First Quarterly Groundwater Level Measurement Report
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works
Sandusky, Ohio

Submitted To:

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List of Acronyms

D&M	Dames & Moore
H_2S	hydrogen sulfide
IT	IT Corporation
msl	mean sea level
NASA	National Aeronautics and Space Administration
PBOW	Plum Brook Ordnance Works
PID	photoionization detector
PVC	polyvinyl chloride
QAPjP	quality assurance project plan
SAP	sitewide sampling and analysis plan
SHP	sitewide safety and health plan
TNT	trinitrotoluene
USACE	U.S. Army Corps of Engineers

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1.0 Introduction

IT Corporation (IT) conducted the first of four quarterly groundwater level measurement events of the overburden and bedrock water-bearing zones at the former Plum Brook Ordnance Works (PBOW) on August 27, 1997. The former PBOW is located in Sandusky, Erie County, Ohio. It is a Defense Environmental Restoration Program (DERP) Formerly Used Defense Sites (FUDS) project currently being managed and technically overseen by the Nashville District of the U.S. Army Corps of Engineers (USACE). This 9,000-acre facility was utilized for the manufacture of explosives during World War II. The site is currently owned by the National Aeronautics and Space Administration (NASA) and operated as the Plum Brook Station by the NASA Lewis Center (LeRC) based in Cleveland, Ohio.

The first quarterly groundwater level measurement event was conducted as part of the on-going sitewide groundwater investigation, as prescribed in the May 1997 Site-Specific Sampling and Analysis Plan Attachment VI for the Sitewide Groundwater Investigation (IT, 1997a), under contract to the Nashville District of the USACE. The purpose of the quarterly groundwater level measurements is to provide temporal as well as spatial considerations in evaluating the groundwater flow regime in both the overburden and bedrock water-bearing zones. The quarterly water level measurements will also help to determine the seasonal fluctuations in groundwater levels and the hydraulic connectivity between the two water-bearing zones. The first quarterly event included all wells that are documented at the site, including those wells that have not been sampled or measured since their completion or installation. This report presents:

- Reconnaissance of existing monitoring wells
- Water level elevation measurements
- Interpreted groundwater flow directions in both the overburden and bedrock water-bearing zones
- Recommendations for subsequent quarterly measurements and sampling events.

2.0 Field Activities

This section of the report presents the monitoring points and field procedures that were utilized during the groundwater level measurement event. The field activities were executed in such a manner so as to maintain compliance with the sitewide sampling and analysis plan (SAP), (IT, 1996a), sitewide quality assurance project plan (QAPP), (IT, 1996b), and the sitewide safety and health plan (SHP) (IT, 1996c).

2.1 Monitoring Points and Data Collection

A total of 73 monitoring wells known to exist at the site were included in this initial field event (Figure 1). These wells were installed over the past 10 years by various contractors retained by either USACE or NASA for the purpose of environmental monitoring and site inspection. Of the 73 wells, 13 are installed in the bedrock water-bearing zone, 59 are in the overburden water-bearing zone, and 1 is a temporary piezometer in the overburden water-bearing zone. Well identification, construction details, and other pertinent information concerning these existing wells are provided in Table 1.

Prior to commencing groundwater level measurements, reconnaissance of these wells was conducted to determine the accessibility and condition of each well. This included locating wells that are in remote areas, clearing and flagging paths to wells, and identifying any potential health and safety hazards such as bee hives and poison ivy in the vicinity of the wells. All inoperable (rusted) locks were cut off and replaced with special-ordered, keyed-alike pad locks. Keys were provided to PBS personnel. Construction details of each existing well including well identification, well depth, well diameter, the year of completion, and available survey coordinates as well as previously measured depth to water data were tabulated and provided to each field group. A specially designed water level measurement form was used for data collection (Table 2). On August 27, 1997, field measurements of static water levels began at 0800 and were completed at 1930. No significant precipitation was recorded in the Sandusky area for at least 3 days prior to water level measurements.

2.2 Water Level Measurement Procedures

Groundwater level measurements were made over a single 11.5-hour period to provide a snapshot of site conditions. The measurements were conducted following the procedures set forth in the sitewide SAP (IT, 1996a) and as described below.

Table 1
Existing Monitoring Well Construction Details
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well ID	Well Depth (feet)	Date Installed	Installed By	Casing Type	Casing Diameter (inches)	Borehole Diameter (inches)	Screen Interval (feet bgs)	Top of Filter Pack (feet bgs)	TOC Elevation (feet msl)	Ground Elevation (feet msl)	Well Location
EB-GM-01	27	1990	EBASCO	NA	NA	NA	NA	NA	640.99*	638.49	NE of Bldg.9210
EB-GM-02	29	1990	EBASCO	NA	NA	NA	NA	NA	638.17*	635.80	N of Bldg.7131
EB-GM-03	18	1990	EBASCO	NA	NA	NA	NA	NA	639.28*	636.69	Behind Bldg.7131
EB-GM-04	16	1990	EBASCO	NA	NA	NA	NA	NA	636.89*	634.49	SW of Bldg.7122
EB-GM-05	18	1990	EBASCO	NA	NA	NA	NA	NA	640.26*	637.79	NE corner of Bldg.7121
EB-GM-06	18	1990	EBASCO	NA	NA	NA	NA	NA	640.1*	637.80	SE corner of Bldg.7121
EB-PS-02	18	1990	EBASCO	NA	NA	NA	NA	NA	638.8*	636.48	NW of Bldg.8133
EB-PS-03	18	1990	EBASCO	NA	NA	NA	NA	NA	637.53*	635.13	NE of Bldg.8133
EB-PS-04	16	1990	EBASCO	NA	NA	NA	NA	NA	638.32*	636.07	N of Bldg.8133
EB-RA-01	16	12/4/90	EBASCO	Stainless	2	8	5.5 - 15.5	4	634.88	632.30	Pentolite Rd at PBRF
EB-RA-02	20	12/13/90	EBASCO	Stainless	2	8	7.75 - 17.75	6	634.76	632.06	NE of Bldg.1134
EB-RA-03	22	12/13/90	EBASCO	Stainless	2	8	6.75 - 21.75	5	634.36	631.74	W of Bldg.1131
EB-RA-04	10	1990	EBASCO	Stainless	2	8	4.75 - 9.75	2.75	634.40	631.66	S W of Bldg.1131
EB-RA-05	10	1990	EBASCO	Stainless	2	8	4.75 - 9.75	2.75	634.00	631.41	S of Bldg.1131
EB-RA-06	10	1990	EBASCO	Stainless	2	8	3.7 - 8.7	3.4	633.47	630.72	S of Bldg.1153
EB-SP-01	9.5	1990	EBASCO	NA	NA	8	NA	NA	656.79*	654.29	S of Bldg.9115
EB-SP-03	9.5	1990	EBASCO	NA	NA	8	NA	NA	659.56*	657.29	N of Bldg.1461
EB-SP-04	9.5	1990	EBASCO	NA	NA	8	NA	NA	659.75*	657.25	W of Bldg.1411 Boiler Room
EB-SP-05	9.5	1990	EBASCO	NA	NA	8	NA	NA	659.14*	656.87	SW of Bldg.1411 Boiler Room
EB-SP-06	9	1990	EBASCO	NA	NA	8	NA	NA	660.28*	657.70	S of Bldg.1411
GCL-MW01	11.03	3/12/92	H+GLC	Stainless	1	8	5.99 - 10.97	4	674.74	671.31	SE of the Snake Rd burn pit
GCL-MW02A	22.15	3/11/92	H+GLC	Stainless	1	8	12.09 - 22.09	9.9	672.66	669.68	N of the Snake Rd burn pit
GCL-MW02B	9.83	3/12/92	H+GLC	Stainless	1	8	4.82 - 9.82	3.75	673.07	669.6	N of the Snake Rd burn pit
GCL-MW03	10.6	3/12/92	H+GLC	Stainless	1	8	4.56 - 9.45	3	671.52	668.67	W of the Snake Rd burn pit
IT-MW01	9.5	1989	IT	PVC	2	8	4.0 - 9.0	2	678.24	674.52	Scheid Road Burn Gound
IT-MW02	18.3	1989	IT	PVC	2	8	6.0 - 16.0	3.8	639.63	636.53	West Area RWP
IT-MW05	21	1989	IT	PVC	2	8	8.5 - 18.5	6.5	634.99	631.91	Pentolite Road RWP
IT-MW06	18.5	1989	IT	PVC	2	8	6.0 - 16.0	4.4	632.97	628.9	Reactor Facility / PRA

Table 1
Existing Monitoring Well Construction Details
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well ID	Well Depth (feet)	Date Installed	Installed By	Casing Type	Casing Diameter (inches)	Borehole Diameter (inches)	Screen Interval (feet bgs)	Top of Filter Pack (feet bgs)	TOC Elevation (feet msl)	Ground Elevation (feet msl)	Well Location
IT-MW07	5.5	1996	IT	PVC	2	4.25	0.5 - 5.5	none	635.03	632.3	West Area RWP, temporary
IT-MW08	13.4	1996	IT	PVC	2	8.25	3.1 - 13.1	3.6	633.16	630.6	West Area RWP
IT-MW09	14.5	1996	IT	PVC	2	8.25	4.1 - 14.1	2	647.45	645.4	TNT Area C
IT-MW10	19.8	1996	IT	PVC	2	8.25	9.3 - 19.3	8.6	644.8	642.2	West Area RWP
MK-MW09	15	1993	MK	PVC	2	10	5.0 - 15.0	3	645.91	643.04	West Area RWP
MK-MW10	14	1993	MK	PVC	2	10	4.0 - 14.0	2	641.25	638.23	West Area RWP
MK-MW11	13	1993	MK	PVC	2	10	3.0 - 13.0	2	638	634.88	West Area RWP
MK-MW12	13	1993	MK	PVC	2	10	3.0 - 13.0	2	641.73	673.78	Pipe Creek
MK-MW14	11.5	1993	MK	PVC	2	10	4.0 - 9.0	2	681.93	679.04	Toluene Tank No. 645
MK-MW15	9	1993	MK	PVC	2	10	4.0 - 9.0	2	681.45	678.35	Toluene Tank No. 655
MK-MW16	8	1993	MK	PVC	2	10	2.0 - 7.0	1	674.64	671.45	TNT Area B
MK-MW17	6	1993	MK	PVC	2	10	2.0 - 6.0	1	661.9	661.43	TNT Area B
MK-MW19	13	1993	MK	PVC	2	10	3.0 - 13.0	2	639.85	636.82	Garage Maintenance Area
MK-MW20	23	1993	MK	PVC	2	10	5.0 - 20.0	3	637.86	635.04	Toluene Tank No. 265
MK-MW22	9.5	1993	MK	PVC	2	10	2.5 - 7.5	1.5	638.95	635.84	TNT Area A
MK-MW23	16	1993	MK	PVC	2	10	6.0 - 16.0	4	640.01	637.01	TNT Area A
MK-MW24	9.5	1993	MK	PVC	2	10	4.5 - 9.5	2.5	657.59	654.57	TNT Area A
PB-MW01	NA	NA	NA	NA	NA	NA	NA	NA	N/A	N/A	NE of Bldg.9206
PB-MW02	NA	NA	NA	NA	NA	NA	NA	NA	N/A	N/A	NW of Bldg.9206
PB-MW03	NA	NA	NA	NA	NA	NA	NA	NA	N/A	N/A	SE of Bldg.9206
PB-MW04	NA	NA	NA	NA	NA	NA	NA	NA	N/A	N/A	SW of Bldg.9206
PR-MW07	22.3	1994	D&M	PVC	2	8	4.3 - 22.3	3	633.99	631.5	Pentolite Road RWP
PR-MW08	27.5	1994	D&M	PVC	2	8	5.0 - 27.5	4	635.02	632.5	Pentolite Road RWP
PR-MW09	19	1994	D&M	PVC	2	8	4.0 - 19.0	3	633.7	630.7	Pentolite Road RWP
TNTA-MW10	11	1994	D&M	PVC	2	8	3.0 - 11.0	2.5	640.18	637.5	TNT Area A
TNTA-MW11	11.4	1994	D&M	PVC	2	8	3.4 - 11.4	2.5	640.5	637.86	TNT Area A
TNTC-MW03	14	1994	D&M	PVC	2	8	5.0 - 14.0	3.2	645.41	642.57	TNT Area C
TNTC-MW04	18.8	1994	D&M	PVC	2	8	8.8 - 18.8	6	654.43	651.89	TNT Area C

Table 1
Existing Monitoring Well Construction Details
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well ID	Well Depth (feet)	Date Installed	Installed By	Casing Type	Casing Diameter (inches)	Borehole Diameter (inches)	Screen Interval (feet bgs)	Top of Filter Pack (feet bgs)	TOC Elevation (feet msl)	Ground Elevation (feet msl)	Well Location
TNTC-MW05	29.7	1994	D&M	PVC	2	8	4.7 - 29.7	3.7	651.81	649.07	TNT Area C
TNTC-MW06	12.2	1994	D&M	PVC	2	8	3.2 - 12.2	2.5	659.4	656.82	TNT Area C
WA-MW01	22.3	1994	D&M	PVC	2	8	4.3 - 22.3	3.7	644.43	642.32	West Area RWP
WA-MW02	13	1994	D&M	PVC	2	8	3.0 - 12.0	2.5	633.65	631.16	West Area RWP
Bedrock Monitoring Wells											
PB-BED-MW13	75.5	1994	D&M	PVC	4	3 (A)	29.5 (B)	none	648.27	645.81	TNT Area C
PB-BED-MW14	52.2	1994	D&M	PVC	4	3 (A)	23.2 (B)	none	646.04	643.05	West Area RWP
PB-BED-MW15	74.4	1994	D&M	PVC	4	3 (A)	42.9 (B)	none	631.64	629.08	Pentolite Road RWP
PB-BED-MW16	74	1994	D&M	PVC	4	3 (A)	24.8 (B)	none	636.02	633.68	Pentolite Road RWP
PB-BED-MW17	64.4	1994	D&M	PVC	4	3 (A)	19.4 (B)	none	629.97	627.37	TNT Area A
PB-BED-MW18	75.4	1994	D&M	PVC	4	3 (A)	24.4 (B)	none	651.5	648.83	TNT Area A
PB-BED-MW19	49.5	1994	D&M	PVC	4	3 (A)	17.5 (B)	none	643.07	640.51	West Area RWP
PB-BED-MW20	49.5	1994	D&M	PVC	4	3 (A)	14.5 (B)	none	676.33	673.57	BG Well - Southern PBS
REACTOR1	NA	NA	NA	NA	NA	NA	NA	NA	630.12	630.21	Reactor Facility / PRA
REACTOR2	NA	NA	NA	NA	NA	NA	NA	NA	630.68	630.72	Reactor Facility / PRA
REACTOR3	NA	NA	NA	NA	NA	NA	NA	NA	630.88	630.73	Reactor Facility / PRA
REACTOR4	NA	NA	NA	NA	NA	NA	NA	NA	631.15	630.76	Reactor Facility / PRA
REACTOR5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Reactor Facility / PRA

A — 3-inch diameter open borehole into bedrock.

B — Depth at which PVC casing ends; remainder of well is open borehole in bedrock.

RWP — Red Water Ponds

PRA — Pentolite Road Area

BG — Background location

PBS — Plum Brook Station

NA — Information not available

Table 2
Groundwater Level Measurement Record
Site-Wide Groundwater Investigation
Plum Brook Ordnance Works
Sandusky, Ohio

IT Project Number: 771481

Well Identification	Date	Time	Depth to Water Table (feet) [a]	Point of Reference[b]	Height of Stick-Out[c] (feet)	PID Reading (ppm)	H_2S Reading (ppm)	Initials	Comments

FIELD FORM *PBOWLEL.XLS*

[a] - *Depth to water table should be measured to the nearest 0.01 foot.*
[b] - *Measured from the mark on top of the riser.*
[c] - *Height from the top of the riser to the protective concrete pad.*

FIELD CREW MEMBERS: _____ _____

Upon opening the well cap, real-time air monitoring was conducted using a photoionization detector (PID) for the overburden wells and a PID and a hydrogen sulfide (H_2S) detector for the bedrock wells. The purpose of the air monitoring was to protect field personnel from organic vapor and acid gas exposure and to document the quality of trapped air in each well for future monitoring and sampling use. Organic vapor had been detected in several overburden wells and H_2S encountered in bedrock wells during previous investigations (Dames & Moore [D&M], 1997; IT 1997b).

Water level indicators and oil/water interface probes were decontaminated before the first use, between each use, and after the final use in order to prevent possible cross contamination per the procedures outlined in Section 4.2 of the PBOW sitewide QAPjP (IT, 1996b). Field testing and monitoring equipment were inspected and calibrated as specified in Section 6.0 of the PBOW sitewide QAPjP (IT, 1996b) and according to the manufacturers specifications. To further minimize the likelihood of cross contamination, water level measurement activities began with the least contaminated well and progressed in sequence to the most contaminated well as determined by the degree of known contaminant concentrations.

The static water level in each well was measured using an electronic water level indicator or an oil/water interface probe to the nearest 0.01 foot. The oil/water interface probe was used in all bedrock wells because of previous detection of free product in some of these wells (IT, 1997b). The depth from the marked point on the rim of the inner polyvinyl chloride (PVC) casing (or stainless-steel casing) of the well to the water table was recorded. When a marked point was not found, the highest point on the rim of the inner casing was marked as a datum for current and future reference, and the water level was measured from that point.

3.0 Water Level Measurements

Groundwater level data acquired during the first quarterly groundwater measurements are presented in Table 3 as elevations above mean sea level (msl). The elevation of the water level in a well was calculated by subtracting the depth-to-water measurement made relative to the top of the inner casing from the top of inner casing elevation. For most existing wells installed by NASA, the elevation at the top of inner casing was not available. To calculate the water level elevation at these wells, the height of the inner casing stick-out was carefully measured and added to the ground elevation to obtain the top of casing elevation. The water level elevation was then calculated by subtracting the depth-to-water table measurement made at the top of the inner casing from the top of inner casing elevation. The lack of surveyed elevations at the top of the inner casing for some wells may have introduced error in the reported groundwater elevations. However, it is believed that the errors introduced during the calculation process are not significant and should not impact the interpretation of the groundwater flow patterns at the site.

Of the 73 wells measured, five wells (PB-MW01, PB-MW02, PB-MW03, PB-MW04, and the Reactor 5 bedrock well) have no survey data. These wells were not included in the water level calculations and were consequently not utilized in the construction of water level contour maps. For the purpose of evaluating seasonal water level fluctuations at the PBOW site, historical water level data from selected wells are provided in Table 3, including the December 1994 and March 1995 data (D&M, 1997), as well as the October 1996 data (IT, 1997b).

3.1 Water Levels in the Overburden Water-Bearing Zone

Figure 2 presents the water level elevation contour map for the overburden water-bearing zone at PBOW using the data collected during the first quarterly monitoring event. The contour map was constructed based on readings from 57 overburden wells (including one piezometer) using the manual triangulation technique. The distribution of the 57 overburden wells are such that they are clustered around the areas where previous groundwater investigations were conducted. Some portions of the PBOW site, particularly, in the area south of trinitrotoluene (TNT) Area A and east of TNT Area B, have no existing monitoring wells. Groundwater contours in these areas were constructed by either interpolation or extrapolation and should be considered speculative.

The August 1997 contour map (Figure 2) indicates that the general groundwater flow direction in the overburden water-bearing zone is from south to north in much of the central portion of the

Table 3
Groundwater Level Measurements
Site-Wide Groundwater Investigation
Plum Brook Ordnance Works
Sandusky, Ohio

Well ID	Coordinates (PBS)		TOC Elevation (ft msl)	Ground Elevation (ft msl)	Previous Measurements			August 1997 Measurements					
	Northing	Easting			GW Elevation 1994 (ft msl)	GW Elevation 1995 (ft msl)	GW Elevation 1996 (ft msl)	GW Elevation 1997 (ft msl)	Date Measured	Depth to Water (ft)	Height of Stick-Out (ft)	PID Reading (ppm)	H_2S Reading (ppm)
EB-GM-01	31667	22328	640.99*	638.49	NM	NM	NM	632.22	8/27/97	8.77	2.50	0	N/A
EB-GM-02	32525	21889	638.17*	635.80	NM	NM	NM	627.41	8/27/97	10.76	2.37	0	N/A
EB-GM-03	32220	21849	639.28*	636.69	NM	NM	NM	633.00	8/27/97	6.28	2.59	0	N/A
EB-GM-04	32132	21517	636.89*	634.49	NM	NM	NM	631.33	8/27/97	5.56	2.40	0	N/A
EB-GM-05	31961	21882	640.26*	637.79	NM	NM	NM	634.02	8/27/97	6.24	2.47	0	N/A
EB-GM-06	31813	21884	640.1*	637.80	NM	NM	NM	634.02	8/27/97	6.08	2.30	0	N/A
EB-PS-02	32492	24134	638.8*	636.48	NM	NM	NM	632.83	8/27/97	5.97	2.32	0	N/A
EB-PS-03	32476	24261	637.53*	635.13	NM	NM	NM	631.88	8/27/97	5.65	2.40	0	N/A
EB-PS-04	32452	24334	638.32*	636.07	NM	NM	NM	629.45	8/27/97	8.87	2.25	0	N/A
EB-RA-01	34061	21813	634.88	632.30	NM	NM	NM	628.27	8/27/97	6.61	3.40	0.4	0
EB-RA-02	35053	22289	634.76	632.06	NM	NM	NM	626.66	8/27/97	8.10	3.88	0.4	0
EB-RA-03	34898	22357	634.36	631.74	NM	NM	NM	DRY	8/27/97	DRY	3.04	0.4	0
EB-RA-04	34842	22402	634.40	631.66	NM	NM	NM	626.33	8/27/97	8.07	3.20	0.4	0
EB-RA-05	34831	22504	634.00	631.41	NM	NM	NM	626.05	8/27/97	7.95	2.11	0.4	0
EB-RA-06	34868	22761	633.47	630.72	NM	NM	NM	624.82	8/27/97	8.65	4.28	0.4	0
EB-SP-01	21936	31880	656.79*	654.29	NM	NM	NM	650.36	8/27/97	6.43	2.50	NM	N/A
EB-SP-03	21716	31172	659.56*	657.29	NM	NM	NM	654.30	8/27/97	5.26	2.27	NM	N/A
EB-SP-04	21483	31279	659.75*	657.25	NM	NM	NM	652.55	8/27/97	7.20	2.50	NM	N/A
EB-SP-05	21371	31242	659.14*	656.87	NM	NM	NM	654.06	8/27/97	5.08	2.27	NM	N/A
EB-SP-06	21381	31418	660.28*	657.70	NM	NM	NM	653.48	8/27/97	6.80	2.58	NM	N/A
GCL-MW01	25945	25489	674.74	671.31	NM	NM	NM	666.42	8/27/97	8.32	2.58	NM	N/A
GCL-MW02A	26316	25186	672.86	669.68	NM	NM	NM	665.29	8/27/97	7.57	2.92	NM	N/A
GCL-MW02B	26321	25208	673.07	669.60	NM	NM	NM	664.75	8/27/97	8.32	3.14	NM	N/A
GCL-MW03	25984	24970	671.52	668.67	NM	NM	NM	665.52	8/27/97	6.00	2.85	NM	N/A
IT-MW01	24944	19783	678.24	674.52	NM	NM	NM	672.79	8/27/97	5.45	3.48	NM	N/A
IT-MW02	30428	14380	639.6	636.69	627.32	633.75	629.33	631.51	8/27/97	8.09	2.85	0	N/A

Table 3
Groundwater Level Measurements
Site-Wide Groundwater Investigation
Plum Brook Ordnance Works
Sandusky, Ohio

Well ID	Coordinates (PBS)		TOC Elevation (ft msl)	Ground Elevation (ft msl)	Previous Measurements			August 1997 Measurements					
	Northing	Easting			GW Elevation 1994 (ft msl)	GW Elevation 1995 (ft msl)	GW Elevation 1996 (ft msl)	GW Elevation 1997 (ft msl)	Date Measured	Depth to Water (ft)	Height of Stick-Out (ft)	PID Reading (ppm)	H_2S Reading (ppm)
IT-MW05	33483	23520	634.99	631.91	620.19	629.62	623.36	625.11	8/27/97	9.88	3.06	0	N/A
IT-MW06	36752	22732	632.97	628.90	NM	NM	NM	624.63	8/27/97	8.34	3.04	0	N/A
IT-MW07	22983	13988	635.35	632.64	NM	NM	DRY	DRY	8/27/97	DRY	NM	NM	N/A
IT-MW08	30435	15248	633.48	630.92	NM	NM	619.96	625.26	8/27/97	8.22	2.36	0	N/A
IT-MW09	28882	14852	647.77	645.72	NM	NM	DRY	641.77	8/27/97	6.00	1.71	0	N/A
IT-MW10	30924	13588	645.12	642.51	NM	NM	626.41	633.87	8/27/97	11.25	2.59	0	N/A
MK-MW09	31783	12954	645.91	643.04	NM	NM	NM	639.82	8/27/97	6.09	2.50	0	N/A
MK-MW10	31783	14647	640.89	638.06	626.66	NM	632.23	633.76	8/27/97	7.13	2.70	0	N/A
MK-MW11	31783	15925	637.69	634.71	625.22	631.36	628.89	630.56	8/27/97	7.13	2.77	0	N/A
MK-MW12	29113	12910	641.73	638.78	NM	NM	NM	631.87	8/27/97	9.86	2.54	NM	N/A
MK-MW14	26301	17540	681.93	679.04	NM	NM	NM	673.76	8/27/97	8.17	2.58	NM	N/A
MK-MW15	26477	17515	681.45	678.35	NM	NM	NM	673.23	8/27/97	8.22	2.95	0	N/A
MK-MW16	24937	22260	674.32	671.33	667.14	669.36	668.42	668.35	8/27/97	5.97	2.83	NM	N/A
MK-MW17	26671	22021	664.64	660.97	659.58	661.10	660.56	660.32	8/27/97	4.32	3.42	60	N/A
MK-MW19	31961	21616	639.85	636.82	NM	NM	NM	631.86	8/27/97	7.99	2.55	0	N/A
MK-MW20	31075	24642	637.86	635.04	NM	NM	NM	632.89	8/27/97	4.97	2.42	0.2	N/A
MK-MW22	32580	27845	638.05	635.56	628.85	631.55	630.07	629.85	8/27/97	8.20	2.50	NM	N/A
MK-MW23	32935	29414	639.43	636.95	620.88	628.12	632.14	630.94	8/27/97	8.49	2.42	NM	N/A
MK-MW24	30493	27421	657.12	654.44	648.31	650.77	649.61	650.04	8/27/97	7.08	2.56	NM	N/A
BED-MW13	29007	16325	648.27	645.81	607.85	619.29	621.79	620.47	8/27/97	27.80	3.25	0.4	0
BED-MW14	30641	14567	646.04	643.05	621.76	624.39	625.23	627.53	8/27/97	18.51	2.35	8.8	0
BED-MW15	34311	23308	631.64	629.08	603.54	598.91	610.22	601.69	8/27/97	29.95	2.15	8.2	0.12
BED-MW16	31463	24687	636.02	633.68	571.38	633.68	630.17	624.22	8/27/97	11.80	1.70	22	0
BED-MW17	33666	28164	629.97	627.34	602.57	602.90	602.76	603.49	8/27/97	26.48	2.30	17.2	0
BED-MW18	32130	29563	651.5	648.83	625.05	620.39	621.68	620.92	8/27/97	30.58	2.11	4.2	0
BED-MW19	31783	14257	643.07	640.51	621.07	623.52	622.92	623.22	8/27/97	19.85	2.05	9.6	0

Table 3
Groundwater Level Measurements
Site-Wide Groundwater Investigation
Plum Brook Ordnance Works
Sandusky, Ohio

Well ID	Coordinates (PBS)		TOC Elevation (ft msl)	Ground Elevation (ft msl)	Previous Measurements			August 1997 Measurements					
	Northing	Easting			GW Elevation 1994 (ft msl)	GW Elevation 1995 (ft msl)	GW Elevation 1996 (ft msl)	GW Elevation 1997 (ft msl)	Date Measured	Depth to Water (ft)	Height of Stick-Out (ft)	PID Reading (ppm)	H_2S Reading (ppm)
BED-MW20	20647	27307	676.33	673.57	661.35	661.28	661.98	662.05	8/27/97	14.28	2.06	0	0
PB-MW01	N/A	N/A	N/A	N/A	NM	NM	NM	N/A	8/27/97	5.05	2.27	0	N/A
PB-MW02	N/A	N/A	N/A	N/A	NM	NM	NM	N/A	8/27/97	6.27	1.60	0	N/A
PB-MW03	N/A	N/A	N/A	N/A	NM	NM	NM	N/A	8/27/97	6.27	2.15	0	N/A
PB-MW04	N/A	N/A	N/A	N/A	NM	NM	NM	N/A	8/27/97	3.50	1.42	0.1	N/A
PR-MW07	33122	23075	633.99	631.50	626.32	631.65	629.64	628.64	8/27/97	5.35	2.04	0	N/A
PR-MW08	33022	23365	635.02	632.50	624.55	629.98	627.56	628.36	8/27/97	6.66	2.08	0	N/A
PR-MW09	33230	23561	633.7	630.70	622.92	630.12	626.57	627.20	8/27/97	6.50	2.12	0	N/A
WA-MW01	30550	14060	644.43	642.32	NM	NM	NM	630.43	8/27/97	14.00	2.25	0	N/A
WA-MW02	30038	14301	633.65	631.16	NM	NM	NM	629.76	8/27/97	3.89	2.08	0	N/A
REACTOR 1	34875	21995	630.12	632.21	NM	NM	NM	614.80	8/27/97	15.32	None	0.4	0
REACTOR 2	34762	22017	630.68	630.72	614.71	601.89	NM	615.28	8/27/97	15.40	None	3.2	0
REACTOR 3	34790	22162	630.88	630.73	NM	NM	NM	616.28	8/27/97	14.60	None	0.4	0
REACTOR 4	34735	22161	631.15	630.76	NM	NM	NM	625.16	8/27/97	5.99	1.37	0.4	0
REACTOR 5	N/A	N/A	N/A	N/A	NM	NM	NM	N/A	8/27/97	14.61	1.00	1	0
TNTA-MW10	32095	27479	640.18	637.50	633.71	637.04	635.62	636.02	8/27/97	4.16	2.20	0	N/A
TNTA-MW11	31734	26833	640.5	637.86	630.56	632.82	633.56	635.01	8/27/97	5.49	2.33	NM	N/A
TNTC-MW03	29409	15531	645.41	642.57	dry	639.20	635.01	637.34	8/27/97	8.07	2.30	0	N/A
TNTC-MW04	28335	14636	654.43	651.89	634.87	651.07	648.51	648.28	8/27/97	6.15	2.12	0	N/A
TNTC-MW05	28646	15970	651.81	649.07	628.01	647.62	643.28	646.19	8/27/97	5.62	2.29	0	N/A
TNTC-MW06	28412	17171	659.4	656.82	651.93	655.20	654.56	654.94	8/27/97	4.46	2.25	0	N/A

N/A --- Not Applicable

NM --- Not Measured

647.45 --- October 1996 survey data

* --- TOC Elevation = Ground Elevation + Height of Stick-Out

625.16 --- Not used for the contour map

site, consistent with previous interpretations. In the western part of the site, the water level contours indicate a northwest flow direction. However, the shallow groundwater flow pattern in the vicinity of the West Area Red Water ponds is complicated by the presence of surface water bodies and local groundwater moves towards the ponds. This reversal in local shallow water direction near the surface water ponds was also reported in the October 1996 investigation (IT, 1997). Throughout the southeastern portion of the site, including the entire Magazine Area, the shallow groundwater appears to flow northeastward or eastward, differing from the north direction as previously reported. The flow pattern in this portion of the PBOW site, as indicated in Figure 2, is believed to be a better representation of site condition than those previously reported. This is because five monitoring wells located in the southeast corner of the site, near the Space Power Facility, were added during the most recent measurements and provided site-specific water level data in that area.

In comparison to the October 1996 water level data from 20 overburden wells, the changes in water levels ranged from plus 9.77 feet (IT-MW09) to minus 1.20 feet (MK-MW23). There is no apparent correlation between water level changes and the well locations. The most pronounced water level changes were observed in IT-MW08 (plus 5.30 feet), IT-MW09 (plus 9.77 feet), and IT-MW10 (plus 7.64 feet). The significant water level rise in these three wells is likely attributable to the prolonged water level recovery since their completion in September 1996.

3.2 Water Levels in the Bedrock Water-Bearing Zone

Figure 3 is the water level elevation contour map for the bedrock water-bearing zone at PBOW using the data collected from 11 bedrock wells during this monitoring event. Three bedrock wells (Reactor 1, Reactor 2, and Reactor 3) located in close proximity to the Reactor Building were measured, along with 8 bedrock wells installed in 1994 by D&M. As indicated in Figure 3, groundwater in the bedrock water-bearing zone moves in a predominantly northerly direction, being similar to what has been previously reported. However, in two areas the local flow directions were shown to deviate from this general orientation. In the northwestern portion of the site, the flow direction is towards the northeast as defined by three wells (BED-MW13, -14, and -19). In the vicinity of the Reactor Building, the groundwater contour pattern indicates an east to southeast direction . Similar localized flow patterns were also reported by D&M in their 1994 study (D&M, 1997).

The water level elevation contour map (Figure 3) was constructed based on a total of 11 wells that are located in several segregated areas. In much of the central and southern portions of the site, no monitoring wells are currently available, except BED-MW20 located along the south boundary of the site. Therefore, considerable interpolation was exercised in order to estimate water level elevations in these areas.

Most of the existing bedrock monitoring wells are known to have been placed in the competent limestone bedrock where fractures are suspected to exist (D&M, 1997). The limestone water-bearing zone is known to be highly heterogenous and anisotropic, and hydraulic conductivity can vary by several orders of magnitude within a short distance. Groundwater flow patterns within a limestone water-bearing zone are often more complicated than in the unconsolidated materials. However, on a regional scale, the groundwater flow direction in the limestone bedrock is governed by the regional hydraulic gradient. On a local scale, the flow direction in the limestone bedrock water-bearing zone is likely to be dictated by the orientation and connectivity of solutionally enlarged fractures, causing deviations in local groundwater flow from the regional gradient. With this in mind, the groundwater flow direction in the bedrock water-bearing zone indicated by the contour pattern in Figure 3 is best viewed as the flow direction caused primarily by the difference in observed hydraulic heads rather than local fractures. With the limited number of bedrock wells, determination of any local preferential flow is tenuous.

In comparison to the October 1996 water level data from 8 bedrock wells (BED-13 through BED-MW20), the changes in water levels range from plus 2.30 feet (BED-MW14) to minus 8.53 feet (BED-MW15), with the minimum positive change recorded at BED-MW20 (0.07 feet). The reason for the dramatic decrease in measured water level in BED-MW15 since the last measurement in September 1996 is not clear. However, this well released considerable amount of H_2S gas during the last sampling event, indicating a possible linkage to a deep fracture zone. It is also possible that extensive blasting and resulting fracturing in a nearby limestone quarry might have contributed, in part, to the erratic water level changes observed in some bedrock wells.

During water level measuring, 6-feet of free-phase petroleum product was detected in BED-MW16, located in the old toluene storage area. Free product was also reported at this well location during 1996 groundwater sampling and is the likely result of former National Aeronautics Space Administration storage of fuels.

The hydraulic connection between the overburden and bedrock water-bearing zones were not investigated during this monitoring event. However, the water level data shows that groundwater elevations in the overburden water-bearing zone are generally higher than those in the bedrock zone. Given the direct contact between the two water-bearing zones in most areas, it is believed that shallow groundwater tends to move downward into the bedrock water-bearing zone. However, this downward migration may be limited by the hydraulic conductivity in either zone and by the availability of water in the overburden water-bearing zone.

4.0 Summary

The first of the four quarterly groundwater monitoring was conducted at PBOW on August 27, 1997 and the results are presented in Table 3 and in Figures 2 and 3. In the overburden water-bearing zone, groundwater generally flows northward in much of the central portion of the site. In the western part of the site, water level contours indicate a northwesterly flow direction with local groundwater flowing toward surface ponds. Through the southeastern portion of the site, including the entire Magazine Area, the shallow groundwater appears to flow northeastward or eastward, which differs from the north direction previously reported. Four new overburden wells are being installed as part of the ongoing groundwater investigation at PBOW. With the addition of these wells, groundwater flow conditions in the overburden water-bearing zone will be further refined during the second quarterly monitoring event.

Groundwater flow patterns in the bedrock water-bearing zone have been interpreted from limited well locations as predominantly northerly. Detailed interpretation of flow patterns requires additional control points since only 11 wells were used to construct the bedrock groundwater elevation contour map. A total of 8 new bedrock wells are being strategically installed at locations where data gaps were identified. With the addition of these wells, groundwater flow conditions in the bedrock water-bearing zone will be further refined during the second quarterly monitoring event.

5.0 Recommendations for Subsequent Quarterly Groundwater Monitoring

The second quarterly monitoring event is scheduled for the month of November 1997. Based on the results of first quarterly monitoring, the following recommendations are made for the second and subsequent quarterly monitoring events:

- Twelve newly installed monitoring wells listed in Table 4 will be included in the remaining quarterly water level measurement events.
- According to well reconnaissance conducted during the beginning of the first quarterly monitoring event, IT recommends elimination of six existing wells as listed in Table 5 from further monitoring or sampling. The rationale for their elimination are summarized in Table 5.
- All existing monitoring wells that do not have adequate survey data, excluding those listed in Table 5, should be re-surveyed to ensure the accuracy of water level elevation data. The survey could be conducted concurrently with the survey for the newly installed monitoring wells.

Table 4

List of New Monitoring Wells to be Included in Future Measurement Events Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Well Location	Well Type
IT-BG8-BEDGW-001	G-8 Burning Ground	Bedrock well
IT-TNTB-BEDGW-001	TNT Area B, near MK-MW17	Bedrock well
IT-TNTB-BEDGW-002	TNT Area B, near MK-MW16	Bedrock well
IT-MNTA-BEDGW-001	Maintenance Shop Area, near the intersection between Taylor and Maintenance Road	Bedrock well
IT-AA1-BEDGW-001	Acids Area 1	Bedrock well
IT-AA1-GW-001	Acids Area 1	Overburden well
IT-AA2-BEDGW-001	Acids Area 2	Bedrock well
IT-AA2-GW-002	Acids Area 2	Overburden well
IT-AA3-BEDGW-001	Acids Area 3	Bedrock well
IT-AA3-GW-002	Acids Area 3	Overburden well
IT-ABG-BEDGW-001	Additional Burning Ground	Bedrock well
IT-ABG-GW-002	Additional Burning Ground	Overburden well

Table 5

List of Existing Wells to be Eliminated from Further Measurement
Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Well Location	Well Type	Rationale for Elimination
Reactor 4	Reactor Building 1111	Bedrock	Iinside the Reactor Building, no drilling log
Reactor 5	Reactor Building 1111	Bedrock	Inside the Reactor Building no drilling log, no survey data
PB-MW-01	Northeast of Building 9206	Overburden	No drilling log, no survey data
PB-MW-02	Northwest of Building 9206	Overburden	No drilling log, no survey data
PB-MW-03	Southeast of Building 9206	Overburden	No drilling log, no survey data
PB-MW-04	Southwest of Building 9206	Overburden	No drilling log, no survey data

6.0 References

IT Corporation (IT), 1996a, ***Sitewide Sampling and Analysis Plan, Site Investigation and Groundwater Investigation at the Former Plum Brook Ordnance Works, Sandusky, Ohio***, Revision 1, May.

IT Corporation (IT), 1996b, ***Quality Assurance Project Plan, Site Investigation and Groundwater Investigation at the Former Plum Brook Ordnance Works, Sandusky, Ohio***, Revision 1, May.

IT Corporation (IT), 1997a, ***Site-Specific Sampling and Analysis Plan, Attachment VI, Sitewide Groundwater Level Investigation, Former Plum Brook Ordnance Works, Sandusky, Ohio***, May.

IT Corporation (IT), 1997b, ***Draft Report Sitewide Groundwater Investigation at the Former Plum Brook Ordnance Works, Sandusky, Ohio***, Revision 0, May.

Dames & Moore, Inc., 1997, ***Final Report - Sitewide Groundwater Investigation, Plum Brook Ordnance Works, Sandusky, Ohio***, April, 1997.