. Several trailer parks are located within the 3-mile radius, which are also served by one or several ground water wells, per park. The number of trailers at each park was estimated at:

2 parks northwest of NTC : 50 & 100 trailers each
1 park east of NTC : 100 trailers
1 park north of NTC : 120 trailers

Groundwater is not used for irrigation within the 3-mile radius area.

Action Required:

Distribution: _____ _____ _____ _____

REFERENCE 5

FILE MEMO

Name Dennis Papa - Versar Date 9/14/88
Time 3:30 PM File No. 5065.5.9
Subject Town of Port Deposit water use

Persons Contacted:

Name Nancy Peters Name
Company Clerk - Town of Port Deposit Company
Phone (301) 378 - 2121 Phone

Comments:

Nancy Peters stated that the Town of Port Deposit has a population of 667. Currently, no private wells within city limits are being used - all Port Deposit residents are on city water. The water is obtained from the Susquehanna River (upstream from town), processed in a water treatment facility in Port Deposit, and stored for distribution in the Port Deposit Reservoir tank on Rt. 276. Port Deposit also sells their water supply to Bainbridge NTC (current population = approx. 500 members of Job Corps Center)

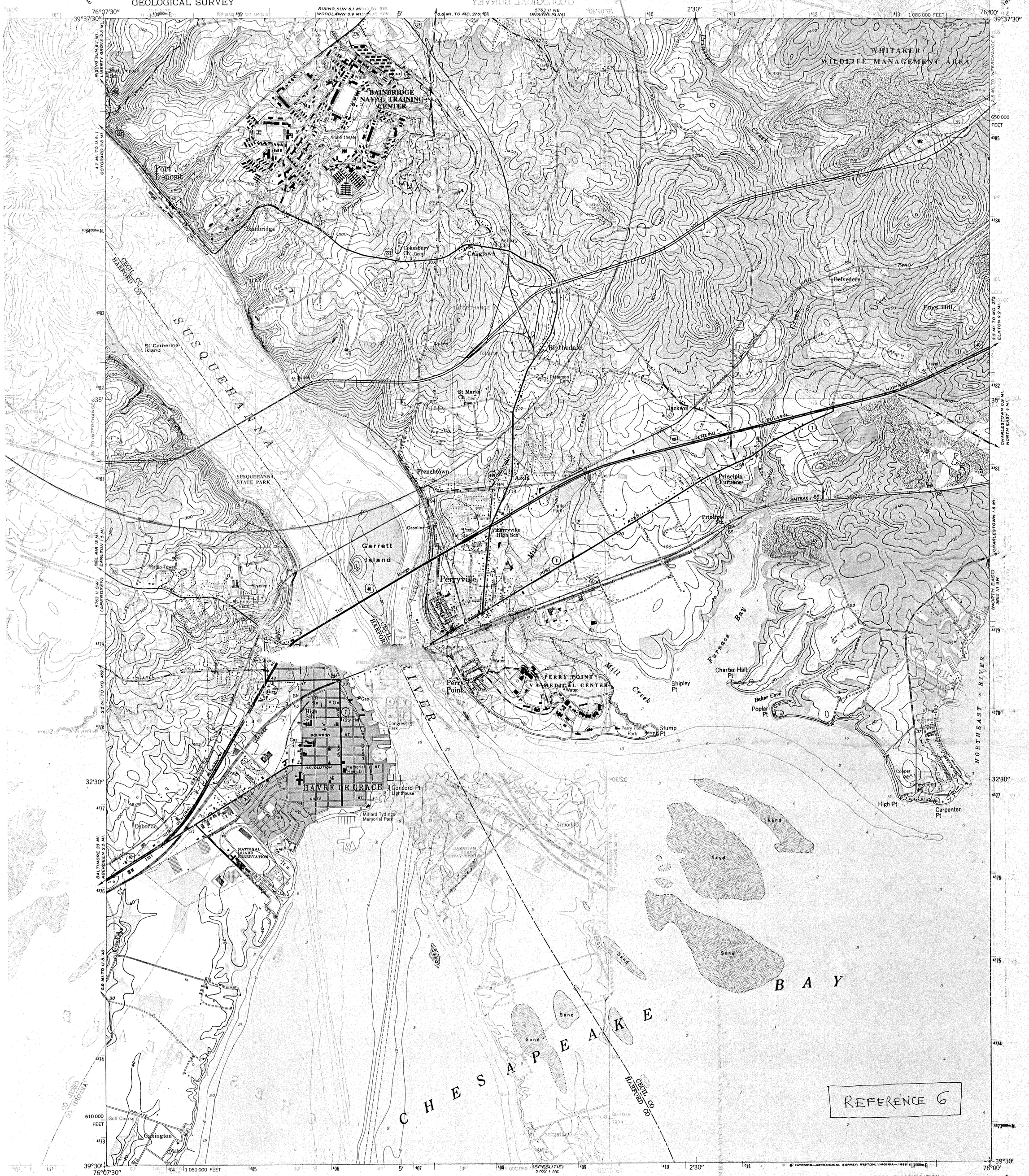
Action Required:

Distribution:

REFERENCE 6

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HAVRE DE GRACE QUADRANGLE
MARYLAND
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Planimetry in part compiled from aerial photographs taken 1952

Topography enlarged from 1:62 500 scale map of Havre de Grace quadrangle, 15 minute series. Original map by planetable surveys 1939-1940. Revised 1953

Selected hydrographic data compiled from NOS chart 572 (1947)
This information is not intended for navigational purposes

Polyconic projection. 10,000 foot grid ticks based on Maryland coordinate system
1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue
1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines 7 meters south and 29 meters west as shown by dashed corner ticks

Red tint indicates area in which only landmark buildings are shown

There may be private inholdings within the boundaries of the National or State reservations shown on this map

UTM GRID AND 1985 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Revisions shown in purple and woodland compiled from aerial photographs taken 1981 and other sources
This information not field checked. Map edited 1986

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
THE RELATIONSHIP BETWEEN THE TWO DATUMS IS VARIABLE
SHORLINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS 1.9 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

ROAD CLASSIFICATION

Primary highway, all weather, hard surface — Light-duty road, all weather, improved surface

Secondary highway, all weather, hard surface — Unimproved road, fair or dry weather

Interstate Route — U. S. Route — State Route

MARYLAND
QUADRANGLE LOCATION

HAVRE DE GRACE, MD.
39076-E1-TF-024
1953
PHOTOREVISED 1985
DMA 5763 II SE—SERIES V833

REFERENCE 7

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ABERDEEN QUADRANGLE
MARYLAND
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Planimetry in part by photogrammetric methods from aerial photographs taken 1952. Topography enlarged from 1:62 500 scale map of Havre de Grace quadrangle, 15 minute series
Original map by planetable surveys 1939–1940. Revised 1953

Polyconic projection. 10,000-foot grid ticks based on Maryland coordinate system
1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue
1927 North American Datum
To place on the predicted North American Datum 1983 move the projection lines 7 meters south and 29 meters west as shown by dashed corner ticks
There may be private inholdings within the boundaries of the National or State reservations shown on this sheet

MN GN
10½° 187 MILS
0°45' 13 MILS
UTM GRID AND 1985 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

MARYLAND
QUADRANGLE LOCATION

Revisions shown in purple and woodland compiled from aerial photographs taken 1982 and other sources
This information not field checked. Map edited 1985

Purple tint indicates extension of urban areas

ROAD CLASSIFICATION

Primary highway, hard surface
Light-duty road, hard or improved surface
Secondary highway, hard surface
Unimproved road
Interstate Route
U. S. Route
State Route

ABERDEEN, MD.
39076-E2-TF-024

1953
PHOTOREVISED 1985
DMA 5763 II SW—SERIES V833

REFERENCE 7

REFERENCE 6

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

RISING SUN QUADRANGLE
MARYLAND - PENNSYLVANIA
7.5 MINUTE SERIES (TOPOGRAPHIC)

REFERENCE 8

Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

Planimetry in part by photogrammetric methods from aerial photographs taken 1952. Topography by planetable surveys 1939 and 1940. Revised 1953

Polyconic projection. 10,000-foot grid ticks based on Maryland coordinate system, and Pennsylvania coordinate system, south zone

1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue

1927 North American Datum

To place on the predicted North American Datum 1983 move the projection lines 7 meters south and 29 meters west as shown by dashed corner ticks

Revisions shown in purple and woodland compiled from aerial photographs taken 1981 and other sources This information not field checked. Map edited 1985

MN GN
10½° 187 MILS
0°41' 12 MILS
UTM GRID AND 1985 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

.5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

MARYLAND
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Heavy-duty — 4 LANE | 6 LANE
Medium-duty — 4 LANE | 6 LANE
Light-duty
Unimproved dirt
U. S. Route
State Route

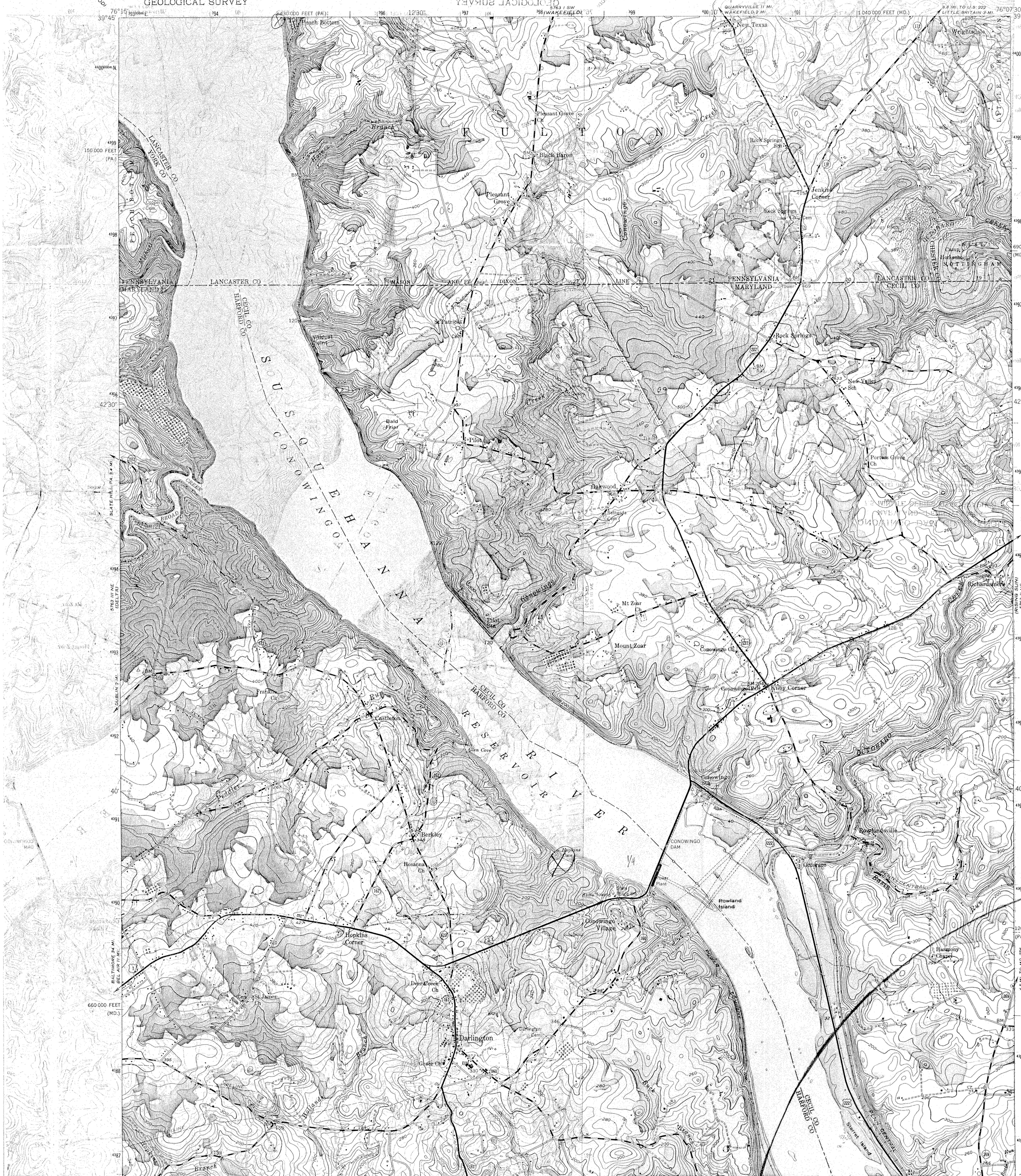
RISING SUN, MD.-PA.
39076-E1-TF-024

1953
PHOTOREVISED 1985
DMA 5763 II NE-SERIES V833

REFERENCE 8a

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CONOWINGO DAM QUADRANGLE
MARYLAND—PENNSYLVANIA
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Culture and drainage in part compiled from aerial photographs taken 1952. Topography by plane-table surveys 1939 and 1940
Revised 1953

Polyconic projection. 1927 North American datum
10,000-foot grids based on Maryland coordinate system, and Pennsylvania coordinate system, south zone
1000-metre Universal Transverse Mercator grid ticks, zone 18, shown in blue

Revisions shown in purple compiled from aerial photographs taken 1970. This information not field checked

UTM GRID AND 1970 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

MARYLAND
QUADRANGLE LOCATION

ROAD CLASSIFICATION

Heavy-duty — 4 LANE | 6 LANE — Light-duty
Medium-duty — 4 LANE | 6 LANE — Unimproved dirt
U. S. Route — State Route

CONOWINGO DAM, MD.—PA.

N3937.5—W7607.5/7.5

1953
PHOTOREVISED 1970
AMS 5763 II NW—SERIES V833

REFERENCE 8a

4

REFERENCE 9

Facility No.	Area (Sq. Ft.)						
702	1980	736	360	725	750	631	98
304B	192	404B	192	[redacted]			

b. The following facilities were identified as public works shops:

Facility No.	Area (Sq. Ft.)
936	390
668	12,768
694	9,408
683	4,233

c. Laboratory

Facility No.	Area (Sq. Ft.)
837	5,040

d. Incinerator Building and Incinerator

Facility No.	Area (Sq. Ft.)
861	2,589
1053	216
695	5186

e. Auto Vehicle Maintenance NONCOMB

Facility No.	Area (Sq. Ft.)
874	330
688	12 768
688A	10,080

444-9566

114:JGW

MEMORANDUM TO FILE

Subj: Review of property records, general development mapping, file information and discussions with knowledgable personnel relative to Proposed Property Excessing Naval Training Center, Bainbridge, Maryland

1. Subject effort was undertaken to provide a data base on which to predict the degree of contamination, if any, at NTC Bainbridge prior to the planned excessing of property.

2. The sources of information include property records, development maps, file review, and discussions with LANTNAVFACENGCOM personnel knowledgeable with NTC Bainbridge.

The findings include:

a. Class 2 Property Records, ~~VIC~~ UIC N00693, NTC Bainbridge Maryland, list the following facilities as Hazardous/Flammable Storehouses:

Facility No.	Area (Sq. Ft.)						
505A	96	502B	168	624C	96	688C	96
707C	64	681A	240	858A	6144	870	264
871	187	768	40	771	160	872	[illegible]

f. High Explosive Magazine

200145 104A 63

g. Small Arms/Pyrotechnics Mazagine

200182 204A 63
200274 404A 63
200300 304A 63
200361 696A 63

h. Small Arms Range

200210 204 19056
200297 404 19056

3. General Development Maps indicate an oil separation pit near Bldg. 53. Additionally, it appears there was a MCON Project, P-144, to rehabilitate a fire fighting school.

4. There was an open salvage, storage, and supply area near Building 754.

5. During a 1980 visit, LANTNAVFACENGCOM personnel noted 2 or 3 pole mounted transformers which had dropped from their supporting structures and had broken open. The chemical nature (PCB vs. non-PCB) of the contents was unknown.

6. It is understood that the property to be excessed includes a raw water

mp station and a raw water metering vault. These should be examined for PCB transformer and mercury flow gauge, respectively.

7. The file information is unclear, but it appears these may have been more than one landfill. Development Maps indicate a sanitary fill just north of the golf course, while an employee recalls a landfill under the golf course.

8. A 1978 Pest Control Program Review indicated the use of: BHC, DDT, Korlan, Dioyinon, Malathion, Chlordane, Captan, Zineb, Karathane, Lead Ars, Aramite, and non-specific herbicides and soil sterilants.

9. A 1968 Pest Control Program Review includes the recommended landfill sposal of the following:

Aramite 15-W (Miticide)	60 lbs
BHC 11% E.C.	150 gal
Block Leaf 40 (Nicotine Sulfate)	60 gal
Captan 50 WP	110 lbs
Copper Sulfate	20 lbs
DDT 25% E.C.	350 gal
DDT 20% O.S.	350 gal
DDT 5% O.S.	100 gal
Ferbam	20 gal
Karathane	80 lbs
Red Squill	15 lbs
Ryania	60 lbs

10. Two water samples from springs at the golf course collected in 19__ indicated no PCB or pesticide contamination to these waters.

11. Based only on the above information and emphazing that no site survey has yet been performed, it appears that there is likely contamination of some portions of NTC Bainbridge by PCB's and pesticides. The oil separation pit and fire fighting school may be additional sites of contamination.

DOCUMENT SUMMARY

Document Id: 0246N
Document Name: Memo to file
Operator: Dickerson
Author: Wallmeyer

Comments:

STATISTICS

OPERATION	DATE	TIME	WORKTIME	KEYSTROKES
Created	01/29/81	13:23	:39	4431
Last Revised	/ /	:	:	
Last Printed	01/29/81	14:05		
Last Archived	/ /	:	onto Diskette	

Total Pages: 3
Total Lines: 64
Total Worktime: :39
Total Keystrokes: 4431

Pages to be printed: 3

REFERENCE 10

Uncontrolled Hazardous Waste Site Ranking System

A Users Manual

(HW-10)

Originally Published in
the July 16, 1982, *Federal Register*

United States
Environmental Protection
Agency

1984

REFERENCE 11

SOIL SURVEY OF

Cecil County, Maryland

United States Department of Agriculture
Soil Conservation Service
In cooperation with
Maryland Agricultural Experiment Station

Issued December 1973

REFERENCE 12

FILE MEMO

Name: Dennis Papa
Date: 9/30/88
Time: 2:30
File No. 5065.5.9
Subject: Recreational use of Susquehanna River; tidal influence and location of stream gaging stations

Persons Contacted:

Name	Linda Zynjuk	Name	
Company	MD Geological Survey	Company	
Phone	(301) 828-1535	Phone	

Comments:

Linda Zynjuk stated that the Susquehanna River is tidal below the Conowingo Dam and non-tidal above it. The gaging station at the dam provides this information.

The Susquehanna River is used for boating and sport fishing.

Action Required:

Distribution:

REFERENCE 13

FILE MEMO

Name: Dennis Papa
Date: 10/3/88
Time: 10:45
File No.:
Subject: critical habitats near Bainbridge

Persons Contacted:

Name: District Wildlife Administration
Company: Maryland Dept. Natural Resources
Phone: (301) 928-3650

Name:
Company:
Phone:

Comments:

Critical habitats have not been identified within the Bainbridge / Port Deposit area. The bald eagle (Haliaeetus leucocephalus) may be a transient visitor to the area.

Action Required:

Distribution:

REFERENCE 14

MARYLAND GEOLOGICAL SURVEY

Kenneth N. Weaver, Director

REPORT OF INVESTIGATIONS NO. 10

GROUND-WATER OCCURRENCE IN THE MARYLAND PIEDMONT

by

L. J. Nutter and E. G. Otton

Prepared in cooperation with the Geological Survey
United States Department of the Interior

1969

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COMMISSION OF
MARYLAND GEOLOGICAL SURVEY

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G. VICTOR CUSHWA .....Williamsport

JOHN C. GEYER .....Baltimore

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GROUND-WATER OCCURRENCE IN THE MARYLAND PIEDMONT

by

L. J. Nutter and E. G. Otton

ABSTRACT

Factors governing the occurrence of ground water in the crystalline rocks of the Maryland Piedmont are complex and variable. The crystalline rocks consist of schist, gneiss, granite, quartzite, marble, metagabbro, and other rock types of lesser importance. The rocks of the area range in geologic age from Precambrian to early Paleozoic.

Analysis of the hydrologic cycle, an important factor governing the occurrence of ground water, indicates that effective ground-water recharge is about 11 inches per year, or about 500,000 gpd (gallons per day). Much of the ground water in the area is stored in the weathered zone (saprolite), having an average thickness of about 45 feet. Many wells yield water occurring in joints, fractures, and other crevices in the rocks; the occurrence and distribution of these features are difficult to predict, but the drainage pattern and surface topography of the Piedmont reflects the existence of major joint systems in the rocks. Statistical analysis of well yields and specific capacities shows that wells situated in valleys or draws yield three to four times as much water as wells on hilltops or divides. Based on an analysis of more than 1,300 well records, little significant difference was observed for the yield of wells in different rock types, although, based on mean yields, wells in marble are the most productive. The mean yield of all wells is about 9 gpm (gallons per minute) and the mean specific capacity is 0.6 gpm per foot of drawdown. Most of these wells were drilled for domestic use.

The ability of the crystalline rocks to transmit and store water is shown by aquifer tests to be extremely variable. Coefficients of transmissibility range from less than 100 to 35,000 gpd per foot, but commonly are in the range of 2,000 to 7,000 gpd per foot. Coefficients of storage, based on aquifer tests, range from 0.002 to 0.05. However, the long-term gravity yield of the regolith (the zone contributing to the base flow of streams) is about 8 percent.

Electric, gamma-ray, temperature, and caliper logs of several wells in the crystalline rocks provide a useful means of identifying water-bearing zones and identifying changes in the character of the rocks.

Statistical analysis of wells grouped by 100-foot depth intervals indicates a decreasing probability of obtaining a specified yield with increasing depth below 100 feet. A map in the report shows the extreme areal variability of the yields of wells in the crystalline rocks, and indicates specific areas where the wells are of lower than average productivity. Wells in other areas are shown to have higher than average productivity.

INTRODUCTION

Purpose and Scope

The occurrence, movement, and distribution of ground water in crystalline-rock[1] terranes have been studied by several workers during the last 60 years. Among the first comprehensive reports was one by Ellis (1906), which described ground-water conditions in schistose and gneissic rocks in Connecticut. Although the records of several thousand wells have been studied and related to rock type, topography, and geologic structure, a complete understanding of crystalline-rock geohydrology has not yet been attained. The lack of complete understanding of crystalline-rock geohydrology is the result of several factors, among which are the extreme variability of the occurrence of fractures and joints in crystalline rocks and the lack of detailed well logs in which the lithology is accurately described and the zones of water entrance are delineated. In many areas faults, joints, and fracture planes in the rocks cannot be observed because of the overlying thick cover of weathered rock (saprolite) and subsoil. Hence, the relationship of these features to the occurrence of ground water can only be inferred.

The purpose of the investigation was to study, in greater detail than had formerly been done in Maryland, the occurrence and availability of ground water in crystalline-rock aquifers. Objectives of the report include appraising the factors governing yields of wells in crystalline rocks, describing the methods of analysis used, compiling all available data and presenting new data relating to the hydraulic properties of crystalline rocks in Maryland, and describing geophysical logging techniques as they relate to crystalline-rock wells. The data presented in the report should be helpful in selecting favorable drilling sites and in recognizing the hazards in attempting to develop ground-water supplies in unfavorable sites or areas.

Area Covered

The crystalline rocks, lying chiefly within the Piedmont physiographic province, are present in a broad band extending northeastward from Washington, D. C. to the vicinity of Elkton in Cecil County (fig. 1). These rocks extend westward from the Fall Line to the Frederick Valley, where Ordovician limestones and Triassic sandstones and shales crop out. Crystalline rocks also occur along a relatively narrow belt lying within the Blue Ridge province but are separated from their main body to the east by younger limestones and sandstones. The area covers the major part of 5 counties and about one-half of each of 2 other counties, and totals about 2,100 square miles.

Methods of Investigation

The study of ground water in crystalline rocks has involved several methods of approach. First, various factors such as well depth, yield, rock type, and topographic situation, have been analyzed statistically to determine their interrelationships. Approximately 8,000 well records from the Piedmont region were available for this purpose. Most of these have been published by the Maryland Geological Survey and the U. S. Geological Survey as part of the cooperative series of water-resources investigations in Maryland.

In some areas the availability of cores or sample cuttings permitted close correlation between geologic and hydrologic factors. Streamflow measurements, precipitation data, and records of water-level fluctuations in observation wells made possible a study of the hydrologic budget in the crystalline-rock terrane. Use of geophysical well logs assisted in understanding subsurface conditions in the boreholes. Study of the geomorphology of the region, including the patterns of streams, has provided insight into the occurrence of ground water in the rocks. Aquifer tests and laboratory determination of the hydrologic properties of the rocks have contributed to an understanding of the movement of ground water.

Previous Investigations

The authors of this report have drawn heavily on information compiled for a number of previous reports. Among these are: *The Ground-Water Resources of the Piedmont Part* in The Water Resources of Baltimore and Harford Counties (Dingman and Ferguson, 1956); *The Ground-Water Resources* in The Water Resources of Carroll and Frederick Counties (Meyer, 1958); *The Ground-Water Resources* in The Water Resources of Howard and Montgomery Counties (Dingman and Meyer, 1954); *The Ground-Water Resources* in The Water Resources of Cecil, Kent, and Queen Annes Counties (Overbeck and Slaughter, 1958); Water Resources of the Baltimore Area, Maryland (Otton, Martin, and Durum,

[1] Crystalline rocks, for the purpose of this report, are considered to be relatively hard dense rocks which are either 1) metamorphosed sediments or 2) intrusive or extrusive igneous rocks which have been metamorphosed to varying degrees.

Well-Drilling Methods

Because well data largely form the basis of this report, it is pertinent to discuss briefly the two principal well-drilling methods, percussion and air-rotary, used in crystalline-rock areas.

Percussion drilling, the older and simpler of the two methods, is known by several terms including cable-tool, churn, and spudder drilling. The hole is drilled by lifting and dropping a heavy string of tools in the borehole. The drill bit crushes the rock into small fragments which are removed periodically in the form of a slurry by means of a bailer. It is necessary that water be put into the borehole to form the slurry if no water is present. The main disadvantages of this method are the slow rate of penetration and the difficulty in identifying the precise depths at which the water is entering the borehole. Some well drillers claim that the cable-tool method has the advantage of being less likely than the rotary method to cause clogging or blocking of the water-yielding crevices during the drilling operation. This claim is challenged by other drillers.

Air-rotary drilling is rapidly becoming the most commonly used method in the Maryland Piedmont. Compressed air is circulated downward through the drill pipe, out through ports in the drill bit, and upward through the annular space around the drill pipe. Air moving at a high velocity through the annular space carries the cuttings to the surface. Roller-type rock bits, similar to those used in mud-rotary drilling, are sometimes used in air-rotary drilling, but the "down-the-hole-hammer," a pneumatic hammer operated at the lower end of the drill pipe, is generally more efficient for crystalline-rock well drilling. The main advantages of the air-rotary method are the rapid rate of penetration and the fact that, by observing the amount of water being blown out of the well, the water-bearing zones can be determined more accurately than by the cable-tool method. Modern air-rotary drills are considerably more expensive than the older cable-tool drilling machines, but this disadvantage is compensated for by the rapidity with which holes can be drilled by the air method. Commonly, wells are drilled at a rate of 100 to 200 feet per day by the air method.

Well Protection and Development

Some wells drilled in the crystalline rocks are grouted from the land surface down to the base of the saprolite zone, or occasionally to seal off an undesirable zone of flowing mud or caving materials at greater depths. The chief purposes of grouting are to protect the water supply from pollution and to preserve the well casing from exterior corrosion.

Neat cement and cement slurry are the chief grouting materials. The cement may be pumped down the outside of the casing if the borehole is sufficiently large, or it may be pumped into the annular space at the base of the casing where it rises upward between the casing and the borehole wall. In the latter instance, it may be necessary later to drill out the cement plug in the bottom of the casing in order to proceed with the drilling of the hole. Caution should be exercised in placing the grout at the base of the saprolite so that the grout does not seal off the water-bearing zone commonly encountered at this horizon.

Various regulations concerning grouting of wells have been adopted by the Maryland Department of Water Resources, and modifications of these regulations are in effect in certain counties. Information concerning these regulations is available from the regulating agency.

Different methods of well improvement have been tried where the yield of a well is inadequate, even for domestic use. One such method, not known to have been applied to wells in the Maryland Piedmont, is the use of dilute hydrochloric acid in wells in marble or limestone formations. Acidizing of wells is an expensive technique requiring specialized equipment and knowledge, but, in certain instances, the results may be worth the cost. Bialek (1956) reports that satisfactory results were obtained in about 70 percent of the limestone wells acidized during the period 1945–55 in five mid-western states. Acidizing is considered to be successful where the yield of a well has been significantly improved as a result of the use of the technique.

Another method of well improvement which has been occasionally tried in the crystalline rocks is the use of dynamite. The object of dynamiting is to shatter the rock near the borehole and thus intercept water-bearing crevices which may lie near the hole but have not been intercepted by it. Drillers have reported little success with this method, especially in schistose rocks, but information on specific tests of the method is meagre.

Dynamiting was unsuccessfully tried in a well penetrating the Baltimore Gabbro Complex in eastern Baltimore County. The well is 430 feet deep and the gabbro, a hard dense rock, is overlain by 127 feet of sedimentary deposits. Approximately 32 pounds of dynamite were exploded in four charges (8 pounds each) at depths ranging

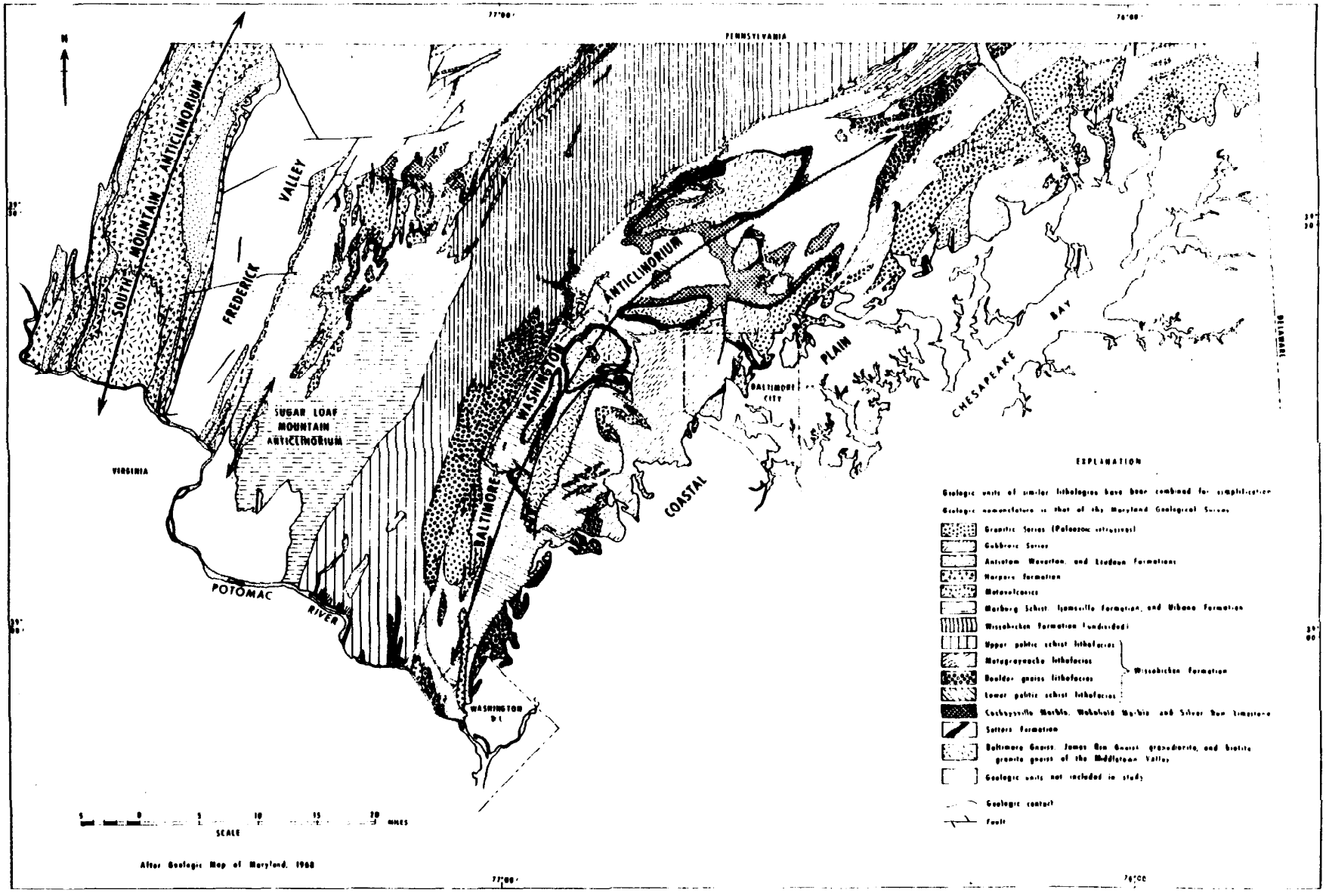

Figure 2.—Geologic map showing distribution and extent of the crystalline rocks in Maryland.

System and Group		Geologic unit, lithology, and thickness
		C. Eastern Piedmont metasedimentary rocks.
ORDOVICIAN		Peach Bottom Slate Hard, bluish-black graphitic slate, thin beds of fine-grained black quartzite near base; apparent maximum thickness 1,000 feet.
		Cardiff Metaconglomerate Silvery-gray, well foliated, micaceous quartz pebble metaconglomerate and quartzite; apparent maximum thickness 700 feet.
LATE PRECAMBRIAN(?)	WISSAHICKON FORMATION (Undivided)	Upper Pelitic Schist (Formerly mapped as albite facies of Wissahickon Formation.) Albite-chlorite-muscovite-quartz schist with sporadic thin beds of laminated micaceous quartzite; coarsens from west to east; primary sedimentary structures include normal bedding, graded bedding and soft-sediment deformational structures; apparent thickness 14,000 feet or more.
		Metagraywacke (Formerly mapped as Peters Creek Formation.) Rhythmically interbedded chlorite-muscovite metagraywacke and fine-grained chlorite-muscovite schist; graded bedding locally preserved; thickness probable 2,000 to 3,000 feet.
		Metaconglomerate Silvery-gray, well foliated, micaceous quartz-pebble metaconglomerate and quartzite; thickness about 1,200 feet at Deer Creek, Harford County.
		Boulder Gneiss (Formerly mapped as Sykesville and Laurel Formations.) Thick-bedded to massive, pebble and boulder-bearing, arenaceous to pelitic metamorphic rock; typically a medium-grained, garnet-oligoclase-mica-quartz gneiss; locally an intensely foliated gneiss or schist; apparent thickness 15,000 feet.
		Lower Pelitic Schist (Formerly mapped as oligoclase facies of Wissahickon Formation.) Medium to coarse-grained biotite-oligoclase-muscovite-quartz schist with garnet, staurolite, and kyanite; fine-to-medium-grained semipelitic schist; and fine-grained granular to weakly schistose psammitic granulite; psammitic beds increase upward; apparent thickness 5,500 feet or more.
		Cockeysville Marble Metadolomite, calc-schist, and calcite marble are predominate; calc-gneiss and calc-silicate marble widespread but minor; thickness about 750 feet.
		Setters Formation Upper member: Feldspathic mica schist and mica gneiss; middle member: Impure quartzite inter-stratified with thin beds of mica schist; lower member: Medium-grained, feldspathic mica schist; locally granitized; total thickness 200 to 500 feet.
PRECAMBRIAN		Baltimore Gneiss Biotite-quartz-feldspar gneiss and biotite-hornblende gneiss; amphibolite widespread but subordinate; texturally varied; granitic gneiss, veined gneiss, augen gneiss, banded gneiss, and migmatite, in places complexly intermingled; age 1,100 m.y.* by radiogenic dating. Layered paragneiss in Baltimore City southwest of Relay Quartz Diorite.

* Radiogenic date from Wetherill and others, 1966

FACTORS GOVERNING THE OCCURRENCE OF GROUND WATER IN CRYSTALLINE ROCKS

Several factors govern the occurrence of ground water in the crystalline rocks. Among these are: the elements of the hydrologic cycle such as precipitation and evapotranspiration; the nature and thickness of the weathered rock mantle; jointing, fracturing, and faulting of the rocks; topographic factors; and lithologic, mineralogic, and textural characteristics of the rocks.

Hydrologic Cycle and Water Budget

Precipitation, the source of all ground water in the crystalline rocks in the Maryland Piedmont, ranges from about 43 to 46 inches per year. Precipitation is the beginning element of the vast unending circulation of the waters of the earth, known as the hydrologic cycle. This gigantic water-circulating system is operated chiefly by the energy of the sun (fig. 3). Water is evaporated from the ocean, from the land, and from smaller bodies of water such as ponds and streams. Some of the water falling on the land returns to the sea as overland runoff, but some of it enters the soil zone and percolates downward to saturate the underlying rocks. The water level in the saturated rocks rises to a position sufficiently high to cause the water to discharge into nearby streams or ponds. Thus, a lag-time is introduced into the system and some water is stored in the rocks for a variable period of time. Ultimately, however, the system is balanced, and over a long period of time the input into the rocks (or aquifers) must equal the output. Thus, the water in storage in the rocks

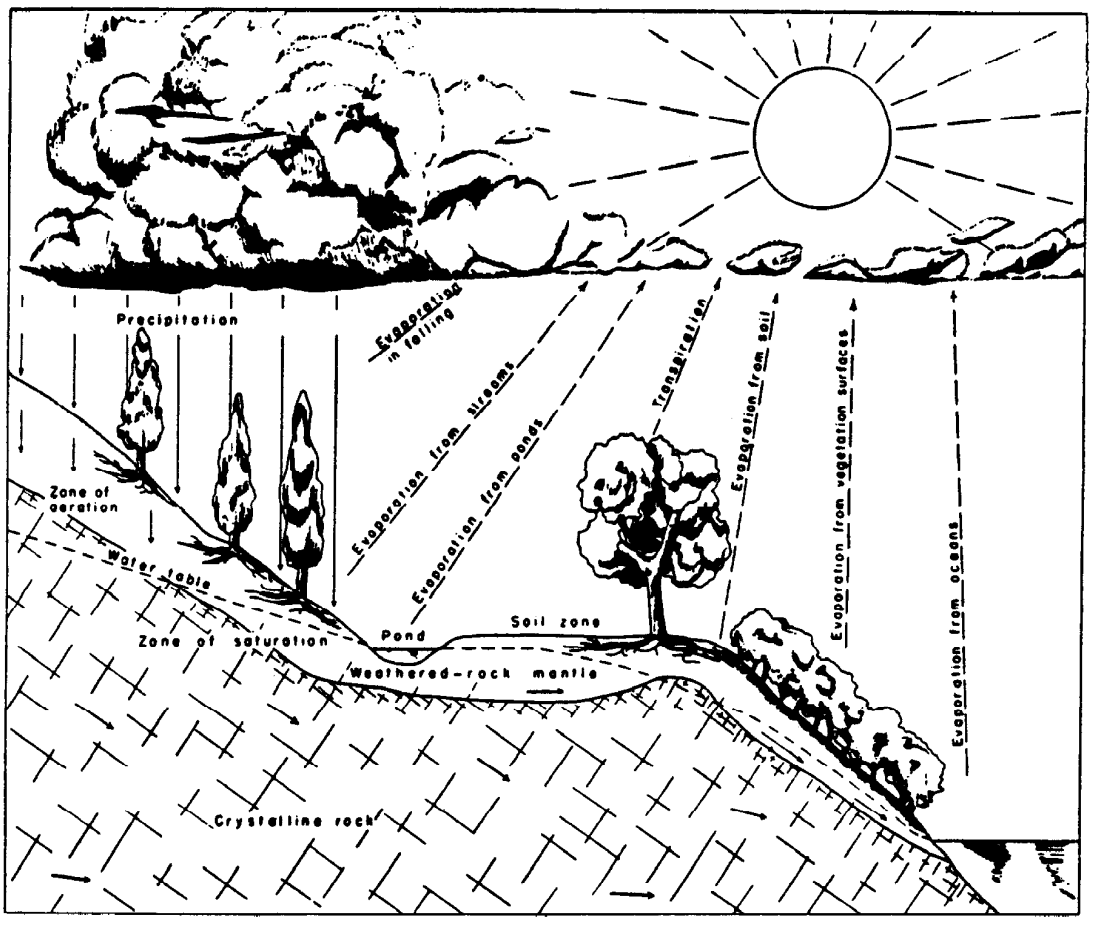

Figure 3.—The hydrologic cycle in the crystalline-rock areas of Maryland (from Dingman and Ferguson, 1956).

used by Dingman and Ferguson, was determined on the basis of equating ground-water recharge with long-term base flow of the stream, or ground-water discharge.

In summary, the 11.3 inches of ground-water runoff reported for the Little Gunpowder Falls basin appears to be a more reliable measurement of the ground-water runoff component of the hydrologic cycle in this region. Over a long period of time ground-water runoff must equal ground-water recharge. Thus, the ground-water recharge for the Gunpowder Falls basin is approximately 197 million gallons per year per square mile, or about 540,000 gpd per square mile. This rate compares favorably with the 535,000 gpd per square mile reported by Olmsted and Hely (1962, p. A-8) for the Brandywine Creek basin in southeastern Pennsylvania. Probably these values are applicable to other Piedmont drainage basins having similar geologic, topographic, and meteorological parameters.

Water-table Fluctuations: Ground water occurs in aquifers under unconfined (water-table) or confined (artesian) conditions. *Water-table conditions* occur where the top of the zone of saturation is in direct contact with the atmosphere through the porous soil and weathered mantle. Under *artesian conditions* the water in the aquifer occurs beneath a confining bed and when tapped by a well the water level rises to some point in the well determined by the head in the recharge area less frictional losses in head resulting from transmission of the head through the aquifer. In the crystalline rocks water encountered in the deeper crevices may be under localized artesian head. The *piezometric surface* of an artesian aquifer is an imaginary pressure surface existing in a localized or regional artesian system. The line of demarcation between confined and unconfined conditions is not sharp, and in many cases it is difficult to determine whether artesian or water-table conditions prevail at a given well.

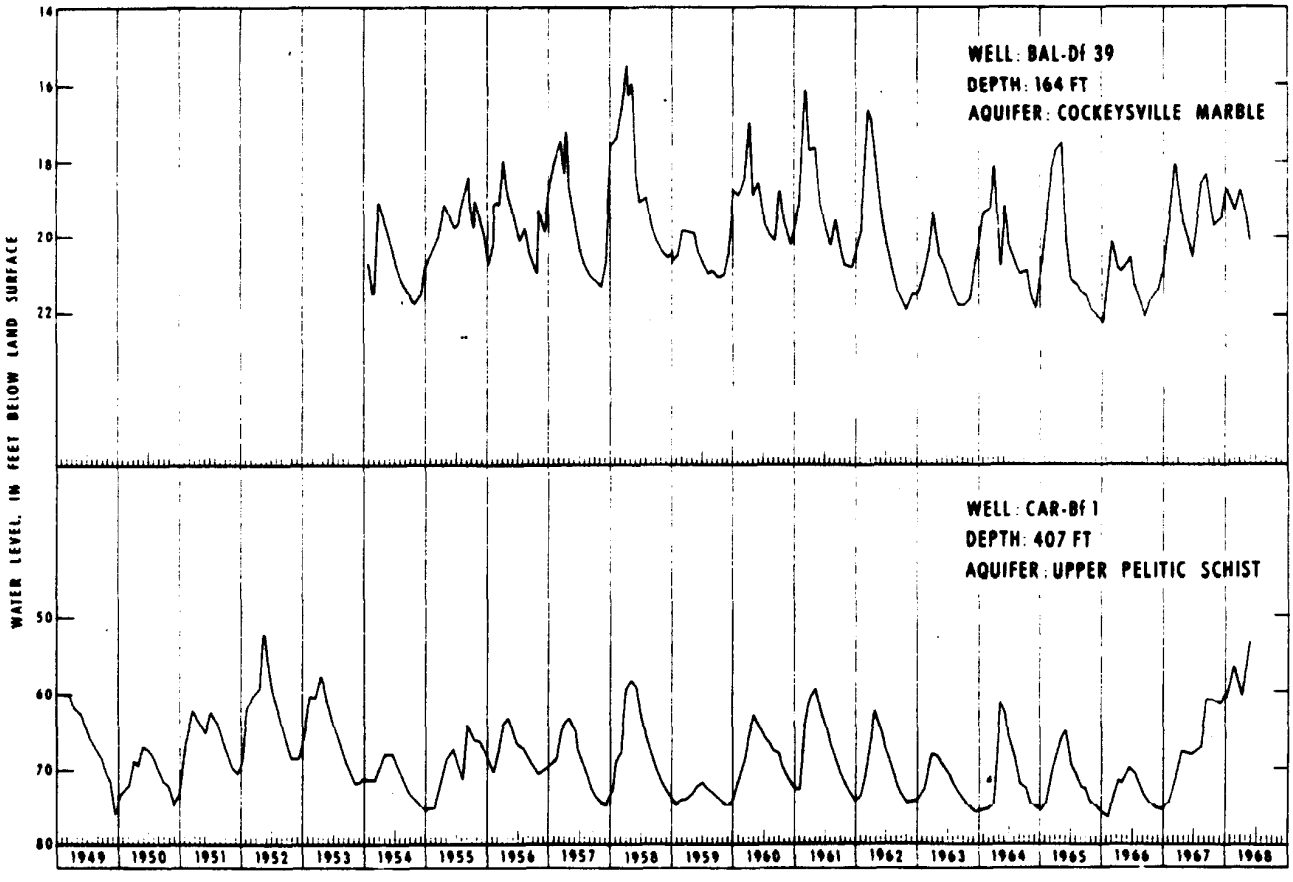

Figure 4.—Hydrographs showing water-level fluctuations in observation wells Car-Bf 1 and Bal-Df 39.

the range of 5 to 6.5. The silicate minerals in the rocks are altered to hydrated alumina, silica, and soluble compounds in the hydrolyzate. Cations such as sodium, potassium, magnesium, and calcium are removed from the saprolite by leaching. The more resistant minerals tend to remain behind in the form of alteration products. Where an oxidizing environment exists in the soil profile, ferrous iron is oxidized to form limonite and hematite zones. The clay-size fraction of the saprolite commonly consists mainly of kaolinite and muscovite; the silt-size fraction mainly of kaolinite, quartz, and muscovite; the sand and rock fragments are largely quartz and feldspar.

Stewart (1962, p. B-106) reports that the maximum porosity of the saprolite at a site near Atlanta, Ga., occurs at a depth of about 30 to 45 feet. Observations at several localities in the Maryland Piedmont tend to substantiate the conclusions of Stewart that the saprolite is somewhat more permeable within the soil zone (0-3 feet) and tends to decrease below this depth, but the permeability increases again near the contact of the saprolite with the underlying bedrock. Well drillers frequently report "sand" material and boulders in this basal zone, and this zone commonly is the place where the first ground water in a well is reported by the drillers. Stewart states (p. B-107) "the porosity of the saprolite is greatest—as much as 54 percent—at depths of 30 to 40 feet, but decreases with depth as saprolite grades into unweathered rock. The porosity of the unweathered rock is about 5 percent, or about one-ninth the average porosity of the saprolite. The specific yield determined from the samples decreases with increasing depth, and the amount of water in storage below 40 feet decreases markedly. The average specific yield of the saprolite is about 21 percent and ranges from about 28 percent in the upper part of the saprolite to 0 in unweathered rock. . . . . For practical purposes the specific yield of the unweathered rock is zero."

In massive equigranular rocks such as marble, granite, and gabbro, weathering occurs primarily along joints, whereas in schistose and gneissic rocks weathering also occurs along planes of schistosity, cleavage, and mineral layering (Cleaves, 1968, p. 10). One of the chief differences between saprolites derived from massive rocks and those derived from schistose rocks is the tendency toward the formation of residual boulders in the massive rock. This is especially true of marble, where residual boulders are very common and, where present, cause problems in well drilling. Residual boulders also occur in saprolite in areas underlain by gabbro.

Although data relating differences in the character of saprolite with changes in the character of the underlying fresh rock are scanty and could not be studied in detail in the present study, certain general statements can be made. Rocks such as gneiss and quartzose schist, which contain significant proportions of quartz, tend to weather to a sandy, fairly permeable saprolite, whereas rocks with little quartz, such as gabbro and metabasalt, tend to weather to less permeable saprolite with higher clay content. In some areas marble weathers to saprolite with high clay content and low permeability, but in other areas it weathers to permeable dolomite sand (Choquette, 1960, p. 1039). In the areas where thick deposits of dolomite sand occur, excellent conditions exist for obtaining moderate quantities of water from wells having well screens or slotted casings surrounded by graded gravel envelopes.

The thickness of the saprolite can be approximated by using the length of casing reported by well drillers. Commonly, casings are seated at the top of hard, dense rock.

The saprolite in the Maryland Piedmont ranges in thickness from a few feet to over 100 feet and averages about 45 feet. It is normally thickest beneath hilltops and ridges and thinnest beneath valleys, although there are exceptions to this generalization. For example, near Laytonsville, Montgomery County, the saprolite found in four wells located in a broad valley is as thick as, or thicker than, that found in two adjacent wells on hilltops.

The average thickness of the saprolite is slightly different in the various formations. Table 3 lists the average saprolite thickness (based on length of casing) for wells drilled in several rock units in Baltimore, Harford, and Carroll Counties.

The data from the three sources listed in table 3 are in agreement with the single exception of the metagraywacke data from Carroll and Frederick Counties. This discrepancy is probably due to the small size of the sample, as only 19 wells were used to compute average saprolite thickness for the metagraywacke.

Metamorphic Rank

The metamorphic rank in the Piedmont rocks is the highest in the vicinity of the gneiss domes and decreases progressively away from them. Figure 7 is a map showing the gneiss domes and the approximate positions of the sillimanite, kyanite, staurolite, and garnet isograds in the Pied-

joints were counted across a distance of 1,100 feet, or an average spacing of 10.3 feet between joint planes. The average angle of dip of 60 joints is 73° from the horizontal; the rocks in the quarry are designated as the Port Deposit Gneiss.

Balk (1937, fig. 7) shows that in the lower Swenson granite quarry near Concord, New Hampshire, there are 34 joints along a distance of 315 feet, having an average spacing of 9.3 feet between joint planes; the average dip of 33 joint planes was 67° from the horizontal. Presumably, the mean spacing of joint planes in New Hampshire is about the same as it is in Maryland in similar types of rocks.

In summary, from the data given above, it appears that in many areas underlain by crystalline rocks the average spacing of joint planes may be expected to range from 10 to 20 feet. Thus, wells drilled several hundred feet into the rocks may be expected to intercept several joint planes, especially where angles of dip of the joints range widely from vertical. In general, schists are poorly jointed, compared to equigranular rocks such as granite or diorite. The relative absence of major joints in places in schists may account for the poor yield of wells in some localities underlain by schistose rocks.

A fault may occur in rocks where two blocks or rock masses have been displaced, or sheared, along a plane of rupture. Faults are important with regard to the occurrence of ground water in crystalline rocks, as they may provide conduits for movement of water through the rocks, or they may cause abrupt changes in the hydrologic properties of the rocks where rock masses of differing character are placed in contact with one another due to displacement along major zones of faulting.

Although faults are common in the crystalline rocks, they can usually be observed in detail only in quarry walls or along road cuts. Displacement of rock masses along faults in the Piedmont ranges from a fraction of an inch to several thousand feet.

Where openings in the rocks persist along fault planes the movement of ground water is facilitated, and such openings may exist along many faults. However, in many places faulting is accompanied by the creating of "gouge" or the crushing of the rock along the plane of displacement. Gouge commonly weathers to impermeable clay or silt. Where it is present, it retards the movement of ground water.

Data concerning the spacing and frequency of faulting in crystalline rocks are meagre, but the little information available suggests that faults, at least minor ones, are far more common than might be assumed. Warner and Robinson (1967, p. 115) indicate that along the 77,020 feet of the Harold D. Roberts Tunnel faults occur on the average of one per 56 feet of tunnel. Hershey (1937, pl. 17) indicates that in the Port Deposit quarry (Port Deposit Gneiss) the average spacing of shear zones across 600 feet of quarry is 66 feet, or one per 9 feet of quarry wall.

Describing an area underlain by Triassic shale and sandstone in Lancaster County, Pa., H. E. Johnston (1966, p. 30) states: "Movement of rock masses along a fault plane may produce a zone of intensely fractured rock along the fault, thereby giving rise to a linear zone of high permeability. Data on a few wells near faults in the New Oxford Formation south of Denver indicate that highly permeable zones do exist near some faults. Several high-yielding wells are on or near faults in the New Oxford Formation at the edge of the borough of Akron."

In a few places in the Maryland Piedmont faults may be indicated by linear zones of springs, but the geologic evidence for faulting is inconclusive at these places.

To evaluate the role of faults in the geohydrology of the crystalline rocks the writers assembled data for nine wells in the Maryland Piedmont known to be situated along faults; these data are in table 4.

Only one of the wells in table 4, Mont-Dc 3, has a yield or specific capacity which is significantly higher than the average for either of the formations in contact along the fault plane. The average yield of the nine wells shown in table 4 is about 6 gpm, which is less than the average yield (about 9 gpm) of more than 1,100 crystalline-rock wells in the Maryland Piedmont (table 5). The average specific capacity of the six wells for which data are shown in table 4 is about 0.8 gpm per foot of drawdown; this value is only slightly greater than the average specific capacity (0.6 gpm per foot) of more than 1,300 rock wells (table 5).

Because of the relatively small number of wells along faults for which data are available, no statistically valid conclusion can be drawn from the information in table 4. However, the data suggest that the role of faults in the occurrence of ground water may be more complex than previously indicated. It is likely that the kind of rocks involved in the faulting may be important in determining whether or not faults can function as ground-

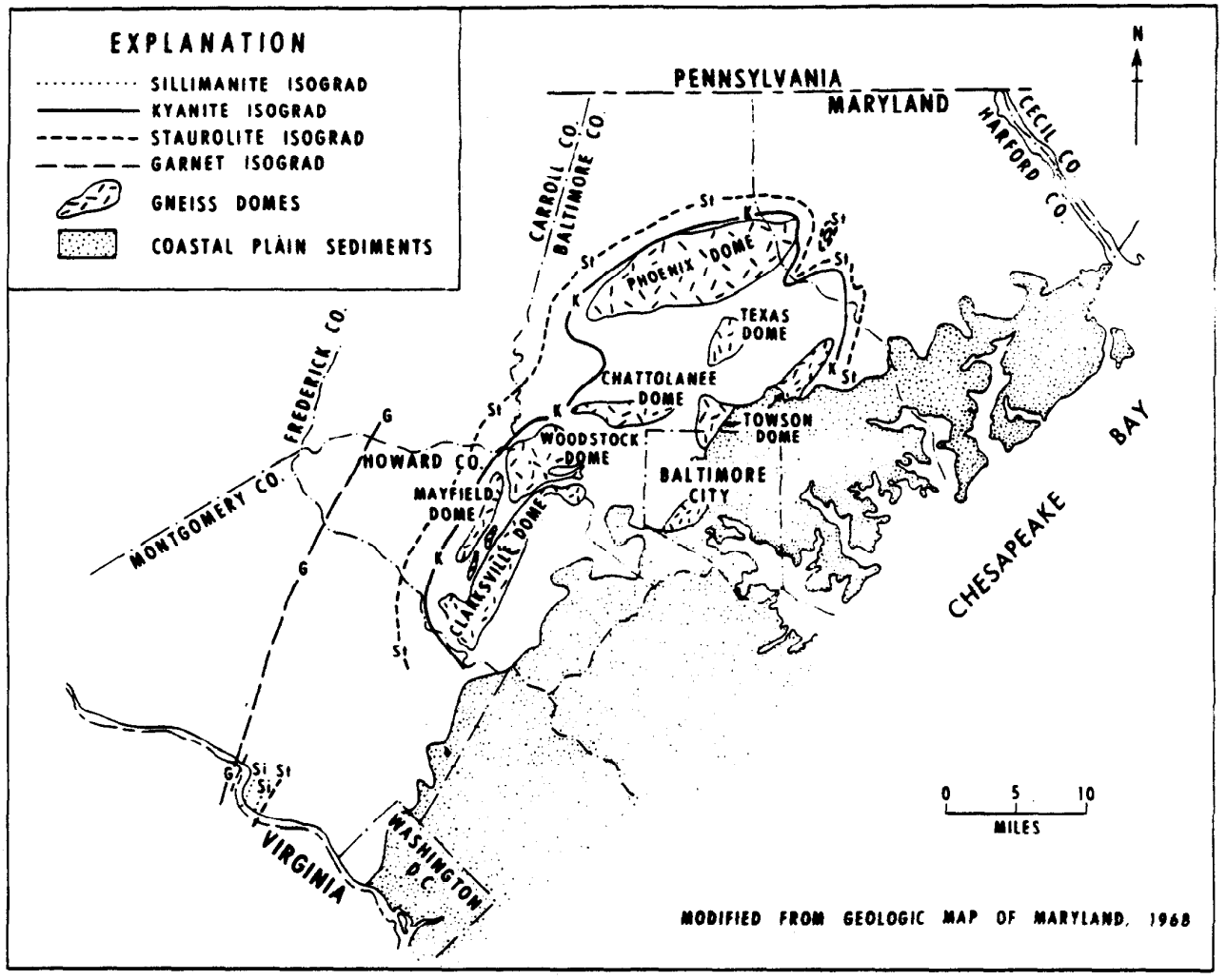

Figure 7.—Map of the gneiss domes showing metamorphic isograds.

by the underlying crystalline rocks is shown in figure 8, which covers an area of about 300 square miles in northern Baltimore, Harford, and Carroll Counties. Analysis of stream azimuths in the figure shows close agreement between the azimuths of the streams and azimuths of joints in rocks in quarries in nearby areas, as reported by Broedel (1937, pl. 30) and Hershey (1937, pl. 17). Knowledge of the trend and pattern of joints and fractures in the rocks, as revealed by the drainage pattern, thus may serve to show, by extension of the stream trend, where the larger joints may be expected in upland localities, distant from streams.

The significance of joints and fractures with regard to the occurrence of ground water is at least three-fold: First, wells penetrating one or more joints, two or more joints, or the intersection of two or more joints, may be expected to have greater yields than wells which fail to intersect any joints. Second, the depth of weathering is often significantly greater along joint planes, or at their intersection, than where joints are absent. Third, joint planes contributing water to an uncased well bore may intersect a nearby stream or ditch, thus providing a direct source of recharge to a well and a likely source of pollution of the well water. Although many wells have been drilled along extensions of the trends of joint or fracture plans. as inferred from topographic maps, it has seldom been possible to determine that the wells of better-than-average

capacity commonly encountered along such trends owe their better yields to the existence of the underlying joint planes. This is largely due to the practical difficulty of identifying joints or fractures in the well bore. Probably most of the water-yielding planar openings are less than 1 inch in width and many may be less than one-fourth inch in width. In most instances, the nature of the underlying rock structure and texture is completely masked by the products of rock weathering, soil cover, vegetation, and (in urbanized areas) cultural features.

Topography

Statistical Analysis of Topographic Position of Wells: Previous workers studying the geohydrology of crystalline-rock terranes (Meyer, 1958, p. 44; Dingman and Ferguson, 1956, p. 36; and LeGrand, 1967, p. 2) have observed that wells situated in valley flats, draws or lowlands are more productive than wells situated on hilltops or dissected uplands. For example, Meyer reports that in Carroll and Frederick Counties the average yield of wells on hilltops is 10 gpm and the yield of wells in valleys, valley flats, and draws is 27 gpm. The yield ratio of the two classes of wells is slightly less than 1 to 3.

A more detailed analysis was made in this investigation of the yields, specific capacities, static water levels, and depths of 150 randomly selected Piedmont wells, of which 75 wells are situated on hilltops (uplands) and 75 wells are in valleys or draws, but with the additional factor of depth of penetration included. The results of this analysis are in figure 9. Well data in the two major categories (valley and hilltop) were tabulated in order of magnitude, and the frequencies computed by the method used by Kimball (1946, p. 846). A given specific capacity-penetration (S.C.P.) factor value is plotted against the percent of wells whose S.C.P. factor is greater than that value on logarithmetic probability paper. The position of the graph for a topographic category indicates the relative water-yielding properties with respect to the graph of the other category. The slope of the line indicates the water-yielding properties of a given category; steeper slopes generally signify greater variability.

Two important variables govern the yields of crystalline-rock wells. These are: 1) the gross permeability of the rock, which is dependent on the number of water-yielding fractures or interstices penetrated by the borehole; and 2) the total depth of penetration of the hole below the top of the zone of saturation. Thus, a well pene-

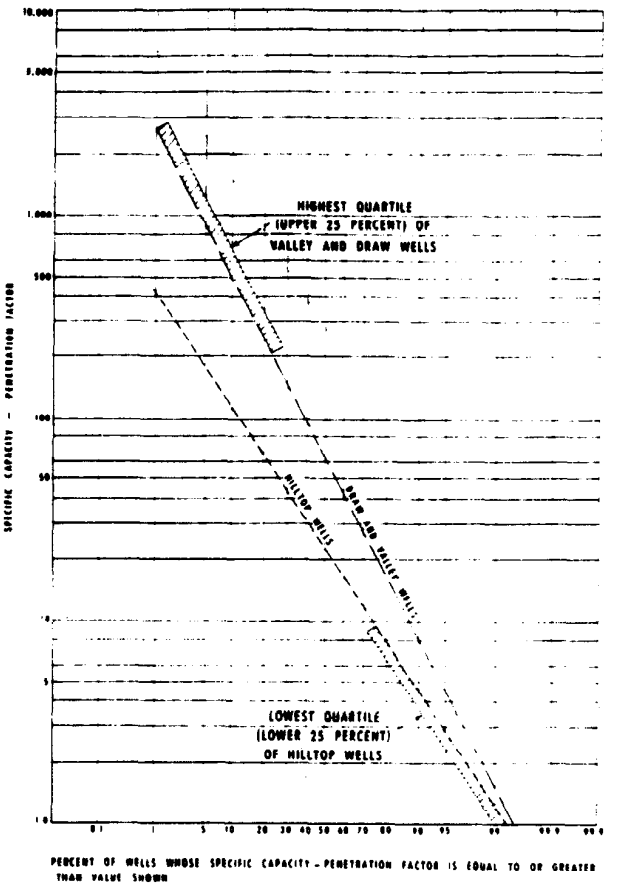

Figure 9.—Specific capacity-penetration factor frequency graph showing effect of topographic position of wells.

trating several hundreds of feet below the top of the zone of saturation should have a greater opportunity to intersect water-bearing crevices than a well penetrating only a few tens of feet. This has been designated the penetration factor and commonly ranges within 1 to 2 orders of magnitude. The specific capacity (yield in gallons per minute per foot of drawdown) of a well is an approximate measure of the permeability of the water-yielding zones and commonly ranges within 3 to 4 orders of magnitude. Therefore, multiplying the specific capacity of a rock well by its penetration factor affords a means of comparing the productivity of wells which weighs the results in favor of the specific capacity value but utilizes the factor of depth of penetration of the well.

The upper graph on figure 9 clearly shows the greater productivity of the valley and draw wells compared to the lower graph for the hilltop and upland wells.

fers. However, it is difficult to separate the effect of rock type from other factors such as topographic position, which is itself partially determined by rock type, and from metamorphic rank which is, to a large extent, dependent on proximity to the gneiss domes (fig. 7).

Basic Data Report No. 1 (Laughlin, 1966) contains well data for more than 4,000 crystalline-rock wells in Baltimore County, the greatest concentration of well data anywhere in the Maryland Piedmont. Statistical data representing the large number of wells inventoried in Baltimore County, assembled from Basic Data Report No. 1, are presented in several tables and figures in this report. The data included in the basic-data report were obtained primarily from drilling permits and completion reports filed with the Maryland Geological Survey and the Maryland Department of Water Resources. The reported locations of all the wells inventoried were verified in the field, and other reported information was verified for many of the wells.

The data used contain a few limitations: varying length of pumping tests, the fact that some holes are "dry" was not reported by the drillers, and the fact that some domestic wells are not pumped at the maximum rate because usually only moderate quantities of water are needed. However, it is believed that these limitations are minimized because the sample is large and because most of the data are sufficiently reliable to be useful.

Yield and specific-capacity data for crystalline-rock wells exhibit a marked negatively-skewed frequency distribution. The median should be more representative than the mean for both the yield and the specific capacity because the median is usually more appropriate for skewed distributions (Moroney, 1960, p. 42).

A sample consisting of the yield and specific-capacity data for about 1,300 wells was selected, and the mean, median, and standard deviation[1] were computed for wells penetrating each crystalline-rock formation or rock unit in Baltimore County. These data are summarized in table 5.

Comparison of Different Rock Types: The data given in table 5 show that the metagraywacke and the upper pelitic schist have nearly identical average yields, specific capacities, and standard deviations, and for all practical purposes could be considered the same hydrologic unit. The

[1] Standard deviation is the most important and commonly used method for measuring the dispersion of a sample. It is computed by the following formula:

$$S=\sqrt{\frac{\Sigma(x-\bar{x})^2}{N}}$$

where Σ = summation
x = value of of an item (yield or specific capacity)
$\bar{x}$ = arithmetic mean
N = number of items

Table 5. Statistical data relating well yields and specific capacities to rock type.

Hydrologic unit	Formation or rock unit	Mean yield (gpm)	Median yield (gpm)	Standard deviation	No. of wells	Mean specific capacity	Difference from mean	Median specific capacity	No. of wells
I	Cockeysville Marble	11.9	10	10.2	159	0.94	+0.30	0.30	135
	Wissahickon Fm. (metagraywacke facies)	11.1	10	8.5	81	.75	+ .11	.34	120
	Wissahickon Fm. (upper pelitic schist facies)	11.0	10	8.1	242	.89	+ .25	.33	342
II	Baltimore Gneiss and Setters Fm.	8.6	8	6.9	174	.28	− .36	.17	119
	Gabbro and serpentine	7.8	6	6.4	278	.49	− .15	.17	435
	Wissahickon Fm. (lower pelitic schist facies)	7.8	5	5.0	208	.42	− .22	.08	167
I and II	All formations	9.4	--	--	1142	0.64	--	--	1318

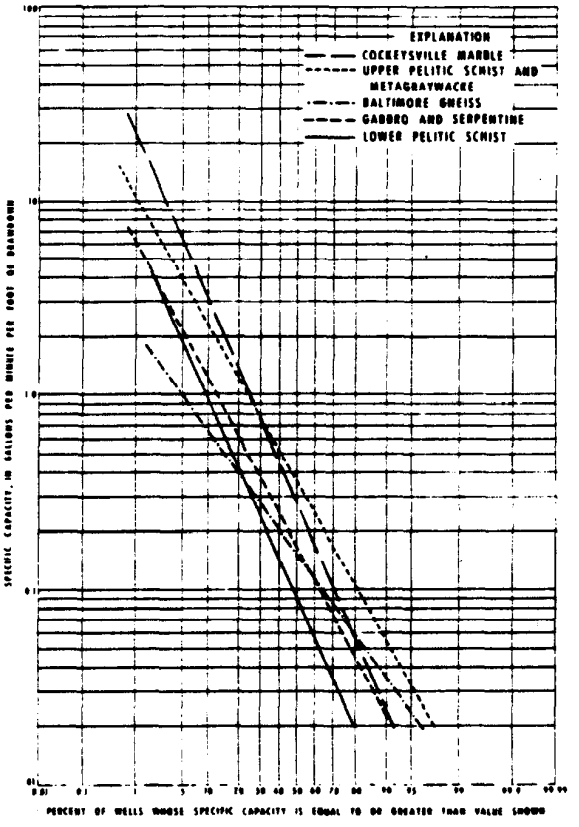

Figure 12.—Specific capacity-frequency graph comparing the crystalline-rock aquifers of Baltimore County.

lower pelitic schist of the Wissahickon Formation. The position of the Cockeysville Marble curve with respect to the lower pelitic schist curve indicates that the marble has superior water-yielding properties. For example, 50 percent of the wells drilled in marble have a specific capacity of 0.3 gpm per foot or more, whereas 50 percent of the wells drilled in the lower pelitic schist have a specific capacity of only .08 gpm per foot or more. The slope of the two curves is approximately the same, although the Cockeysville curve consists of three fairly distinct segments. The reason for the changes in slope of the marble curve, a phenomenon not observed for the other formations, is not fully understood, but for some reason there exists less variability within the intermediate range of specific capacities for the marble wells.

Figure 11 shows the comparative water-yielding properties of the Cockeysville Marble and those of the combined upper pelitic schist and metagraywacke. The position of the two curves is similar and the chief difference between the two curves is the greater variability of the marble wells.

Figure 12 shows the comparative water-yielding properties of all the crystalline-rock aquifers of Baltimore County. The Baltimore Gneiss exhibits substantially less variability than the other aquifers and the chance of obtaining wells whose specific capacities are in the higher range is less likely in the Baltimore Gneiss than in the other aquifers. To summarize: on the basis of the data in table 5 and figure 12, the crystalline-rock aquifers can generally be placed into two groups: 1) the Cockeysville Marble, upper pelitic schist, and metagraywacke; and 2) the Baltimore Gneiss, Setters Formation, gabbro, serpentine, and lower pelitic schist. The former group (1) is generally superior to the latter (2) in regard to water-yielding properties.

Contact Zones: Contact zones between rocks of different lithology or between two different geologic units might be expected to provide favorable sites for obtaining better than average yields. However, contact zones are not everywhere favorable sites for this purpose. An analysis of the yields and specific capacities of 50 wells in the Maryland Piedmont at or near contact zones shows a range in yield from 0 to 600 gpm and a range in specific capacities from less than 0.1 to 11.3 gpm per foot of drawdown.

Three of the most productive wells, Car-Ce 2, -Ce 3, and -Ce 4, are in the town of Westminster (Carroll County) and their yields are so anomalously large as to warrant detailed discussion. When pumped separately, these wells yielded 600, 600, and 500 gpm, respectively, at the end of 6 hours of pumping. Wells Car-Ce 2 and -Ce 3 are 75 feet from each other and show pronounced interference characteristics.

Well -Ce 4 is about 2,000 feet from the other two wells and its pumping does not effect them markedly. All three wells penetrate the Wakefield Marble at its contact with the Sams Creek Metabasalt. They are situated along a small valley underlain chiefly by the Wakefield Marble. Meyer (1958, p. 116-117) discusses these wells and describes an aquifer test conducted on them. The following driller's log of well Car–Ce 3 shows the general nature of the rocks penetrated:

Material	Thickness (feet)	Depth (feet)
Clay and boulders	37	37
Limestone, solid	17	54
Openings	4	58
Limestone, solid	58	116
Gravel, coarse (water)	at	116

Table 6. Laboratory analyses of core samples of saprolite from sites in Georgia and Maryland (analyses by the Hydrologic Laboratory, U.S. Geological Survey, Denver, Colo.).

Underlying rock type	Site description	Depth below land surface (feet)	Specific retention (percent)	Porosity (percent)	Specific yield (percent)	Coefficient of permeability (gpd per sq ft)
Quartz-[1] mica schist	Disposal pit no. 1	5.0-5.2	10.1	50.5	40.4	0.009
		5.0-5.2	16.4	52.9	36.5	.02
		5.0-5.2	38.8	50.7	11.9	.008
		5.0-5.2	27.9	49.1	21.2	2
		5.0-5.2	20.3	47.0	26.7	.2
		5.0-5.2	26.3	52.0	25.7	8
		4.5-4.7	13.1	47.9	34.8	2
		4.5-4.7	15.2	45.3	30.1	3
		4.5-4.7	11.4	49.5	38.1	9
		4.5-4.7	13.3	45.1	31.8	2
		4.5-4.7	26.0	43.5	17.5	.3
		4.5-4.7	20.9	51.5	30.6	3
	Disposal pit no. 2	5.0-5.2	13.6	41.6	28.0	0.5
		5.0-5.2	18.1	43.5	25.4	.4
		5.0-5.2	15.4	49.3	33.9	4
		5.0-5.2	12.9	42.2	29.3	4
		5.0-5.2	10.3	43.5	33.2	2
Wissahickon [2] Formation (lower pelitic schist)	--	4.5	--	48.8	--	14
	--	8.0	--	46.2	--	12
	--	12.0	--	51.9	--	93
		16.5	--	45.7	--	24
Woodstock [2] Quartz Monzonite	--	2.5	--	50.4	--	.2
	--	5.5	--	56.6	--	39
	--	8.3	--	52.9	--	45
	--	12.8	--	51.8	--	115
Port Deposit [2] Gneiss	--	10.0	--	34.3	--	9
	--	14.0	--	39.1	--	15
	--	19.0	--	40.7	--	18
	--	19.0	--	35.1	--	7
Baltimore [2] Gabbro Complex	--	3.0	--	45.0	--	4.7
	--	10.0	--	41.7	--	2.9
	--	11.0	--	43.0	--	.2
	--	10.5	--	42.2	--	7.6
	--	6.0	--	60.3	--	1.0
Cockeysville [3] Marble	--	6.0	--	--	--	790
	--	3.0	--	--	--	670
	--	2.0	--	--	--	530
	--	3.0	--	--	--	470
		3.0	--	--	--	730
Average	--	--	18.2	46.8	29.1	[4]
No. of samples	--	--	17	34	17	--

[1] Samples from Georgia Nuclear Laboratory near Dawsonville, Ga. (from Stewart and others, 1964).

[2] From Table 10, Maryland Dept. of Geology, Mines and Water Resources Bull. 17 (Dingman and Ferguson, 1956).

[3] From unpublished records, U.S. Geological Survey, Towson, Md. Samples collected from west wall of abandoned materials pit near Texas, Md.

[4] Average not computed, as this value is of little significance.

mentary origin. Unfortunately, the distribution of the zones of permeable sand overlying the fresh marble appears to be erratic and unpredictable

The term *transmissibility* (T), used to express the permeability of an entire aquifer, is the coefficient of permeability times the thickness of saturated aquifer. The *coefficient of transmissibility* is defined as the rate of flow of water, in gallons per day at the prevailing water temperature, under unit hydraulic gradient, across a section of the aquifer 1 foot wide that extends the full saturated thickness of the aquifer.

Aquifer Tests

Aquifer tests provide a method by which the properties of an aquifer to transmit and store water are measured. This may be accomplished by pumping water from a well at a constant rate and measuring the drawdown at accurately measured times after pumping began. These data are used to prepare a time-drawdown graph from which the coefficients of transmissibility (T) and storage (S) are determined.

When water is pumped from a well the balance between natural recharge and natural discharge is disturbed and a new state of equilibrium is reached by the propagation of a cone of depression. This occurs where the natural recharge is increased or the natural discharge is decreased by an amount equal to the withdrawal from the well (Ferris, 1959, p. 152). The manner and rate at which this cone forms and its ultimate shape can be used to determine the hydraulic characteristics of an aquifer (Lang, 1967 p. 35).

The methods most commonly used for computing T and S values are the nonequilibrium formula developed by Theis (1935) and the modified nonequilibrium formula developed by Cooper and Jacob (1946).

The nonequilibrium formula is used for computation of T and S by plotting the rate of drawdown as a function of time or the drawdown as a function of distance at one time. The derivation of the formula was based on the analogy between ground-water flow and heat flow.

The Theis equation is solved graphically by superimposing a plot of the field measurements of drawdown versus time upon a type curve, both the type curve and the field data being on log-log paper. A matchpoint is obtained and substitution is made into the Theis equation to obtain T and S.

The nonequilibrium formula is based on the following principal assumptions:

1) the aquifer is homogeneous and isotropic;
2) the aquifer has infinite areal extent;
3) the discharge well penetrates and receives water from the entire thickness of the aquifer; and
4) water removed from storage is discharged instantaneously with declining head.

These assumptions, particularly 1) and 3), are not attained in crystalline-rock areas, but where they are approached the formula is applicable to problems of ground-water flow.

The modified nonequilibrium formula (Cooper and Jacob, 1946) is a simplified form of the Theis equation. The field data are plotted in semilogarithmetic paper with the drawdown on the arithmetic scale and time on the logarithmetic scale. The data will plot as a straight line if ideal conditions are approached. The transmissibility is computed by the following formula:

$$T = \frac{264Q}{\Delta s}$$

where Q is the discharge in gpm and Δs is the drawdown in feet per log cycle.

The conditions that exist in many crystalline-rock aquifers depart substantially from the ideal conditions listed above. The saprolite, which can be considered the aquifer in most crystalline-rock areas, is neither homogeneous nor uniform, although in many cases these conditions may be approached. Therefore, the results from many aquifer tests in crystalline-rock aquifers are useful only as an approximation of the T and S values in the vicinity of the wells tested.

The nonequilibrium and modified nonequilibrium formulae describe fairly accurately the hydraulic characteristics of an extensive artesian system, although they have been widely used where water-table conditions prevail. Several workers have pointed out that the nonequilibrium formula is not valid for the early phases of aquifer tests under water-table conditions—those most commonly existing in crystalline-rock aquifers. This is because the condition of instantaneous release of water from storage simultaneously with a decline in head is not satisfied, especially where the saprolite aquifer has low permeability. During the early phase of an aquifer test the water level declines rapidly and as pumping continues the rate of water-level decline decreases because of slow drainage of water from the poorly permeable saprolite material. Therefore, a short test gives a computed T value that is too high and an S value that is too low (Stewart and others, 1964). This limitation makes it difficult to separate the

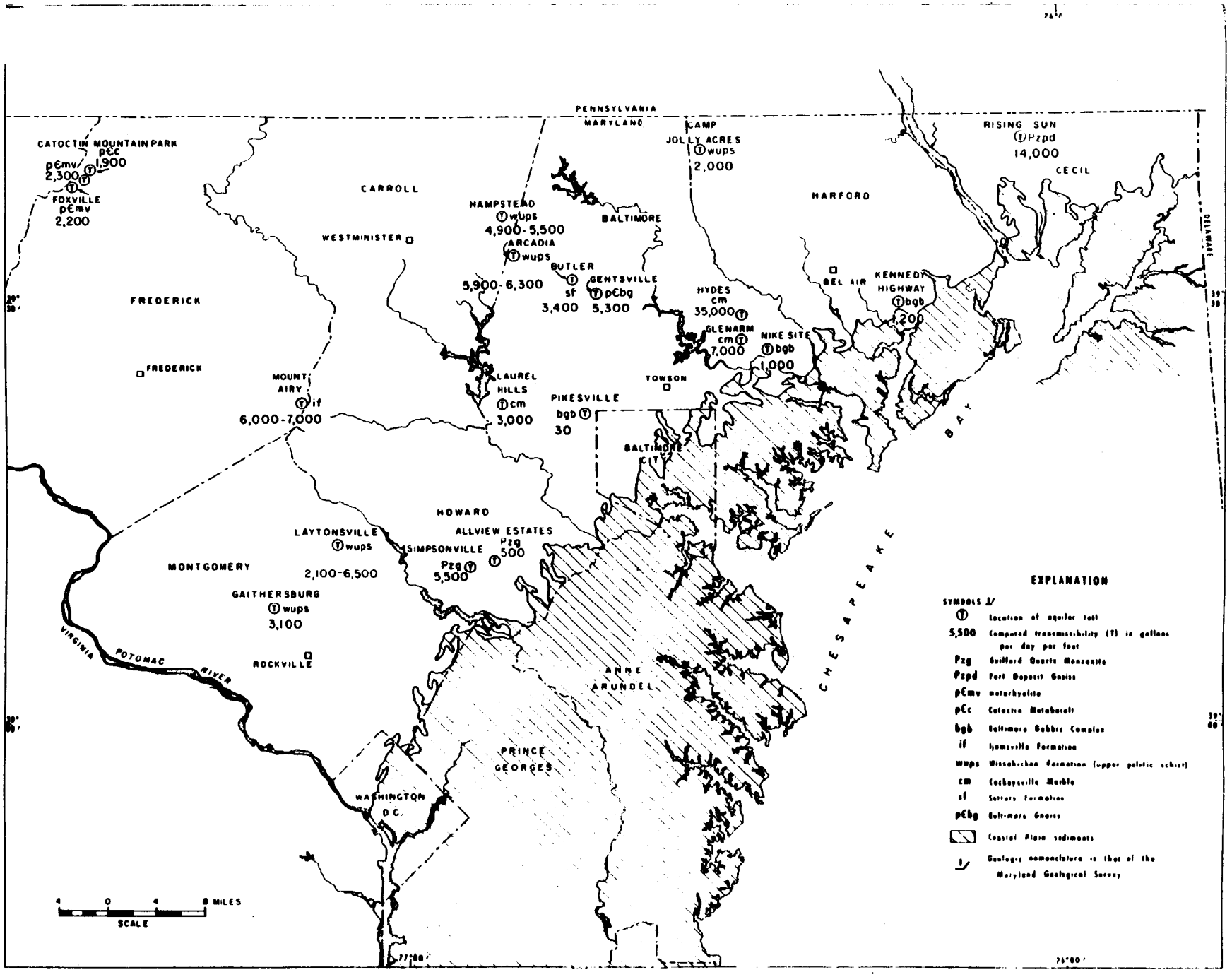

Figure 13.—Map showing transmissibility coefficients in crystalline-rock areas of Maryland.

Table 8. Aquifer tests near Laytonsville.

Well number (pumped well)	Average discharge (gpm)	Total drawdown (feet)	Specific capacity (24 hr. dd)	Length of test (hours)	Thickness of saprolite (feet)	Aquifer	Transmissibility—pumped well (gpd/ft)	Transmissibility—observation well (gpd/ft)	Distance from pumped well (feet)	Storage coefficient [3]
Mont-Cf 19	53	15.0	5.6	113	83	Upper pelitic schist	2,700(?)	3,600	58	0.017
Do.	150	54.2	2.8	22	83	do.	2,300(?)	--	--	--
Mont-Cf 20	55	25.0	2.2	106	80	do.	4,400	2,100	62	0.12
Mont-Cf 21	32	32.4	1.0	122	--	do.	2,800	6,500 (See fig. 16)	65	.003
Mont-Cf 22	34	41.3	.8	55	58	do.	T uncertain from pumped well	3,500	48	--
Mont-Cf 23	38	36.7	1.0	91	60	Boulder gneiss	[1]	--	--	--
Mont-Cf 24	41	16.3	2.5	71	65	do.	1,500[2]	2,800	42	.002
Mont-Cf 18	8.5	10.2	.8	24	60	Upper pelitic schist	1,700	--	--	--

[1] T uncertain from pumped well data (due to induced infiltration from Hawlings River after 400 minutes).

[2] T before induced infiltration from Hawlings River became effective.

[3] The storage coefficient may be computed from the formula $S = \frac{0.3Tt}{r^2}$, where T = transmissibility, in gpd/ft; t = time, in days; and r = distance between observation well and pumped well, in feet.

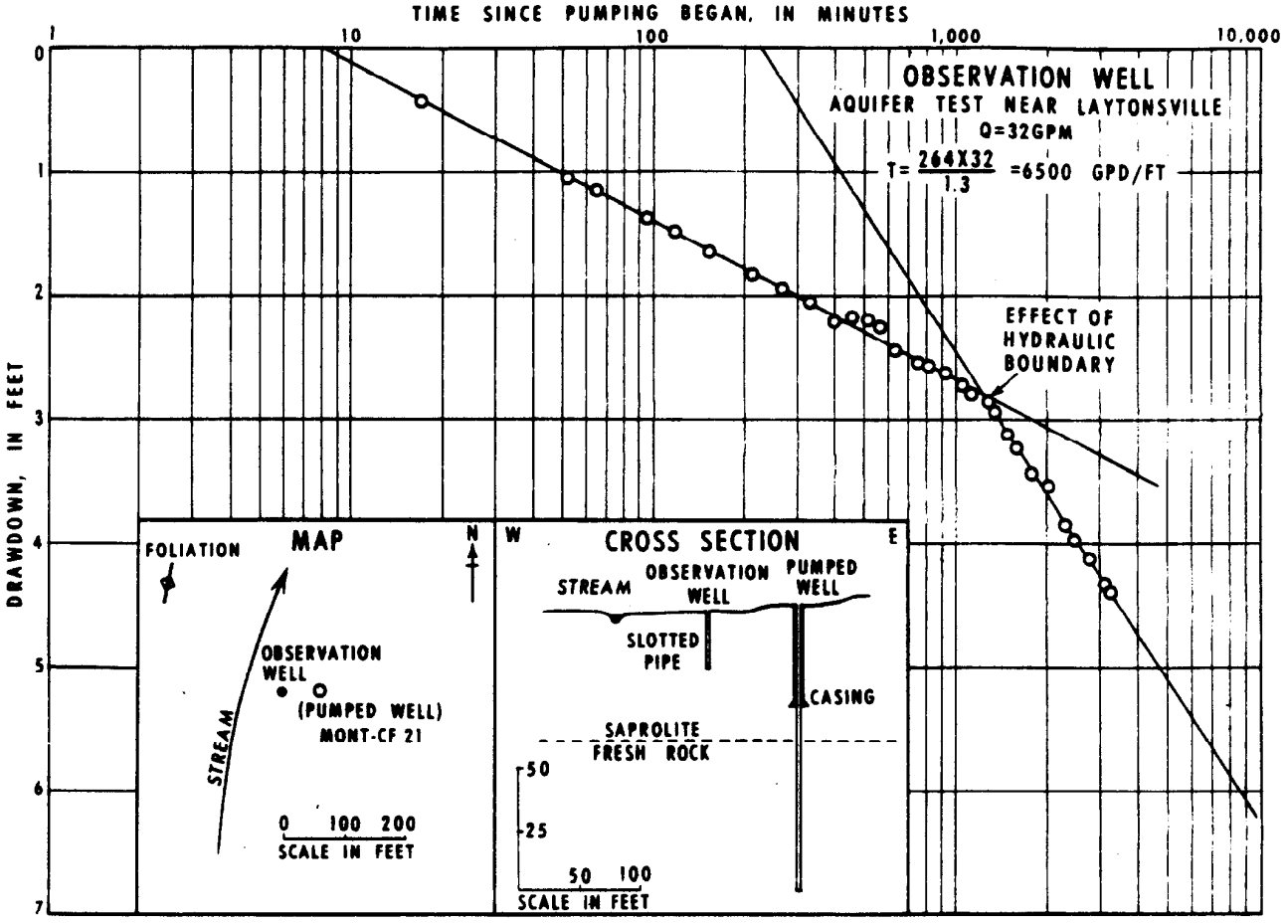

Figure 16.—Time-drawdown graph of observation well near Mont-Cf 21.

DEPTH OF DRILLING

What is the optimum depth to which wells should be drilled in the crystalline rocks? In general, joints and fractures in the crystalline rocks tend to become thinner, less weathered, and to decrease in frequency with increasing depth. Nevertheless, mining and tunneling operations have demonstrated that water-yielding openings occur in some places at depths of several thousand feet. Various workers (Davis and Turk, 1964, p. 8; LeGrand, 1967, p. 5) have indicated that the yield of crystalline-rock wells decreases substantially below a depth range of 300 to 500 feet.

Within the area of this report 30 wells are known to have been drilled to depths of 500 feet or more. The yields of these wells range from 0 to 80 gpm, but the records of some of them indicate that most of the water was obtained from the upper part of the hole. The deepest well, Bal-Dd 11, penetrated 1,800 feet into the Cockeysville Marble at Lutherville, a few miles north of Baltimore. Unfortunately, no record is available of the yield and specific capacity of this well.

Data pertinent to the crystalline rocks of the Maryland Piedmont were obtained by an analysis of the depths, yields, and specific capacities of 300 wells grouped according to the depth of drilling. The data were grouped into three depth classes of 100 wells each; these are, 100-199 feet, 200-299 feet, and 300-399 feet. The wells in each class were ranked according to their yields and the data plotted in figure 17 according to the Kimball method. However, a degree of bias exists in the ranking of well yields by depth categories. This bias results from the fact that most of the water yielded by crystalline-rock wells occurs in the uppermost 100 feet of material penetrated. Thus, in many instances, wells are drilled to greater depths only because the yield is inadequate at

Electric Logging

Electric logging methods have been employed successfully for many years in evaluating wells in unconsolidated sediments and sedimentary rocks. Electric logging was developed as a result of its usefulness to the petroleum industry and in recent years has been used more extensively in evaluating water wells. However, little application of these methods has been made in crystalline-rock wells. The lack of extensive application is due to the fact that in crystalline-rock wells electric logs are not useful for correlation or tracing of a particular strata from one site to another. Correlation is one of the chief applications of electric logs in layered strata.

Electric logging methods have been found to be useful in determining the location of water-bearing fractures, changes in mineralogy, the location of slightly weathered zones and the thickness of saprolite in crystalline-rock wells.

An electric log consists of a spontaneous-potential curve and one or more resistivity curves, each recorded as a function of depth. Each of these curves is discussed below.

Spontaneous-Potential: The spontaneous-potential or self-potential (S-P) curve is a record of naturally occurring potential differences between a surface (ground) electrode and an electrode being raised or lowered in the fluid occupying the

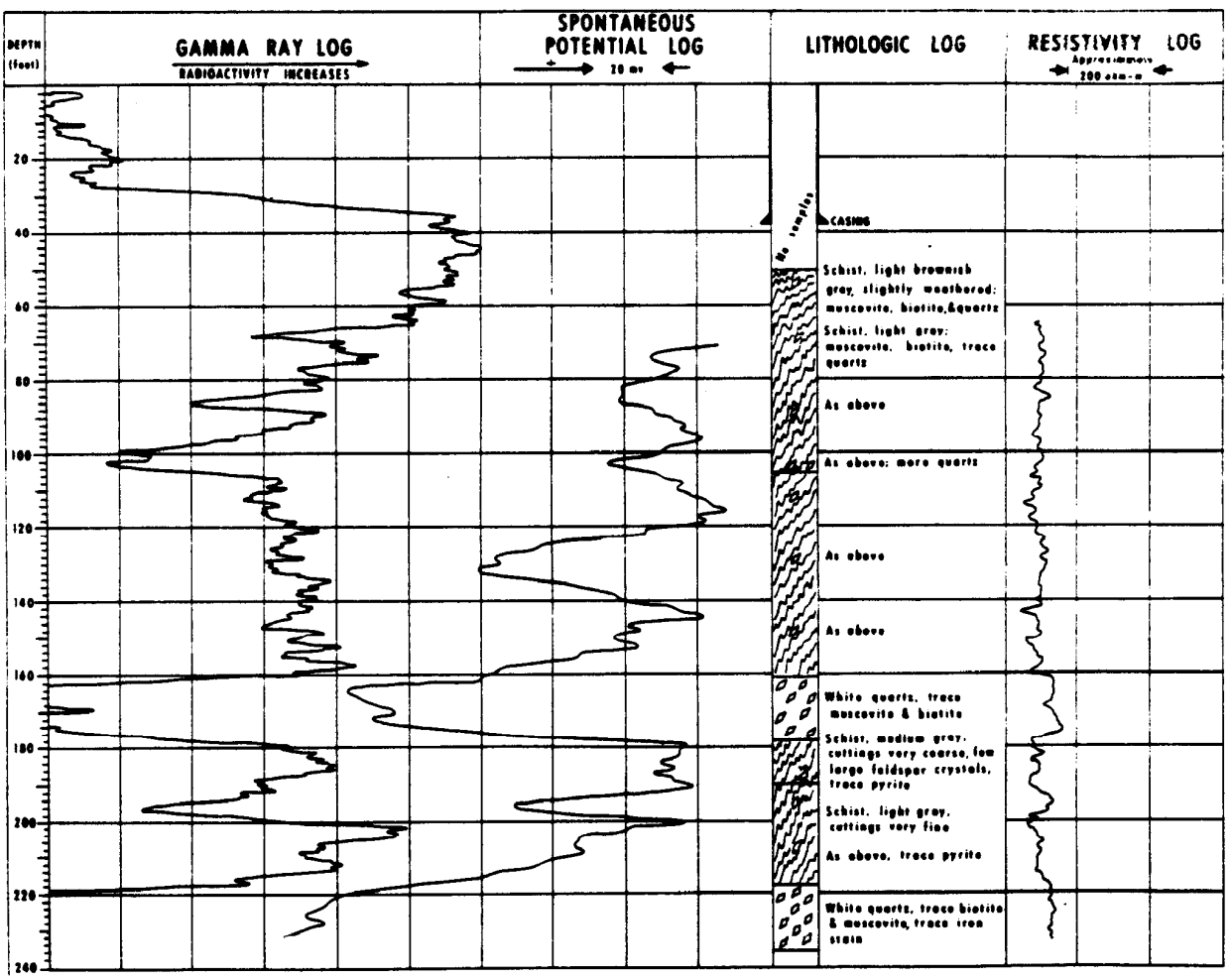

Figure 18.—Electric and gamma-ray logs of Bal-De 579 near Loch Raven Reservoir.

within a dense section of crystalline rock does not appear to be the same as occurs in conductive zones in dense limestone. Figure 19 shows schematically the response of the S-P curve to conductive and shaly zones in dense limestone. The response of the S-P curve to conductive zones in most crystalline-rock wells is in the opposite direction to that shown in figure 19. Figure 20 shows that the S-P curve responds to a conductive zone in the same manner it responds to the shale bed in the limestone section in figure 19. The most logical explanation for this seems to be that the clay minerals formed by weathering adjacent to the fractures have the same effect as a shale or clay on the S-P.

Resistivity: The resistivity of a material is that property which characterizes its opposition to the flow of an electric current and is equal to the reciprocal of the conductivity. It is the electrical resistance of a cube of material, each edge of which is one meter in length. The units are therefore ohm-meters. The resistivity is recorded as a function of depth, and the resulting record is the resistivity log.

There are several types of resistivity logs in existence, but the point-resistance, the short normal, and the long normal are the most common. These three types of resistivity logs differ primarily in the depth they measure into the formation. The zone of investigation of the point-resistance device extends only slightly beyond the borehole, the short normal includes a larger proportion of the surrounding material, and the long normal includes an even greater proportion. The greater

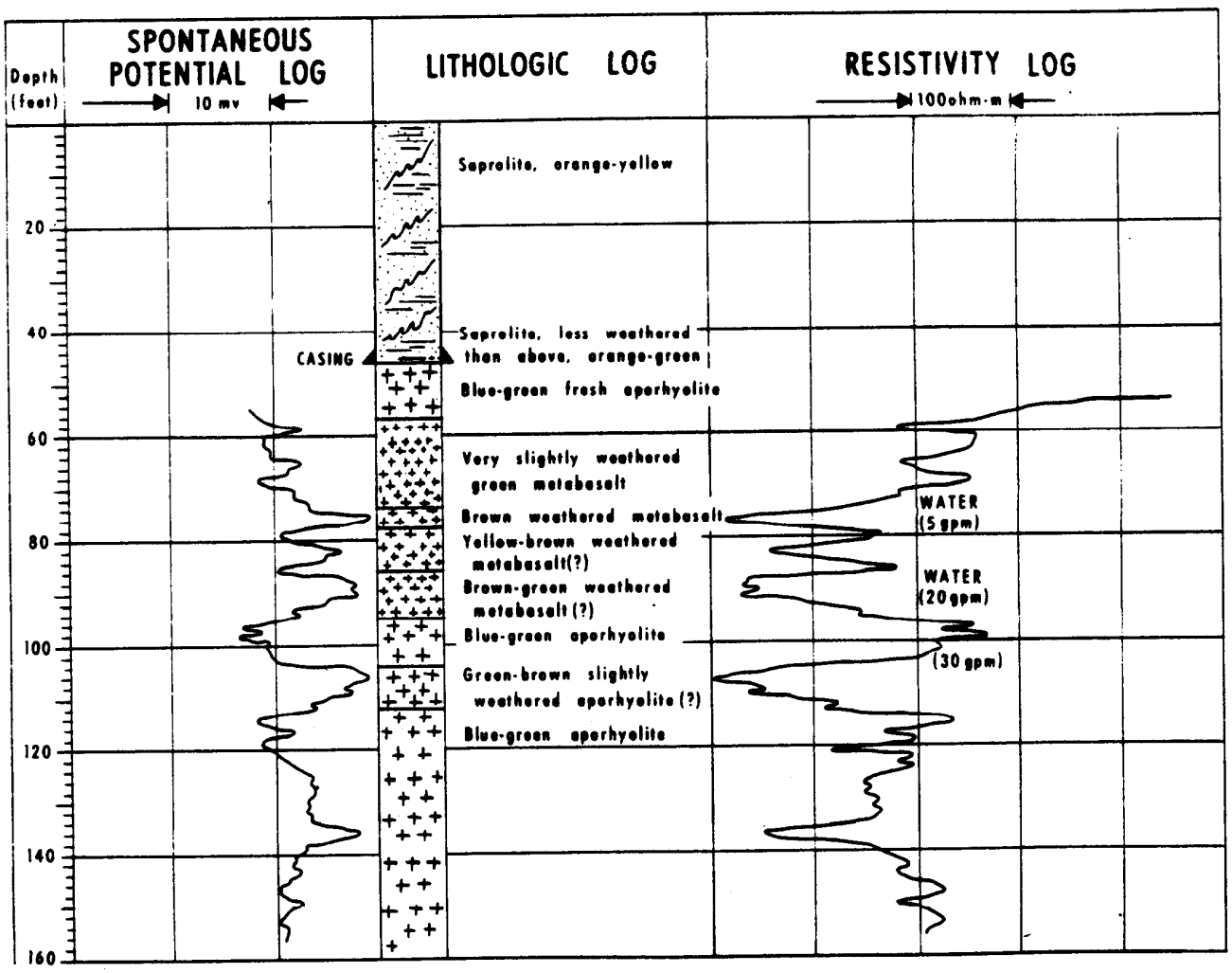

Figure 20.—Electric log of Fr-Bd 41 at Catoctin Mountain Park.

and the special electric logging sonde for limestones, which would be more likely to detect these small fractures, have not been available for logging shallow water wells in the Maryland Piedmont. However, often a slightly weathered zone adjacent to many water-bearing fractures contains enough water, due to greater porosity within the weathered zone, to be considerably more conductive than the surounding fresh rock, thus causing a lower resistivity reading on the resistivity log. These conditions are shown in figure 20.

Occasionally zones of lower resistivity are observed on resistivity logs which do not correspond to a measurable increase in well yield. A probable explanation for this is that the fracture and associated slightly weathered zone possess relatively higher porosity, but the permeability is sufficient only to transmit insignificant quantities of water. Another condition which might cause a lower resistivity reading is the existence of a zone containing substantial quantities of pyrite or some other metallic sulfide mineral.

The resistivity curve also varies with the type of rock penetrated by the well. Schistose material generally has lower resistivity than gneiss or other rock containing a large proportion of quartz-

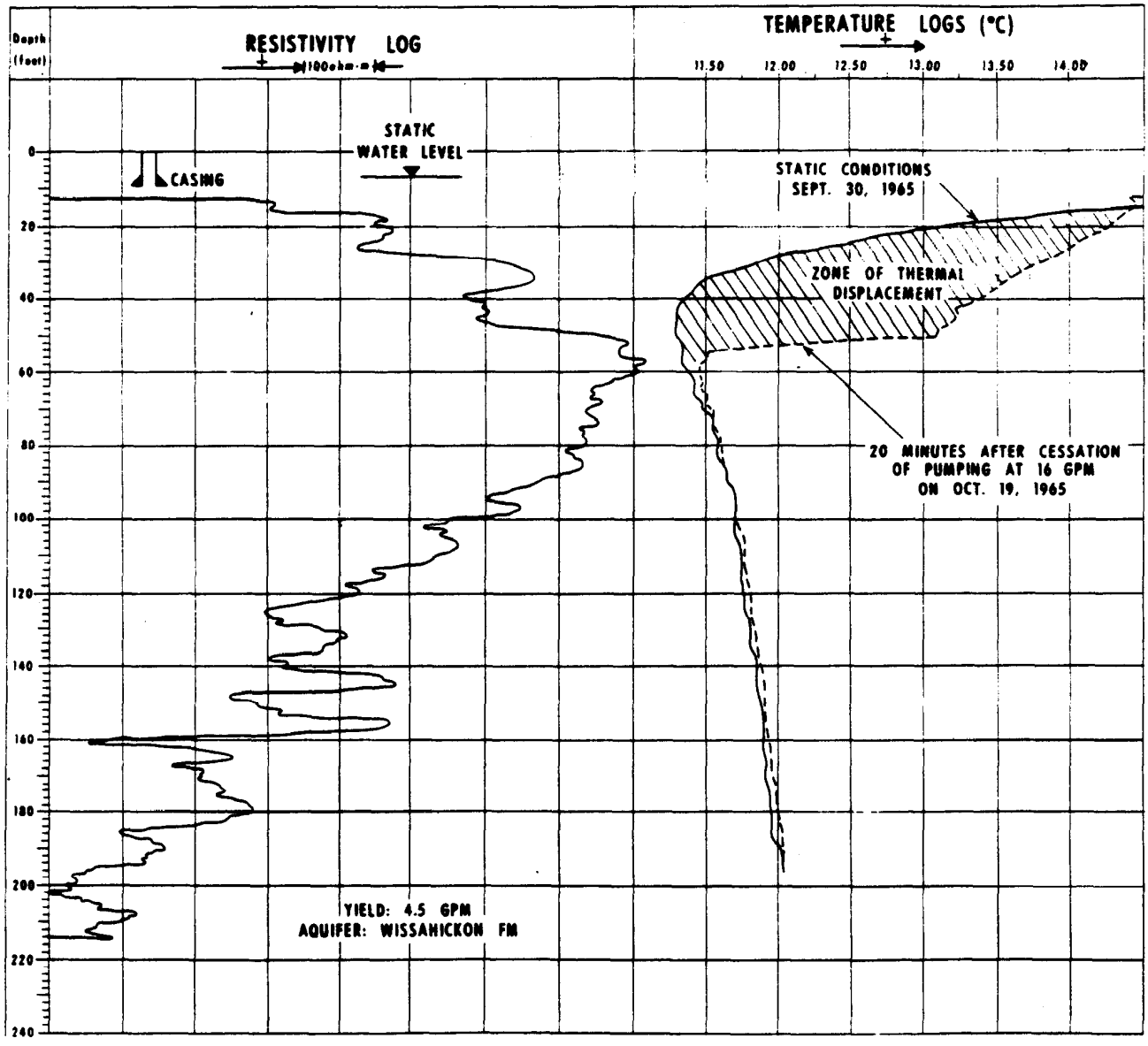

Figure 22.—Temperature and resistivity logs of Bal-De 54 at Sunnybrook.

ose material (fig. 21). The resistivity contrast between different types of rock is especially evident when a quartz vein is penetrated. The substantially higher resistivity of quartz can be observed on the log of well Bal-De 587, shown in figure 25, in the section on gamma-ray logging.

Temperature Logging

Methods and Uses: Temperature logs (profiles) were run on about 40 crystalline-rock wells during the course of this investigation. The logs were run only in the water-filled part of the hole and could be made only to a maximum depth of 250 feet as this was the limiting length of the thermal probe used. Temperature measurements were made by means of a null-balance, portable, battery-operated temperature device, using a thermistor probe. This device was designed for shallow oceanographic work by Robert Crosby of the Chesapeake Bay Institute of The Johns Hopkins University. The device measures temperature differences to a precision of about 0.02°C.

The purpose of temperature logging was to determine to what extent temperature profiles in an open borehole might delineate zones of ground-water entrance or movement in a well, and to correlate thermal logs of wells with electric and lithologic logs for the same purpose.

Although it is beyond the scope of this report to describe the physics of heat transfer, the thermal properties of water and rocks are such that circulating ground water transfers or accepts heat energy somewhat slowly to or from the surrounding rocks. Hence, ground water moving through crevices in the crystalline rocks may have a residual temperature slightly different from the surrounding rocks.

The specific heat of water is about five times that of granite or limestone and the thermal conductivity of water is about 23 percent that of granite and about 35 percent that of limestone (Skibitzke, 1961, p. A-7). Thus, the temperature of circulating ground water in crystalline rocks may differ from the rock temperature by as much as an order of magnitude. However, in a borehole where the ground water is not in circulation through the rocks, or is moving at extremely slow rates, it will adjust to the temperature of the surrounding rocks.

Using the above concept, it is possible to determine empirically "dead" zones, or zones of no apparent ground-water movement in rock wells. When a well is pumped, fresh water enters the hole and a zone of thermal displacement is created. Figure 22 illustrates this phenomenon resulting from pumping a well in the Wissahickon Formation. The major zone of water entrance in well Bal-De 54 is believed to occur at a depth of 40 to 50 feet. The temperature profile also shows the existence of the dead zone in the interval from 55 to 196 feet. Within this zone the temperature of the water has adjusted to the rock temperature. Temperature measurements in the dead zone are useful in determining the geothermal gradient at the site.

Seasonal effects of temperature change may be detected at various depths in the water-saturated part of boreholes, but commonly do not extend much below a depth of 50 feet. Figure 23 shows temperature profiles run during the fall and the spring. The fall profile (November 9, 1956) shows the existence of warm summer precipitation stored in the ground-water reservoir between a depth of 22 to 40 feet. However, by April the warm summer precipitation had been replaced by the cooler precipitation of early spring (profile of April 10, 1957).

Figure 24 shows the temperature log of an unsuccessful well (Bal-Dc 435) west of Cockeysville in the north-central part of Baltimore County. This well yielded only ¼ gpm from the base of the saprolite at a depth of about 50 feet. The temperature profile of -Dc 435 shows the characteristic profile of the dead zone in rock wells. As the log was made several days after the well was drilled, the water temperature in the hole is believed to have adjusted to the temperature of the surrounding rocks.

Geothermal gradients: A sufficient number of Piedmont wells were temperature profiled to provide data on mean temperatures at various depths, although the data are somewhat biased because a large number of the temperature logs were made during the fall months of September, October, and November. Thus, temperatures in the upper parts of the holes tend to be slightly higher than if the logs had been made during the spring, due to the residuum of summer heat stored in the ground. The mean ground temperatures at three depth horizons are:

Number of wells	Depth horizon (feet below land surface)	Mean temperature °C	°F
31	50	12.3	54.1
35	100	11.8	53.2
11	200	12.4	54.3

Examination of the yield data, well logs, and temperature logs indicates that the temperature

profiles (or segments thereof) of 20 wells might provide information on the geothermal gradients in the Piedmont rocks. These data show that below a depth of 50 feet the mean geothermal gradient is about 0.3°C per 100 feet of depth increment. This value is in approximate agreement with gradients of 0.46 to 0.49°C per 100 feet reported by Diment and Werre (1964, p. 2143) from three deep boreholes in quartz-mica schist near Washington, D. C.

Gamma-Ray Logging

Another useful geophysical logging device for determining lithologic changes in the material penetrated by a well is the gamma-ray log. Gamma-ray logs have been available for the past 20 years but have been used extensively in ground-water studies only in the past few years. They are especially useful because wells can be logged through casing, above the water table, and in almost any type of fluid occupying the borehole.

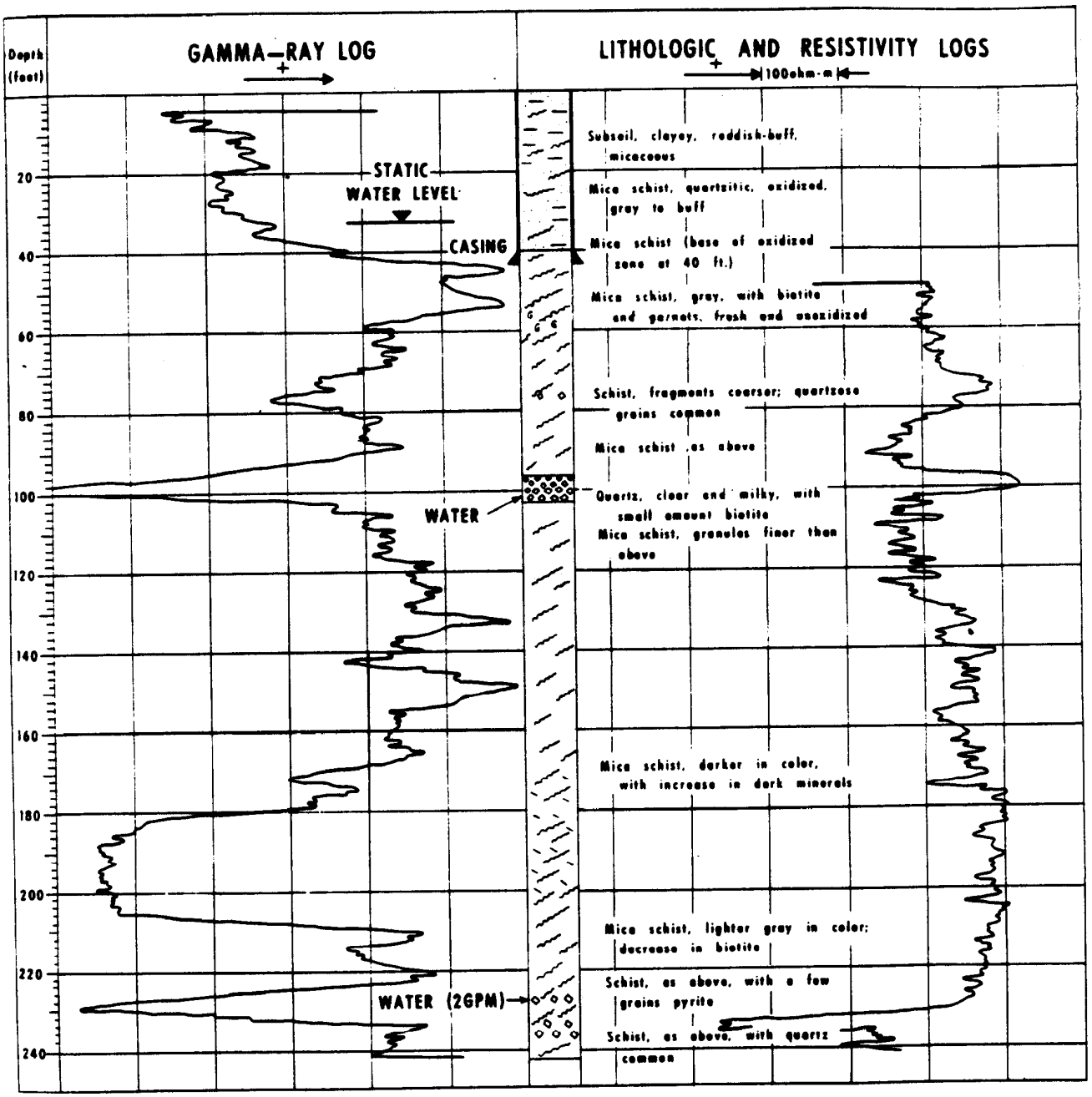

Figure 25.—Gamma-ray and resistivity logs of Bal-De 587 north of Loch Raven Reservoir.

Standard Deviation Map

When yields and specific capacities of crystalline-rock wells are studied, one cf the first properties to become apparent is their extreme areal variability. In fact, well-yield and specific-capacity data show the existence of substantial variability within small areas such as housing-development tracts, as well as within larger areas.

In an attempt to understand better the areal variability of well yields and specific capacities, statistical data were assembled from the Baltimore County well-inventory report (Laughlin, 1966). A sample of the yield data was selected, and the mean and standard deviation were computed for each formation. These data are in table 5 in a previous section of this report.

Using the statistical data which form the basis for table 5, a map of part of Baltimore County was prepared on which each well was plotted whose yield is more than one standard deviation above or below the mean (plate 1). The wells whose yields are more than one standard deviation above the mean are designated by blue dots, which represent wells whose yields are 17 gpm or more. Those wells whose yields are more than one standard deviation below the mean are designated by red dots, which represent wells whose yields are 2 gpm or less. Although the standard deviation was computed for each formation, the standard deviations for all the crystalline-rock aquifers were lumped together in preparing the map. It should be emphasized that plate 1 contains only about one-third of the wells inventoried, and that only those wells whose yields are greater than one standard deviation above or below the mean were plotted on the map.

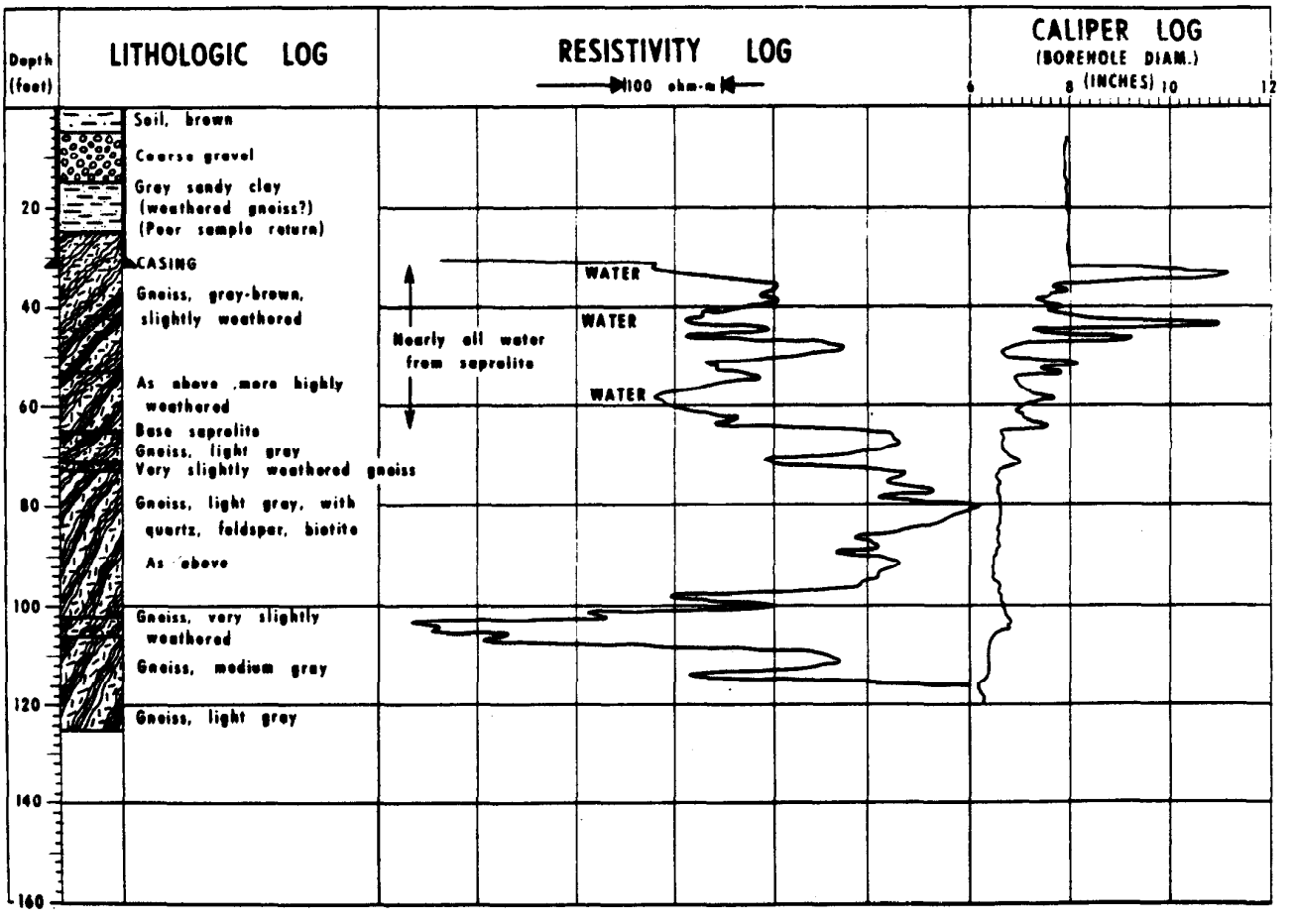

Figure 27.—Caliper, resistivity, and lithologic logs of well Mont-Cf 24 near Laytonsville.

foot, a total of $7,800 was spent at this site in searching for an adequate ground-water supply.

A second example of this problem occurred on a 2- to 3-acre tract of land near Glenarm at a site where the Wissahickon Formation is in contact with the Cockeysville Marble. In this instance, seven wells were drilled on the property, representing a total of 1,313 feet of drilling. Five of the wells were in the Wissahickon, four of which yielded no water; and the fifth well yielded less than ½ gpm. Two of the wells were drilled in the marble; one of these, 200 feet deep, was abandoned because a zone of flowing mud was penetrated near the bottom of the hole. A successful well was finally obtained at a depth of 40 feet in the Cockeysville Marble; this well yielded 10 gpm, a more than adequate domestic supply. It is estimated that more than $5,200 was spent in searching for ground water at this site.

USES OF GROUND WATER

Ground water is used in the Maryland Piedmont as a source of supply for farm, domestic, commercial, institutional, industrial, and public supplies. Water is obtained chiefly from drilled wells. and in a relatively few instances from springs.

Where the water requirements of the user amount to only a few hundred thousand gallons per day or less, ground-water sources have generally proven adequate, although some users have reported temporary failures of their supply during prolonged drought periods of 60 to 90 days or more. However, attempts to develop supplies in excess of a few hundred thousand gallons per day does not appear warranted in most instances.

At present (1968) the towns of Hampstead (Carrroll County), Walkersville (Frederick County), Mount Airy (Carroll County), and Damascus (Montgomery County) depend on wells as a source of water supply. Inadequacy of the well supply was reported at the town of Damascus during the drought period of 1966-67.

The largest single user of ground water in the Piedmont was the town of Rockville located about 9 miles northwest of Washington, D. C. Dingman and Meyer (1954, p. 44) report that the first municipal well for the town was drilled in 1895 and that during the period of 1895-1954 more than 42 public-supply wells were drilled, of which about 30 were in use by 1957. Nearly all of these were in the Wissahickon Formation at depths ranging from 38 to 425 feet. The yields of these wells ranged from a few gallons a minute to a maximum of 183 gpm. It is reported that the total use of ground water by the town in 1930 was 100,000 gpd and by 1952 this use had increased to about 750,000 gpd. The demand for water continued to increase during the period from 1952 to 1958 and the yields of some of the more productive wells declined during seasonal droughts in the mid-1950's. In 1958 the City of Rockville began using surface water from the Potomac River and the ground-water supply was abandoned.

The history of the Rockville ground-water supply emphasizes the problem created by the limited storage capacity of the crystalline rocks. During seasonal droughts the yields of even the best wells decreased after sustained periods of pumping. The yields of the wells recovered during periods of substantial recharge to the ground-water reservoir, but, unfortunately, the interval of decreased well output corresponded with the period of greatest demand. Thus, the town had to seek a more dependable supply.

SUMMARY OF AVAILABILITY OF GROUND WATER IN CRYSTALLINE ROCK TERRANES

In summary, several factors govern the occurrence and availability of ground water in crystalline rocks: the degree to which the rocks are jointed, fractured, and faulted; the topographic position of the well; the porosity, permeability, and thickness of the saprolite; the amount of precipitation and evapotranspiration in the area; regional structure and metamorphism; and the lithologic, mineralogic, and textural characteristics of the aquifer.

The degree to which rocks are jointed, fractured, and faulted is one of the most important factors governing ground-water availability and one of the most difficult to predict. It is virtually impossible to predict where a given well will intersect a joint or other fracture, although in some cases a major joint can be projected from another site if its orientation is known.

The topographic position of a well site is an important factor governing ground-water avail-

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[1] The name of this agency was changed to the Maryland Geological Survey in June 1964.

APPENDIX

Table 9. Lithologic Description of Selected Wells.
—Continued

Well No.: Bal-De 587
Owner: Colonial Development Corporation (Ravenhurst)
Elevation: 455 ft
Geologic unit: Wissahickon Fm.
Driller: Water, Inc.
Sample examination by: E. G. Otton

Depth (ft)	Description
0– 9	Subsoil reddish buff, highly micaceous, clayey, silty, and gritty
9– 15	Subsoil, clayey, buff-gray, highly micaceous; gritty with some quartz and limonite
15– 20	As above but mica flakes coarser; some biotite and few pieces yellow quartz; color changes to gray; material grades into true saprolite
20– 25	Micaceous silty, quartzose weathered rock; biotite common; some yellow quartz
25– 40	As above, with a few pieces weathered garnet
40– 45	Rounded granules of biotite, quartz, and garnet; some clay lumps (garnets large and common). Base of oxidized zone at about 40 feet
45– 50	Mica schist and biotite; quite a bit of mica clay; some clear quartz and garnet
50– 55	Mica schist, clean, with abundant biotite; some garnet; pinkish
55– 71	Mica schist, clean, with abundant biotite; some garnet; pinkish (common 60–71 ft)
71– 77	Mica schist; garnet and yellow quartz common (slightly oxidized); some kyanite
77– 78	Change to coarse gray fragments quartzose schist; white quartz grains common
78– 81	Mica schist, finer pieces; color similar to 71–77 ft (oxidized); garnets common
81– 95	Mica schist, fresh, light gray color; garnets, common, pinkish (biotite common 85–95 ft)
95–100	As above, but a few oxidized grains; pink glassy grains common (garnet?)
100–105	Quartz, finely pulverized, clear and glassy, with a few pieces biotite
105–135	Mica schist, coarse fragments, gray; whole grains of red to pink garnet common (schist fragments finer below 110 ft)
135–140	As above, but fragments coarser
140–145	No sample
145–150	Similar to 135–140; some coarse fragments (up to 0.5 inch diameter)
150–160	Similar to 135–140; some coarse fragments (up to 0.5 inch diameter), but finer pieces
160–165	As above, but more garnets
165–170	As above, but more micaceous; dark gray
170–175	As above, with more biotite and dark minerals
175–190	As above with increase in garnet and dark minerals; biotite common 180–190 ft
190–210	As above, with slight increase in quartz
210–215	Mica schist, light gray; decrease in biotite from 205–210 ft; increase in pink garnet
215–220	As above, with pink garnets common
220–230	As above, with one piece pyrite
230–235	Mica schist as coarse gray fragments; some garnets (sample contains very little fine material)
235–240	Mica schist, finer grains than above, with several large pieces quartz
240–247	As above, with one grain pyrite; clear and milky quartz common (quartz grains abundant 245–247 ft)

Well No.: Car-Ee 27
Owner: Maryland Dept. of Forests and Parks (Patapsco State Park)
Elevation: 545 ft
Geologic unit: Wissahickon Fm (boulder gneiss)
Driller: Water, Inc.
Sample examination by: E. G. Otton

Depth (ft)	Description
0– 6	Subsoil, clayey reddish tan; micaceous; some quartz
6– 18	Similar to above
18– 30	As above, but changes in color to buff-grayish; some biotite and chlorite; color more grayish at 24 ft
30– 36	As above, mica flakes somewhat coarser
36– 40	As above, a few pieces feldspar (all cuttings fine-grained down to 40 ft)
40– 42	No sample
42– 48	Change to coarser fragments of quartz, mica and chlorite; speckled gray color, some yellow quartz; a few pieces orange mineral (base of weathered zone at 42 ft)
48– 78	As above, gray in color; sample mostly clear quartz; chlorite, biotite and mica; cuttings finer below 60 ft
78– 84	As above, but darker gray than above; more chlorite and dark minerals
84– 90	As above, but appears to contain small amount clay or oxidized material; abundant chlorite and biotite
90–102	As above, with fewer clayey pieces; biotite slightly coarser; cuttings very fine at 96 ft
102–108	Sample changes to dark gray color; quartz, mica, and chlorite; some grains coated with clay and some aggregates of minerals cemented by limonite (zone may be a weathered fracture)
108–114	Similar to above, but slightly more quartz and less clayey material
114–138	Similar to above; dark gray color; material finely pulverized; increase in quartz at 126–132 ft
138–139	No sample
139–162	Similar to 132–138 ft depth; cuttings coarser at 156 ft with increase in quartz

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Peter Lyttle

GEOLOGY OF THE CRYSTALLINE ROCKS OF CECIL COUNTY, MARYLAND*

Michael W. Higgins
U.S. Geological Survey

INTRODUCTION

In the eastern Maryland Piedmont, southeast of the extensive terrane of pelitic and psammitic rocks that have traditionally been assigned to the Wissahickon Formation (Wissahickon terrane of Drake and Morgan, 1981), is a terrane of layered gneisses, massive but fine-grained granofels with blocky phenocrysts of plagioclase, and layered, massive, and pillowed amphibolites collectively called the James Run Formation. Interspersed with and locally grading into the James Run rocks are coarser grained granitic plutons. The plutons and the James Run rocks are believed to represent the roots, products, and debris of ancient volcanoes. There also is a large outcrop belt of ultramafic and mafic rocks belonging to the Baltimore Complex (Baltimore gabbro of early workers). The relations between the metasedimentary rocks, the James Run Formation and its associated plutons, and the Baltimore Complex are important to our understanding of the history of the central Appalachians. The James Run metavolcanogenic rocks and associated plutons are perhaps best exposed in Cecil County, the northeasternmost county in Maryland (fig. 1; pl. 1), where a small part of the sequence has long been called "the volcanic complex of Cecil County." There too are thick and diverse sections of the metasedimentary rocks, and the most intact section known of the Baltimore Complex.

This paper gives descriptions of the rocks exposed in Cecil County, interpretations of the origins of these rocks, and interpretations of the geologic, structural, and tectonic history of the area.

roved by the Director of the U.S. Geological Survey May, 1983.

event, eroded, and resubmerged, and a sequence of rocks known as the Glenarm Group was deposited upon the old erosion surface. The gneiss was then remetamorphosed and deformed during the Paleozoic, along with its cover rocks.

In the Maryland Piedmont, the Baltimore Gneiss is unconformably overlain by potassium-rich quartzite and quartz-rich schist (Hopson, 1964), that locally contains pelitic rocks and metaconglomerate (Fisher, 1971), named the Setters Formation. The Setters is conformably overlain by the Cockeysville Marble (Choquette, 1960; Hopson, 1964; Crowley, 1976), a unit consisting of metalimestones and metadolostones that is divisible into several mappable members (Crowley and others, 1976). Conformably overlying the Cockeysville with gradational contact is a sequence of pelitic schist and lesser amounts of metagraywacke called the lower pelitic schist by Southwick and Fisher (1967), Southwick and Owens (1968), and Southwick (1969). Crowley (1976) divided this unit into the Loch Raven Schist and Oella Formation. The Setters Formation, Cockeysville Marble, Loch Raven Schist, and Oella Formation constitute the Glenarm Group as presently defined, and are thought to represent an autochthonous shelf sequence (Setters and Cockeysville) transitional into a deeper water clastic sequence (Loch Raven and Oella) of probable Early Paleozoic age.

Most of the rocks that lie structurally above the Loch Raven Schist and Oella Formation are now considered allochthonous and thus not part of the Glenarm Group. This thick sequence of metamorphosed clastic metasedimentary rocks, which was formerly considered to constitute the major part of the old Wissahickon Formation (or Wissahickon Group of Crowley, 1976), is now believed to be a complex sequence of stacked thrust sheets and melanges (pl. 2), probably similar in age and origin to the Manhattan Schist and Taconic thrust slices in New York and New England (A.A. Drake, Jr., written communication, 1982; Drake and Morgan, 1981). In addition, the Baltimore Complex, which was considered to be intrusive before the work of Crowley (1976), as well as rocks of the James Run Formation, are now regarded as allochthonous (Crowley, 1976; Fisher and others, 1979; Drake and Morgan, 1981).

ROCKS EXPOSED IN CECIL COUNTY

Only the rocks exposed in Cecil County are described in this paper. For descriptions of rocks units elsewhere in the Maryland Piedmont, the reader is referred to Hopson (1964), Southwick and Owens (1968), Crowley (1976), Fisher and others (1979), and Drake and Morgan (1981).

Metasedimentary rock sequence

The metasedimentary rock sequence in Cecil County, formerly termed the Wissahickon Formation (Southwick and Fisher, 1967; Cleaves and others, 1968; Higgins and Fisher, 1971; Higgins, 1972), contains three distinct lithofacies: pelitic rocks, diamictite, and metagraywacke. Each of these lithofacies is further divisible into two or more subfacies. Because of structural and stratigraphic complications, as well as uncertainty of correlation between different outcrop belts, these subfacies have not been assigned formal names.

Pelitic lithofacies

Pelitic rocks underlie large areas in Cecil County (pl. 1). These rocks are similar to those described as part of the "eastern sequence" of the Wissahickon Formation by Hopson (1964), and as the "lower pelitic schist" by Southwick and Fisher (1967) and Southwick (1969). The pelitic schists in Cecil County can be traced around the flank of the Mill Creek dome of Baltimore Gneiss a few kilometers to the northeast in Pennsylvania and Delaware (Higgins and others, 1973; Gohn and others, 1974). Because of this, they are thought to be correlative with the Loch Raven Schist and part of the Oella Formation in the upper part of the Glenarm Group in Baltimore County, as revised by Crowley (1976), and are probably autochthonous. However the Cecil County rocks are separated from the Loch Raven and Oella by Baltimore Complex rocks.

Pelitic schist

The pelitic schist in north-central Cecil County (pl. 1) is very

poorly exposed, and most exposures are weathered. In the few relatively fresh outcrops it is a strongly crinkled, brownish- to silvery gray, fine- to medium-grained quartz-biotite-plagioclase-muscovite schist* with opaque minerals as sparse accessories (table 1). It weathers to a reddish clayey soil containing quartz grains and flakes of muscovite. To the northeast, the schist appears to grade over a wide interval into pelitic gneiss by increase in grain size, increase in quartzofeldspathic segregations, and increase in abundance of pegmatite dikes and veinlets. These changes probably reflect an increase in metamorphic grade, but may also involve changes in chemical composition.

To the north and northwest, the pelitic schist is in contact with the Baltimore Complex (Higgins, 1977a). This contact is never well exposed, but appears to be sharp. Crowley (1976), Morgan, (1977), and Fisher and others (1979) proposed that the contact is a fault. To the west the schist is in contact with the Conowingo diamictite, but the contact is unexposed. To the southeast, the schist is in contact with pelitic schist containing scattered stringers of amphibolite and with the pelitic gneiss unit.

Fresh outcrops of pelitic schist are limited to the valley of Northeast Creek and to the fairly deep cut of the abandoned line of the old Pennsylvania Railroad south of Rising Sun (pl. 1). In all outcrops the schist is strongly crinkled. Most outcrops also show a crosscutting cleavage.

In thin section, the schist shows an unlayered, strongly schistose but wavy texture, in which brown biotite and muscovite weave around quartz grains and grains of sodic plagioclase (An_{12-38})*. Scattered opaque minerals appear to be magnetite. Table 1 gives modal analyses of two fresh samples of the pelitic schist and other schists in Cecil and Harford Counties.

* Mineral modifiers are listed in order of increasing abundance in this paper.

Pelitic schist with amphibolite

Pelitic schist, identical with the pelitic schist described above but containing scattered amphibolite stringers, bears similar contact relations with other facies of the metasedimentary sequence. In addition, it is in possible thrust contact with metagraywacke facies rocks to the southeast (pl. 2). Contacts with James Run Formation rocks are not well exposed.

The amphibolites in this unit are fine-grained quartz-plagioclase-hornblende amphibolites. Plagioclase generally ranges from albite to andesine (An_{9-36}), but most is oligoclase. Rare grains as calcic as An_{54} occur. The hornblende is dark green and the quartz occurs in irregularly shaped grains about the same size as the plagioclase. Hornblendes are aligned in two directions in a strongly lepidoblastic texture. Tiny grains of magnetite are scattered throughout the matrix. Table 1 gives modal analyses of the schist and amphibolite in this subfacies.

Pelitic gneiss

Pelitic gneiss forms a southwestward curving outcrop belt along the Pennsylvania border from Delaware to about 3 kilometers southeast of the town of Calvert, in north-central Cecil County (pl. 1). In fresh outcrops, the gneiss is a lustrous, brown, medium- to coarse-grained, layered, strongly schistose rock riddled with quartzofeldspathic and aplitic segregations and cut by numerous pegmatite veins and veinlets. It is generally a muscovite-biotite-quartz-plagioclase gneiss, but locally has abundant dark-red, 3-5 mm garnets. The gneiss commonly has two or more cleavages in addition to the strong schistosity and streaking. Bascom and Miller (1920) mapped this rock as Baltimore Gneiss, but it has since been shown to be part of the metasedimentary cover sequence (Higgins and others, 1973; Gohn and others, 1974). The gneiss weathers to a red-brown, clayey saprolite

* Plagioclase compositions were determined optically unless otherwise stated.

containing fairly abundant quartz grains and abundant vein quartz fragments.

In thin section, the pelitic gneiss shows lepidoblastic to granoblastic textures. Commonly, reddish-brown biotite laths and lesser amounts of muscovite laths weave in and out among elongate, interlocked grains of plagioclase and quartz. Plagioclase is generally oligoclase. In some sections, small grains of potassium feldspar, probably microcline, are scattered through the groundmass. Garnets appear to be rolled, and some have helicitic textures. Tiny grains of magnetite are seen in some sections. Table 1 gives modal analyses of some fresh samples of the pelitic gneiss.

The contacts of the pelitic gneiss appear to be gradational with other units of the pelitic facies. The gneiss is apparently in sharp contact with Baltimore Complex rocks south of the town of Lombard (pl. 1), although the contact is not exposed. Fresh outcrops of the pelitic gneiss are fairly abundant along the several creeks that cross its outcrop belt, and particularly good outcrops are found along Big Elk Creek. The pelitic gneiss outcrop belt appears to widen to the east and northeast in Pennsylvania and Delaware. The metamorphic grade also becomes higher in that direction, and kyanite crystals are locally present in the gneiss just across the state line in Pennsylvania.

Diamictite lithofacies

Diamictite crops out in two belts in Cecil County (pl. 1). In the northwestern corner of the county, diamictite forms a small, wedge-shaped outcrop belt that appears to be faulted out a short distance to the northeast in Pennsylvania. This outcrop belt is a continuation of the diamictite that defines the northeastern nose of the Baltimore-Washington anticlinorium in Harford County (Southwick and Owens, 1968; Southwick, 1969; Plate 2, this paper). This is probably the same unit that outlines and defines the anticlinorium to the southwest in Baltimore, Carroll, Howard, and Montgomery Counties, Maryland, and in northern Virginia, where it is called the Sykesville

Formation (Hopson, 1964; Fisher, 1970; Higgins, 1972; Crowley, 1976; Fisher and others, 1979; Drake and Morgan, 1981). The diamictite in Howard, Carroll, and Montgomery Counties had been mistaken for granite and called Sykesville Granite by Keyes (1895), Jonas (1928), Cloos and Broedel (1940), and Stose and Stose (1946). Cloos (Cloos and Cooke, 1953) became convinced of its sedimentary origin while mapping in Montgomery County and designated it the Sykesville Formation. Fisher (1963) and Hopson (1964) presented evidence for a sedimentary origin and added the Sykesville Formation to the Glenarm Series. Fisher (1963) also recognized that similar rocks in eastern Howard and Montgomery Counties, called Laurel Gneiss by Chapman (1942), are sedimentary in origin and correlated these rocks with the Sykesville. Hopson (1964, p. 112-114) renamed the eastern unit the Laurel Formation and considered the Sykesville and Laurel to be "...stratigraphic equivalents that outline the southward-plunging nose of the Baltimore anticlinorium." Southwick and Fisher (1967) demoted the Sykesville and Laurel Formations to a single lithofacies of the Wissahickon Formation, chiefly because of Southwick's mapping in Harford County (Southwick and Owens, 1968; Southwick, 1969), and suggested that all the diamictite there is not at the same stratigraphic level as the Sykesville and Laurel diamictite belts. Higgins and Fisher (1971) changed the name of Southwick and Fishers' (1967) "boulder gneiss lithofacies" to the diamictite facies of the Wissahickon, but followed the same general concept as did Southwick and Fisher. Crowley (1976; Crowley and others, 1976) proposed that the name Sykesville Formation be readopted for the diamictites in the Sykesville and Laurel outcrop belts. Drake and Morgan (1981) followed Crowley and reinstated Sykesville Formation for the diamictites in northern Virginia as well as Maryland. Therefore, Sykesville Formation is used in this paper for the northwesternmost belt of diamictite in Cecil County and for the diamictites to the southwest in Maryland and Virginia.

The second belt of diamictite in Cecil County is located southeast of the Baltimore Complex from around Conowingo Dam to just south of the town of Rising Sun (pl. 1). Diamictites in this belt are well

exposed on the northeast side of the Susquehanna River downstream from Conowingo Dam for approximately 4.8 km southeast. The most spectacular exposures are found along the river, under and around the large powerlines just downstream from the dam, but excellent exposures are also found northeast of Rowlandsville, along Octoraro Creek. This belt of diamictite is informally called the Conowingo diamictite. It extends for several kilometers to the southwest in Harford County. Included in this unit is a strange zone of quartz-bearing mafic rocks that most earlier workers mapped as quartz gabbro and quartz diorite which they associated with the mafic and ultramafic that I have mapped as the Baltimore Complex.

Like the diamictites to the southwest in the Maryland Piedmont, all the diamictites in Cecil County and adjacent Harford County had been mistaken for plutonic rocks (Grimsley, 1894; Leonard, 1901; Bascom, 1902; Hershey, 1936, 1937; Cloos and Hershey, 1936) and called Port Deposit Granite or Port Deposit Granodiorite until Hopson (1960, p. 31-32) suggested that some of the rocks along the Susquehanna River just below Conowingo Dam are sedimentary in origin. Later mapping by Southwick (Southwick and Owens, 1968) showed a thin belt of "boulder gneiss" (about 400 m thick) just below the dam on the southwestern side of the Susquehanna in Harford County. Southwick (Southwick and Owens, 1968) also mapped the Sykesville Formation in Harford County as "boulder gneiss." My mapping has extended the Sykesville Formation into Pennsylvania and has expanded the area considered underlain by the Conowingo diamictite (pl.1), although there is still disagreement over the origin of some of the rocks that I mapped as fine-grained Conowingo diamictite.

Hopson (1964, p. 101, 103) and Fisher (1970, p. 303) estimated the thickness of the Sykesville Formation in Montgomery County to be as much as 4,600 m. About 2,100 m of Sykesville diamictite and as much as 4,000 m of Conowingo diamictite are exposed in Cecil County. Both diamictites have been divided into coarse and fine phases (pl. 1).

Conowingo diamictite (coarse)

Called "boulder gneiss lithofacies" by Southwick and Fisher (1967), the spectacular coarse part of the Conowingo diamictite superficially resembles a weakly foliated granite, but it contains abundant grains, granules, and scattered pebbles of quartz, and chips, blocks, and slabs of quartz, quartzite, granofels, gneiss, schist, graywacke, amphibolite, and calc-silicate rock (figs. 1-3). Locally, slabs as long as 100 m are present in the coarse diamictite.

Many of the gneiss, granofels, and amphibolite clasts in the coarse-grained diamictite (fig. 2) are lithic matches of metavolcanic rocks in the James Run Formation (Fisher and others, 1979), and some of the granitic clasts appear to be Port Deposit Gneiss. Most of the clasts in the diamictite, including clasts thought to be derived from the James Run Formation and Port Deposit Gneiss, appear to have been mildly metamorphosed and deformed before their incorporation in the diamictite (also see Hershey, 1936). Many of the quartz grains in the Conowingo are blue, and interestingly, many quartz grains in James Run volcanic-epiclastic rocks are also blue.

The Conowingo diamictite is generally massive and poorly bedded. Over large areas, no bedding or layering are visible at all, but in a general way the exotic blocks appear to be concentrated along definite zones or lenses. The coarse-grained diamictite commonly forms good outcrops, even on hilltops. Where it is deeply weathered, it forms a gray, quartz-rich saprolite in which scattered, weathered fragments of the rock clasts are locally recognizable.

Mineralogically, the coarse-grained diamictite is very similar to the Sykesville and Laurel gneisses described by Hopson (1964, p. 107, 115), and to some of the diamictite ("boulder gneiss" and metagraywacke) in Harford County, described by Southwick (1969, p. 34); the only difference being in the potassium feldspar content (table 2). The coarse-grained Conowingo diamictite has a relict clastic texture, in which quartz occurs as relict clastic grains, tiny matrix grains, and rounded aggregates of two or more grains. Hopson (1964, p. 106) stated of the diamictite in the Sykesville Formation:

"There is no difference, other than size, between the clastic quartz grains seen in thin section and the quartz 'lumps' so conspicuous in outcrop. Moreover, there are all gradations in size between them. It is evident that the quartz lumps are relict pebbles and granules, in a partly sandy matrix."

Plagioclase in the diamictite shows three forms similar to those described by Hopson (1964) in the Sykesville Formation: (1) Relict, rounded, clastic grains that have few inclusions but are commonly clouded by sericite and tiny grains of epidote or clinozoisite. Zoning or twinning has been broken or rounded off in many of these grains, and some have new overgrowths on the old clastic grains. This relict plagioclase generally ranges from albite to oligoclase (An_{10-29}), but a few grains as calcic as An_{50} were seen. The overgrowths on relict grains are commonly albite. (2) Newly formed, commonly untwinned, unaltered and unclouded porphyroblasts of albite or sodic oligoclase (An_{7-17}) that are strongly sieved and have irregular amoeba-form shapes with arms that project into the matrix. These are the least common. (3) Tiny granoblastic grains in the matrix that range from albite to sodic oligoclase (An_{9-16}).

Potassium feldspar occurs in two forms: (1) relict, clouded, rounded clastic grains that commonly show the crosshatch twinning of microcline; and (2) rare matrix grains, which show no twinning and are recognizable only when stained.

Polygranular aggregates of feldspar, quartz, or both are fairly common in the diamictite. These are granules of rounded rock fragments in what was a pelitic-psammitic matrix. Tiny slab- and lens-shaped fragments of biotite schist and graywacke or of quartzite and biotite schist are also present.

The micas in the diamictite are similar to those described by Hopson (1964, p. 108) and Southwick (1969, p. 34). Muscovite, in fine flakes and as sericite concentrations, is the most prevalent micaceous mineral (table 2), followed by clusters of biotite and chlorite.

Magnetite is the most common accessory mineral in the Conowingo diamictite and accounts for the high magnetic susceptibility of the unit (Fisher and others, 1979). The diamictite generally coincides with high anomalies on aeromagnetic maps.

Conowingo diamictite (fine)

The rocks mapped as the fine-grained part of the Conowingo diamictite are essentially similar to the coarse-grained diamictite, but have a finer-grained matrix and markedly less abundant clasts of pebble size or larger.

There has been controversy about some of the rocks I mapped as fine Conowingo diamictite southeast of the large coarse lens below Conowingo Dam. These rocks were considered plutonic (or metaplutonic) by Grimsley (1894), Bascom (1902a, 1902b), Hershey (1936, 1937), Cloos and Hershey (1936), Hopson (1960), and Southwick (1969; Southwick and Owens, 1968). I (Higgins, 1972; Plate 1, this paper) considered all the rocks along the Susquehanna River between Conowingo Dam and Sterret Island to be metasedimentary, whereas Southwick (1969; Southwick and Owens, 1968) had mapped most of the "granitic" rocks across the Susquehanna River in Harford County as metaplutonic Port Deposit Gneiss. This conflict spurred Southwick to remap and restudy the rocks on both sides of the river (Southwick, 1979). The results of this new effort (reproduced in fig. 5) are in only partial agreement with the geologic map of Cecil County (pl. 1). We now agree that the rocks along the river from about 900 m northwest of Conowingo Dam to about 300 m southeast of Octoraro Creek and the rocks from about 650 m southeast of Octoraro Creek to about 350 m northwest of Sterret Island (labeled a in fig. 5) are diamictites of one kind or another. The two belts of rocks labeled b and c in Figure 5 are open to question.

Southwick (1979, p. 106) described his unit b, "medium-grained gneissic biotite quartz diorite," as follows:

> "Somewhat metamorphosed biotite quartz diorite, locally with hornblende also, occurs in a belt about 1 km

wide south of Shures Landing in Harford County. It contains less quartz and muscovite, and more plagioclase and biotite, than the quartz augen gneiss (unit c) which it otherwise resembles closely. Moreover, it possesses well-preserved hypidiomorphic granular texture with subhedral zoned plagioclase, wedge-shaped volumes of interstitial quartz..., and scattered euhedral crystals of zoned allanite... The southern contact of this material against diamictite is indistinct and difficult to map precisely with the available exposure."

Southwick goes on to describe his unit c, "quartz augen gneiss":

"Oval grains of blue-gray quartz on the order of 5-10 mm long constitute about 20-25% of this rock; the remainder is plagioclase, biotite, finer grained quartz, and muscovite together with variable small amounts of iron-poor epidote and garnet. Foliation ranges from strong to barely detectable. In well foliated rocks particularly the quartz grains resemble clastic granules; in less foliated rocks the hand specimen appearance is more 'granitic'."

Southwick (1979, p. 106, 115-116) concluded that his unit b (fig. 5), "biotite quartz diorite," is probably metaplutonic, and (1979, p. 114-116) that the "quartz augen gneiss" of his unit c might be metamorphosed trondhjemite. His evidence for the biotite quartz diorite being metaplutonic consists of the following: (1) It is slightly different mineralogically and texturally from the diamictites on either side. (2) It has zoned, subhedral plagioclases with interstitial, wedge-shaped, polycrystalline masses of quartz. (3) It has scattered, euhedral crystals of zoned allanite. His evidence for the quartz augen gneiss being metaplutonic consists of its lithologic and chemical similarities to altered, metamorphosed, and deformed trondhjemites in Minnesota and New Mexico.

I concede that some of the rocks along the Susquehanna River south of Octoraro Creek, that I mapped as fine diamictite (unit b of Southwick, 1979), may be partly of igneous origin. However, they may not be strictly plutonic. The zoned, subhedral plagioclases in these rocks (Southwick, 1979, fig. 3) are strikingly similar to plagioclase phenocrysts and broken phenocrysts in many of the James Run Formation metavolcanic, metavolcaniclastic, and metasubvolcanic rocks (Marshall, 1937; Higgins, 1972, p. 1000-1002, fig. 10) and to phenocrysts in volcanic and subvolcanic rocks elsewhere. Moreover, this "quartz diorite" as described by Southwick (1979) is similar in texture, mineralogy, and composition to other "quartz diorites" such as the Norbeck quartz diorite and related rocks in the Maryland Piedmont to the southwest (Hopson, 1964). Higgins (1972) and Crowley (1976) presented evidence that many of these rocks are either submarine slide deposits composed largely of volcanogenic debris or complexes of metasubvolcanic rocks, metavolcanic rocks, and shallow hypabyssal plutons genetically related to and approximately the same age as the metavolcanic rocks. Perhaps this is also true for the "biotite quartz diorite" south of Octoraro Creek. Alternatively, these quartz diorites may be megaclasts or "knockers" within the diamictite (see Drake and Morgan, 1981).

I must also concur with Southwick (1979) that many of the quartz augen gneisses in his unit c northwest of Sterret Island may indeed be metamorphosed plutonic rocks that were mistakenly identified as diamictite. However, some of the finer grained diamictites (including fine-grained diamictites within the coarse-grained diamictites), the metavolcanic and metasubvolcanic rocks, and the metaplutonic rocks are so similar in the field that, unless one had virtually continuous thin sections, the assignment of origin to these rocks is extremely difficult. Moreover, some of these rocks may be megaclasts within diamictites. I suspect that unit c contains more than one rock type.

Conowingo diamictite: mafic zone

Some of the most perplexing rocks in the Piedmont of Cecil County

are those I mapped as the mafic zone of the Conowingo diamictite (pl. 1). This unit forms an outcrop belt about 210 m wide and 12 km long between Rising Sun and the Susquehanna River near Conowingo Dam, and occurs between the gabbroic rocks of the Baltimore Complex and the main mass of the Conowingo diamictite, including both the coarse-grained and fine-grained facies. The mafic zone consists of a heterogeneous mixture of quartz-bearing mafic rocks and rocks that appear to be intermediate between gabbroic igneous rocks and mafic metasedimentary rocks. In addition, occurrences of mafic breccia occur locally within the unit.

Rocks of the mafic zone of the Conowingo diamictite were considered to be associated with rocks of the Baltimore Complex by most previous workers. Leonard (1901) called them "quartz-mica-hornblende dioryte" or "tonalyte" and emphasized their quartz-rich character. Bascom and others (1902) referred to these rocks as "quartz-hornblende gabbro." Modal analyses of "quartz gabbros" and "quartz diorites" from Harford County (Southwick, 1970, p. 408, table 4) show that some of these rocks carry significant amounts of quartz, ranging up to as much as 20.2 percent. Blebs of blue quartz, which are very conspicuous in some of the rocks of the mafic zone, appear identical to blue quartz blebs in the Conowingo diamictite at many localities in Cecil County. Moreover, in some mafic zone rocks these quartz blebs appear to be relict granules made up of more than one quartz grain. Many are rounded or subrounded like the quartz granules in the diamictites, and are unlike the small irregularly shaped interstitial quartz masses of many quartz gabbros (Southwick, 1970, p. 408). In other words, they appear to be relict detrital grains and rock fragments despite the mafic matrix.

Rocks similar to the mafic zone of the Conowingo diamictite have been mapped in the same tectonostratigraphic position in Harford County (Southwick and Owens, 1968), where they were called "quartz gabbro and quartz diorite gneiss." Southwick (Southwick and Owens, 1968) traced this unit southwest from the Susquehanna River for a distance of about 11 km. This zone was described by Southwick (1969, p. 60-61) as follows:

"Hypersthene gabbro grades southeastward into a belt of quartz gabbro and quartz diorite, which can be traced from Thomas Run to the vicinity of Conowingo Dam. It goes on into Cecil County, but its extent there is imperfectly known. The variable appearance and extremely poor exposure of these rocks have led to conflicting interpretations of them, but earlier workers all agree that they are somehow related to the gabbro complex... Some rocks in this belt are dark, hornblende-rich, medium- to coarse-grained uralite gabbros having a few percent quartz; others are rather light biotite-hornblende quartz diorite. Commonly the dioritic rocks contain abundant dark inclusions that increase in abundance toward the northwest edge of the belt.

The southeast contact of the diorite belt is a complex zone that is confused by extensive shearing and by injection of phases of Port Deposit Gneiss. A highly sheared zone of mixed rocks involving diorite, epidote amphibolite of uncertain affiliation, quartzite and boulder gneiss of the Wissahickon Formation, and aplite to quartz diorite phases of the Port Deposit Gneiss is exposed near the intake structure of the Baltimore-Susquehanna aqueduct of Conowingo Dam. A similar situation is inferred from a somewhat poorer outcrop along strike at Deer Creek."

In Cecil County, however, these rocks are in contact on the southeast with the Conowingo diamictite and not the Port Deposit Gneiss (pl. 1, and fig. 5). This has been confirmed by the more recent work of Southwick (1979). The rocks of the mafic zone appear to grade into the Conowingo diamictite on the southeast, and approximately at the point where the diamictite pinches out in the vicinity of Rising Sun, the mafic zone also pinches out. An identical situation was mapped by Southwick (Southwick and Owens, 1968) along strike

to the southwest in Harford County; a long, narrow belt of "Wissahickon Formation, undivided" extends 12 km to the southwest along the southeastern side of the "quartz gabbro and quartz diorite gneiss" (the mafic zone of the Conowingo diamictite) from the Susquehanna River to just southeast of the village of Thomas Run. Southwick (Southwick and Owens, 1968) described the "Wissahickon Formation, undivided" as "mica schist, chlorite schist, boulder gneiss, and micaceous quartzite occurring as septa between and inclusions within post-Glenarm igneous plutons." He also mapped amphibolite lenses in this belt of rocks and lenses of "Wissahickon Formation, undivided" within the belt of "quartz gabbro and quartz diorite gneiss." My reconnaissance work in Harford County, and Southwick's (1979) later work, indicates that the rocks of the "Wissahickon Formation, undivided" belong to the Conowingo diamictite. Where this diamictite belt pinches out in Harford County, southeast of Thomas Run, the belt of "quartz gabbro and quartz diorite gneiss" also pinches out, just as it does near Rising Sun in Cecil County. This strongly suggests that these two belts of rock are related.

The two most difficult contacts of the Conowingo diamictite to define in Cecil County are the contact between the mafic zone and the main body of the diamictite to the southeast, and the contact between the mafic zone and the gabbro unit of the Baltimore Complex to the northwest. Near the contact with the diamictite in Cecil County, the mafic zone rocks contain as much as 35 percent quartz. In addition, rocks that clearly belong to the Conowingo diamictite along its northwestern contact with the mafic zone are more mafic than "normal" diamictites elsewhere in the Maryland Piedmont. Leonard (1901, p. 137, 141, 172-174) gave good descriptions of the transitional nature of both the northwestern and southeastern contacts of the mafic zone. Hershey (1937, p. 143) also noted the gradational contact between the Baltimore Complex and the Conowingo diamictite (which he mapped as Port Deposit granodiorite), and stated: "The hornblende content of the granodiorite, which in this locality appears to increase toward the contact, suggests a mixing of the two rock types." On the geologic

map of Cecil County (pl. 1), the northwestern contact of the mafic zone was placed at the last appearance of quartz grains that are visible to the naked eye, and thus is arbitrary. The southeastern contact was placed where diamictite-appearing rocks have a greenish matrix in outcrop owing to abundant chlorite or amphibole.

Together, the mafic zone and the Conowingo diamictite have all the characteristics of a melange (Silver and Beutner, 1980; Drake and Morgan, 1981). All who have studied these rocks have noted that they are a heterogeneous mixture of a wide variety of rock types. In fact, this zone contains more clasts of different rock types than is known for any outcrop of diamictite of the Sykesville Formation in Maryland. Many of these clasts appear to have been derived from the James Run Formation.

Mafic breccia

Spectacular mafic breccias crop out locally within the mafic zone of the Conowingo diamictite (also see Hershey, 1937, p. 143). These breccias are composed of clasts of amphibolite and metagabbroic rocks that range in size from a few centimeters to several meters in a matrix resembling slightly mafic diamictite. One particularly good exposure of mafic breccia is in the bluffs along the northeast side of Octoraro Creek just southwest of where U.S. Rte. 1 crosses the creek (pl. 1).

Sykesville Formation

Like the Conowingo diamictite, diamictites of the Sykesville Formation in the relatively narrow, wedge-shaped area in northwestern Cecil County have also been divided into coarse-grained and fine-grained units (pl. 1). These rocks are essentially identical with the Conowingo diamictite, but with two important differences: (1) they are virtually devoid of potassium feldspar; and (2) they contain a fair amount of large and small clasts of ultramafic rocks. Excellent descriptions of these rocks have been given by Hopson (1964), Southwick (1969), and Drake and Morgan (1981).

The diamictites of the Sykesville Formation have been interpreted as olistostromes (Hopson, 1964; Southwick and Fisher, 1967; Southwick, 1969; Fisher, 1970; Higgins and Fisher, 1971; Higgins, 1972; Crowley, 1976; Fisher and others, 1979). More recently, they have been considered to be a precursory ophiolitic melange that is dominantly olistostromal in aspect (Drake and Morgan, 1981, p. 492-493).

Metagraywacke lithofacies

Interbedded pelitic schists, metasiltstones, and metagraywackes, hereafter collectively referred to simply as metagraywacke, crop out in two separate outcrop belts in Cecil County. One belt forms a narrow arc across the northeastern part of the county (pl. 1), and has been traced for about 1.5 km into Delaware. These rocks are best exposed in the valleys of streams that cut across their outcrop belt. The metagraywackes appear to have sharp contacts (possibly fault contacts) with pelitic gneiss and pelitic schist with amphibolite of the metasedimentary rock sequence to the north and against units of the James Run Formation to the south (pl.2). The second belt of metagraywacke underlies the northwestern corner of Cecil County and extends along strike to the northeast into Pennsylvania (pl. 1). To the southwest in Harford County, these rocks have been mapped as the "metagraywacke facies of the Wissahickon Formation" (Southwick and Owens, 1968), and are shown as grading along strike into the "lower pelitic schist of the Wissahickon Formation" (Southwick and Owens, 1968; Southwick, 1969). In Cecil County, this unit is best exposed in the railroad cuts along the gorge of the Susquehanna River and in its tributary stream valleys.

The metagraywacke sequences commonly consist of graded metagraywacke and metasiltstone beds, ranging in thickness from about 30 cm to about 2.5 m, interbedded with sections of approximately the same thickness of finely laminated pelitic schist. Many of the metagraywacke beds have sharp contacts with underlying pelitic sections, but grade upward with diffuse contacts into overlying pelitic beds (see Hopson, 1964) and thus give good facing criteria. Flame structures are relatively common at the bases of the metagraywacke beds.

Metagraywacke with amphibolite

Metagraywacke sequences containing thin stringers of amphibolite form an outcrop belt that wraps around the Port Deposit Gneiss (pl. 1). In this belt, psammitic beds of metamorphosed graywacke, subgraywacke, and quartzose graywacke are rhythimically interbedded with pelitic schist and quartzose pelitic schist sections. In most outcrops, beds of psammitic rocks and sections of pelitic schist are remarkably uniform in thickness, ranging from about 60 to 180 cm; laminae within schist sections are generally less than 1 mm thick. These rocks display a wide variety of original sedimentary features, including spectacular pull-aparts and slump structures. Their most characteristic feature in Cecil County, however, is the ubiquitous presence of large (2-6 cm long) crystals of staurolite that have been altered to sericitic "shimmer aggregates" and smaller (3-8 mm) crystals of green chloritoid. Garnets (as large as 1 cm) with rims altered to chlorite are also fairly common in the metagraywacke-with-amphibolite unit.

In addition to a well-developed bedding plane schistosity, the rocks of the metagraywacke-with-amphibolite unit display classic strain-slip cleavage. The best exposures of structural, sedimentary, and mineralogical features in the metagraywackes are along both sides of the bridge on the road leading south from Colora (pl. 1). The best examples of altered staurolite crystals are found in the valley of Basin Run, just south of Liberty Grove.

Both the metagraywacke layers and the pelitic layers in the metagraywacke-with-amphibolite unit show strong lepidoblastic textures in thin section. This is also true of the amphibolite stringers in the unit. The metagraywackes consist of quartz, plagioclase (generally oligoclase), muscovite, and large laths of bent and twisted green biotite (table 3). The pelitic layers are composed of biotite, muscovite, and quartz, and minor magnetite (table 3). The amphibolites are identical with amphibolites in the pelitic schist with amphibolite unit.

The contact of the metagraywacke-with-amphibolite unit with the Port Deposit Gneiss appears to be very sharp from the Susquehanna River to about Principio Creek. To the northeast, in the general vicinity of Cathers Corner (pl. 1), rocks identical with Port Deposit Gneiss occur as lenses within the metagraywacke as far as about 760 m east of the "main" contact between the metagrawacke-with-amphibolite unit and the Port Deposit. The metagraywacke-with-amphibolite unit appears to pinch out near Battle Swamp and is missing southeast of the Port Deposit Gneiss in the area between the Susquehanna River and the long tongue of upland gravel along Maryland Rte. 275.

In Harford County, directly along strike with the metagraywacke-with-amphibolite unit, Southwick (Southwick and Owens, 1968) mapped a unit of "Wissahickon Formation, undivided" that contains amphibolite. This belt of rocks appears to pinch out near Bramblewood, about 13 km southwest of the Susquehanna River.

Mafic breccia

A breccia composed of mafic rock fragments or clasts in a matrix of granitic rock (fig. 5) crops out between Principio Road and Post Road, about one mile (804 m) southwest of College Green (pl. 1), where it is completely surrounded by rocks of the metagraywacke-with-amphibolite unit. The mafic rock fragments, some as large as 40 cm across, are enclosed in an anastomosing granitic matrix that swirls around them and cuts through some as thin dikes (fig. 6). The mafic rock is medium- to coarse-grained and appears to be similar to some gabbroic rocks in the Baltimore Complex, but no thin sections or chemical analyses were made.

Metavolcanic and metaplutonic rocks

Metavolcanic and (or) metaplutonic units in Cecil County include the James Run Formation, Baltimore Complex, Port Deposit Gneiss, and several unnamed and informally named granitic gneisses and gabbroic bodies.

James Run Formation

Southwick and Fisher (1967) gave the name James Run Gneiss to interlayered quartz amphibolite and biotite-quartz-plagioclase gneiss that are well exposed along James Run in Harford County (Southwick and Owens, 1968), and suggested a volcanic and volcaniclastic origin for these rocks. Earlier, Hopson (1964, p. 31-35) had suggested a volcanic and volcaniclastic origin for similar rocks exposed in Baltimore City. Southwick (1969, p. 47-55) recognized the similarity between his James Run Gneiss, Hopson's (1964) "Baltimore paragneiss," parts of the "volcanic complex of Cecil County" (Marshall, 1937), and some of the rocks of the "Wilmington complex" (Ward, 1959) in Delaware, and proposed that all of these rocks are correlative. Later, Southwick and others (1971) named similar rocks in northern Virginia the Chopawamsic Formation and suggested a possible correlation with the James Run Gneiss and the other rocks of similar nature in Maryland and Virginia. In 1972, I changed the name of the Maryland rocks from James Run Gneiss to James Run Formation and proposed formal correlation with the Chopawamsic Formation in Virginia (Higgins, 1972).

The James Run Formation in Cecil County has been divided into seven formally named members: the Principio Furnace, Frenchtown, Gilpins Falls, Little Northeast Creek, Principio Creek, Big Elk Creek, and Happy Valley Branch Members (Higgins, 1971a, 1972, 1977b). In addition, one unnamed felsite lens of limited extent (Higgins, 1977b) has been mapped (pl. 1). Modal analyses of the some of the James Run rocks are given in Table 4.

Principio Furnace Member

Interbedded gray and light-gray to grayish-white, intermediate to felsic metavolcanic rocks and lesser amounts of diamictite composed partly of volcanic and partly of nonvolcanic sedimentary material were named the Principio Furnace Member of the James Run Formation for Principio Furnace on Principio Creek, Cecil County (Higgins, 1977b; pl. 1, this paper). Exposures along Principio Creek, from just south of Maryland Rte. 7 to just north of U.S. Rte. 40, were designated the

type section. The original thickness of the Principio Furnace Member cannot be determined because of subsequent deformation, but the present thickness is approximately 760 m. The member is probably partly equivalent to the Little Northeast Creek Member. To the northeast, it interfingers with, and probably grades into, the biotite gneiss near Rolling Mills (pl. 1). The Principio Furnace Member is apparently overlain with gradational contact by the Frenchtown Member.

In fresh outcrops, the rocks of the Principio Furnace Member are gray, fine-grained, even-grained, intermediate granofels containing scattered blocky phenocrysts of plagioclase feldspar. These rocks are found in beds or layers, generally about 0.3 to 1.2 m thick, that alternate with light-gray, fine-grained, even-grained granofels containing scattered phenocrysts of plagioclase, green amphibole, and quartz, and with beds of gray, medium-grained, biotite-bearing epiclastic diamictite gneiss that contain abundant round to oblong grains and blebs of quartz (fig. 7). Locally, foreign rock fragments are found in the diamictite gneiss (fig. 7). The light-gray granofels generally occurs in beds or lenses of about the same thickness as the gray granofels, but the diamictite gneiss generally occurs in beds or lenses from about (0.6 to 4.6 m) thick. Volcaniclastic features and mafic rocks are rare in the Principio Furnace Member, and this helps differentiate it from the overlying Frenchtown Member.

In thin section, the light-gray granofels generally show granoblastic to weakly lepidoblastic textures comprised of a matrix of fine- to medium-grained quartz and plagioclase, in which are set euhedral and broken phenocrysts of plagioclase as much as 5 mm long and large crystals of bluish-green amphibole as much as 8 mm long. The plagioclase phenocrysts are commonly zoned and range in composition from albite to oligoclase. The gray, intermediate granofels have similar textures and mineral compositions, but their large plagioclase crystals generally range from oligoclase to andesine and are not as abundant as the large plagioclase crystals in the light-gray granofels. Most of the groundmass plagioclase in both types of granofels is albite. Chemically, some of these rocks are keratophyres (table 8) that may originally have been dacites and rhyolites.

Frenchtown Member

Interbedded dark-green mafic, gray intermediate, and light-gray to grayish-white metamorphosed felsic volcanic, volcaniclastic, and volcanic-epiclastic rocks containing relict phenocrysts of plagioclase and (or) quartz, and (or) amphibole, and, locally, relict pumice lapilli, accretionary lapilli, and amygdules (figs. 7-10), were named the Frenchtown Member of the James Run Formation for good exposures around Frenchtown, Cecil County (Higgins, 1977b; pl. 1). The type section consists of the exposures in the gorge of the Susquehanna River, from just northwest of Interstate 95 to the village of Frenchtown. Most fresh exposures of the Frenchtown Member are found in creek valleys, but good exposures are also found in roadcuts along Interstate 95 just north of the Susquehanna River. The Frenchtown Member appears to stratigraphically overlie the Principio Furnace Member and is structurally overlain by the Gilpins Falls Member of the James Run Formation. It may be equivalent to part of the Little Northeast Creek Member.

In fresh outcrops, the rocks of the Frenchtown Member are fine-grained, schistose to massive, commonly amygdaloidal amphibolites; fine- to medium-grained, gray granofels with blocky plagioclase phenocrysts, minor amounts of amphibole phenocrysts, and quartz blebs; and light-gray to grayish-white granofels with blocky plagioclase phenocrysts and quartz blebs. Volcaniclastic features are relatively common (figs. 9 and 10). Amphibolite layers are commonly about .3 to 3.5 m thick and weather to a green saprolite. The felsic rocks occur in layers between 1 and 9 m thick and weather to gray saprolite containing sparse quartz grains and to a very light-gray saprolite with abundant quartz grains.

The amphibolites are composed of plagioclase, colorless cummingtonite, blackish-green sodic hornblende, epidote, accessory magnetite, and minor amounts of quartz (table 4). Most have lepidoblastic textures with medium to large amphiboles (2-6 mm long) in a groundmass of plagioclase spotted with epidote and accessories. The plagioclase is generally albite to andesine (An_{8-33}). Southwick (1969, p. 57)

noted the coexistence of two amphiboles in the rocks now assigned to the Frenchtown Member.

In thin section, the light-gray intermediate granofels show granoblastic or weak lepidoblastic textures. Large, blocky, zoned phenocrysts of plagioclase, generally albite to andesine (An_{9-35}), are interspersed in a groundmass of feldspar, mostly albite to oligoclase, and quartz. Tiny grains of epidote and opaque minerals are seen in the groundmass in some thin sections. The very light gray to grayish-white granofels are composed almost entirely of quartz and plagioclase, although some thin sections show minor amounts of potassium feldspar (orthoclase?). They generally have porphyritic granoblastic textures. Groundmass plagioclase is oligoclase to andesine (An_{11-39}). Large porphyritic plagioclase crystals are also oligoclase to andesine (An_{10-38}), with the most being about An_{25}. These are commonly zoned, and some have outer zones as sodic as An_7.

Chemically, the rocks of the Frenchtown Member are high in Na_2O and low in K_2O (table 8). They may originally have been basalts, andesites, dacites, and rhyolites.

Gilpins Falls Member

The Gilpins Falls Member of the James Run Formation is the most distinctive and readily mappable unit in Cecil County. It consists chiefly of greenschists and greenstones in the southwestern part of its outcrop belt and of amphibolites and amphibole schists in the northeastern part of the belt, although there is much variation along strike. The type locality is Gilpins Falls on Northeast Creek just south of Maryland Rte. 272, northeast of Bay View (Higgins, 1971a, p. 323; pl. 1, this paper). The type section is well exposed along Northeast Creek for about 305 m north of Gilpins Falls and for about 1,830 m south of the falls.

The Gilpins Falls Member has been divided into four stratigraphic subunits (fig. 11). The lowermost of these is composed chiefly of metamorphosed massive, close-packed pillow lava (figs. 12 to 14), locally with thin chert beds near its top. The massive pillow lava

grades upward very gradually into the second subunit composed of isolated pillow breccia (Carlisle, 1963; and fig. 18, this paper) interlayered with thin beds of basaltic aquagene tuff (Carlisle, 1963). This second subunit grades upward into basaltic tuff containing isolated pillows and local lenses of broken pillow breccia (fig. 19). In places, this third subunit has a few thin, discontinuous beds of felsic tuff and of rocks that must have been mixtures of ash and nonvolcanic sedimentary detritus. Subunit three is overlain by massive coarse-grained metabasaltic rocks that were probably lava flows (fig. 17). Locally this metabasalt contains fine-grained mafic volcaniclastic rocks. All of the subunits are not present in every cross section through the member.

The rocks of the Gilpins Falls Member have been metamorphosed to the upper greenschist facies or the amphibolite facies of regional metamorphism (Turner and Verhoogen, 1960; Turner, 1968), and locally, the basaltic rocks have been sheared and recrystallized into amphibole schist or greenschist. It is not known whether the differences in metamorphic grade within the Gilpins Falls are due to prograde or retrograde metamorphism, or to both. Mineralogically, the Gilpins Falls rocks are chiefly epidote-albite-chlorite schists and greenstones, plagioclase-hornblende schists, and hornblende-plagioclase amphibolites. Despite the metamorphism and deformation, however, primary structures and textures are generally well preserved and easily recognizable in the rocks of the Gilpins Falls Member.

The close-packed pillow lavas in the lower part of the Gilpins Falls Member range in shape from round through loaf-shaped to ellipsoidal (figs. 15 to 17). In many outcrops, the pillows are virtually undeformed (figs. 15 and 16) The pillows in this lower part of the Gilpins Falls generally range from about 30 cm to about 90 cm in diameter; most are about 60 cm in diameter. They generally have well-preserved rims as much as 4 cm thick; inward toward the center of the pillow is a zone of amygdules (figs. 15 to 17). Some pillows have a light-greenish-gray central core that differs in color from the main green inner mass (fig. 15). Locally, overlying pillows are molded

against those below and can be used as facing criteria (fig. 17). Isolated pillows in the aquagene tuffs higher in the Gilpins falls are round and have poorly developed rims, or no rims at all. They are also commonly much smaller than the pillows in the close-packed lavas (fig. 18).

Amygdules are generally well preserved in the pillow lavas (fig. 15), even in outcrops where the pillows have been stretched 8:1 or more and where foliation is easily recognizable. The amygdules locally retain their round shapes even where the pillows have been stretched 4:1. Most of the amygdules are filled with subhedral and euhedral crystals of epidote (fig. 21), but some are filled with calcite or with calcite and epidote or clinozoisite, and some are filled with radiating clusters of acicular actinolite crystals. Locally, amygdules are filled with opaque minerals (chiefly magnetite). The size and percentage of amygdules suggest that the pillow basalts were emplaced in relatively shallow water (Higgins, 1971a).

Thin sections of the pillow lavas at Gilpins Falls show a variety of textures and a variety of mineral compositions. In general, these rocks have mineral assemblages characteristic of the greenschist facies. They are composed of various amounts of epidote, clinozoisite, chlorite, albite, actinolite, and tiny grains of magnetite (and lesser amounts of leucoxene). Textures vary greatly, not only from outcrop to outcrop and from pillow to pillow but also within individual pillows. The most common texture is a felted mesh of epidote and clinozoisite and tiny, irregularly shaped masses of albite, in which are scattered subhedral to euhedral crystals of plagioclase that range from albite to sodic oligoclase, and are probably pseudomorphic after calcic plagioclase. Probably the second most common texture consists of very weakly nematoblastic acicular actinolite crystals set in a fine-grained matrix of clinozoisite, chlorite, epidote, and albite.

The mafic tuffs in the Gilpins Falls Member near Gilpins Falls are chiefly rocks that have lepidoblastic textures and are composed of chlorite, epidote, albite, and accessory magnetite. Epidosite clots are fairly common in these rocks.

Where the rocks of the Gilpins Falls Member are at amphibolite grade, as, for example, around Rock Church in the northeastern part of the county (pl. 1), they are nematoblastic hornblende-plagioclase and plagioclase-hornblende amphibolites with minor amounts of epidote. The hornblende is pale-green and the plagioclase is generally andesine ($\sim An_{40}$). Most thin sections show minor amounts of quartz.

All along the Gilpins Falls outcrop belt, the rocks vary over short distances from amphibolites or amphibole schists to greenschists or greenstones due to shearing. The best examples of this variation are in the outcrops around Rock Church. Outcrops 25-30 m uphill from the church have almost undeformed pillows, but, in front of the church, amygdules can be traced from round (nearly undeformed) to long smeared streaks, and the only vestiges of pillows are distorted, flattened pieces of rims.

One of the major folds in the area, interpreted as a synformal anticline, is defined by the outcrop pattern of the Gilpins Falls Member as it crosses Cecil County. Amphibolites of the Gilpins Falls have been traced eastward for nearly 2 km into Delaware, where they appear to grade into coarser grained rocks. Amphibole schists have also been traced to the southwest into Harford County for a few hundred meters.

Little Northeast Creek Member

Grayish-white to gray, fine- to medium-grained, massive granofels containing relict phenocrysts of plagioclase and quartz are best exposed along Little Northeast Creek in central Cecil County (pl. 1). These rocks were named the Little Northeast Creek Member of the James Run Formation (Higgins, 1977b), and the type section was designated as the section along Little Northeast Creek northeast of Bay View, between outcrop belts of the Gilpins Falls Member (pl. 1). The present thickness of the Little Northeast Creek Member is about 1,400 m.

Little Northeast Creek rocks are generally well exposed in the valleys of creeks that flow southeastward across Cecil County. Where

not covered by Coastal Plain sedimentary deposits on the interfluves between streams, rocks of this unit are generally deeply weathered to a grayish-colored saprolite with fairly abundant quartz grains.

In fresh outcrops, the rocks of the Little Northeast Creek Member are generally grayish-white to gray, fine- to medium-grained massive granofels, with small, blocky crystals of plagioclase, small blebs of quartz, and minor amounts of biotite and elongate amphibole crystals. Locally, however, the rocks have a slight foliation and, commonly, more than one weakly developed cleavage. Hints of relict bedding are rare, but this may be due in part to the lack of large, continuous exposures. Very rare hornblende-plagioclase amphibolite layers in the Little Northeast Creek Member may have been basaltic dikes or sills.

In thin section, the granofels of the Little Northeast Creek Member show lepidoblastic to granoblastic textures. Amphibole crystals as long as 8 mm and biotite segregations about 5 mm across show alignments in more than one direction in a matrix of plagioclase and quartz. The alignment of the mafic minerals is generally weak. Crystals of plagioclase that are larger than the groundmass grains generally show no preferred alignment. Relict volcanic and volcaniclastic textures are fairly common (figs. 12 and 13). Glomerocrysts of blocky, zoned plagioclase are seen in many thin sections.

The plagioclase in the groundmass of the Little Northeast Creek granofels is nearly all albite to oligoclase (An_{8-27}, most commonly about An_{22}), as are many of the large, blocky, zoned plagioclase crystals. However, the cores of some of the large crystals are as calcic as andesine (up to An_{46}). The amphiboles are mostly blue-green hornblende, and the biotite is commonly brown. Opaques, chiefly magnetite, and tiny specks of epidote are the principal accessory minerals (table 4).

Chemically, most of the rocks of the Little Northeast Creek Member appear to have been rhyolites (table 8). Like the felsic rocks of other units in the James Run Formation, they are high in Na_2O and low in K_2O.

The rocks of the Little Northeast Creek Member structurally overlie the Gilpins Falls Member. To the northeast, these rocks appear to grade into biotite gneiss of probable sedimentary origin. To the east they appear to grade into rocks of the Frenchtown Member.

Principio Creek Member

Biotite-plagioclase schist characterized by abundant small, blocky plagioclase crystals, numerous blocky epidosite inclusions, and local layers of amphibolite, was named the Principio Creek Member of the James Run Formation (Higgins, 1977b). The exposures of this unit along Principio Creek northwest of Theodore Road in Cecil County were designated the type section. Fresh exposures of the Principio Creek Member occur only in the gorge of Principio Creek. Elswhere, the rocks are weathered to a brownish-red saprolite that commonly contains small blocks of slightly weathered rock. The member pinches out about 2 km northeast of Northeast Creek, and is covered by Coastal Plain sedimentary deposits about 1.6 km southeast of Principio Creek (pl. 1).

Fresh exposures of the Principio Creek Member are of a dark-gray, medium-grained schist speckled with abundant, well-aligned, small, lath-shaped plagioclase crystals that appear to be relict phenocrysts (fig. 21). Numerous blocky epidosite inclusions, as much as 30 cm long and 20 cm wide, are scattered throughout the schist. These are generally aligned with the foliation and some have reaction rims. In many outcrops, layers of fine-grained, equigranular amphibolite parallel the main schistosity.

The schist has an extremely strong lepidoblastic texture and might be mistaken for a mylonite except that rounded colorless blebs in the rocks are probably not porphyroclasts because they are quartz, not feldspar (Higgins, 1971b). In addition, the small crystals of plagioclase are zoned and have all of the characteristics of plagioclase crystals found in volcanic rocks. These plagioclase crystals are generally oligoclase to andesine (An_{12-39}). The biotite is dark-brown, and the laths bend with the wavy foliation. Elongate, strained

quartz also follows the foliation, but large quartz grains, as much as 7 mm across, disrupt the foliation.

Unnamed felsite

The Principio Creek Member is overlain by an unnammed unit composed of light-gray to white, fine- to medium-grained felsite (pl. 1). In thin section, the felsite is seen to be composed chiefly of quartz and plagioclase (An_{10-40}), minor potassium feldspar, and rare biotite. There are very few outcrops of this unit, and its contacts are not exposed. It forms a featureless light-gray, quartz-rieh saprolite.

Big Elk Creek Member

Interlayered amphibolites and felsites composed chiefly of plagioclase and quartz (but locally containing amphibole) were named the Big Elk Creek Member of the James Run Formation for exposures along Big Elk Creek approximately 0.5-0.7 km upstream (northwest) from Maryland Rte. 273 (pl. 1); this section was also designated the type section (Higgins, 1977b). Fresh outcrops of the Big Elk Creek are confined to creek valleys. The mafic and felsic rocks of the Big Elk Creek Member are characterized by their occurrence in layers about 3 to 12 cm thick, but early folds parallel to bedding are common. The rocks weather to a layered green and gray saprolite, but saprolite outcrops are rare.

The schistose and streaked, fine-grained, equigranular amphibolite layers in the Big Elk Creek Member have a strong lepidoblastic texture defined by well-aligned green hornblende and elongate grains of plagioclase. The plagioclase is oligoclase to andesine. Opaque minerals, epidote, and quartz are accessories. The felsites are fine-grained and generally nonporphyritic. They are composed chiefly of plagioclase (albite to andesine) and quartz, and have granoblastic to lepidoblastic textures. Opaque minerals are the main accesssories. Locally, rounded quartzite fragments in these rocks suggest that they are volcanic-epiclastic with some contributions from nonvolcanic sources.

The Big Elk Creek Member structurally overlies the Gilpins Falls Member of the James Run Formation and appears to be partly equivalent to the Happy Valley Branch and Principio Creek Members (pl. 1). The present thickness of the unit is approximately 300 m. This member pinches out about 2 km southwest of Little Northeast Creek. To the northeast, it has been followed into Delaware for about a kilometer.

Happy Valley Branch Member

Chiefly gray to grayish-white, fine-grained, medium- to thin-bedded felsite and granofels containing relict, mostly broken phenocrysts of plagioclase, quartz, and locally of amphibole were named the Happy Valley Branch Member of the James Run Formation (Higgins, 1977b) for Happy Valley Branch, a tributary of the Susquehanna River in Cecil County (pl. 1). The type section consists of the series of exposures along the Susquehanna River from just north of Happy Valley Branch to the contact with the mafic rocks of the Gilpins Falls Member, about 1,200 m northwest of Interstate 95. The present thickness of the unit is approximately 915 m.

Fresh exposures of the Happy Valley Branch Member crop out in creeks and locally on relatively steep hillsides. Where the rock is weathered, it forms a grayish-white saprolite with numerous quartz grains. It can be traced for several hundred meters into Harford County, but is then cut off or covered by the Aberdeen metagabbro of Southwick and Owens (1968; Southwick, 1969).

The most common rock type in the Happy Valley Branch Member is a light-gray to white felsite containing abundant phenocrysts of plagioclase and blebs of quartz (fig. 22). Locally, wispy relict pumice lapilli are seen in some of these rocks. In thin section, this rock is seen to be a meshwork of tiny grains of plagioclase (albite to oligoclase) in which are set large, blocky plagioclase crystals about 6 mm long, glomeroporphyritic clots of plagioclase crystals, and large grains of quartz (fig. 23). Opaque minerals, mostly magnetite, form a very small percentage of the rock, and trace amounts of epidote are

present. Thin layers of hornblende-plagioclase amphibolite are the second most prevalent rock type.

The Happy Valley Branch Member structurally overlies the Gilpins Falls Member. It is apparently equivalent to parts of the Principio Creek Member. Contacts appear gradational with the fine-grained phase of Port Deposit Gneiss, but relatively sharp with other units. Southwick (1979) and I now agree on placement of this unit in the James Run Formation, but there is still disagreement on the exact placement of the northwestern contact and on the nature of some of the rocks northwest of that contact.

Baltimore Complex

The Baltimore Complex (Higgins, 1977a) crops out in a northeast-trending belt approximately 4,575 m wide across the northwest corner of Cecil County, and in fold noses in the north-central part of the county (pl. 1). Despite the fact that parts of the complex are exposed across the Piedmont of Maryland for a distance of about 100 km between Pennsylvania and southern Howard County just north of Laurel, and that the greatest areal extent of the unit is in the vicinity of Baltimore (Crowley and others, 1976), all workers in the area have agreed that the most intact section through the complex is along the Susquehanna River in Cecil County. At the river, the Baltimore Complex consists, from northwest to southeast, of a zone of mostly serpentinized, metamorphosed ultramafic rocks about 305 m wide and a zone of metagabbroic rocks with some ultramafic rocks about 3,350 m wide.

Bascom and others (1902) called the ultramafic part of the Baltimore Complex in Cecil County "serpentinite, peridotite, pyroxenite," and divided the remaining gabbroci part into two units: "hypersthene gabbro and norite" on the northwest, and "gabbro, metagabbro, quartz-hornblende gabbro" on the southeast. Across the Susquehanna River in Harford County, Southwick (Southwick and Owens, 1968; Southwick, 1970, p. 400-401, fig. 2) showed six units within the outcrop area of his "Baltimore-State Line gabbro-peridotite complex"

(Southwick, 1969, p. 59). Included with these in the southwestern part of the county was a unit of "...thoroughly recrystallized, lineated epidiorite and amphibolite; cut by numerous dikes and stringers of quartz-diorite gneiss..." which Crowley (Crowley, 1976; Crowley and others, 1976) considered to be metavolcanic rocks of the James Run Formation.

On the geologic map of Cecil County (pl. 1), the Baltimore Complex is divided into two major units: serpentinite and gabbro. However, each of these units contains significant amounts of other lithologies as well. The serpentinite has within it unserpentinized ultramafic rocks and locally some mafic rocks. The gabbro includes a wide variety of mafic rocks and locally contains ultramafic rocks. In addition, small areas consisting mainly of granitic rocks and of sheared talc schist and subordinate chlorite schist also occur within the Baltimore Complex.

The northwestern contact of the Baltimore Complex is not exposed in Cecil County, but appears to be sharp. Along the Susquehanna River, about 500 m southeast of Bald Friar (pl. 1), good exposures of highly sheared serpentinite and soapstone are separated from good exposures of diamictites of the Sykesville Formation by an interval of no exposure about 60 m wide. A small creek that enters the Susquehanna at this point appears to follow the contact. However, along and just southeast of the unpaved road that follows this narrow creek valley, float from these two units, as well as poorly exposed saprolite, indicates that the serpentinite and diamictite are in sharp contact. Outcrops of serpentinite and diamictite are within 15 m of each other along Conowingo Creek about 300 m due south of the Pennsylvania state line (pl. 1). Elsewhere, the contact was mapped on the basis of float and soils. Southwick (1970, p. 401) reported a "highly sheared, badly weathered, subvertical" contact "between talcose serpentinite and rocks of the Wissahickon Formation" about a kilometer along strike to the southwest in Harford County. He also noted that the straight trace of the northwestern contact of the complex and the steep magnetic gradient across it as shown by Bromery and others

(1964) indicates a steep to vertical attitude for the contact. Pearre and Heyl (1960, p. 718) also reported steep southward dips on this contact in Pennsylvania.

Crowley (1976, p. 26-31) presented evidence that the northwestern contact of the Baltimore Complex is a thrust fault. He reasoned: (1) Where the complex is least deformed and most intact, from its northeastern terminus in southeastern Pennsylvania to near Scarboro, 7 km southwest of the Susquehanna River in Harford County, Maryland, it is bounded on the northwest by a continuous basal sheet of serpentinized ultramafic rocks. Near Scarboro, however, the basal sheet veers westward into clastic metasedimentary rocks, whereas the mafic part of the complex continues southwestward devoid of its ultramafic base; (2) The basal serpentinized ultramafic rocks in the complex from southeastern Pennsylvania to near Scarboro, Maryland, are hosts to podiform chromite deposits. Southwest of Scarboro, identical chromite deposits occur in the pods and lenses of serpentinized ultramafic rocks scattered through the lower part of the clastic metasedimentary sequence on the northwest flank of the Baltimore-Washington anticlinorium (pl.2). These ultramafic rocks are the remains of the sheared-off base of the Baltimore Complex; (3) Where the ultramafic base of the complex is missing, it can be found to the northwest within the clastic rocks; (4) The isolated ultramafic masses northwest of the main mafic belt of the complex are confined exclusively to the clastic sequence, at approximately the same stratigraphic horizon. If they were intrusive, similar ultramafic rocks should be found in the Baltimore Gneiss, Setters Formation, and Cockeysville Marble; (5) Some of the rocks previously considered plutonic in the basal parts of the mafic part of the complex are supracrustal metavolcanic rocks, whereas others are metaplutonic. If the base of the mafic part of the complex is occupied by supracrustal rocks in some places and by plutonic rocks in others, it must be a fault; and (6) Internal units within the complex are truncated by the contact.

Fisher and others (1979, p. 33) stated:

> "Crowley's mapping and our own reconnaissance clearly indicate that the contact between the Baltimore Complex and the underlying Wissahickon metasedimentary rocks is indeed a thrust fault, because it cuts major lithologic units within the Baltimore Mafic Complex as well as within the Wissahickon. This relation is particularly clear in the part of the complex between Baltimore and Conowingo, Maryland. Traced southward from Conowingo, the thrust cuts progressively up section from ultramafic rocks through gabbro to laminated metavolcanic rocks in the Baltimore Mafic Complex (the hanging wall) at the same time as it cuts down section from diamictite through Wissahickon pelite to Cockeysville Marble in the footwall."

In Cecil County, from the Susquehanna River northeastward to Pennsylvania, the thrust on the northwestern (basal) side of the Baltimore Complex cuts down section in the complex (the hanging wall). This accounts for the widening of the serpentinite unit outcrop belt to the northeast (pl. 1; Pearre and Heyl, 1960; Lapham and McKague, 1964).

Numerous workers have studied the petrography of rocks of the Baltimore Complex since the late 1880's (Williams, 1884, 1886, 1890; Leonard, 1901; Bascom, 1902; Knopf, 1921, Insley, 1928; Johannsen, 1928; Knopf and Jonas, 1929; Herz, 1951; Hopson, 1964; Southwick, 1969, 1970; Hanan, 1976, 1980; Morgan, 1977). As Hopson (1964, p. 132) stated, Williams' (1886) study of the complex made it a classic example of uralitization and metamorphism of mafic igneous rocks. Excellent petrologic accounts of the complex have been given by Hopson (1964), Southwick (1970), and Morgan (1977), and the reader is referred to these papers for an overall petrologic description of the complex.

Serpentinite

Near the northwestern thrust contact of the serpentinite unit of the Baltimore Complex (pl. 1) the most common rock type is a lustrous, highly sheared and fractured, bluish-green, talcose serpentinite ("soapstone"), with no visible evidence of original texture or other original features. In thin section this rocks is seen to be composed of serpentine minerals with a mesh or felted-mat texture, cut by numerous shears and thin shear zones filled with antigorite. There are at least three prominent shear directions (also see Lapham and McKague, 1964) that cut across earlier textures. Minor amounts of sagenitic magnetite and (or) very small elongated masses of chromite are found in a few outcrops. The best exposure of this type of rock is in the railroad cut along the northeast side of the Susquehanna River about 120 m southeast of the northwestern contact of the serpentinite unit (pl. 1). Sample S2-1 (table 11) is from this locality. Rocks of this type apparently form an outcrop belt along the northwestern side of the complex that is about 210 m wide, but the paucity of outcrops is such that other rock types may be present within this belt.

To the southeast, across strike and up section, the rocks of the serpentinite unit become more varied, although they are also generally sheared and fractured. Sagenitic magnetite and elongated masses of chromite gradually increase to the southeast, and palimpsest igneous textures are locally present. These rocks were originally dunite, peridotite, various pyroxene-bearing peridotites (see Williams and others, 1954, p. 78), olivine pyroxenite, and pyroxenite. Serpentinization of these rocks has been extensive, however, so that unaltered and even partially unaltered ultramafic rocks are rare. In thin section, most of these rocks show a mesh texture consisting of a felted mat of serpentine minerals cut by numerous thin shear zones that are filled with platy serpentine and (or) cross-fiber asbestos. Veinlets of carbonate are seen in most sections. Sagenitic magnetite is present in many sections, and locally, elongated, thin masses of chromite are present. Despite the deformation and alteration, some of

these rocks can be identified with igneous, premetamorphic rocks by palimpsest textures and structures. Relict layering is locally present in these rocks and is generally contorted, as noted by Hopson (1964).

Perhaps the most distinguishing characteristic of the ultramafic rocks, as noted by Crowley (1976, p. 26-27), is that they commonly contain significant amounts of chromite, both as disseminated elongated grains and as massive podiform ore bodies (Pearre and Heyl, 1960; Thayer, 1960, 1967, 1970, 1971; Southwick, 1970). In the old "State Line Chromite District," which straddles the boundary between Cecil County, Maryland, and Chester County, Pennsylvania, the chromite deposits do not appear to mark a specific horizon or even the basal part of the serpentinite unit but occur throughout the major part of the unit (Pearre and Heyl, 1960). Nevertheless, the presence of significant amounts of chromite is confined to the serpentinite unit. Some of the smaller chromite grains are folded with the rest of the rocks and are cut by fractures filled with serpentine minerals. The fact that the serpentine-filled fractures are not axial planar to the folded chromite grains, suggests that some of the serpentinization took place after one phase of folding and possibly during metamorphism.

Relict minerals, or cores of relict minerals with altered rims, are rare in the serpentinite unit, but Southwick (1970, p. 405) reported: "Relict olivine in the dunitic rocks is highly magnesian, having compositions of Fo_{86-92} ..." To the southwest, in Baltimore County, Herz (1951, p. 986) found that the relict olivine in the ultramafic rocks ranges from Fo_{70} to Fo_{96} (70 percent in the range Fo_{86-90}) and that orthopyroxenes in the ultramafic rocks (pyroxene-bearing peridotites and metapyroxenites) range from about En_{83} to En_{90}. In Harford County, Southwick (1970, p. 405) found that pyroxenites associated with the olivine-bearing rocks in the northwestern part of the complex carry orthopyroxene with a composition near En_{80}. Norms from two traverses across the Baltimore Complex in Cecil County (table 11) suggest that the orthopyroxenes in the ultramafic rocks are

probably very high in enstatite, and that the olivines are probably high in forsterite. Optical measurements indicate enstatite and forsterite values more compatible with those reported by earlier workers, but only a few relict grains were measured.

Clinopyroxene appears to have been a very rare constituent of most of the metapyroxenites in Cecil County. However, according to Southwick (1970, p. 405): "Clinopyroxene, some of it zoned, forms a significant part of some pyroxenites and locally may be dominant." It is not known whether the pyroxenites he was referring to are in the serpentinite part of the complex or in the gabbroic part, but Herz (1951) reported significant amounts of clinopyroxene in rocks associated with the "ultramafic" part of the complex in Baltimore County; this was confirmed by Hopson (1964, p. 138-139, 144). However, Crowley (1976) presented evidence suggesting that the ultramafic rocks in the main mass of the complex around Baltimore City are not part of the basal chromite-bearing unit, and thus not at the same stratigraphic horizon (or tectonostratigraphic horizon) as the serpentinite unit in Cecil County.

Locally, the serpentinite in Cecil County is cut by veins and veinlets of cross-fiber asbestos, which range in width from a few millimeters to about 1.2 m. Most of these veins strike roughly parallel with the predominant schistosity in the serpentinite, but the fact that some cut directly across it, suggests that they formed late in the history of the complex. The asbestos veins are best exposed in the barren field northwest of Conowingo Creek, at the first curve northwest of the creek on the road between Oakwood and Pilot. Good exposures are also found in drainage ditches along this same road going uphill to Pilot. Lapham and McKague identified these veins as filling two sets of fractures, and stated (1964, p. 656):

> "The northeast striking gash fractures now containing chrysotile are younger than antigorite veinlets with the same orientation, but older than a period of shearing."

All previous geologic maps of Cecil County (Bascom and others, 1902; Pearre and Heyl, 1960) show a lens-shaped area of serpentinite extending into the northwest part of the county from Pennsylvania and underlying the area around St. Patricks Church (formerly called Grub Corner). Because no positive evidence to confirm the existence of this serpentinite lens, such as float, soils, outcrops, or vegetation differences, was found in this area, it has not been included on the present geologic map (pl. 1).

Gabbro

Within the gabbroic part of the Baltimore Complex in Harford County, Southwick (1970, p. 400, fig. 2) drew a boundary between rocks on the northwest, where relict orthopyroxene is more magnesian than En_{60}, and rocks to the southeast, where relict orthopyroxene is less magnesian than En_{60}. My mapping has extended this compositional boundary to the northeast through the thick gabbroic part of the complex in Cecil County, where it approximates the position of a contact drawn by Leonard (1901, pl. XV) between "gabbro and noryte" on the northwest and "dioryte" on the southeast.

Hypersthene gabbro* is by far the most common rock type in the gabbroic part of the Baltimore Complex in Cecil County, although uralitization has been extensive and most rock types described here are based largely on palimpsest textures, mineral forms, and relatively few unaltered or partly unaltered minerals. Although rocks classified as augite gabbro or norite are present within the complex in Harford County (Southwick, 1969, p. 60), most of the gabbros contain approximately equal amounts of hypersthene and augite. Southwick (~~1970, p.~~ 405-407) referred to these rocks as hypersthene gabbro. In his description of the Baltimore Complex in Baltimore and Howard Counties, Hopson (1964, p. 142) also considered hypersthene gabbro to be the predominant type of rock.

* Hypersthene gabbro in the terminology of Williams (1884, 1886, 1890), Hopson (1964), and Southwick (1970).

The principal minerals of the hypersthene gabbro are hypersthene, augite (commonly "diallage"), and calcic plagioclase. The least altered hypersthene gabbros in Cecil County have allotriomorphic or hypidiomorphic granular textures. My few measurements of optic angles of clinopyroxene agree well with Southwick's (1970), and suggest that the pyroxene is a normal Ca-bearing variety. This was confirmed by microprobe analyses (Hanan, 1976, p. 28). Some thin sections of hypersthene gabbro have minor amounts of brown hornblende as an interprecipitate mineral (Hopson, 1964, p. 146). As Hopson stated (p. 146):

> "The brown hornblende occurs as interstitial fillings between the peri-euhedral minerals or encloses them poikilitically. In each case, it is in sharp contact with the pyroxenes and has clearly grown <u>around</u> them. In contrast, the green uralitic hornblende eats into the pyroxenes along their margins, cleavages, and parting planes, gradually replacing them."

Olivine gabbros, for the most part completely uralitized, are very rare in the Cecil County part of the Baltimore Complex. Williams (1884, 1886, 1890), Herz (1951), and Hopson (1964) all described olivine gabbros in the gabbroic part of the complex in Baltimore County, although all stated that they are not common.

Feldspathic "net veins" are found in the gabbroic part of the Baltimore Complex in Cecil County, but most are less than a meter thick and are not mappable. These veins are composed of large uralitized pyroxene crystals in a matrix of plagioclase crystals. I did no petrographic work on the veins, but Hopson (1964, p. 148) gave a petrographic description of the veins in Baltimore County. Both Hopson (1964, p. 140) and Southwick (1969, p. 61) stated that these veins are common in the gabbroic part of the complex elsewhere in Maryland.

Granitic rocks

Small areas of quartz-rich granitic rocks, completely surrounded by gabbroic rocks of the Baltimore Complex, were mapped at several places in Cecil County (pl. 1). The largest of these areas is about 0.5 km east of Oakwood. Another is along the Susquehanna River about 0.4 km southeast of the mouth of Conowingo Creek. Contacts between the granitic rocks and the gabbros are not exposed. Because of their weathered condition and limited exposures, the granitic rocks were not studied in detail. The only good outcrop is on the east side of U.S. Rte. 222 south of Old Conowingo Road. The relations between the granitic and gabbroic rocks and the significance of the granitic rocks is unknown. The granitic rocks could be: (1) granitic intrusions into the Baltimore Complex, either before or after it was emplaced in its present position; or (2), late-stage differentiates of the complex; or (3), may crop out in antiformal windows through the Baltimore Complex thrust sheet.

Talc schist

Bodies of talc schist occur at several places within the gabbro unit of the Baltimore Complex (pl. 1). The largest of these, about 1.6 km long, is in the vicinity of Octoraro, on Octoraro Creek at the intersection of New Bridge Road and Horseshoe Road. Another is exposed along the Susquehanna River about 0.8 km northwest of Pilot Station, where Bell Manor Road turns northeast away from the river. The rock in these bodies is predominately a fine-grained talc schist with lesser amounts of chlorite schist and shows the effects of strong shear deformation. Except for outcrops along stream banks, the talc schists are poorly exposed.

Gabbro and serpentinite at Grays Hill

Poorly exposed and generally deeply weathered gabbroic rocks and lesser amounts of serpentinite occur in the valley of Big Elk Creek and its tributaries north of Elkton, in deep railroad cuts and small stream valleys near the Delaware State line northeast of Elkton, and

on and around Grays Hill, east of Elkton (pl. 1). An additional very small outcrop area of gabbro is present along Little Elk Creek about 4 km northwest of Elkton. The gabbroic rocks range from extremely coarse-grained hypersthene metagabbro to finer grained, more equigranular metagabbros. The coarse-grained rocks are found as large boulders in and around the small stream that runs westward from Grays Hill. Finer grained metagabbro blocks are found as float on Grays Hill and in outcrops along Big Elk Creek. Deeply weathered serpentinites crop out along with the gabbros in railroad cuts around Interstate 95 and in small stream valleys nearby. In this area the rocks are commonly covered and coated with iron silicates and have a "honeycomb" texture. This material was mined in the area of Chestnut Hill and Iron Hill in Delaware.

Mineralogically and chemically (table 11) some of the gabbroic rocks of the gabbro and serpentinite unit are similar to some of the rocks northeast of Havre de Grace, in Harford County, that Southwick (1969; Southwick and Owens, 1968) called "metagabbro at Aberdeen."

Amphibolite dikes and sills

Hundreds of blackish-green, fine- to medium-grained plagioclase-hornblende amphibolite dikes have intruded the Port Deposit Gneiss and some units of the James Run Formation along the Susquehanna River. Only the thickest dikes are shown on the geologic map (pl. 1). Lithologically identical sills are present in some of the bedded James Run rocks. Hershey (1936, p. 26-27; 1937, p. 118) counted more than 150 of these dikes along the northeast side (Cecil County side) of the Susquehanna (also see Bascom, 1902, p. 97-98). As all who have studied these dikes have noted, they cannot be traced far from the river, although I found several thin, weathered ones in James Run rocks as far as 3.2 km northeast of the river.

The mafic dikes range in thickness from a few centimeters to about 6 m. Many have well developed fine-grained chilled margins, and some have relict flow structures (fig. 24). Bascom (1902, p. 97-98) described the location of many of the larger dikes in detail, and

correctly called them "hornblendic dikes." Hershey (1936, p. 26-27), however, stated: "Since hornblende is always present in large amounts, usually (sic) over 60%, these dark dikes are called hornblende lamprophyres." Southwick (1969, p. 70) followed Hershey and described the dikes as "lamprophyric dikes." Both Hershey (1936, p. 26) and Southwick (1969, p. 70) reported orthoclase in the dikes along the Susquehanna, but my sampling failed to find any potassium feldspar. Thus, there may be lamprophyre dikes along the Susquehanna, but most of the dikes are not lamprophyres, even though some are rich in hornblende (table 6). The mineralogy and chemical composition (table 6) of these dikes indicates that they are metabasalt. They have intruded the Port Deposit Gneiss and part of the James Run Formation, but have been metamorphosed along with the intruded rocks. The chilled margins on some of the dikes indicate that the host rocks (including the Port Deposit Gneiss) were relatively cool when the dikes were intruded. Because of this, and because the dikes cut at least one schistosity in the host rocks (also see Hershey, 1936, p. 27; Marshall, 1936, p. 119; Southwick, 1969, p. 70), a period of lowered temperatures between metamorphic and deformational events or phases is indicated. Thus, the evidence suggests that the James Run and Port Deposit rocks were deformed and metamorphosed before the dikes were intruded.

Perhaps the most significant thing about the amphibolite dikes is their limited distribution (also see Bascom, 1902; Hershey, 1936, p. 26). The dikes appear to be exclusively confined to the Port Deposit Gneiss and the James Run Formation. No dikes of this kind are seen in any of the rocks northwest of Steel Island (pl. 1). This constitutes evidence that the Port Deposit Gneiss and some of the rocks of the James Run Formation are allochthonous. Crowley (1976) suggested that the James Run rocks in Baltimore and Harford Counties are in thrust contact with Baltimore Complex rocks, and this was supported by the work of Fisher and others (1979), but the evidence from the dikes indicates that the Port Deposit is allochthonous with the James Run rocks. Moreover, because the amphibolite dikes cut schistosity in the Port Deposit and James Run, have chilled margins indicating that they

intruded relatively cool rocks, but have been metamorphosed, the Port Deposit and James Run rocks must already have been metamorphosed before they were thrust. This suggests that the Port Deposit and James Run are far-traveled, having been metamorphosed elsewhere, or perhaps even during transport. That they were metamorphosed before being emplaced in their present positions is also supported by the fact that clasts of James Run rocks in the Sykesville and Conowingo diamictites were already metamorphosed and deformed before being deposited (Fisher and others, 1979, p. 32).

Port Deposit Gneiss

A variety of plutonic and plutonic-appearing granitic rocks crop out along both sides of the Susquehanna River in northeastern Maryland and underlie large areas of Harford and Cecil Counties. Grimsley (1894) named these rocks the Port Deposit Granite for exposures in the quarry on the east side of Maryland Rte. 222, just north of the town of Port Deposit, Cecil County. At the same time, he gave the name Rowlandsville Granite, for the small community of Rowlandsville on Octoraro Creek in Cecil County, to the large outcrop belt of gneissic rocks northwest of the his Port Deposit Granite. Bascom (1902) and Insley (1928) followed Grimsley. Hershey (1937) considered all the granitic and granitic-appearing rocks to be part of a single large plutonic intrusive complex, which he named the Port Deposit Granodiorite complex. Southwick (1969) followed Hershey, but changed the name to Port Deposit Gneiss because the rocks are obviously foliated and metamorphosed.

My work has shown that much of the northwestern outcrop belt of granitic-appearing gneiss, which I (Higgins, 1972) informally called Conowingo gneiss, and now Conowingo diamictite, is mostly metasedimentary. In addition, large parts of the southern outcrop belt of granitic-appearing gneisses have been found to be metavolcanic and metasubvolcanic rocks that belong to the James Run Formation (pl. 1). Most of these rocks in Harford County were originally mapped by

Southwick (Southwick and Owens, 1968) as Port Deposit Gneiss, but his later remapping (Southwick, 1979) showed us more in agreement (fig. 5) and also provided some new insights into the origin of some of these rocks.

Coarse-grained phase

At its type locality, the Port Deposit Quarry, the Port Deposit Gneiss is a coarse-grained, thoroughly recrystallized, doubly-foliated, even-textured, plutonic-appearing rock with the mineralogical composition of a quartz-rich biotite granodiorite (Hopson, 1960; Southwick, 1969, 1979; and table 5, this paper). Despite the thorough recrystallization and the lack of definitive plutonic textures in the Port Deposit, the uniformity and overall plutonic appearance of this rock have caused everyone who has studied it to conclude that it is plutonic in origin. I mapped this rock as the coarse-grained phase of the Port Deposit Gneiss (pl. 1).

Coarse-grained Port Deposit Gneiss crops out in a northeast-trending belt about 2 km wide and 8 km long in Cecil County (pl. 1). It extends at least 12 km southwestward into Harford County. To the northwest, the coarse-grained gneiss is in sharp contact with metagraywacke, and the gneiss appears to be folded with the metagraywacke unit. Beyond its northeastern contact, small occurrences of the gneiss are found within the metagraywacke. Part of the southeastern contact of the coarse-grained Port Deposit Gneiss is covered by Coastal Plain deposits, but for about 2 km northeast and 3 km southeast of these deposits, the coarse-grained phase of the gneiss is in gradational contact with rocks that I mapped as fine-grained Port Deposit.

In thin section, the texture of the coarse-grained Port Deposit Gneiss is very similar to its texture in outcrop. Large ellipsoidal or lozenge-shaped pods of quartz and feldspar are outlined by biotite. These pods are formed by intersecting foliations. Locally, the gneiss has small amounts of microcline, chlorite, epidote, allanite, and garnet (Southwick, 1969, 1979; Higgins, 1972).

Fine-grained phase

As one follows the Susquehanna River southeastward from about the middle of the long, narrow town of Port Deposit, finer grained phases of Port Deposit Gneiss become more prevalent. Where exposed in the southern part of the town, coarse-grained Port Deposit Gneiss, although generally not as coarse as at the type locality, is intercalated with the fine-grained phase on a scale of tens of meters. The finer grained gneisses and granofels increase in abundance and thickness through an interval of about 1.3 km, until rocks of unquestionable subvolcanic and (or) volcanic parentage are present. The latter have blocky relict phenocrysts of plagioclase, relict volcanic or subvolcanic textures in thin section, and locally, relict pumice lapilli, accretionary lapilli, and amygdules. I assigned the metavolcanic and metasubvolcanic rocks to the James Run Formation and the mixed interval to the fine-grained phase of the Port Deposit Gneiss (pl. 1), even though some of the finer grained rocks in this mixed interval are probably transitional between plutonic and subvolcanic.

Some of the rocks in the fine-grained phase of the Port Deposit are similar to coarse-grained Port Deposit in thin section; others have textures similar to subvolcanic rocks like some of those depicted by Cater (1969) in his description of the Cloudy Pass batholith in Washington state, and the subvolcanic rocks it grades into. Still another type of rock mapped as fine-grained Port Deposit is the quartz augen gneiss described by Southwick (1979, p. 106). Mineralogically, many of the rocks in the fine-grained phase are similar to those of the coarse-grained phase.

In summary, the fine-grained phase of the Port Deposit Gneiss is composed of interlayered rocks of probable plutonic and subvolcanic origin, and of rocks that appear to be transitional between plutonic and subvolcanic. These rocks are so intimately interlayered that it is virtually impossible to map them separately.

The intimate association of epizonal plutons with chemically similar volcanic rocks of approximately the same age has long been recognized in many different areas (for example: Fuller, 1925; Daly,

1933, p. 141-146; Buddington, 1959, p. 678, 685-694; Cater, 1969; Fiske and others, 1963; Hopson and others, 1966; Hamilton and Myers, 1967; Tabor and Crowder, 1969; Atherton and Brenchley, 1972; Myers, 1975; Elston and others, 1975; Taylor, 1976; Bussell and others, 1976; Bussell and McCourt, 1977; Pitcher, 1978; Thorpe and Francis, 1979; Atherton and others, 1979). In fact, this association is so common that it led Hamilton and Myers (1967, p. C1) to conclude that batholiths generally crystallize at relatively shallow depths, and that "many of them reach the surface and crystallize beneath a cover of their own volcanic ejecta."

There are numerous descriptions in the literature of epizonal plutons that broke surface to feed volcanic eruptions, the products of which were generally intruded only slightly later by younger parts of the plutons. Each of these plutons has some characteristics that make it unique, but all the plutons have one characteristic in common: they are all closely associated in time and space with volcanic rocks whose chemical compositions either match or partially overlap those of the plutonic rocks. In addition, most of the plutons show some of the following characteristics: (1) They have some kind of finer grained border phase, or subvolcanic phase, representing the transition between plutonic and volcanic rocks. Such a border phase of subvolcanic rocks is well displayed in the late Cenozoic Cloudy Pass batholith in the northern Cascades of Washington State (Cater, 1969; Tabor and Crowder, 1969). Tabor and Crowder (1969, p. 22) stated:

> "The border complex is a broad zone of nonporphyritic to highly porphyritic andesite and dacite that occurs along the steep contact near Hart Lake. The chilled rock in this zone both grades into and is intruded by the main pluton.";

(2) They have intricate dike-and-sill complexes in which the dikes and sills have intruded the consanguineous volcanic rocks and in turn are intruded by the pluton. A good example of this is the dike-and-sill

complex associated with the Cenozoic Tatoosh pluton in Mount Ranier National Park, Washington State, which Fiske and others (1963, p. 48) described as "an unbelievably complex assemblage of hypabyssal rocks." Fiske and others (1963, p. 48-52) described the hypabyssal complexes as follows:

> "The Tatoosh pluton is bordered by complex swarms of sills and dikes, which are similar in composition to the rocks of the core but are even more varied in texture. *** ...sill is piled on sill until 50 to 90 percent of the rock is intrusive. Septa of wallrock between sills are thin or have been so shredded and mangled by crosscutting dikes and sills that in places an indescribable jumble of interpenetrating intrusive rocks replaces the orderly succession of superposed sills. *** ...larger sills are composite; two to five or more intrusions share a single chamber. Many of the younger sills cluster near the centers, or intrude along the edges of older sills; but some wander irregularly, breaking from one side to another, subdividing, or even turning abruptly upward and leaving the sill chamber as dikes. *** The intrusive rocks of the sill complexes are chiefly aphanitic to medium-grained porphyries, ranging in composition from diorite to quartz monzonite. Somewhat coarser sheetlike bodies of quartz diorite, quartz monzonite, and granodiorite occur within the tops of some of the larger stocks and show features that suggest huge 'cedar-tree laccolith' complexes.... These complexes appear to represent a transition between the main massive body of the stock and the surrounding complex of individual sills separated by septa of wallrock. *** The interrelations between pluton core and hypabyssal sheath are complicated in other ways... The pluton core only rarely grades upward and outward into sills; in most places it cuts them abruptly, or is

separated from them by an intervening plutonic breccia composed of angular or rounded fragments of sill rock invaded by a coarser grained matrix. *** These contact relations seem to establish that the sills are at least slightly older than the main mass of the pluton -- they do not invade the core of the pluton, and in many places the pluton invades them. But on the other hand, there is equally good evidence that the sills were intruded after parts of the core had already solidified; the most striking evidence is afforded by inclusions that are thickly sprinkled through many sills and dikes. In general, the sill rocks have the same range in composition as the rocks from the main pluton and its roof zone, but they are finer grained and most of them are markedly porphyritic.";

(3) The plutons locally broke through to the surface to feed volcaniclastic eruptions, forming welded tuffs and tuff breccias that locally grade into highly vesicular and (or) amygdaloidal hypabyssal rocks (Fuller, 1925; Fiske and others, 1963, p. 52-59); (4) In many of the plutons it can be shown that the upper parts crystallized beneath a roof composed of their own volcanic ejecta (Hamilton and Myers, 1967); (5) The country rocks around and above many of the plutons show effects of contact metamorphism and metasomatism, and have been intruded by swarms of dikes that are late-stage differentiates of the pluton (Tabor and Crowder, 1969; Buddington, 1959); and (6) There is a tendency for the younger parts of many of the plutons to be more silicic and more potassic than the older parts, the associated hypabyssal rocks, and the associated volcanic rocks (Fiske and others, 1963; Cater, 1969; Tabor and Crowder, 1969; Atherton and others, 1979; Thorpe and Francis, 1979).

Despite the fact that it has been subjected to multiple deformation and metamorphism, the Port Deposit Gneiss preserves many of the characteristics of an epizonal, surface-breaking pluton: (1) Radiometric ages (Higgins and others, 1977; A.K. Sinha, oral communication,

1981) show that it is contemporaneous within experimental error with the metavolcanic rocks of the James Run Formation; (2) Its chemical composition overlaps that of some of the James Run rocks, but it is slightly richer in silica and slightly more potassic than many of the James Run rocks (see GEOCHEMISTRY section, and figs. 26 and 29); (3) It has a finer grained border phase that is probably subvolcanic and appears to grade into both the coarser grained plutonic rocks and the volcanic rocks; (4) Some of the James Run rocks are volcaniclastic, probably welded tuffs, and have broken phenocrysts like those in the volcaniclastic rocks associated with the Tatoosh pluton (Fiske and others, 1963, p. 52-59); and (5) The complex, partly volcanic, partly hypabyssal, partly plutonic sequence exposed in the Susquehanna River gorge southeast of the town of Port Deposit is probably a dike-and-sill complex like those associated with the Tatoosh pluton. Therefore, I suggest that the Port Deposit Gneiss was an epizonal, surface-breaking pluton that fed the eruptions for some of the James Run rocks. A similar origin is suggested for some of the other plutons associated with the James Run Formation.

Gneiss on Garrett Island

A quartz-rich, "hobnail-textured" granitic gneiss crops out over the southeastern two-thirds of Garrett Island in the Susquehanna River (pl. 1) and on the adjacent mainland of Cecil County. Exposures are good along the southwestern shore of the island, but accessability is limited. Southwick (1979; Southwick and Owens, 1968) considered this to be Port Deposit Gneiss, like that of the coarse-grained phase at the Port Deposit Quarry. It is strikingly similar to rocks in the Virginia Piedmont that Pavlides (1981) considered trondhjemitic, but it also resembles some gneisses in the James Run Formation.

Gneiss near Elk Mills

About 600 m south of Elk Mills is a plutonic-appearing gneiss (pl. 1) that I earlier (Higgins, 1973) informally called "Elkton gneiss," or (Higgins and others, 1977) "gneiss in the vicinity of

Elkton." Because the gneiss is closer to Elk Mills, it is here referred to informally as the "gneiss near Elk Mills." The gneiss crops out only along Big Elk Creek and in the large quarry of D.M. Stoltzfus and Son, Inc., on the east side of the creek, the interfluves being covered by Coastal Plain deposits. Because of this Coastal Plain cover the extent of the gneiss is unknown.

In the Stoltzfus Quarry near Elk Mills, the rock is a homogeneous biotite granodiorite gneiss with a granoblastic texture. An important aspect of this gneiss is its close association with metavolcanic or (and) metasubvolcanic porphyritic felsites of the James Run Formation that crop out along Big Elk Creek just north of Elk Mills. This association is probably much the same as that between the Port Deposit Gneiss and the James Run metavolcanic rocks.

Gneiss near Rolling Mill

A biotite-plagioclase gneiss underlies a large area around Rolling Mill on Big Elk Creek (pl. 1); the gneiss is well exposed along the creek. It generally has tiny garnets and magnetite crystals. The gneiss is everywhere in contact with James Run Formation metavolcanic rocks, but the contact is never exposed. The gneiss near Rolling Mill is petrographically similar to the gneiss near Elk Mills, and it may be correlative because the two are separated only by a thin belt of James Run rocks.

Pegmatite dikes

Several large pegmatites crop out in Cecil County, but only those that exceed about 7 m in width have been shown on the geologic map (pl. 1). Most of the dikes are weathered and cannot be traced very far. Some of the dikes are as much as 30 m thick (Bascom, 1902, p. 101-103). Most of the dikes are composed of large crystals of microcline, fairly large irregularly shaped quartz grains, and large books of muscovite. They are most prevalent in the pelitic schist and

pelitic gneiss units. The locations, thicknesses, and compositions of these dikes were described in detail by Bascom (1902). Her map (Bascom and Miller, 1902) shows several pegmatite dikes that I was unable to locate. The dikes generally strike northeast. Some of the thicker dikes were mined in the last century for feldspar and muscovite (Singewald, 1928, p. 106-109).

Quartz veins

Small quartz veins, generally with tourmaline, are common in the rocks of Cecil County. Several large quartz veins or dikes, as much as 30 m thick, are also present, and those more than about 7 m thick are shown on the geologic map (pl. 1). Most of the larger veins are composed of opaque, milky white quartz, but many carry small amounts of yellow-stained muscovite and tourmaline. Some of the larger quartz veins appear to be associated with small shear zones.

Diabase dikes

Several northeast-trending Late Triassic or Early Jurassic dikes of equigranular, fine-grained, dark-grayish-black diabase are found in Cecil County (pl. 1). The largest of these dikes was followed for about 2,750 m, and passes just southeast of Colora. I was unable to locate several dikes mapped by Bascom (Bascom and Miller, 1902).

The diabase dikes have ophitic textures and are composed of augite, labradorite, opaques (chiefly magnetite), small amounts of brown biotite, and sparse accessories. Fisher (1964, p. 15-17) gave detailed petrographic descriptions of similar dikes farther southeast in Maryland.

One Cecil County diabase dike (table 7) is high in titanium and quartz-normative. It is chemically similar to the Mesozoic high-Ti, quartz-normative tholeiitic dikes of eastern North America (Weigand and Ragland, 1970).

GEOCHEMISTRY

All chemical analyses made in the course of this project were

preformed in the laboratories of the U.S. Geological Survey at Reston, Virginia. Major element oxides were determined by P. Elmore, H. Smith, J. Kelsey, and F. Brown, using the methods described by Shapiro (1975) supplemented by atomic-absorption spectrometry. Large cation trace elements, minor ferromagnesian elements, and rare-earth elements were analyzed by L.J. Schwarz, using instrumental neutron activation (see Pavlides, 1981, p. A9 for details). Other elements were determined by N. Rait, using quantitative spectrographic analysis. Descriptions of the sample locations are on open file with the Maryland Geological Survey.

James Run Formation and Port Deposit Gneiss

Except for scattered amphibolites and some of the rocks in the "volcanic complex of Cecil County " (Marshall, 1936, 1937), metavolcanic rocks were unknown in the eastern Maryland Piedmont until Hopson (1964) convincingly argued for a volcanic origin for a sequence of rocks in Baltimore City that he called the "Baltimore paragneiss." All previous workers had mapped these rocks as Baltimore Gneiss, and thus part of the ~1.1 b.y. old "basement complex." In addition to field evidence and the striking resemblance of these rocks to unmetamorphosed volcaniclastic and epiclastic rocks in the Cascades and Japan, Hopson (1964) used the chemical compositions of the rocks of his Baltimore paragneiss as evidence of their volcanogenic origin. He compared them with average sedimentary rocks, a series of average calc-alkaline lavas, altered marine volcanic siltstones, and quartz keratophyres formed by alteration of volcanic ash, and concluded (Hopson, 1964, p. 35) that the paragneiss represents "a thick sequence of rhyodacitic to basaltic sediments, which may have been albitized prior to high-grade metamorphism." These rocks are now considered part of the James Run Formation (Southwick, 1969; Southwick and others, 1971; Higgins, 1971a, 1972; Crowley, 1976; Crowley and others, 1976).

Southwick (1969, p. 47-50, 54, 57-59) studied the chemical characteristics of the James Run Formation rocks in Harford County,

and a few of these rocks in Cecil County. Like Hopson (1964), he noted (1969, p. 47) "the large excess of Na_2O over K_2O, even in very siliceous rocks, and the variable amounts of CaO in the mafic layers," and concurred with Hopson on the volcanogenic origin of the James Run Formation. Southwick (1969, p. 49) concluded that the James Run rocks had normal calc-alkaline compositions when erupted, but were altered after deposition either by reaction with resurgent connate water during diagenesis and incipient metamorphism accompanying deep burial, or by direct hydration of plagioclase to calcium zeolites followed by base exchange with sea water. He made a point of the uneven extent of diagenetic sodium enrichment (spilitization), citing the variable ratio of Na to Ca in James Run amphibolites. He further concluded (1969, p. 49), that adjustments in the distribution of Ca, Na, and K probably took place during metamorphism, but that the presence of different plagioclase feldspars in different beds a few meters apart indicates that the migration of Na and Ca was sluggish, and that there is no evidence of large-scale metasomatism of lime or alkalis during metamorphism. Hopson (1964, p. 32) had earlier concluded that "The high-grade metamorphism of the paragneiss was evidently isochemical."

Metavolcanic rocks of the Chopawamsic Formation and of Pavlides' (1981) Ta River Metamorphic Suite in northern Virginia have been tentatively correlated with the James Run Formation (Pavlides, 1981; Southwick and others, 1971; Higgins, 1972). Pavlides' (1981) extensive geochemical study shows that the rocks in his "central Virginia volcanic-plutonic belt" are geochemically similar to the rocks of the James Run Formation. Like Southwick (1969), Pavlides (1981, p. A9) favored alteration as the process by which some of the Virginia rocks became highly sodic. He (1981, p. A9-A11) stated that the mobility of K_2O since the rocks were erupted "is demonstrated by the marked reversals of K_2O abundances in some of the metafelsites having about the same SiO_2 content."

Major oxides

The major oxide compositions of rocks of the James Run Formation

in Cecil County (table 8) are similar to those in Baltimore and Harford Counties. Most are high in Na_2O, low in K_2O, and have variable CaO. Many of these rocks could be called spilites, keratophyres, and quartz keratophyres. In a plot of normative quartz-orthoclase-albite + anorthite (fig. 26), most of the James Run rocks plot along the quartz-plagioclase side of the triangle. The three rocks that plot slightly more toward the orthoclase apex have high biotite contents, and are thus richer in K_2O. On this same plot, the Port Deposit Gneiss plots close to some of the more silicic James Run rocks, but generally slightly more toward the Or apex (fig. 26). In figure 27, the James Run rocks, including previously published analyses from Ward (1959), Hopson (1964), Southwick (1969), and Higgins (1972), are compared with average sedimentary rocks, altered marine volcanic rocks, average calc-alkaline volcanic rocks, and some spillites and keratophyres. Figure 28 compares the James Run rocks with the metavolcanic rocks of Pavlides (1981) "central Virginia volcanic-plutonic belt." The chemical similarity between the Virginia rocks and the James Run rocks supports their geologic correlation. The Q-Or-Ab + An plots suggest that some of the James Run rocks were altered marine volcanic rocks before metamorphism, as suggested by Hopson (1964), Southwick (1969), and Higgins (1972). However, some of the James Run rocks are almost certainly metamorphosed subvolcanic rocks, and parts of some members may be shallow metaplutonic rocks.

Figure 29 is a plot of normative orthoclase-albite-anorthite for James Run felsic rocks with silica contents greater than 55 percent, Port Deposit Gneiss, as well as some data from Southwick (1979). The volcanic and plutonic fields on the diagram are from O'Connor (1965). This figure clearly shows the <u>apparent</u> trondhjemitic affinities of some parts of the Port Deposit Gneiss and some of the probable metasubvolcanic rocks in the James Run Formation. It also illustrates the range in composition of the James Run felsic rocks, from somewhat Or-poor dacites to highly albitic quartz keratophyres.

Figure 30 is an F'-M-A (F' is total iron calculated as FeO) plot for the James Run metavolcanic and metasubvolcanic rocks and the Port

Deposit Gneiss. The partial overlap in composition between the James Run rocks and the Port Deposit rocks is evident from the plot, and supports the field and petrographic evidence suggesting that these rocks are genetically related. Considered as a suite, these rocks have a trend that is intermediate between the "Cascade trend" toward alkali enrichment with differentiation and the "Skaergaard trend" toward extreme iron enrichment. However, the scatter of points makes it difficult to define an exact trend. This scatter may be due to differences in alteration among the samples.

Alteration

Of critical importance in classifying igneous rocks and igneous rock suites and in making interpretations about their origins based on chemical compositions, and particularly on major element compositions, are the types and degrees of alteration that have affected the rocks since eruption, deposition, or emplacement. Alteration processes can be generally divided into premetamorphic, metamorphic, and postmetamorphic, but these processes are commonly gradational from one category to another.

Some of the premetamorphic processes that alter igneous rocks are devitrification, deuteric alteration, diagenesis (including diagenetic zeolitization), weathering, hydrothermal alteration, hydrolysis, and halmyrolsis. These processes merge into low-grade metamorphic processes that include burial diagenesis, burial metamorphism, and metasomatism, which, in turn merge into higher grades of regional metamorphism and metasomatism. Postmetamorphic processes that alter the rocks include hydrothermal alteration, weathering, and chemical exchange with ground water. Most igneous rocks have been subjected to more than one of these alteration processes.

Types and degrees of alteration are controlled by rock type and geologic environment. Specifically, alteration is controlled by such factors as grain size, texture, mineral composition, and, probably most important, permeability. Plutonic rocks are generally less susceptible to alteration than volcanic rocks, particularly

volcaniclastic rocks. Because volcanic rocks are erupted into air or water, they begin being altered almost as soon as they leave the vent. Volcaniclastic rocks are by far the most readily and commonly altered igneous material, whether they are erupted subaerially or subaqueously, and whether mafic or felsic. Volcanic glass is extremely susceptible to devitrification, palagonitization, and zeolitization, subaerially, subaqueously, or with shallow burial (Bramlette and Posnjak, 1933; Ames and others, 1958; Deffeyes, 1959; Mumpton, 1960, 1977; Dickinson, 1962a, 1962b; Hay, 1962, 1963, 1966, 1977; Brown and Thayer, 1963; Fiske and others, 1963; Van Houten, 1964; Sheppard and Gude, 1965, 1968, 1973; Horne, 1968; Hay and Iijima, 1968; Surdam and Hall, 1968; Smith, 1968, 1969; Utada, 1971; Surdam, 1973, 1977; Murata and Whiteley, 1973; Galloway, 1974; Stewart, 1974; Walton, 1975; Boles and Coombs, 1975, 1977; Boles, 1977; Hay and Sheppard, 1977). Thick accumulations of altered (zeolitized, palagonitized, albitized) marine volcanic and volcaniclastic rocks are present in Japan (Sudo, 1950; Matsudo and Mizuno, 1955; Fiske and Matsuda, 1964; Utada, 1970, 1971; Iijima and Utada, 1972), in New Zealand (Coombs, 1954; Coombs and others, 1959; Boles, 1971, 1974; Boles and Coombs, 1975, 1977), in eastern Australia (Smith, 1968, 1969), in the Indonesian region (Hamilton, 1979, and references therein), in Puerto Rico (Christman, 1953; Otalora, 1961; Glover, 1971), in the Virgin Islands (Donnelly, 1959a, 1959b, 1963, 1966), in the western United States (Wells and Waters, 1935; Warren and others, 1945; Waters, 1955; Dickinson, 1962a, 1962b; Fiske, 1963; Hamilton, 1963; Fiske and others, 1963; Brown and Thayer, 1963; Snavely and Wagner, 1964; Peck and others, 1964; Snavely and others, 1968), in western Canada (Carlisle, 1963; Surdam, 1973), and in the Aleutian Islands (Hamilton, 1963, and references therein).

The volcanic and volcaniclastic rocks of the James Run Formation are very similar lithologically and chemically to these altered marine volcanogenic rocks, even though the James Run rocks have been metamorphosed to amphibolite facies grades of regional metamorphism and multiply deformed. So, in spite of the fact that caution must be

exercised when interpreting chemical analyses of altered and metamorphosed rocks, chemical compositions can be used in a qualitative way to help decipher rock origins. It seems fairly certain that the James Run Formation rocks are mostly metamorphosed altered marine volcanic and volcaniclastic rocks, as proposed by Hopson (1964) and Southwick (1969).

I agree with Hopson (1964, p. 32) and Southwick (1969, p. 49), that the regional metamorphism of the James Run Formation was essentially isochemical. This is supported, as Southwick noted (1969, p. 49), by the presence of relict plagioclase phenocrysts of different compositions in closely spaced samples, and also by the fact that most of the James Run rocks plot identically with unmetamorphosed (though altered) submarine volcanic and volcaniclastic rocks (fig. 27). Ratios of Na_2O to CaO in the James Run rocks (fig. 31) are variable, as Southwick's (1969) limited number of analyses suggested. Much more impressive, however, are the extremely variable Na_2O to K_2O ratios (fig. 32); these ratios vary as much as 60 to 1 for rocks with essentially the same silica contents. On variation diagrams (fig. 33), oxides of the James Run rocks form relatively broad zones characteristic of altered submarine volcanogenic suites (Hamilton, 1963, p. 70-71), but in contrast to the narrow zones of most subaerial volcanic suites. In the James Run rocks, CaO ranges downward from a maximum about equal to the normal amount in calc-alkaline rocks, and Na_2O varies upward from a minimum about equal to the normal amount in calc-alkaline rocks. This too is characteristic of most altered submarine volcanogenic sequences (Hamilton, 1963).

The erratic variations in the chemical compositions of the James Run Formation rocks are characteristic features of the "spilite-keratophyre association" of Turner and Verhoogen (1960), or the "andesite-keratophyre association" of Hamilton (1963), in which keratophyre, quartz keratophyre, and spilite are intercalated with calc-alkaline andesite, dacite, rhyodacite, and basalt, with trondhjemite a common plutonic rock type. The origin of the sodic rocks has been a source of controversy for many years - reviews and summaries

were given by Gilluly (1935), Eskola (in Barth and others, 1939), Turner and Verhoogen (1960), and Hamilton (1963). As Hamilton (1963, p. 68) stated:

> "Current theories explain these sodic rocks variously as formed from primary sodic magmas or from calc-alkaline rocks altered by sodium added from magmatic, geosynclinal, or sea water sources."

The problems are as follows: (1) In most sequences, normal calc-alkaline rocks are intercalated with the sodic rocks, precluding theories of wholesale alteration of the entire volcanic pile by any method. Therefore, either the sodic rocks originated from sodic magmas erupted along with, or alternating with, normal calc-alkaline magmas, or parts of a calc-alkaline volcanic pile had to be selectively altered by enrichment in Na and depletion in Ca and K; (2) If the sodic rocks originated as sodic magmas, what is the origin of such magmas, and how could such magmas and normal calc-alkaline magmas have been erupted at virtually the same time and place?; (3) In this same context, what is the origin of the trondhjemitic plutonic rocks that are commonly associated with the sequences of sodic and calc-alkaline volcanic rocks, and what relation do these plutonic rocks have to the volcanic rocks?; (4) If, on the other hand, the sodic rocks were derived by selective alteration, what factors controlled the selectivity, and what was the mechanism of alteration?; and (5) If the sodic rocks were derived by alteration of calc-alkaline rocks, what was the medium for such alteration? Was it from a magmatic source, or by fluids expelled from older rocks being metamorphosed beneath the volcanic pile, or was it by interaction with sea water, either contemporaneously with eruption or after eruption?

Waters (1955, p. 707) noted that some dolerite sills, dikes, and subaerial flows in the Olympic Mountains and Oregon Coast Ranges are as thoroughly albitized as the pillowed flows, and that some thick masses of pillow lavas show little or no albitization. Following

Gilluly (1935) he proposed (1955, p. 707) that:

> "...the alteration of the lavas to 'spilites' and greenstones, and the simultaneous albitization, silicification, and chloritization of the underlying sediments and intrusive bodies have been produced by water, alkalis, silica, and other easily removable constituents stewed from the slowly metamorphosing root of geosynclinal sediments as it was downbuckled to form a tectogene. Fluids expelled from this metamorphosing-root rose along zones of mechanical deformation altering the overlying volcanics and sedimentary rocks."

Hamilton (1963, p. 72-74), on the other hand, emphasized the differences between what he called "the uncommon 'keratophyre'" in subaerial sequences and what he considered true keratophyres of island-arc sequences. He stated (1963, p. 73):

> "The distinctive compositions of spilite and keratophyre must be due to postmagmatic processes, and these processes seem somehow connected to the submarine environment in which these rocks almost exclusively occur. That diabase sills and other rocks intruded within the sequences are also albitized shows that the changes are not restricted to rocks that formed in direct contact with sea water."

Hamilton (1963) presented fairly conclusive evidence that: (1) all known rocks that should properly be called spilites and keratophyres were either erupted under sea water, or flowed into sea water, or were covered by sea water after eruption or deposition; (2) the sodic rocks were erupted as calc-alkaline magmas and the albitized rocks owe their distinctive character to post-eruptive transformations; (3) (p. 73) "the sodium was introduced, and calcium removed, by the sea water in some sort of diagenetic process."; and (4) mineralogic capture of sea

water sodium is the most likely process. Hamilton (1963, p. 73-74) concluded:

> "If bases in the volcanic rocks -- and particularly in the porous and already partly water-laid tuffs -- could be exchanged for bases in circulating water and the capture thus be diagenetic, the subsequent albitization could be explained easily."

He proposed that zeolitization is the process by which this is accomplished.

The past 20 years have seen tremendous advances in our knowledge of zeolites, their mineralogy, chemistry, processes of formation, and their remarkable chemical-exchange capabilities. Hamilton (1963, p. 74) probably guessed right about zeolites being the chief culprits in the alteration processes that ultimately produce spilites and keratophyres. Nevertheless, zeolitization is an extremely complex process and commonly a multiphase process in which first-formed zeolites are replaced by other zeolites, and so on, with changing diagenetic or low-grade metamorphic conditions.

In most volcanic rocks, and especially in volcaniclastic rocks, the first part of the rock to be affected by zeolitization is glass, which is rapidly transformed into (or replaced by) heulandite or (and) analcime (Gulbandsen and Cressman, 1960; Fiske and others, 1963; Hamilton, 1963; Boles, 1977, and references therein). With the increasing temperatures and pressures of burial, heulandite is converted to laumontite and analcime. Then, Ca-plagioclase is converted partly to laumontite and albite, and then laumontite to pumpellyte and phrenite, which are finally converted to albite along with analcime, which goes to albite and quartz (see Boles, 1977, p. 127). This is simplistic, and many other minerals (and other zeolites) may be involved, depending upon rock type, geologic environment, and other factors, but it probably represents a general case in the complex transformation from calc-alkaline to sodic volcanic rocks, and could

account for the gradual change from "normal" compositions to spilitic and keratophyric compositions.

Still a problem is the apparent selectivity of the chemical transformations from normal calc-alkaline rocks to sodic rocks. Even if Hamilton (1963) was right in his conclusion that subaerial rocks were unaffected by these transformations, we must still account for the fact that within the submarine volcanogenic sequences are "rocks that belong to both calc-alkaline and albitized series (Hamilton, 1963, p. 71)." How then, can we account for the selective alteration of rocks within the submarine piles? This question must inevitably lead to its companion question about the origin of the trondhjemitic "plutonic" rocks within the sequences and how these sodic rocks relate to the sodic volcanic rocks.

Perhaps at least part of the answer to the questions lies in the recognition of subvolcanic rocks and shallow hypabyssal "plutonic" rocks. Although the pioneering works of Fuller (1925) and Buddington (1959) had forseen the existence and importance of these classes of rocks, it was not until the 1960's that their widespread occurrence and importance became apparent.

In figure 32, which is one of the plots that is most demonstrative of sodic alteration, rocks that show clear lithologic and petrographic evidence of volcaniclastic origin (symbols with large circle) have much higher Na_2O/K_2O values for rocks in the same silica range than rocks that have lithologic and petrographic characteristics of flows or subvolcanic parentage (symbols with large triangle); many of the other chemical plots also show this difference. This is a strong indication that premetamorphic alteration of the James Run volcanogenic rocks was largely dependent upon porosity and permeability, so that volcaniclastic rocks were preferentially altered over subvolcanic and plutonic rocks. Notable is the fact that one of the Port Deposit Gneiss samples (arrows point to Port Deposit fine-grained phase samples), which I consider subvolcanic and Southwick (1979) considered probably a trondhjemite, could be just a somewhat altered calc-alkaline rock. This is supported by the fact that the "typical" plutonic

Port Deposit samples plot close to normal calc-alkaline granodiorites in figures 26 and 29.

It seems incongruous to postulate primary sodic magmas to form plutonic trondhjemites in volcanogenic sequences that show evidence of secondary sodic alteration, especially where there is also evidence that the volcanogenic rocks are genetically related to the plutonic rocks. It seems more reasonable to suggest that "trondhjemites" intimately associated with approximately contemporaneous volcanogenic rocks that have been altered and enriched in soda may owe their "trondhjemitic" compositions to the same processes that altered the volcanogenic rocks. I suggest that this is the case for the James Run Formation metavolcanic rocks and the fine- to medium-grained, probably subvolcanic and hypabyssal, plutonic rocks.

Trace elements

Despite the obvious limitations imposed by possible alteration and by metamorphism on using geochemistry to decipher the origins, and particularly the original tectonomagmatic setting, of the James Run Formation rocks, and the general objection to comparing metamorphosed rocks with unmetamorphosed rocks, it is generally accepted that some of the more immobile major and trace elements, and especially the rare-earth elements (REE), are useful to some extent for these purposes. Most of the geochemical schemes for determining the original tectonomagmatic setting of igneous rock suites are based on mafic rocks, chiefly basalts. Thus, the generally well-exposed, unweathered, metamorphosed pillow lavas and amygdaloidal amphibolites of the Gilpins Falls Member of the James Run Formation are perhaps as well suited for application of these geochemical schemes as any rocks in the central Appalachian Piedmont.

Comparison of the trace-element data in Table 9 shows that the Gilpins Falls metabasalts (GFM) and an amphibolite from the Big Elk Creek Member of the James Run Formation are exceptionally rich in Ni and Cr relative to basalts and metamorphosed basalts from a variety of tectonomagmatic settings, and to the average abundances in tholeiitic

basalts given by Prinz (1967; table 10). However, the abundance of Co in the GFM is slightly lower than that in many of the rocks in table 10 and slightly below the average abundance in tholeiitic basalts (Prinz, 1967), and the abundance of Cu in the GFM is significantly lower than that in most of the rocks in table 10 and the average abundance in tholeiitic basalts. In addition, the GFM are somewhat enriched in vanadium. The GFM are close to the Chopawamsic metabasalts in abundances of Zr, Sc, Hf, Th, Co, and Zn, but greatly exceed the Chopawamsic rocks in Ni and Cr. Overall, except for the Chopawamsic metabasalts, the trace-element abundances of the GFM appear closest to those of the tholeiitic basalts (low-K tholeiites) of the island arc series (table 10; Pearce and Cann, 1973).

The low abundance levels of Co and Zn and the very high abundance levels of Ni, Cr, and V in the GFM are petrologically significant. Copper, although known to be mobile in many cases (David Gottfried, written communication, 1982), is low in the GFM. Copper is generally enriched in the residual liquids during differentiation of basaltic magma until immiscible sulfides rich in Cu appear, at which point a severe decrease in Cu occurs (Wager and Mitchell, 1951; McDougall and Lovering, 1963; McDougall, 1964; Walker, 1969; Greenland and Lovering, 1966; Paster and others, 1974; Gottfried and others, 1977). Fleischer (1968) showed that the Ni/Co ratios in tholeiitic diabase-granophyre suites decrease systematically from ~3 to <1 during differentiation, and are useful as an index of fractionation, and Paster and others (1974) showed that Ni and Cr are successfully removed from the liquid in a crystallizing basaltic magma by the early cumulus minerals. In the the GFM, much of the chromium was probably removed by chrome spinel and (or) chromite. Gunn (1971), Henderson and Dale (1969\-1970), and Paster and others (1974) found that the values for the distribution coefficients for Co and Zn entering olivine are greater than unity, and that the values for Co entering clinopyroxene also exceed unity. However, Paster and others (1974) found that the agreement between the predicted concentrations based on the distribution coefficients and the observed concentrations of these elements is

poor, and that liquid in middle stages of crystallization had higher concentrations than original liquid or cumulus stages. At any rate, Co, Zn, Cu, Ni, and Cr appear to be useful as qualitative indices of fractionation. All these relations and the elemental abundances in the GFM suggest that the GFM are primitive and poorly fractionated, and possibly represent part of the cumulus stage of crystallization. This is supported by the MgO contents of amygdaloidal amphibolites and interiors of pillows in the GFM which average 9.9 percent and range from 6.1 to 13.9 percent MgO (table 8); these values are significantly higher than for most basalts and metabasalts.

Rare-earth element (REE) abundances for 12 samples of the GFM are given in table 9. The lack of significant differences in abundances of REE between samples of interiors of pillows and pillow rims suggests that neither any possible alteration nor the amphibolite grade metamorphism of these rocks caused any appreciable changes in the abundances or distribution of the REE. Chondrite-normalized (Haskin and others, 1968) REE patterns for the GFM (fig. 34) show slight enrichment of the light REE (La-Sm) relative to the heavy REE (Gd-Lu); slight Tb enrichment in four of the samples is probably an analytical problem. Figure 35 shows the average (mean) chondrite-normalized pattern and the field (range) of the GFM. Figure 36 compares the average REE pattern of the GFM with the average patterns of oceanic-ridge tholeiitic basalts, Charleston corehole basalts, and basalts from the Mesozoic eastern North America (ENA) tholeiitic province. The fact that the light-REE depleted pattern of the oceanic-ridge tholeiitic basalts is in contrast to the slightly light-REE enriched and markedly heavy-REE depleted pattern of the GFM supports the trace-element data described earlier, which suggest that the GFM are probably not normal ocean-floor basalts that originated in an oceanic-ridge system. By the same token, the pattern of the GFM does not match the more light-REE enriched, less heavy-REE depleted patterns of the ENA quartz-normative dolerites, although the pattern of the GFM is somewhat similar to the pattern of the primitive ENA olivine-normative diabases.

Figures 37-44 compare the average pattern and field of the GFM with those of the Chompawamsic metabasalts (Pavlides, 1981), the Ta River amphibolites (Pavlides, 1981), island arc tholeiites (Jakes and Gill, 1970), interarc basin basalts from the Lau Basin (Gill, 1976), basalts from the FAMOUS area (White and Bryan, 1977), ENA olivine-normative tholeiitic diabases (Ragland and others, 1971), tholeiites from the Othris (Greece) ophiolite complex (Menzies, 1976), and Archean komatiites from Ontario, Canada (Arth and others, 1977). The Chopawamsic metabasalts and the Ta River amphibolites are approximately along strike from the GFM to the southwest in Virginia, and the Chopawamsic Formation has been correlated with the James Run Formation on geologic grounds (Southwick and others, 1971; Higgins, 1972; Pavlides, 1976, 1980, 1981). The other rock suites were chosen either because they are from tectonic settings that might be similar to the original tectonic setting of the GFM or because they have REE patterns in some way similar to those of the GFM. The fields for the GFM and the Chopawamsic metabasalts (fig. 37) overlap for the lighter REE from La through Nd, but from Nd through Lu the GFM are more strongly depleted. The Chopawamsic metabasalts also have a slight, but consistent, Sm enrichment that is not seen in the GFM patterns. There is much less overlap between the GFM and that Ta River amphibolites (fig. 38), but some of the Ta River data may be analytically poor (David Gottfried, written communication, 1982). The average REE pattern of the GFM lies almost completely within the broad field of island arc tholeiites (fig. 39), but the field of the GFM and the average GFM pattern compared with the average island arc tholeiite pattern, indicate greater depletion in the heavier REE in the GFM. The average pattern of interarc basin basalts has a similar trend to the GFM trend, but is slightly more light REE enriched and markedly less heavy REE depleted than the GFM field (fig. 40). The basalts from the FAMOUS area have about the same light REE enrichment as the GFM (fig. 41), but are markedly less depleted in heavy REE. The ENA olivine-normative tholeiitic diabases are less enriched in light REE than the GFM (fig. 42), but less depleted in heavy REE. Tholeiites from the

Othris ophiolite complex define a REE field similar to that of the GFM (fig. 43), but the field is based on sparse data. Archean komatiites are slightly less light REE enriched than the GFM and are slightly less depleted in heavy REE than the GFM (fig. 44).

The most striking features of the REE in the GFM are the low-level abundances (table 9) and the depletion in heavy REE (figs. 34 amd 35). These features can be accounted for if the GFM magmas were primitive and associated with a cumulus phase of crystallization, as suggested by the major and trace elements. Studies of REE in ultramafic rocks from ophiolite complexes and "alpine" ultramafic bodies (Frey and others, 1971; Menzies and others, 1975; Menzies, 1976) and layered mafic intrusions (Frey and others, 1971) show that these rocks are strongly depleted in REE relative to basalts. In Figure 45, REE patterns of some representative ultramafic rocks and metamorphosed mafic rocks from the Soapstone Ridge Complex, Atlanta, Georgia (Higgins and others, 1980) are compared with the average REE pattern and field for the GFM. Most of the ultramafic rocks are probably cumulates. The metamafic rocks of the Soapstone Ridge Complex are probably part of an ophiolite. There is an order of magnitude difference in abundance levels between the ultramafic rocks (fig. 45) and the GFM, but the trends of the patterns are similar. Menzies (1976, p. 649 stated:

> "If a chondritic relative REE distribution is assumed for the parent, conventional ideas on REE distribution and partitioning imply that refractory peridotites are heavily depleted in REE because light REE are strongly partitioned into the liquid (Schilling, 1971)."

The REE depletion that is generally associated with cumulates can be used to infer that the slightly depleted REE patterns of the GFM may result from their having crystallized during a late-stage cumulus phase. The similarity (fig. 43) between the REE patterns of the GFM and those of "ophiolitic basalts" (Menzies, 1976) suggests that the

GFM may be ophiolitic. In this regard, it is interesting to compare the REE pattern of the GFM with those of metatroctolites and metagabbros from the Soapstone Ridge Complex (fig. 45). The Soapstone Ridge metamorphosed mafic rocks are enriched in light REE to about the same extent as the GFM, but they are much more strongly depleted in heavy REE, plotting between the GFM and the ultramafic rocks. These relations would seem to support Menzies' (1976) and Schilling's (1971) model of light REE enrichment through partitioning into the liquid, while leaving the heavy REE depleted. The ophiolite with which the GFM is associated would be the Baltimore Complex (Crowley, 1976; Morgan, 1977).

Original tectonomagmatic setting

The original tectonomagmatic setting of mafic volcanic rocks is based on the relative motions of lithospheric plates. Therefore, these rocks are broadly divided into three categories (Pearce and Cann, 1973): (1) ocean-floor basalts formed at diverging plate margins; (2) low-K tholeiites and calc-alkaline basalts of the island arc series formed at converging plate margins; and (3) intraplate oceanic island and continental basalts formed within oceanic crust or within continental crust. Elements commonly used to distinguish these categories are Ti, Zr, Y, Nb, P, K, and Sr (Pearce and Cann, 1973; Floyd and Winchester, 1975; Winchester and Floyd, 1976, Pearce and others, 1975). The discrimination diagrams most widely used for unaltered, unmetamorphosed volcanic rocks are the Ti-Zr, Ti-Zr-Y, and Ti-Zr-Sr diagrams of Pearce and Cann (1973). Despite the fact that these diagrams were originally devised to distinguish the tectonic settings of unaltered, unmetamorphosed rocks, many workers have used them to investigate past environments of metamorphosed mafic rocks (for example: Pearce and Cann, 1971; Bickle and Nisbet, 1972; Seidel, 1974; Pearce, 1975; Smewing and others, 1975; Kay and Senechal, 1976; Menzies, 1976; Aleinikoff, 1977; Tull and others, 1978; Wrucke and others, 1978).

On Ti-Zr and Ti-Zr-Sr diagrams (figs. 46 and 47), the fact that the GFM plot in both the low-potassium tholeiitic basalt of the island arc series field and the calc-alkalic basalt of the island arc series field lends support to the field evidence and other geochemical evidence suggesting that the James Run metavolcanic rocks formed in an island arc. Caution must be exercised in using these diagrams, however, because: (1) While Ti and Zr are generally thought to be relatively immobile during alteration and metamorphism (Cann, 1970; Pearce and Cann, 1971, 1973; Pearce and others, 1975; Floyd and Winchester, 1975; Winchester and Floyd, 1976; Gottfried and others, 1977), Sr is generally considered mobile (Philpotts and others, 1969; Hart, 1971; Pearce and Cann, 1973; Hart and others, 1974; Gottfried and others, 1977); and, (2) Gottfried and others (1977) have shown that the diagrams may be inappropriate for identification of the tectonomagmatic setting of some rock types. They stated (Gottfried and others, 1977, p. 110):

> "...no single group or pair of geochemically associated elements could be used alone for distinguishing magma type and tectonic setting of the corehole basalts from basalts of all of the contrasting tectonic envirionments considered. This emphasizes the importance of using trace elements of widely different chemical properties and sizes for discrimination purposes."

The consistency of all the geochemical data from the James Run Formation rocks that suggests that these rocks originally formed in an island-arc setting.

Baltimore Complex

The geochemistry of the Baltimore Complex has been studied by Herz (1951), Thayer (1960), Southwick (1969, 1970), and Hanan (1976). These workers all emphasized the differentiation trend toward iron enrichment shown on F'-M-A diagrams for suites of rocks from the

complex. However, both Southwick (1970) and Hanan (1976) recognized possible problems due to changes in the MgO/FeO ratios caused by alteration and metamorphism. Hanan (1976) also studied the Sr isotope geochemistry of the complex and concluded that greater equilibration through exchange with the "country rocks" during metamorphism had occurred in the vicinity of the Susquehanna River than in the vicinity of Baltimore. He attributed the difference to the greater water content of the metasedimentary rocks in contact with the complex along the Susquehanna, as opposed to the "dry" Baltimore Gneiss near the complex in the Baltimore area.

Major oxides

Major oxide analyses of Baltimore Complex rocks from Cecil County are given in table 11; many of these analyses were also used by Hanan (1976). On an F'-M-A diagram (fig. 48), most of these analyses plot along the F'-M side of the triangle, with a trend toward iron enrichment. However, several of the analyses plot farther toward the F'-A side of the triangle, and could be construed as marking the beginning of a trend "turning the corner" toward the alkali apex. Some of the analyses plot closer to the M apex of the triangle than previously known for the complex (compare with Southwick, 1970, p. 410). As noted by Southwick (1970), the scatter of points on the F'-M-A diagram suggests the possibility of changes in the ratios due to alteration and (or) metamorphism.

In figure 49, the James Run metavolcanogenic rocks are plotted along with the Baltimore Complex rocks, including eight analyses of Baltimore Complex rocks from Southwick (1970, p. 412). Southwick's analyses 9-12 ("quartz-bearing metagabbro" and "dark quartz diorites") are not plotted in figure 49 because these rocks are now considered to belong to the mafic zone of the Conowingo diamictite. Analysis 8 of Southwick (1970, p. 412), shown by a separate symbol, may also be from the mafic zone near Rising Sun. Deletion of these analyses of probable metasedimentary rocks lowers the trend toward iron enrichment noted by previous workers. However, the points show so much scatter

(fig. 49) that an average trend is difficult to discern and may be meaningless because of alteration and (or) metamorphism. The overlap between the Baltimore Complex analyses and the analyses of mafic rocks from the James Run Formation on the F'-M-A diagram is evident, but the scatter of points in the area of the overlap is so great that the overlap may not be significant.

In figure 49, the James Run and Baltimore Complex analyses are compared with several well-known differentiation trends. If the point scatter is ignored, and if the James Run rocks and the Baltimore Complex are genetically related, the differentiation trend would start with highly magnesian rocks, trend toward moderate iron enrichment, like slightly iron-enriched alkali-poor tholeiites, and end with a trend similar to the Hawaiian alkali series or the Cascade lavas. Both Crowley (1976) and Morgan (1977) interpreted the Baltimore Complex as at least a partial ophiolite. In figure 50 the James Run and Baltimore Complex field from figure 49 is compared with suites of analyses from three well-known ophiolite complexes. There is considerable overlap between the ophiolite suites and the James Run and Baltimore Complex field, but there is also a considerable scatter of points. Nevertheless, the fact that the three ophiolite suites are altered and metamorphosed (Moores and Vine, 1971; Montigny and others, 1973; Mendes, 1976) lends some credence to the comparison.

Perhaps the most important geochemical factors tying the James Run metavolcanic rocks genetically to the Baltimore Complex are the high Cr abundances in the James Run mafic rocks (table 9) and some of the rocks of the complex (Johannsen, 1928; Singewald, 1928; Knopf and Jonas, 1929, p. 120; Southwick, 1970, p. 412). Disseminated and massive chromite deposits have long been known in the basal ultramafic part of the complex (Johannsen, 1928; Singewald, 1928; Mathews and Watson, 1929; Pearre and Heyl, 1960). Nickel and vanadium are also in high abundance in some of the Baltimore Complex rocks (Johannsen, 1928; Southwick, 1970, p. 412) as they are in the James Run mafic rocks (table 9). Unfortunately, no rare-earth element data are available from the Baltimore Complex rocks.

Although all the available geochemical data suggest that the mafic rocks of the James Run Formation are genetically linked to the Baltimore Complex, an apparent geochemical problem is also associated with the hypothesis of a genetic relation between these rocks. The problem is the great volume of felsic and siliceous rocks in the James Run. I estimate that felsic and siliceous rocks make up at least 70 percent of the James Run Formation, taken as a whole throughout Maryland and Delaware, not even including hypabyssal plutons. If the Baltimore Complex is interpreted to be an obducted slab of ancient ocean floor (oceanic crust and mantle), as inferred by Crowley (1976, p. 32-33), then the great volume of felsic and siliceous rocks in the James Run is anomalous. Moreover, abundant data indicates that some of the felsic rocks in the James Run were emplaced in relatively shallow water, and some of the more massive felsic rocks may even have been subaerial flows and subaerial pyroclastic deposits. This is incompatible with any hypothesis requiring both that the James Run rocks and the Baltimore Complex are genetically related and that the Baltimore Complex is obducted ocean floor. There is an alternative, however. All available evidence indicates that the James Run rocks were part of an island arc, and while there is good evidence that the Baltimore Complex was emplaced by thrusting (Crowley, 1976; Morgan, 1977; Fisher and others, 1979; Drake and Morgan, 1981), there is no real evidence that the complex was once oceanic crust. It may have been a pluton that was the remnant of the magma that produced the James Run volcanic rocks, or a piece of back-arc basin crust derived from the same magmas that produced the volcanic rocks.

STRUCTURE

The results of structural studies of the northeastern Maryland Piedmont and adjacent areas in southeastern Pennsylvania have been published by Cloos and Hershey (1936), Jonas (1937), Freedman and others (1964), Lapham and McKague (1964), Southwick (1969), Higgins (1973), and Amenta (1974). All these studies documented multiple deformation in this area. The reader is referred to Higgins (1973)

for a description of the minor structural features in the northeastern Maryland Piedmont.

Major structure

The major regional structural feature of the eastern Maryland Piedmont is the Baltimore-Washington anticlinorium (Fisher, 1963, 1970; Hopson, 1964; Southwick, 1969; Crowley, 1976), a refolded, doubly plunging anticlinorium that extends from the vicinity of Washington, D.C., to central Harford County, Maryland (fig. 1). The anticlinorium is cored by complexly refolded "domes" and nappes (Fisher and others, 1979) of ~1.1 b.y. old Baltimore Gniess. The northeastern end of the anticlinorium is complicated by faulting and by superimposed folding, so that there is no single axial trace or single nose for the major fold (pl. 2). In addition, through most of northeastern Baltimore and southwestern Harford Counties, the southeastern limb of the anticlinorium is covered by the Baltimore Complex thrust sheet (Southwick and Owens, 1968; Crowley and others, 1976; Fisher and others, 1979). Cecil County is located just northeast of the complicated northeastern end of the Baltimore-Washington anticlinorium.

Plate 2 is a generalized geologic map with structural interpretations, that is modified from Southwick and Owens (1968), Crowley (1976, pl. 2), Fisher and others (1979), and plate 1 of this paper. On this map, the Baltimore Complex is shown as thrust upon the diamictites of the Sykesville Formation following Crowley (1976), Morgan (1977), Fisher and others (1979), and Drake and Morgan (1981). The evidence for this interpretation, as summarized by Fisher and others (1979, p. 32-33), consists mainly of the fact that the northwestern contact of the Baltimore Complex places the complex in contact with different units throughout its course (cuts down section in the footwall) and places footwall rocks in contact with successively higher units of the complex (cuts up section in the hanging wall). The presence of clasts of Baltimore Complex rocks in the Sykesville diamictites shows that the complex is not intrusive. The

interpretation shown in plate 2 differs from that of Crowley (1976) and Fisher and others (1979) in showing the ultramafic and mafic-ultramafic rocks that veer westward from the rest of the complex in Harford County bounded on the south by a thrust. The same reasoning used to interpret the northern contact of this largely ultramafic mass as a thrust fault also applies to the southern contact because it also cuts different units within the mass and different units in the footwall (pl. 2; Southwick and Owens, 1968). In addition, the southeastern contact of the Baltimore Complex is shown as a thrust fault along which the James Run Formation, Conowingo diamictite, and pelitic schist units are thrust upon the complex (pl. 2). This thrust also cuts different units in the footwall (Baltimore Complex) and different units in the hanging wall.

The map patterns and other evidence in Cecil County (pl. 1) are compatible with the interpretation, shown in plate 2, that the James Run Formation and the Port Deposit Gneiss are thrust upon the Baltimore Complex, the Conowingo diamictite, the metagraywacke units, and the pelitic schist units (Glenarm). This interpretation is supported by: (1) Some members of the James Run Formation appear to be truncated by this thrust in Cecil County (pls. 1 and 2), and different members of the James Run are in contact with the metagraywacke and pelitic schist units; (2) The Conowingo diamictite melange has sedimented clasts of James Run rocks and Port Deposit Gneiss; (3) The narrow outcrop belt of metagraywacke in northeastern Cecil County appears to have been overridden by the James Run Formation; and (4) Amphibolite dikes and sills that have intruded the James Run Formation and the Port Deposit Gneiss along the Susquehanna River appear to be confined to these units.

Problems still remain in the assignment and nature of the metagraywacke units and the placement of the thrust faults: (1) Are the metagraywacke units (pl. 1) melange beneath the James Run-Port Deposit thrust sheet, with the outliers of Port Deposit Gneiss in the metagraywacke northeast of the main Port Deposit body being sedimented debris rather than intrusive bodies? Or is the Port Deposit intrusive

into the metagraywacke?; (2) If the metagraywackes are a melange, are they part of the Conowingo diamictite melange, or a separate melange that overrode the Conowingo?

Several lines of evidence suggest that the metagraywacke units are melange: (1) In addition to the outliers of Port Deposit Gneiss in the metagraywacke unit (pl. 1), the metagraywacke units contain what may be megaclasts of mafic breccia near College Green and mafic rocks in the northeastern corner of Cecil County near the Delaware State line (pls. 1 and 2); (2) Scattered amphibolites within the metagraywacke unit (and some of the pelitic schist unit as well) may be sedimented debris from the James Run Formation; and (3) The Conowingo diamictite melange contains sedimented clasts of metagraywacke (fig. 62) that are lithic matches of the rocks in the metagraywacke units. These metagraywacke clasts were metamorphosed and deformed prior to incorporation in the melange. The diamictite melange also contains zircons that have yielded radiometric ages of ~1.1 b.y. (Sinha and others, 1971). If the metagraywacke clasts in the diamictite are derived from the metagraywacke units, as they appear to be, then the metagraywacke units must constitute a separate melange and thrust sheet that is structurally stacked above the Conowingo melange. A similar situation exists between the Peters Creek Schist and the Sykesville Formation in northern Virginia (Drake and Morgan, 1981).

Strongly lineated epidiorites and epidote amphibolites underlie a large area southeast of the James Run Formation and Port Deposit Gneiss in Harford County (Southwick and Owens, 1968; pl. 2, this paper). Southwick (1969, p. 61-63) called these rocks "Metagabbro near Aberdeen," but they have more recently (Crowley, 1976; Morgan, 1977) been referred to as Aberdeen metagabbro. Crowley (1976, p. 32, and pl. 2) suggested that the Aberdeen metagabbro might be a thrust sheet. Such an interpretation is shown in plate 2, and the gabbro and serpentinite at Grays Hill are also included in this Aberdeen thrust sheet. With this interpretation, the James Run Formation metavolcanic rocks within the Aberdeen metagabbro outcrop area in Harford County (Southwick and Owens, 1968; pl. 2, this paper) are considered to be

exposed in windows. Alternatively, the "strongly lineated epidiorite and epidote amphibolite" (Southwick and Owens, 1968) may belong to the James Run Formation.

The bulk of the evidence in Cecil and Harford Counties supports the interpretation, given in plate 2, that there are several stacked thrust sheets in this area.

AGE RELATIONS

Interpretations of the ages of the rocks in the Maryland Piedmont (see review in Higgins, 1972) have been dependent upon: (1) correlations with upper Precambrian-lower Paleozoic rocks in the Blue Ridge at South Mountain and Mine Ridge in southeastern Pennsylvania, with lower Paleozoic rocks on the flanks of the West Chester-Avondale-Woodville anticlinorium in southeastern Pennsylvania, with lower Paleozoic rocks in the Hanover-York, Lancaster, and Chester Valleys in southeastern Pennsylvania, with lower Paleozoic rocks in the Valley and Ridge province, and with upper Precambrian flysch sequences in Virginia (Lynchburg Formation) and in the southern Appalachians (Ocoee Supergroup); (2) radiometric ages and their interpretation; and (3) interpretations of the relations between the Maryland Piedmont rocks and the Quantico Formation (formerly Quantico Slate, see Pavlides, 1980) in the northern Virginia Piedmont.

Correlations

Basically, there have been two different views on the correlation and age of the Maryland Piedmont rocks: (1) That the Maryland Piedmont rocks are Precambrian and not correlative with uppermost Precambrian and (or) lower Paleozoic rocks in the Blue Ridge, on the flanks of the West Chester-Avondale-Woodville anticlinorium, in the Martic Hills, in the Hanover-York, Lancaster, and Chester Valleys, or in the Valley and Ridge province (Bascom and others, 1909; Bliss and Jonas, 1916; Bascom and Miller, 1920; Knopf and Jonas, 1922, 1923, 1929a, 1929b; Jonas, 1928, 1929; Jonas and Stose, 1930; Stose and Jonas, 1939; Stose and Stose, 1946, 1948; Hopson, 1964; Southwick, 1969; Fisher, 1970;

Seiders and others, 1975; Rankin, 1975; Seiders, 1976a, 1976b), but essentially correlative with the upper Precambrian Lynchburg Formation in Virginia and the Ocoee Supergroup in the southern Appalachians (Hopson, 1964); and (2) That the Maryland Piedmont rocks are correlative with the uppermost Precambrian and lower Paleozoic rocks to the west (Mathews, 1905; Bascom, 1905; Mathews and Miller, 1905; Miller, 1935; Mackin, 1935; Cloos and Hietanen, 1941; Swartz, 1948; McKinstry, 1961; Higgins, 1972, 1973, 1976a, 1976b; Fisher and others, 1979).

The recognition that many of the rocks in the Maryland Piedmont (including most of the old Wissahickon Formation - now abandoned) are allochthonous (Drake and Morgan, 1981, and references therein) makes most previous correlations untenable. Emphasis must now be placed on times of thrusting and interrelations between different thrust sheets.

Radiometric ages

Numerous radiometric ages have been published from rocks in the Maryland and northern Virginia Piedmont. Compilations of most of the radiometric data published before 1977 were given by Higgins (1972) and Higgins and others (1977).

U-Pb zircon ages and Rb-Sr whole-rock and mineral ages showed that the Baltimore Gneiss went through a period of crystallization about 1 to 1.3 b.y. ago (Tilton and others, 1958; Wetherill and others, 1966, 1968; Tilton and others, 1970), thus defining a maximum age of tectonic emplacement for all of the rocks above the Baltimore Gneiss in the Maryland Piedmont. On the basis of U-Pb analyses, zircons from metavolcanic rocks of the the James Run and Chopawamsic Formations were interpreted to be about 550 m.y. old (Tilton and others, 1970; Higgins and others, 1971), or between 500 and 600 m.y. old (Higgins. 1972). On the basis of U-Pb analyses, zircons from the supposed synkinematic granitic rocks were interpreted to be about 500 m.y. old (Davis and others, 1958; Tilton and others, 1959; Davis and others, 1960; Hopson, 1964; Davis and others, 1965; Wetherill and others, 1966), or between 500 and 600 m.y. old (Higgins, 1972), and zircons from the "late-kinematic" plutons were interpreted to be about

425 to 450 m.y. old (Tilton and others, 1959; Hopson, 1964; Wetherill and others, 1966) -- this age was supported by a Rb-Sr whole-rock age for the Guilford Quartz Monzonite of Hopson (1964).

Since 1972, several radiometric ages have been published that bear on the ages of the rocks in the eastern Maryland Piedmont. Grauert (1973a) dated zircons from the Baltimore Gneiss and interpreted their pattern on a concordia diagram as indicating episodic lead loss about 450 m.y. ago. He also (Grauert, 1973b) dated zircons from the Gunpowder Granite, and found that the data have a lower intercept on a concordia diagram of about 330 m.y. He stated (1973b, p. 290):

> "If Steiger and Hopson's method of interpretation were applied to the new data, the minimum age of crystallization for the euhedral zircons would be considerably lower, about 430 m.y. instead of 500 m.y. It is, however, striking that the age of 330 m.y., given by the lower intersection of the best-fit line with the concordia, nearly coincides with the ages of the Rb-Sr mineral isochrons (biotite, muscovite, feldspars) of three pegmatites determined by Wetherill _et al_ (1966). It is therefore possible that a distinct thermal (and tectonic?) event took place 320-350 m.y. ago."

In another study, Grauert and Wagner (1975) found that detrital Precambrian zircons (about 1.5 b.y. old) in rocks of the Wilmington Complex in Delaware (probably correlative with part of the James Run Formation -- Southwick, 1969; Higgins, 1972) have lower intercepts on a concordia diagram at 441 m.y. They suggested that 440 _ 40 m.y. is the age of the granulite facies metamorphism in the Wilmington area. Seiders and others (1975) dated zircons from two granitic plutons in the northern Virginia Piedmont. One of these plutons, the Dale City Quartz Monzonite, was thought by Seiders and others (1975) to have intruded the Quantico Formation as well as the Chopawamsic Formation.

The other pluton, the Occoquan Granite (Occoquan Adamellite of Seiders and others, 1975) was thought to have intruded the Chopawamsic and Sykesville Formations. Seiders and others (1975) interpreted the zircon ages as indicating an age of 560 m.y. for the two plutons.

The validity of most of the ~550 m.y. zircon ages in the Maryland and northern Virginia Piedmont was questioned by Higgins and others (1977; see also Seiders, 1978, and Zartman, 1978), who showed that there is a possibility that the ages are too old because the zircons may have inherited a component of older radiogenic lead. Muth and others (1979) published the results of Rb-Sr dating of muscovites from two pegmatites in the Potomac River gorge near Washington, D.C. According to Muth and others (1979, p. 349) the pegmatites and associated small granitic bodies,

> "intruded the Wissahickon during the climax of regional metamorphism just after formation of the major early folds and prior to formation of the latest folds and associated crenulation cleavage (Fisher, 1971)."

They concluded (1979, p. 349):

> "They show ages of 469 _ 20 m.y. and 469 _ 12 m.y. The ages may represent the time of intrusion or cooling of the rocks below about 500°C. The pegmatites crosscut the foliation of the Glenarm metasediments, and thus their age places a younger limit on the time of deposition of the series and of high-grade metamorphism in the area."

To the southwest, in the Virginia Piedmont, Pavlides and others (1982) have interpreted U-Pb dates on zircons and Rb-Sr whole-rock and mineral dates as indicating ages of about 410 m.y. for early plutons and 300-325 m.y. for late plutons and dikes that crosscut the latest generation of folds in the area. More recently, A.K. Sinha (oral communication, 1981) has dated zircons from most of the granitic rocks and rocks of the James Run Formation in Maryland (many are the same

rocks for which zircon dates were earlier interpreted as indicating ages of about 550 m.y.) and from felsic differentiates of the Baltimore Complex, and Mose and Nagel (1982) have published Rb-Sr ages for many of the plutonic rocks in the northern Virginia Piedmont. Sinha interprets the U-Pb zircon dates as indicating ages of 480-510 m.y. for the James Run metavolcanic rocks, the Port Deposit Gneiss, the Relay "quartz diorite," and the Baltimore Complex, about 430 m.y. for the gneiss near Elk Mills, and about 330 m.y. for the Gunpowder Granite (also see Sinha and others, 1979). Mose and Nagel (1982) reinterpreted published U-Pb zircon ages from the Occoquan and Dale City plutons as too old because of xenocrystic zircons, and interpreted their Rb-Sr dates as indicating ages of about 500 m.y. for both plutons.

Quantico Formation

In the eastern part of the northern Virginia Piedmont the narrow Quantico syncline is cored with slate of the Quantico Formation and flanked by metavolcanic rocks of the Chopawamsic Formation and finally, on the west, by rocks of the Sykesville Formation (Mixon and others, 1972; Seiders and Mixon, 1980). To the southwest, the metamorphic grade of the Quantico increases and the slate has been transformed to a garnetiferous schist that locally contains staurolite, chloritoid, and sillimanite or kyanite (Pavlides, 1980; Pavlides and others, 1980). For many years, the Quantico was considered to be of Late Ordovician age on the basis of fossils reported by Watson and Powell (1911). Geologic mapping by D.L. Southwick, J.C. Reed, Jr., and R.B. Mixon (Southwick and others, 1971; Mixon and others, 1972; Higgins, 1972, p. 1009) suggested that the sequence from Sykesville diamictites up through the metavolcanic rocks of the Chopawamsic and through the Quantico Formation is conformable and without major faults (Southwick and others, 1971, p. D9). Southwick and others (1971) and Mixon and others (1972) accepted the Late Ordovician age for the Quantico Formation, and a late Precambrian age for the Sykesville diamictite (or "Wissahickon diamictite facies"), and assigned an age

of Cambrian or Ordovician to the Chopawamsic Formation. I suggested (Higgins, 1972) that, in light of what appeared to be an unbroken, conformable sequence, the Quantico should be added to the Glenarm Group (as defined at that time), and would define a minimum age of Late Ordovician for the Glenarm.

Seiders and others (1975) disputed the Ordovician age of the Quantico Formation and the validity of the fossils on which that age was based. They contended that the Dale City Quartz Monzonite, which has a discordant zircon age that they interpreted as an intrusion age of about 560 m.y., intrudes the Quantico (Seiders and others, 1975, p. 492-495) as well as the Chopawamsic. Thus, they concluded that the Quantico predates the Dale City pluton and is no younger than Early Cambrian, thereby placing an Early Cambrian minimum age on the Glenarm Group. I argued (Higgins, 1976a, 1976b) on geologic grounds that such an assignment was erroneous.

Pavlides and others (1980) have shown through excavations of the contact between the Dale City pluton and the Quantico Formation that the Quantico is unconformable upon the Dale City, and that the Quantico was deposited on an erosional surface that had some topographic relief. They considered this unconformable contact to be the same as the unconformable contact that Pavlides (1973, 1976) had earlier shown separates the Quantico from the underlying Chopawamsic Formation in the Fredericksburg, Virginia, area. Even more important, however, Pavlides and others (1980) discovered a suite of fossils in the Quantico Formation no more than 20 m above the basal unconformable contact of the Quantico with the Dale City pluton. The fossils indicate that the Quantico is Ordovician or younger (Pavlides and others, 1980, p. 290), probably Middle Ordovician or younger, and probably correlative with the well-dated Arvonia Slate (Higgins, 1972; Pavlides, 1980; Pavlides and others, 1980). Pavlides and others (1980, p. 290) suggested a Late Ordovician age for the Quantico Formation, as originally assigned by Watson and Powell (1911).

Discussion

All of the available evidence indicates that the Baltimore Complex, the James Run Formation, and the plutons associated with the James Run are allochthonous. Moreover, these rocks supplied detritus to the Sykesville Formation melange. Therefore, the Sykesville Formation must be younger than the Baltimore Complex and the James Run Formation and its associated plutons. Earlier published U-Pb zircon dates were interpreted as indicating ages of about 550 m.y. for the James Run metavolcanic rocks and associated plutons (Tilton and others, 1970; Higgins and others, 1971; Higgins, 1972), but extensive reanalysis by A.K. Sinha (oral communication, 1981) indicates ages of 480 to 510 m.y. for the Baltimore Complex and the James Run Formation and its associated plutons. Thus, the radiometric ages indicate that the Sykesville Formation is at least younger than about 550 m.y., and probably younger than 510 m.y.

Seiders and others (1975) published zircon ages from the Dale City and Occoquan plutons in northern Virginia, indicating intrusion ages of about 560 m.y. Both of these plutons appear to have intruded the Chopawamsic Formation, which has been interpreted as at least partly correlative with the James Run Formation (Southwick and others, 1971; Higgins, 1972; Seiders and others, 1975; Pavlides, 1976, 1980). The Dale City has intruded only the Chopawamsic Formation (Pavlides and others, 1980), but the Occoquan has intruded the Sykesville Formation as well (Drake and Morgan, 1981, p. 504; Drake, written communication, 1982). Therefore, the Chopawamsic must be older than the Dale City and Occoquan plutons, and the Sykesville must be older than the Occoquan. More recent radiometric age dating of the Dale City and Occoquan plutons by Mose and Nagel (1981) indicates ages of about 500 m.y. for these rocks (494 _ 14 m.y. for the Occoquan).

The radiometric ages and geologic relations in Maryland indicate that the Sykesville Formation is younger than 480-510 m.y., and that the James Run Formation is 480-510 m.y. old, whereas radiometric ages and geologic relations in northern Virginia indicate that both the Sykesville and Chopawamsic Formations are older than about 495 m.y. Moreover, geologic relations in northern Virginia indicate that the

Chopawamsic must be older than the Sykesville, and additionally, that the Chopawamsic rocks were metamorphosed and deformed before the Sykesville was deposited (Drake and Morgan, 1981; Drake and Lyttle, 1981; Drake, written communication, 1982). Therefore, one or both sets of radiometric data are wrong, or the Chopawamsic and James Run Formations are not strictly correlative, or the Chopawamsic and James Run are about 510 m.y. old, the Sykesville is about 500 m.y. old, and the Occoquan pluton is about 495 m.y. old. The last possibility would require that geologic events took place at a very rapid rate in the eastern Maryland and northern Virginia Piedmont (also see Pavlides and others, 1980, and Mose and Nagel, 1982). If Sinha's 480-510 m.y. zircon ages for the James Run are correct and are crystallization ages rather than reset metamorphic ages, then the James Run would have to have been metamorphosed and deformed, and thrust along with the Baltimore Complex in the time period between about 510 and 500 m.y.

Confirmation of the Late Ordovician age of the Quantico Formation and documentation of its unconformable relation to the underlying rocks (Pavlides and others, 1980) coupled with the age determination of 469 _ 20 m.y. for pegmatites associated with late granitic rocks that have intruded metasedimentary rocks in the Potomac River gorge (Muth and others, 1979) poses a real problem for interpretation of the times of metamorphism and deformation in the Maryland and northern Virginia Piedmont. Muth and others (1979, p. 350) concluded that "sillimanite-grade metamorphism and at least two episodes of deformation took place before 469 _ 20 m.y. ago." Most time-scales (Holmes, 1959; Geological Society of London Phanerozoic time-scale, 1964; U.S. Geological Survey time-scale, 1981; Salvadore, 1985*) indicate that: 489 m.y. (469 + 20 m.y.) is Early Ordovician, or at about the boundary between Early and Middle Ordovician; 469 m.y. (no _) is Middle or

* Since this paper was written, in 1981, three new time-scales have been published: (Harland and others, 1982; Palmer, 1983; Salvadore, 1985). None of these new time-scales significantly alters the ages used here.

early Late Ordovician, or at about the boundary between Middle and Late Ordovician; and 449 m.y. (469 - 20 m.y.) is Late Ordovician. However, the Upper Ordovician Quantico Formation has locally been metamorphosed to sillimanite-grade and folded into the major regional Quantico syncline that has been modified by subsequent folding (Southwick and others, 1971; Higgins, 1972, 1976a, 1976b; Mixon and others, 1972; Seiders and others, 1975; Pavlides, 1976, 1980, and oral communication, 1981; Pavlides and others, 1980).

The Late Ordovician age of the Quantico Formation is well established on faunal evidence and is in agreement with faunal ages from the correlative Arvonia Slate (Darton, 1892; Stose and Stose, 1948; Applegate, 1955; Tillman, 1970; Pavlides and others, 1980). Therefore, the possibilities are that the 469 _ 20 m.y. age for the pegmatites is in error, or the time-scales are incorrect for this part of the Paleozoic, or the interpretation that the pegmatites are related to the late granitic intrusives and postdate the sillimanite-grade metamorphism and deformation is in error. At any rate, the Upper Ordovician Quantico Formation has been metamorphosed to amphibolite facies grades and folded at least twice. This is conclusive evidence that high-grade metamorphism and deformation occurred after Late Ordovician time in the northern Virginia Piedmont and probably in the Maryland Piedmont as well.

Pavlides and others (1982) obtained radiometric ages (U-Pb and Rb-Sr) of about 410 m.y. from a plutonic rock that had been metamorphosed and folded twice along with the Quantico Formation, and ages of about 330 m.y. from plutons that postdate folding and metamorphism. He concluded that the last major metamorphism and deformation in the area took place between 410 and 330 m.y. ago. These ages are virtually identical to ages from the Maryland and Delaware Piedmont. Both Grauert (1973b) and A.K. Sinha (oral communication, 1981) found zircon ages of about 330 m.y. from the Gunpowder Granite in Maryland, and Grauert (1973b) showed that published ages from undeformed pegmatites could be interpreted as indicating an event 320-350 m.y. ago (also see Higgins, 1973, p. 186-187). Grauert and Wagner (1975) found zircon

ages suggesting that granulite facies metamorphism in Delaware took place about 440 _ 40 m.y. ago, and A.K. Sinha (oral communication, 1981) found zircon ages of about 430 m.y. from the gneiss near Elk Mills. These ages are also similar to the 425-450 m.y. ages from "late-synkinematic" granitic plutons in the Maryland Piedmont (Tilton and others, 1959; Hopson, 1964; Wetherill and others, 1966). Thus, all available geologic and radiometric evidence indicates that the last metamorphism and deformation in the central Appalachian Piedmont took place between about 440 and 330 m.y. ago.

SUMMARY AND CONCLUSIONS

In the Maryland Piedmont, an ~1.1 b.y. old "basement complex," known as the Baltimore Gneiss, is unconformably overlain by the Setters Formation consisting of potassium-rich micaceous quartzite, quartz schist, and lesser amounts of pelitic rocks and metaconglomerate. Conformably overlying the Setters is a unit composed of a variety of metamorphosed carbonate rocks called the Cockeysville Marble. The Cockeysville is conformably overlain by a sequence of pelitic rocks that includes the Loch Raven Schist and much of the Oella Formation in Baltimore County, and unnamed schist and metagraywacke-schist sequences in Harford and Cecil Counties. The Setters Formation, Cockeysville Marble, and the part of the pelitic sequence appear to be autochthonous and make up the redefined Glenarm Group.

Structurally above the autochthonous Glenarm Group is a sequence of allochthonous stacked thrust sheets and associated melanges. In Cecil County, this sequence is composed of the Sykesville Formation melange, the Baltimore Complex thrust sheet, the Conowingo diamictite melange, an unnamed metagraywacke-schist melange, the James Run-Port Deposit thrust sheet, and the Aberdeen metagabbro thrust sheet.

Structurally lowest allochthonous rocks in Cecil County constitute the Sykesville Formation melange composed of a thick sequence of diamictite with abundant sedimented clasts from the overlying Baltimore Complex thrust sheet, and less abundant clasts from the James Run-Port Deposit thrust sheet. The Sykesville is interpreted as

olistostromal, and the submarine slides may have been triggered by arrival of the structurally overlying stack of thrust sheets and melanges.

In northeastern Maryland, the Sykesville melange is structurally overlain by the Baltimore Complex thrust sheet. This thrust sheet is composed almost entirely of the Baltimore Complex, a thick sequence of mafic and ultramafic rocks that has been interpreted as an ophiolite by some workers.

In Cecil and Harford Counties, the Baltimore Complex thrust sheet is locally overlain structurally by a thick sequence of diamictite melange, called the Conowingo diamictite, that is interpreted to include the zone of mixed rocks (mafic zone of this paper), including "quartz gabbros and quartz diorites," that has previously been considered part of the Baltimore Complex. The Conowingo diamictite contains sedimented debris from all the structurally higher thrust sheets and melanges and is considered a precursory melange to the stack of higher sheets.

Locally, a unit of metagraywacke and schist is present structurally beneath the James Run-Port Deposit thrust sheet. This unit contains sparse detritus, which is interpreted as derived from the overlying thrust sheet and which also may be melange.

In the James Run-Port Deposit thrust sheet, the James Run Formation consists of as much as 4,000 m of metavolcanic, metasubvolcanic, metavolcaniclastic, and metavolcanic-epiclastic rocks ranging in composition from basalt through rhyolite. Size and percentage of amygdules in pillow basalts and relict accretionary lapilli indicate that some of these rocks were deposited or emplaced in shallow water, whereas pumice lapilli and the massive character of other rocks in the sequence suggest subaerial deposition. All geologic evidence suggests that the James Run rocks formed in an island-arc environment.

Several metamorphosed granitic plutons are closely associated with the James Run Formation -- the largest of these is the Port Deposit Gneiss in Cecil and Harford Counties, Maryland. These plutons have radiometric ages that are the same as those of the James Run

metavolcanic rocks, and their chemical compositions partly overlap those of the metavolcanic rocks. Moreover, they locally have finer grained phases that appear to grade into James Run metavolcanic rocks. All available evidence indicates that the plutons are shallow, hypabyssal intrusives that were the sources for some of the James Run rocks.

The mafic rocks in the James Run Formation have geochemical characteristics of primitive magmas that probably crystallized during a late cumulus stage of differentiation. Trace-element abundances suggest that the James Run rocks are genetically linked with the Baltimore Complex. The Baltimore Complex was probably derived from a sub-arc magma.

Earlier radiometric ages of zircons from the Port Deposit Gneiss and metavolcanic rocks of the James Run Formation suggested ages of about 550 m.y., but extensive redating by A.K. Sinha suggests ages of about 480 to 510 m.y. for these rocks and the Baltimore Complex as well. Therefore, the structurally lower melanges, which contain sedimented debris from the James Run Formation, Port Deposit Gneiss, and Baltimore Complex, must be younger than about 510 m.y.

The highest thrust sheet exposed in Cecil and Harford Counties is composed of lineated epidiorite and epidote amphibolite collectively called the Aberdeen metagabbro and the gabbro and serpentinite at Grays Hill.

In northern Virginia, the Sykesville Formation and the Chopawamsic Formation, which is considered correlative with the James Run Formation, have both been intruded by the Occoquan Granite. Recent Rb-Sr age dating suggests that the Occoquan is about 495 m.y. old. If this age and the 480-510 m.y. ages from the James Run Formation, Port Deposit pluton, and Baltimore Complex are correct, it means that deposition of the Sykesville Formation in northern Virginia took place between 510 and 495 m.y. ago, and that the James Run, Port Deposit Gneiss, and Baltimore Complex must have been metamorphosed, deformed, and thrust during this same short time period. Moreover, the Chopawamsic Formation in northern Virginia is unconformably overlain by the

Quantico Formation, which has yielded Late Ordovician fossils, but has been multiply folded and locally metamorphosed to sillimanite grade. All available geologic and radiometric evidence indicates that the last metamorphism and deformation in the Maryland and northern Virginia Piedmont took place between about 440 and 330 m.y. ago.

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REFERENCE 16

FILE MEMO

Name: Dennis Papa
Date: Oct. 4, 1988
Time: 09:30
File No.: 5065.5.9
Subject: inclusion of waste fuel oil in Hazard Ranking Scores

Persons Contacted:

Name: Michele Mrozek
Company: Mitre Corporation
Phone: 522-8802

Name:
Company:
Phone:

Comments:

Mrozek stated that fuel oil, even waste fuel oil, is not scoreable under HRS. It may be scored if there is proof that the oil was "adulterated" - combined with another hazardous substance when disposed. As a result, waste oil pits do not need to be scored.

Action Required:

Distribution:

REFERENCE 17

FILE MEMO

Name: Dennis Papa
Date: 10/4/88
Time: 3:10 PM
File No. 5065.5.9
Subject: irrigation of farm land near Bainbridge NTC

Persons Contacted:

Name	Eric Webberking	Name	
Company	Cecil County Soil Conservation	Company	
Phone	(301) 398-2482	Phone	

Comments:

- farm land near Bainbridge or the entire northern Maryland area is not irrigated by surface water from the Susquehanna River, due in part to the steep gradients from the river to the upland farms, which would require a powerful pump. Farm land is generally not irrigated in the region.

Action Required:

Distribution: