Expert Witness Report
of
Dr. Timothy D. Bechtel

Dr. Timothy Bechtel, Geophysics, Staff Associate, TETHYS Consultants, Inc., will testify as to the migration offsite of contaminants in the groundwater from the landfill and the use of groundwater background levels that are not representative of uncontaminated groundwater.

I. Basis for Report

I have completed a review of available hydrogeologic data concerning Modern Sanitation Landfill (Modern Landfill or the "site") in York County, Pennsylvania. The purpose of the review was to evaluate the potential impact of the landfill on the regional ground water system -- particularly the ground water beneath the 17 acre northern expansion, and the ground water used by local residents. The following report does not attempt to present a comprehensive summary of the local hydrogeologic conditions of history -- such summaries are contained in many public record documents (see below). Instead, this report addresses three geologic and hydrogeologic issues that have been questioned by local residents and/or (in my opinion) have been inadequately addressed in previous studies and comments/responses by PADER and USEPA (note: please refer to Appendix A for definitions of these and other acronyms used throughout the following report.

The hydrogeologic evaluation on which this report is based included a site inspection on May 19, 1992, review of PAGS and USGS maps and publications, and review of voluminous reports and correspondence concerning the site contained in the PADER Harrisburg Regional Office files and the USEPA Administrative Record File (ARF) available at the Windsor Township Municipal Building. These documents included (but were not limited to); studies by REWAI, AGES and GAI dated 1982 through 1991 concerning the local and regional geology and hydrogeology, and the design, construction, and performance of the eastern and western ground water/leachate collection systems; workplans and studies between 1982 and 1991 by EEI, NUS, GAI, and ICF during the federal Superfund process (i.e., PA, NPL rating and listing and RI/FS); the Phase I and II Permit Modification applications for both the northern and southwest expansions prepared by WMNA and dated 1989 and 1990, respectively; and written or transcribed public comments on the permit modification applications and USEPA RI/FS. These documents and correspondence are too numerous to list or reference individually in this report. For complete references, please refer to the ARF Index of Documents and the bibliography of Modern Landfill Studies contained in the 1986 Remedial Action Master Plan by EEI (contained in the ARF).

Following review of the available information on Modern Landfill, I have identified three principle interrelated issues that are addressed in this report: (1) the location of a reported fault (or faults) beneath the landfill and its possible effects on both the offsite migration of ground water contamination, and the stability and integrity of the landfill structure in the presence of expected seismic activity; (2) the possibility of past and/or ongoing northward migration of ground water contamination beneath the northern expansion; (3) the ubiquitously cited, yet poorly defined "background" ground water quality in the vicinity of the site. These issues are discussed in detail below.

II. Groundwater Flow

There appears to be a WSW-ENE trending high permeability zone crossing the southern end of the Modern Landfill site. Such a zone does not appear on the maps depicting the areal distribution of subsurface permeabilities based on direct borehole permeability measurements (e.g., Figures 4-20 and 4-21 of the 1990 Phase I RI Report), but there are several empirical indications of a high permeability zone.

The first indication of a high permeability zone is simply the presence of the deep saprolite zone, a linear zone of deep weathering. The Harpers Formation phyllite through which the feature extends weathers chemically -- a process which involves removal of certain ions from the original rock forming minerals. The ions are removed by infiltration or flowing groundwater, and the weathering product or saprolite is generally more permeable than the original rock. Simply, the presence of a deep saprolite zone suggests a pre-existing zone of higher permeability rock which was subject to chemical weathering, therefore becoming more permeable, leading to increased weathering, etc. The RI/FS studies concluded that the deep saprolite zone is the result of a lens or bed of more soluble (higher calcium) phyllite rather than the previous mapped Ore Valley fault, but as described above, the resulting hydrogeologic effects are comparable.

A corollary argument for the presence of a high permeability zone is the reported presence of former ore pits beneath the southern portion of the landfill. The inferred ore deposits would most likely have formed close to fault lines or other zones of high permeability where ores would precipitate out of circulating ground water. However, it is possible that the ores developed millions of years ago, and the associated zones of high permeability were sealed through later metamorphism or deformation.

The second indication of a high permeability zone is the recent trend in ground water quality along the trace of the deep saprolite zone. In particular, wells MD125 (east of the landfill) and W07 (west of the landfill) have historically shown high and generally increasing levels of several leachate-characteristic chlorinated VOCs, while nearby wells register decreasing or non-detectable levels (see e.g., Table 9 and Figures 13 through 16 of the 1990 Groundwater Extraction System Annual Assessment). This indicates migration of leachate eastward and westward from the landfill in a distinct narrow zone.

Hydraulic conductivities for many wells were measured using various methods at various depth intervals during the RI/FS study (see Table 4-6 of the 1990 Phase I RI Report). For MD125, a single measurement was performed using a rising head test in the depth interval 83 to 42 feet below grade. The resulting conductivity of 2.3E-07 centimeters per second (cm/s) is very low. However, a step test on the stratigraphically wider and deeper 19 to 96 foot interval in W07 yielded a much higher conductivity of 4.8E-04 cm/s, and a packer test in the narrow and very deep interval of 136 to 109 feet in core hole 316 (in the deep saprolite zone on the east side of the landfill) yielded a remarkably high conductivity of 1.1E-03 cm/s. This result is particularly interesting when compared to the results for both shallower and deeper zones in core hole 316 that show much lower conductivities between 5.8E-05 cm/s and 6.6E-07 cm/s.

These results indicate that there are probably relatively narrow (tens of feet or less) zones of surprisingly high permeability (e.g., 1E-03 cm/s) at surprising depths (greater than 100 feet -- despite the fact that one of the overall conclusions of the RI/FS studies was that ground water flow is restricted to depths above 100 feet). In particular, there appears to be a zone or zones of high permeability in and beneath the deep saprolite zone near the southern end of the landfill.

If this zone (whether it is actually a fault or a bed of differing composition and therefore more highly weathered) is extrapolated eastward along strike, it passes within several hundred feet of the Jan Wright, Richard Doering, Timothy Klunk, and James Smith residential wells at distances from the landfill of less than one mile. Tests of these four wells have at various times since 1982 detected levels of many of the same chlorinated

VOCs considered characteristic of Modern landfill leachate and its breakdown products (TCE, Perc, 1,1,1-TCA, 1,1-DCA and Chloroform) as detected in many wells within and immediately adjacent to the landfill.

Although Mr. Smith in particular has long contended that the contamination of his well is caused by eastward migration of landfill leachate, PaDER and USEPA have dismissed his claims based on the observations that; 1) his well is southeast and therefore apparently somewhat upgradient (although mostly crossgradient) from the landfill based on current water table mapping; 2) his well is on the opposite side of a tributary of Kreutz Creek which supposedly acts as a discharge point for the local ground water and is therefore a hydrogeologic barrier; and 3) the eastern ground water extraction system (installed in 1986) now captures any eastward flow of ground water.

Assertion 3 above is almost certainly true, and is not disputed here. However, assertions 1 and 2 can be disputed, and assertion 3, though true, does not eliminate the possibility that a portion of the leachate plume migrated eastward prior to start-up of the extraction system in 1986, and was (and remains) beyond the capture zone of the system. Concerning assertion 1 that the Smith well is southeast of and therefore upgradient from the site, the definition of upgradient has a long and well documented history of revision in the vicinity of Modern Landfill. The undeniably contaminated wells MD125 and B-15, and the former Druck and Brown residential wells are all southeast of the landfill and have all at various times been asserted to be upgradient of the landfill. In addition, the current water table mapping (as depicted on the ground water contour maps in Appendix B) uses only the wells that are screened in the upper part of the aquifer and therefore may not reflect deeper flow patterns. Although numerous well couplets at various locations have been used to gain insight into vertical hydraulic gradients and associated deeper flow patters (see Table 4-7, 1990 Phase I RI Report), none of these data were collected southeast of the landfill, so deep flow there is poorly constrained.

Concerning assertion 2 above (that the Smith well is isolated from the landfill by the eastern tributary of Kreutz Creek), the possibility of deep ground water flow beneath the Kreutz Creek tributaries could be tested by performing stream flow measurements at gauging stations along both tributaries and doing a water balance calculation based on measured precipitation and mapped drainage areas. This calculation was not performed as part of any of the studies available in the files reviewed. In the absence of that calculation, ground water flow beneath the tributaries is empirically demonstrated by several wells that have clearly shown leachate contamination on the far sides of both the eastern (MD133, MD137) and western (MD106, C04, C09) tributaries (see Table 9 of the 1990 Groundwater Extraction System Annual Assessment). All of these wells show contamination by some or all of the same chemicals detected in the Smith and neighboring wells.

The possibility of contamination of the Smith and neighboring wells by Modern Landfill is also supported by the apparent presence of deep zones with conductivities approaching 1E-03 cm/s as described above. Assuming this conductivity and using the measured distance to the Smith well, it could take less than five days for leachate to flow from the landfill to the Smith Well. Assuming that this is actually a maximum conductivity, and that conductivities on the order of 1E-04 cm/s are more likely, it would take just under 50 years for contamination to reach the Smith property. Interestingly, this is also the age of the landfill.

No ground water quality data for wells further east than MD125 along the high permeability zone were found in the files reviewed for this study. In addition, a visual inspection of the area around the Smith property revealed no other nearby or obvious upgradient sources (the Smith property is near the top of a hill) for the observed VOC contamination. Therefore, continued migration of leachate eastward towards the Smith property and environs, and possibly westward past W07 (although no residential wells have been impacted in that direction) is possible.

III. Contaminant Detection Beneath the Northern Expansion

The ability to detect leakage from the northern expansion of Modern Landfill depends on the establishment of background or the expected ground water quality immediately downgradient from the northern expansion in the absence of leaks. The following discussion addresses the expected background conditions specifically beneath the 17 acre northern expansion -- although it is not an entirely separate issue from the overall, regional background relative to Modern Landfill as a whole as described in the following section.

Prior to installation of the eastern and western ground water extraction systems, early hydrogeologic studies of the site indicated that ground water flow directions were driven primarily by topography, with some discrepancies due to the presence of higher permeability joints or fractures. Overall, the regional gradient was generally to the northeast. Therefore, contaminants from the original unlined portion of the landfill would have flowed beneath the current boundaries of the northern expansion.

Installation of the western ground water interceptor trench (1977), the western extraction system wells (1985, augmented 1987), and the eastern extraction system wells (1986) have dramatically altered the original flow as depicted on the enclosed maps (from the 1990 Groundwater Extraction System Annual Assessment). The purpose of the alteration is to capture any contamination originating beneath the unlined portion of the landfill. However, examination of the ground water contour maps suggests that the extraction systems cannot possibly be capturing all of the northward flow. Ground water that flows along the ridge defined by the contours can escape directly north beneath the 17 acre expansion without being pulled to the east or west. This is depicted on the April, 1989 and September, 1990 ground water contour maps in Appendix C (from the 1990 Groundwater Extraction System Annual Assessment). Flow paths for several water particles have been sketched (dashed lines) by directing the path to be perpendicular to each contour that it crosses (a physical necessity). It can be seen that ground water which has passed for relatively great distances beneath the unlined landfill (thereby picking up leachate components) must flow beneath the 17-acre northern expansion.

The possibility for ground water to bypass the extraction systems to the north was recognized in the 1990 Phase I RI study based primarily on the continued detection of leachate contaminants in MD111 (outside the northern end of the western extraction system) and MD120 (inside, but slightly north of the eastern extraction system). In response, MD120 was added to the eastern extraction system in 1990 and redesignated as W60.

A June, 1991 Appendix to the 1990 Ground Water Extraction System Annual Assessment evaluated the effectiveness of W60 and explored possible enhancement strategies for the western system. This study did contain the results of ground water flow path modelling as shown on the capture zone simulations enclosed in Appendix C. Figures A-9 and A-10 (from the above-referenced June, 1991 Report, and Appendix C of this report) depict the capture zones for the northernmost extraction wells. Note that these capture zones are based on the actual construction and pumping rate for W60, but for B20, the capture zones are based on a proposed deepening and enhanced pumping rate. Therefore, the actual capture zone for B20 may in realty be considerably smaller. Note also that even the five year capture zones leave a narrow flow path from beneath the unlined landfill to the 17 acre northern expansion. Interestingly, well MD115D (the closest well to this predicted northern escape route) has, in fact, tested positively for leachate VOCs on five separate occasions.

Additional wells to the north have not detected leachate VOCs, but this is not inconsistent with the hydrogeologic data. Although the northward escape route flow paths apparently exist, both the reported hydraulic gradient (less than 5E-02) and conductivity (less than 1E-06 cm/s) are low along these paths indicating long travel times.

The possibility that contamination from the unlined portion of the landfill may eventually appear beneath the 17 acre northern expansion indicates that monitoring of the northern expansion may become ambiguous. Should the 17 acre expansion leak and leachate compounds appear in the MD200-series downgradient wells, an argument could be made using the available data (as was done above) that the compounds do not indicate a leak, but are the result of migration from beneath the old unlined portion of the landfill. Alternatively, the expansion could never suffer a leak, but would appear to if leachate escapes the extraction systems along the northerly flow paths.

IV. <u>"Background" Ground Water Quality</u>

In the Permit Modification Application for the 17-acre northern expansion, well MU101 south of the landfill is listed on Form 19 as the upgradient well. Therefore, MU101 should be free from any contamination related to the landfill. MU101 (and other upgradient wells) have commonly been classified as uncontaminated since they do not (or rarely) contain compounds above drinking water standards (MCLs or SMCLs). However, MU101 does contain inorganic compounds and elements, and displays physical properties that while not always exceeding MCLs or SMCLs do exceed published background values for water from the same geologic formation in other portions of central and southern York County. Table I lists the formation averages published by Lloyd and Growitz (1977, PAGS Water Resources Report 42) for the Harpers (the formation in which MU101 is installed) and the Antietam (the formation in which the MD200-series monitoring wells for the northern expansion are installed), and recent quarterly sampling results for MU101 (<u>see</u> Form 19 of the Permit Modification Application for the northern expansion). The values for each formation from the PAGS publication are averages for a minimum of 15 ground water samples. In the table, please note that values for the formation averages are total concentrations (where applicable) and values for MU101 are dissolved concentrations (where applicable). This means that the

MU101 concentrations should be considered as minimum values when comparing them to the formation averages.

Comparison of the MU101 data to the formation averages for the Harpers (the host rock) shows that MU101 generally displays elevated values for all parameters except pH, iron and nitrate (elevated values are in bold type). Manganese, sodium, chloride, and specific conductance are particularly elevated. Elevated manganese levels have been detected in several upgradient wells, but these levels were casually dismissed in the Phase I RI as being due to the presence of naturally occurring dendritic manganese oxides in the Harpers Formation. This assertion may be true, but has not been supported with whole rock chemical analyses, mineralogical descriptions, or other data. Elevated sodium, and particularly chloride and specific conductance values are commonly indicative of landfill leachate, but could simply be the result of roadway de-icing on nearby Prospect Road. However, other wells along Prospect Road do not show similar values. Instead, most other wells with elevated chloride levels are all between the old unlined landfill and the western ground water extraction system. Therefore this seems to suggest a component of landfill leachate in MU101.

It might be argued that since no chlorinated VOCs have been detected in MU101 it is not contaminated. However, a comparison of the inorganic chemistries of other nearby wells that were formerly considered to be upgradient but are now classified as contaminated due to the detection of VOCs, reveals that the inorganic chemistry of MU101 more closely resembles these contaminated wells than the formation averages. Table II (<u>see</u> Appendix B) lists the formation averages and the comparable parameters for the clearly contaminated Druck, Brown (hand dug), and B-15 wells (from a 1982 hydrogeologic study by AGES). As with Table I (<u>see</u> Appendix B), elevated levels (relative to the formation averages) are in bold type. These wells were closer to the landfill (or the contemporary boundary of the landfill) but were still considered to be upgradient from the landfill prior to these (and other) chemical analyses which showed VOC contamination.

Therefore, although the upgradient well MU101 has thus far not contained detectable VOCs, it has displayed an inorganic chemistry more similar to nearby contaminated wells that were formerly considered to be upgradient than to the formation average chemistry for central and southern York County. It could be argued that these results indicate that Modern Landfill happens to lie in a region with low grade, pre-existing (<u>i.e.</u>, unrelated to Modern) inorganic contamination. However, there is no regional data to support that assertion, and it relies on a remarkable coincidence.

If MU101 does contain inorganic contamination associated with Modern Landfill leachate, there are two implications. First, it indicates that there is at least a local and/or intermittent component of ground water flow to the south at some depth. This implies the possibility for present and/or future organic contamination in areas now considered to be upgradient (such as the Smith well). Second it adds a further potential ambiguity to monitoring of the 17-acre northern expansion. If analytical results from the MD200-series wells are compared to those from MU101, inorganic (and potentially future organic) contamination could appear in the downgradient wells without exceeding the background as defined by MU101.

Dr. Timothy D. Bechtel

APPENDICES

APPENDIX A. Definitions of Acronyms

APPENDIX B.

TABLE I. Background Water Chemistry Data, Modern Landfill Northern Expansion

TABLE II. Former Background Water Chemistry Data, Modern Landfill

APPENDIX C. Figure 3 and Figure 4, Ground Water Contour Maps

APPENDIX A

DEFINITIONS OF ACRONYMS

DEFINITIONS OF ACRONYMS

AGES	Applied Geotechnical and Environmental Service Corp.
ARF	Administrative Record File
DCA	Dichloroethane
EEI	Ecology and Environment, Inc.
FIT	Field Investigation Team
FS	Feasibility Study
GAI	Golder Associates, Inc.
ICF	ICF Technology Corp.
MCL	Maximum Contaminant Level (Primary Federal Standard)
NPL	National Priorities List (Superfund List)
NUS	NUS Corp.
PA	Preliminary Assessment
PADER	Pennsylvania Department of Environmental Resources
PAGS	Pennsylvania Geological Survey
Perc	Tetrachloroethylene (also called Perchloroethylene)
REWAI	R. E. Wright Associates, Inc.
RI	Remedial Investigation
SMCL	Secondary Maximum Contaminant Level (Federal Standard)
TCA	Trichloroethane
TCE	Trichloroethylene
TCI	TETHYS CONSULTANTS, INC.
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Chemical
WMNA	Waste Management of North America, Inc.

APPENDIX B

TABLE I. Background Water Chemistry Data Modern Landfill Northern Expansion

TABLE II. Former Background Water Chemistry Data, Modern Landfill

Table I
Background Water Chemistry Data
Modern Landfill Northern Expansion

Parameter	Formation Avg.* Harpers	Formation Avg.* Antietam	MU101 Sampling Events** 11/20/86	6/10/87	9/16/87	12/11/87	3/10/88	6/3/88	1089
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Fe	0.07	0.02	ND	0.04	0.037	ND	0.022	ND	
Mn	0.05	0.03	0.7	0.4	0.859	0.475	0.4	0.26	
Ca	22	24	NT	NT	54.1	NT	NT	NT	
Mg	7.9	5.6	20	6.2	13.7	NT	NT	NT	
Na	11	6.8	46	35	66.2	76.6	70.2	75	
K	1.6	3.2	2	1.9	2.5	NT	NT	NT	
HCO3	21	68	NT	NT	NT	NT	NT	NT	
SO4	8.5	25	3	16	NT	NT	NT	NT	
CL	20	11	117	62.8	176	164	152	143	183.5
NO3	10.8	18	1.03	0.9	1.6	2.2	1.9	1.6	
F	0.1	0.1	ND	0.2	NT	NT	NT	NT	
PO4	0.02	0.17	NT	NT	NT	NT	NT	NT	
Hardness	85	50	140	58	NT	NT	NT	NT	
	(mM)	(mM)	(mM)	(mM)	(mM)	(mM)	(mM)	(mM)	(mM)
Sp. Cond.	220	185	584	1004	733	901	925	1007	
	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)
pH	6	6	6.75	6.76	6.71	6.8	6.6	6.59	

* Total Values Listed (where applicable)

** Dissolved Values Listed (where applicable)

ND -- Not Detected

NT -- Not Tested

Table II

Former Background Water Chemistry Data

Modern Landfill

Parameter	Formation Avg.* Harpers	Antietam	B-15** 1/27/81	B-15** 2/11/82	B-15** 2/25/82	Brown** 2/11/82	Druck** 2/25/82
	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
Fe	0.07	0.02	6.1	0.26	1.21	0.92	0.14
Mn	0.05	0.03	0.56	NT	NT	NT	NT
Ca	22	24	NT	NT	NT	NT	NT
Mg	7.9	5.6	NT	NT	NT	NT	NT
Na	11	6.8	NT	0.69	48.9	27.6	13.3
K	1.6	3.2	NT	NT	NT	NT	NT
HCO3	21	68	NT	NT	NT	NT	NT
SO4	8.5	25	1	16	9	15	NT
CL	20	11	73.4	76	79	59	37
NO3	10.8	18	NT	NT	NT	NT	NT
F	0.1	0.1	NT	NT	NT	NT	NT
PO4	0.02	0.17	NT	NT	NT	NT	NT
Hardness	85	50	NT	NT	NT	NT	NT
	(mM)	(mM)	(mM)	(mM)	(mM)	(mM)	(mM)
Sp. Cond.	220	185	960	820	730	290	250
	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)	(pH units)
pH	6	6	6.8	7.05	6.67	6.82	6.95

* Total Values Listed (where applicable)

** Total or Dissolved Not Specified

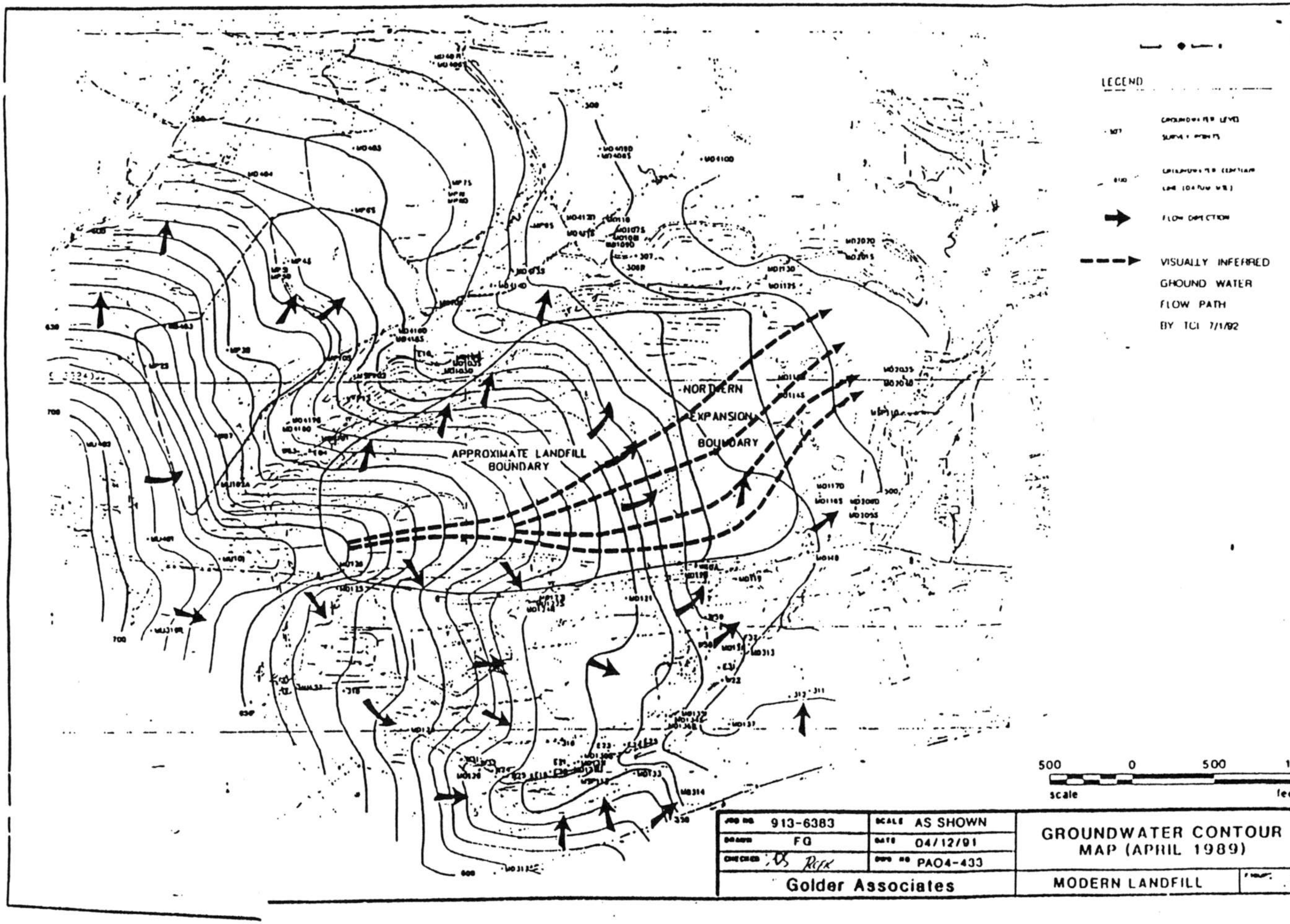
ND -- Not Detected

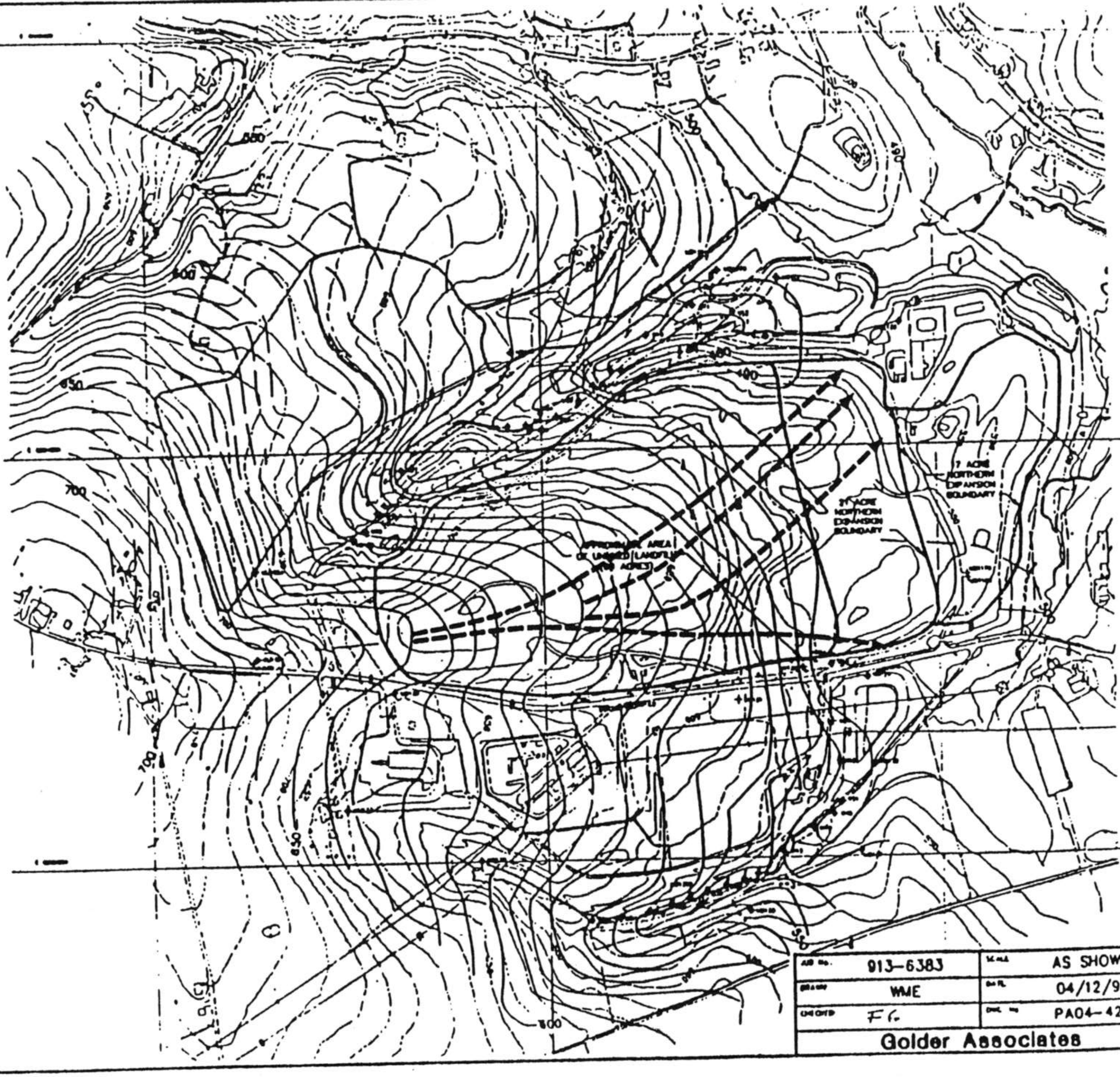
NT -- Not Tested

APPENDIX C

Figure 3 and 4, Ground Water Contour Maps

Figure A-9 and Figure A-10, Capture Zone Simulations


NORTHERN EXPANSION BOUNDARY
APPROXIMATE LANDFILL BOUNDARY
LEGEND
FLOW DIRECTION
VISUALLY INFERRED GROUND WATER FLOW PATH BY TCI 7/1/92
500 0 500
scale
feet
913-6383
AS SHOWN
FQ
04/12/91
PAO4-433
Golder Associates
GROUNDWATER CONTOUR MAP (APRIL 1989)
MODERN LANDFILL



LEGEND

GROUNDWATER SURVEY POINT

800 — GROUNDWATER CONTOUR DATUM MSL, DASHED WH[ERE] INFERRED

FLOW DIRECTION

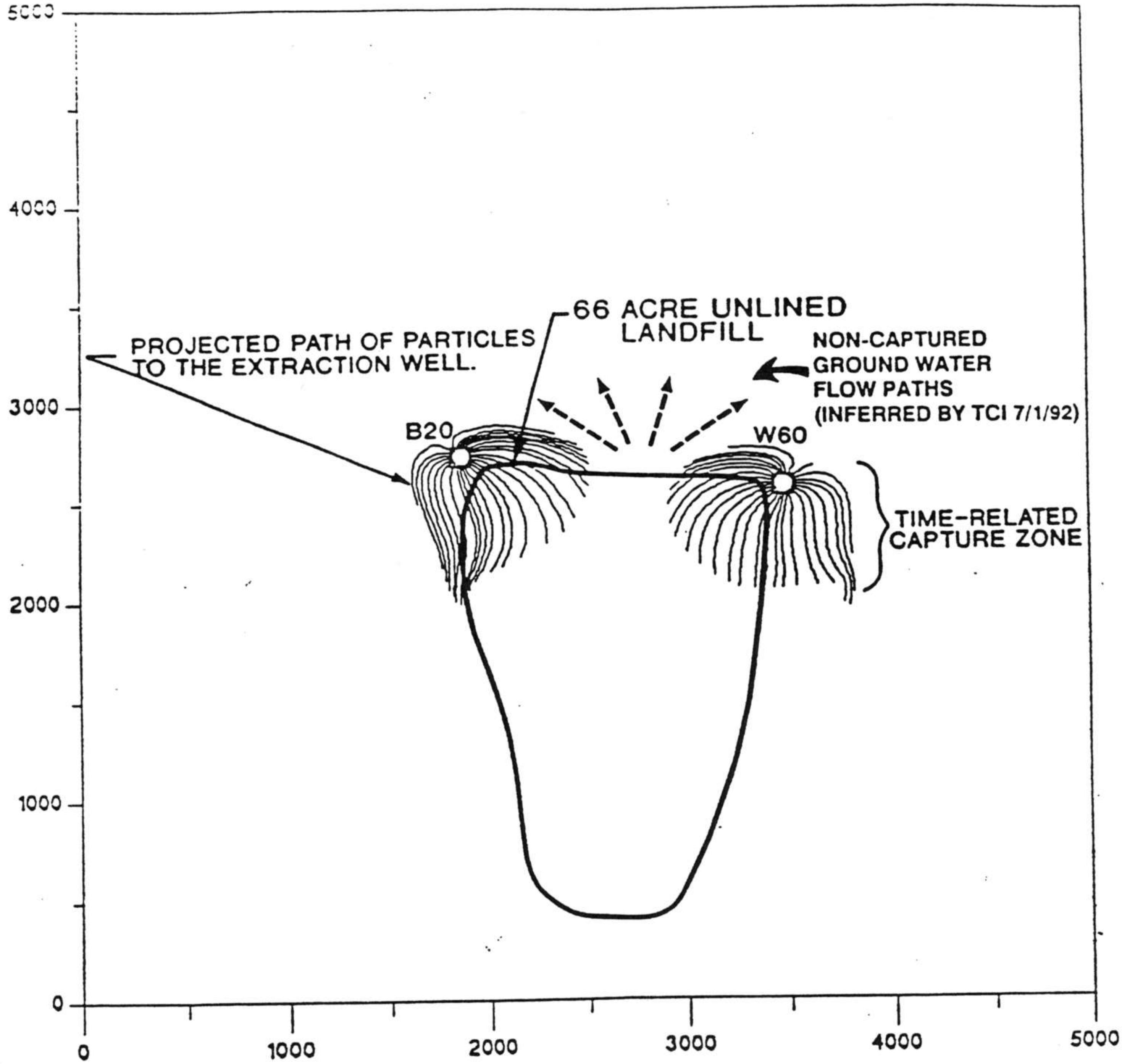
VISUALLY INFERRED GROUND WATER FLOW PATH BY TCI 7/1/92

500 0 50[0]
scale feet

JOB No.	913-6383	SCALE	AS SHOWN
DRAWN	WME	DATE	04/12/91
CHECKED	FG	DWG No.	PA04-421
Golder Associates			

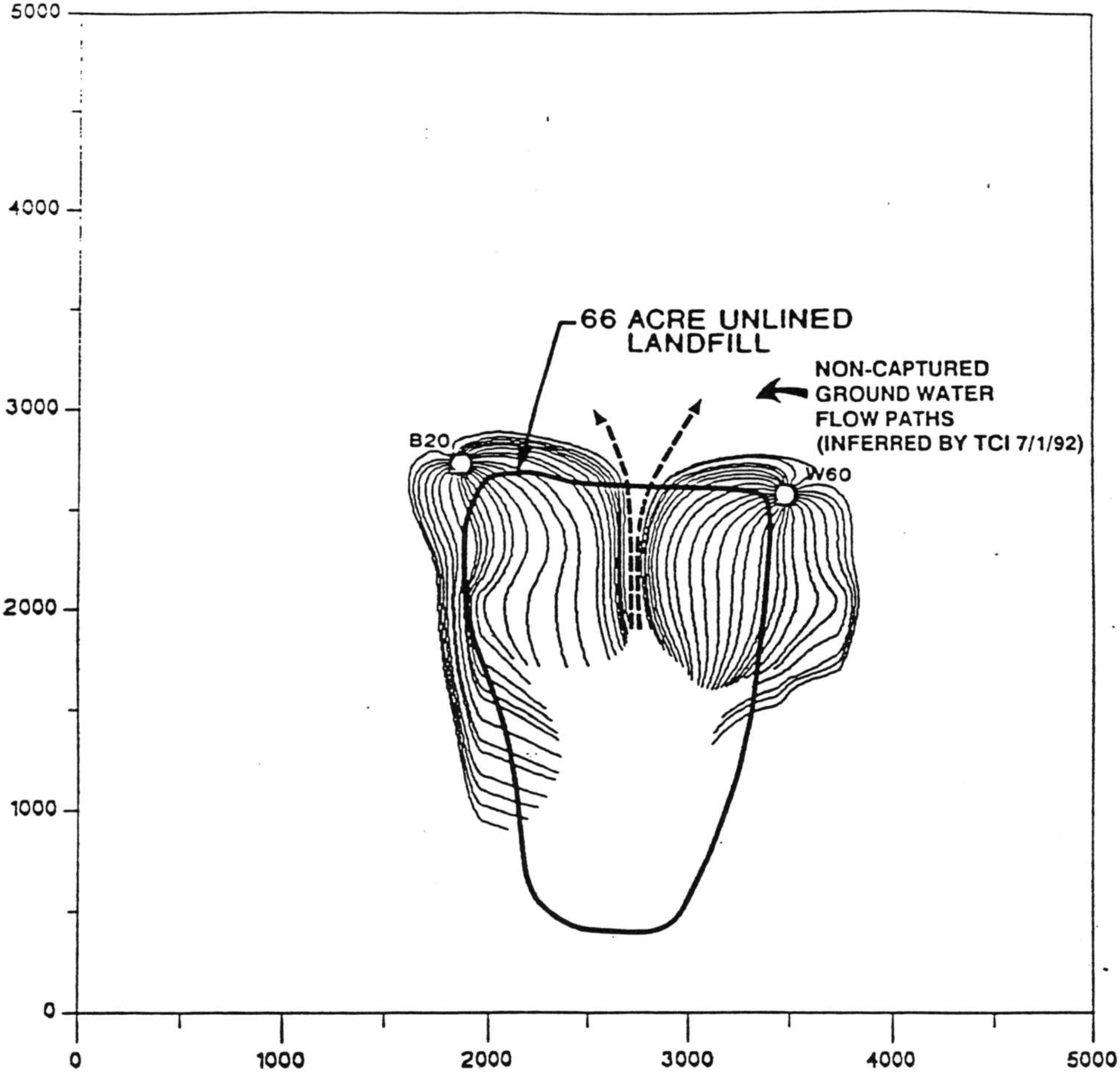
GROUNDWATER CONTOUR M[AP]
(SEPTEMBER 1990)

MODERN LANDFILL



NOTE: A TIME RELATED CAPTURE ZONE IS THE AREA OF AN AQUIFER THAT PROVIDES RECHARGE TO AN EXTRACTION WELL WITHIN SPECIFIED TIME.

JOB No.: 913-6383	SCALE: AS SHOWN	SIMULATED CAPTURE ZONE FOR .1 YEAR CONFIGURATION 1
DRAWN: TPT	DATE: 04/23/91	
CHECKED: FG	DWG. No.: PA04-458	
Golder Associates		MODERN LANDFILL — FIGURE A-9



JOB No.: 913-6383	SCALE: AS SHOWN	SIMULATED CAPTURE ZONE FOR 5 YEARS CONFIGURATION 1
DRAWN: TPT	DATE: 04/23/91	
CHECKED: FG	DWG. No.: PA04-459	
Golder Associates		MODERN LANDFILL — FIGURE A-10

TIMOTHY D. BECHTEL, PH.D.

EDUCATION

B.Sc., Geology (Minor in Mathematics), 1982, Haverford College, PA
M.Sc., Engineering Geology (Rock Mechanics), 1984, Brown University, RI
Ph.D., Geophysics, 1989, Brown University, RI

EXPERIENCE

February 1992 - Present: *Principal*, **Enviroscan, Inc.**, Lancaster, PA.
Supervise all technical operations of a geologic and geophysical consulting firm providing non-intrusive, non-destructive testing and inspection services to engineers, architects, environmental consultants, and archaeologists.

June 1989 - April 1992: *Geophysics Division Manager*, **Tethys Consultants, Inc.**, Harrisburg, PA.
Designed and conducted soil, groundwater, bedrock, marine and borehole geophysical studies. Supervised technical, administrative and marketing operations of Geophysics Division. Served as corporate scientific and technical advisor/reviewer for all other divisions of Tethys.

July 1988 - May 1989: *Branch Manager*, **Kurz Associates, Inc.**, Providence, RI.
Opened and supervised technical operations of branch office of a civil, geotechnical, geophysical and environmental engineering firm.

March 1987 - June 1988: *Geology/Geophysics Project Manager*, **Kurz Associates, Inc.**, Bridgewater, MA.
Performed environmental assessments and geophysical studies.

June 1982 - March 1987: *Research and Teaching Assistant in Geology and Geophysics*, **Brown University**, Providence, RI.

PROFESSIONAL REGISTRATIONS AND AFFILIATIONS

Member - *Society of Exploration Geophysicists*
Member - *American Geophysical Union*
Member - *Society for Archaeological Sciences*
Elected Member - *Sigma Xi, National Scientific Honor Society*
Frequent invited lecturer at local universities and national symposia
Instructor of three state-sponsored and privately sponsored short courses on archaeological geophysics
Six refereed publications
Thirteen abstracts

CONTINUING EDUCATION

Ground Penetrating Radar Training Course, GSSI, 1987
Engineering Geophysics Course, SEG, 1990
Ground Penetrating Radar Refresher Course, GSSI, 1991
Geoarchaeology Short Course, Z Environmental, 1991
OSHA Hazardous Waste Site Workers Training with Annual Updates, 1988 - present