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APPENDIX P

ORIGINAL
(Red)

AR302130

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ARMY CREEK LANDFILL
NEW CASTLE COUNTY
10/22/85

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FAIR GRASS

LAYER 1

VERTICAL PERCOLATION LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	.3710 VOL/VOL
FIELD CAPACITY	=	.1720 VOL/VOL
WILTING POINT	=	.0500 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	16.19999981 INCHES/HR

ORIGINAL (Red)

LAYER 2

WASTE LAYER		
THICKNESS	=	300.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	.5200 VOL/VOL
FIELD CAPACITY	=	.3200 VOL/VOL
WILTING POINT	=	.1900 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	.28300000 INCHES/HR

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	65.84
TOTAL AREA OF COVER	=	2110000. SQ. FT
EVAPORATIVE ZONE DEPTH	=	10.00 INCHES
EFFECTIVE EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
UPPER LIMIT VEG. STORAGE	=	3.7100 INCHES
INITIAL VEG. STORAGE	=	1.1100 INCHES

CLIMATOLOGIC DATA FOR PHILADELPHIA PENNSYLVANIA

MONTHLY MEAN TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
32.31	34.10	41.37	52.19	63.65	72.68
76.86	75.07	67.79	56.98	45.52	36.49

MONTHLY MEANS SOLAR RADIATION, LANGLEYS PER DAY

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
131.61	191.10	284.66	387.22	471.30	514.37
504.89	445.40	351.84	249.28	165.20	122.13

LEAF AREA INDEX TABLE

DATE	LAI
1	.00
123	.00
139	1.23
154	2.01
170	2.01
185	2.01
201	2.01
217	2.01
232	1.81
248	1.31
263	.64
279	.34
366	.00

GOOD GRASS

WINTER COVER FACTOR = 1.20

ORIGINAL
(Red)

AR302132

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MONTHLY TOTALS FOR 74

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	2.95 2.08	2.14 3.83	4.91 4.68	2.77 1.93	3.21 .81	4.43 4.04
RUNOFF (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000
EVAPOTRANSPIRATION (INCHES)	.887 1.228	.841 1.609	1.069 1.935	1.314 .353	1.931 .409	2.256 .581
PERCOLATION FROM BASE OF LANDFILL (INCHES)	2.0091 1.2083	1.3632 1.6959	2.5292 3.0455	3.1251 1.8964	1.3186 .6086	1.6276 2.9287
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ORIGINAL
(Red)

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ANNUAL TOTALS FOR 74

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	37.78	6642982.	100.00

RUNOFF	.000	0.	.00
EVAPOTRANSPIRATION	14.413	2534230.	38.15
PERCOLATION FROM BASE OF LANDFILL	23.3560	4106761.	61.82
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	99.52	17498582.	
SOIL WATER AT END OF YEAR	99.53	17500565.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	6.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 74

SEGMENT	INCHES
1	.014
2	.072
3	.086
4	.086
5	.086
6	.086
7	.086
8	2.410
9	96.604

ORIGINAL
(Red)

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MONTHLY TOTALS FOR 75

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

PRECIPITATION (INCHES)	4.00 6.32	2.91 2.21	4.68 7.21	2.97 3.24	4.99 3.14	7.57 2.89
RUNOFF (INCHES)	.000 .000	.000 .000	.000 .022	.000 .000	.000 .000	.000 .000
EVAPOTRANSPIRATION (INCHES)	.729 2.046	.587 1.272	1.044 1.752	.826 .964	1.975 .548	2.567 .514
PERCOLATION FROM BASE OF LANDFILL (INCHES)	3.2328 4.3998	2.1845 1.5609	3.3416 3.1013	2.2601 4.1929	3.0210 2.7723	5.0725 1.2407
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ORIGINAL
(Red)

ANNUAL TOTALS FOR 75

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	52.13	9166189.	100.00
RUNOFF	.022	3815.	.04
EVAPOTRANSPIRATION	14.826	2606945.	28.44
PERCOLATION FROM BASE OF LANDFILL	36.3803	6396874.	69.79
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	99.53	17500565.	
SOIL WATER AT END OF YEAR	100.43	17659111.	
SNOW WATER AT START OF YEAR	.00	0.	

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SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	9.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 75

SEGMENT	INCHES
1	.016
2	.079
3	.094
4	.094
5	.094
6	.100
7	.105
8	2.413
9	97.437

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ORIGINAL (Red)

MONTHLY TOTALS FOR 76

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	4.50	1.66	2.38	2.06	4.35	3.42
	4.04	2.17	2.44	4.30	.32	1.63
RUNOFF (INCHES)	.000	.000	.000	.000	.000	.000
	.000	.000	.000	.000	.000	.000
EVAPOTRANSPIRATION (INCHES)	.708	.522	.847	.937	1.742	1.551
	1.845	1.035	.994	1.213	.139	.369
PERCOLATION FROM BASE OF LANDFILL (INCHES)	3.9680	2.1949	1.5146	1.1777	2.6303	1.6975
	1.9940	1.6316	.7177	2.7091	1.1691	1.2545

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DRAINAGE FROM BASE OF	.000	.000	.000	.000	.000	.000
LANDFILL (INCHES)	.000	.000	.000	.000	.000	.000

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ANNUAL TOTALS FOR 76

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	33.27	5849973.	100.00
RUNOFF	.000	0.	.00
EVAPOTRANSPIRATION	11.902	2092726.	35.77
PERCOLATION FROM BASE OF LANDFILL	22.6590	3984212.	68.11
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	100.43	17659111.	
SOIL WATER AT END OF YEAR	99.14	17432140.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	7.	.00

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ORIGINAL (Red)

AR302137

SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 76

SEGMENT	INCHES
1	.014
2	.069
3	.083
4	.083
5	.083
6	.083
7	.083
8	2.408
9	96.232

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MONTHLY TOTALS FOR 77

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	2.61 1.47	1.33 7.65	4.19 4.49	5.59 3.11	.70 6.95	5.33 5.96
RUNOFF (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .351	.000 .000
EVAPOTRANSPIRATION (INCHES)	.403 1.139	.293 2.728	.798 1.796	1.298 1.133	.593 1.113	1.996 .752
PERCOLATION FROM BASE OF LANDFILL (INCHES)	2.1434 1.6762	.6092 4.1534	3.1617 2.7426	3.3253 2.3365	1.9639 4.7420	1.9055 5.2957
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 -000	.000 .000	.000 .000	.000 .000

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ANNUAL TOTALS FOR 77

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	49.38	8682648.	100.00
RUNOFF	.351	61782.	.71
EVAPOTRANSPIRATION	14.042	2468986.	28.44
PERCOLATION FROM BASE OF LANDFILL	34.0553	5988051.	68.97
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	99.14	17432140.	
SOIL WATER AT END OF YEAR	100.07	17595963.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	5.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 77

SEGMENT	INCHES
1	.014
2	.070
3	.084
4	.084
5	.084
6	.095
7	.111
8	2.409
9	97.121

ORIGINAL
(Red)

AR302139

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MONTHLY TOTALS FOR 78

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	8.90 4.45	1.35 6.43	4.31 2.02	1.76 1.20	6.00 2.19	1.76 5.42
RUNOFF (INCHES)	.000 .209	.000 .000	.000 .000	.000 .000	.001 .000	.000 .000
EVAPOTRANSPIRATION (INCHES)	.834 1.262	.551 2.312	1.068 1.241	.818 .672	2.115 .514	1.443 .800
PERCULATION FROM BASE OF LANDFILL (INCHES)	6.7639 2.9684	3.0357 2.6032	2.0548 2.2832	2.0239 .5413	2.9489 .6908	1.4489 4.6512
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ORIGINAL
(Red)

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ANNUAL TOTALS FOR 78

	(INCHES)	(CU. FT.)	PERCENT

PRECIPITATION	45.79	8051406.	100.00
RUNOFF	.210	36843.	.46
EVAPOTRANSPIRATION	13.629	2396351.	29.76
PERCOLATION FROM BASE OF LANDFILL	32.0141	5629149.	69.92
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	100.07	17595963.	
SOIL WATER AT END OF YEAR	100.01	17585017.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	8.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 78

SEGMENT	INCHES
1	.014
2	.069
3	.083
4	.083
5	.083
6	.083
7	.085
8	2.408
9	97.100

ORIGINAL
(Red)

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AVERAGE MONTHLY TOTALS FOR 74 THROUGH 78

JAN/JUL FEB/AUG MAR/SEP APR/OCT MAY/NOV JUN/DEC

PRECIPITATION (INCHES)	4.59	1.88	4.09	3.03	3.85	4.50
	3.67	4.46	4.17	2.76	2.68	3.99
RUNOFF (INCHES)	.000	.000	.000	.000	.000	.000
	.042	.000	.004	.000	.070	.000
EVAPOTRANSPIRATION (INCHES)	.712	.559	.965	1.039	1.671	1.963
	1.504	1.791	1.543	.867	.545	.603
PERCOLATION FROM BASE OF LANDFILL (INCHES)	3.6234	1.8775	2.5204	2.3824	2.3765	2.3504
	2.4493	2.3290	2.3781	2.3352	1.9966	3.0742
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000	.000	.000	.000	.000	.000
	.000	.000	.000	.000	.000	.000

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AVERAGE ANNUAL TOTALS FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	43.67	7678639.	100.00
RUNOFF	.117	20488.	.27
EVAPOTRANSPIRATION	13.762	2419848.	31.51
PERCOLATION FROM BASE OF LANDFILL	29.6929	5221009.	67.99
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00

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ORIGINAL
(Red)

AR302142

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PEAK DAILY VALUES FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	3.99	701575.0
RUNOFF	.351	61736.8
PERCOLATION FROM BASE OF LANDFILL	.5523	97104.9
DRAINAGE FROM BASE OF LANDFILL	.000	.0
HEAD ON BASE OF LANDFILL	.0	
SNOW WATER	.00	.0

MAXIMUM VEG. SOIL WATER (VOL/VOL)	.1120
MINIMUM VEG. SOIL WATER (VOL/VOL)	.0500

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ORIGINAL (Red)

AR302143

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ARMY CREEK LANDFILL
NEW CASTLE COUNTY
10/28/85

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GOOD GRASS

LAYER 1

VERTICAL PERCOLATION LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	4.500 MM/DAY**0.5
POROSITY	=	.4580 VOL/VOL
FIELD CAPACITY	=	.2230 VOL/VOL
WILTING POINT	=	.0920 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	2.30999997 INCHES/HR

LAYER 2

BARRIER SOIL LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	3.100 MM/DAY**0.5
POROSITY	=	.5200 VOL/VOL
FIELD CAPACITY	=	.4500 VOL/VOL
WILTING POINT	=	.3600 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	.00014200 INCHES/HR

LAYER 3

WASTE LAYER		
THICKNESS	=	300.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	.5200 VOL/VOL
FIELD CAPACITY	=	.3200 VOL/VOL
WILTING POINT	=	.1900 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	.28300000 INCHES/HR

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	77.42
TOTAL AREA OF COVER	=	2110000. SQ. FT
EVAPORATIVE ZONE DEPTH	=	12.00 INCHES
EFFECTIVE EVAPORATION COEFFICIENT	=	4.500 MM/DAY**0.5
UPPER LIMIT VEG. STORAGE	=	5.4960 INCHES
INITIAL VEG. STORAGE	=	1.8900 INCHES

CLIMATOLOGIC DATA FOR PHILADELPHIA PENNSYLVANIA

ORIGINAL (Red)

MONTHLY MEAN TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
32.31	34.10	41.37	52.19	63.65	72.68
76.36	75.07	67.79	56.98	45.52	36.49

MONTHLY MEANS SOLAR RADIATION, LANGLEYS PER DAY

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
131.61	191.10	284.66	387.22	471.30	514.37
504.89	445.40	351.84	249.28	165.20	122.13

LEAF AREA INDEX TABLE

DATE	LAI
1	.00
123	.00
139	1.23
154	2.01
170	2.01

AR302145

185	2.01
201	2.01
217	2.01
232	1.81
248	1.31
263	.64
279	.34
366	.00

GOOD GRASS

WINTER COVER FACTOR = 1.20

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MONTHLY TOTALS FOR 74

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	2.95 2.08	2.14 3.83	4.91 4.68	2.77 1.93	3.21 .81	4.43 4.04
RUNOFF (INCHES)	.000 .000	.000 .040	.005 .000	.000 .028	.000 .000	.000 .095
EVAPOTRANSPIRATION (INCHES)	1.052 2.151	1.264 2.907	2.464 3.986	2.584 2.051	4.630 1.015	5.503 1.102
PERCOLATION FROM BASE OF COVER (INCHES)	.0713 .1392	.0703 .1378	.1169 .1214	.1321 .1318	.1330 .1206	.1166 .1606
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.0526 .1396	.0655 .1344	.0989 .1239	.1348 .1295	.1343 .1225	.1197 .1544
DRAINAGE FROM BASE OF COVER (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

AR302146

ANNUAL TOTALS FOR 74

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	37.78	6642982.	100.00
RUNOFF	.168	29470.	.44
EVAPOTRANSPIRATION	30.709	5399584.	81.28
PERCOLATION FROM BASE OF COVER	1.4516	255234.	3.84
PERCOLATION FROM BASE OF LANDFILL	1.4103	247976.	3.73
DRAINAGE FROM BASE OF COVER	.000	0.	.00
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	111.37	19581855.	
SOIL WATER AT END OF YEAR	116.86	20547824.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	-17.	.00

SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 74

SEGMENT	INCHES
1	.035
2	.197
3	.626
4	.916
5	.916
6	.916
7	.916
8	5.496
9	10.800
10	96.041

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MONTHLY TOTALS FOR 75

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	4.00 6.32	2.91 2.21	4.68 7.21	2.97 3.24	4.99 3.14	7.57 2.89
RUNOFF (INCHES)	2.010 .237	1.915 .000	2.513 .787	.882 1.006	.093 1.536	1.393 1.476
EVAPOTRANSPIRATION (INCHES)	.927 6.650	1.022 3.510	1.946 2.290	2.346 2.237	5.547 1.319	7.041 .871
PERCOLATION FROM BASE OF COVER (INCHES)	.1479 .1283	.1273 .1339	.1381 .1213	.1372 .1403	.1381 .1394	.1328 .1401
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1475 .1301	.1284 .1350	.1386 .1202	.1368 .1370	.1388 .1394	.1340 .1402
DRAINAGE FROM BASE OF COVER (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ORIGINAL
(Red)

ANNUAL TOTALS FOR 75

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	52.13	9166189.	100.00
RUNOFF	13.849	2435120.	26.57
EVAPOTRANSPIRATION	35.704	6278031.	68.49
PERCOLATION FROM BASE OF COVER	1.6246	285663.	3.12
PERCOLATION FROM BASE OF LANDFILL	1.6258	285876.	3.12
DRAINAGE FROM BASE OF COVER	.000	0.	.00
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	116.86	20547824.	
SOIL WATER AT END OF YEAR	117.81	20715012.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	-26.	.00

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AR302149

SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 75

SEGMENT INCHES

1	.131
2	.753
3	.916
4	.916
5	.916
6	.916
7	.916
8	5.496
9	10.800
10	96.040

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MONTHLY TOTALS FOR 76

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	4.50 4.04	1.66 2.17	2.38 2.44	2.06 4.30	4.35 .32	3.42 1.63
RUNOFF (INCHES)	3.632 .000	.658 .000	.476 .000	.002 .001	.606 .000	.001 .000
EVAPOTRANSPIRATION (INCHES)	.795 3.991	1.079 2.141	2.088 1.519	2.278 2.811	5.254 1.205	4.897 .944
PERCOLATION FROM BASE OF COVER (INCHES)	.1417 .1460	.1323 .1353	.1468 .1195	.1334 .1324	.1364 .1247	.1408 .1395
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1418 .1409	.1326 .1425	.1461 .1190	.1351 .1288	.1374 .1258	.1416 .1411
DRAINAGE FROM BASE OF COVER (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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*** (Rod)

ANNUAL TOTALS FOR 76

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	33.27	5849973.	100.00
RUNOFF	5.377	945462.	16.16
EVAPOTRANSPIRATION	29.002	5099475.	87.17
PERCOLATION FROM BASE OF COVER	1.6289	286407.	4.90
PERCOLATION FROM BASE OF LANDFILL	1.6328	287096.	4.91
DRAINAGE FROM BASE OF COVER	.000	0.	.00
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	117.81	20715012.	
SOIL WATER AT END OF YEAR	115.07	20232937.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	16.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 76

SEGMENT	INCHES
1	.031

2	.153
3	.184
4	.154
5	.302
6	.906
7	.916
8	5.436
9	10.800
10	96.036

ORIGINAL
(Red)

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MONTHLY TOTALS FOR 77

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	2.61 1.47	1.33 7.65	4.19 4.49	5.59 3.11	.70 6.95	5.33 5.96
RUNOFF (INCHES)	.000 .000	.000 .061	1.264 .000	2.804 .000	.000 2.468	.012 5.007
EVAPOTRANSPIRATION (INCHES)	.998 2.631	1.089 6.232	2.124 4.267	2.207 2.718	3.638 1.534	5.137 .835
PERCOLATION FROM BASE OF COVER (INCHES)	.1591 .1371	.1289 .1237	.1505 .1191	.1323 .1279	.1352 .1400	.1238 .1438
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1556 .1371	.1248 .1252	.1525 .1207	.1357 .1268	.1363 .1338	.1237 .1441
DRAINAGE FROM BASE OF COVER (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ORIGINAL
(Red)

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ANNUAL TOTALS FOR 77

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	49.38	8682648.	100.00
RUNOFF	11.615	2042299.	23.52
EVAPOTRANSPIRATION	33.410	5874552.	67.66
PERCOLATION FROM BASE OF COVER	1.6212	285063.	3.28
PERCOLATION FROM BASE OF LANDFILL	1.6163	284191.	3.27
DRAINAGE FROM BASE OF COVER	.000	0.	.00
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	115.07	20232937.	
SOIL WATER AT END OF YEAR	117.81	20714562.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	-20.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 77

SEGMENT	INCHES
1	.127
2	.763

AR302153

ORIGINAL
(Red)

3	.916
4	.916
5	.916
6	.916
7	.916
8	5.495
9	10.800
10	96.041

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MONTHLY TOTALS FOR 78

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	8.90 4.45	1.35 6.43	4.31 2.02	1.76 1.20	6.00 2.19	1.76 5.42
RUNOFF (INCHES)	8.112 .822	.592 .213	1.858 .000	.000 .000	.997 .000	.000 1.187
EVAPOTRANSPIRATION (INCHES)	.763 3.532	1.014 4.702	2.059 3.265	2.258 .906	5.225 1.030	4.771 1.005
PERCOLATION FROM BASE OF COVER (INCHES)	.1428 .1307	.1294 .1328	.1439 .1207	.1347 .1180	.1383 .1321	.1264 .1504
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1432 .1337	.1299 .1295	.1440 .1233	.1355 .1223	.1386 .1215	.1263 .1518
DRAINAGE FROM BASE OF COVER (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ORIGINAL

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ANNUAL TOTALS FOR 78

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	45.79	8051406.	100.00
RUNOFF	13.782	2423266.	30.10
EVAPOTRANSPIRATION	30.530	5368276.	66.68
PERCOLATION FROM BASE OF COVER	1.6002	281376.	3.49
PERCOLATION FROM BASE OF LANDFILL	1.5997	281275.	3.49
DRAINAGE FROM BASE OF COVER	.000	0.	.00
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	117.81	20714562.	
SOIL WATER AT END OF YEAR	117.69	20693175.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	-24.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 78

SEGMENT	INCHES
1	.068
2	.700
3	.916

AR302155

ORIGINAL (Red)

4	.916
5	.916
6	.916
7	.916
8	5.496
9	10.800
10	96.042

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AVERAGE MONTHLY TOTALS FOR 74 THROUGH 78

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	4.59 3.67	1.88 4.46	4.09 4.17	3.03 2.76	3.85 2.68	4.50 3.99
RUNOFF (INCHES)	2.751 .212	.633 .063	1.223 .157	.738 .207	.339 .801	.281 1.553
EVAPOTRANSPIRATION (INCHES)	.907 3.791	1.094 3.898	2.136 3.065	2.334 2.144	4.859 1.221	5.470 .951
PERCOLATION FROM BASE OF COVER (INCHES)	.1326 .1363	.1176 .1327	.1392 .1204	.1339 .1301	.1362 .1314	.1281 .1469
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1281 .1363	.1163 .1333	.1360 .1214	.1356 .1289	.1371 .1286	.1291 .1463
DRAINAGE FROM BASE OF COVER (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ORIGINAL (Red)

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AVERAGE ANNUAL TOTALS FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	43.67	7678639.	100.00
RUNOFF	8.958	1575124.	20.51
EVAPOTRANSPIRATION	31.871	5603983.	72.98
PERCOLATION FROM BASE OF COVER	1.5853	278749.	3.63
PERCOLATION FROM BASE OF LANDFILL	1.5770	277283.	3.61
DRAINAGE FROM BASE OF COVER	.000	0.	.00
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00

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PEAK DAILY VALUES FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	3.99	701575.0
RUNOFF	1.945	342006.1
PERCOLATION FROM BASE OF COVER	.0188	3297.4
PERCOLATION FROM BASE OF LANDFILL	.0128	2242.9
DRAINAGE FROM BASE OF COVER	.000	.0

AR302157

ORIGINAL

DRAINAGE FROM BASE OF LANDFILL	.000	.0
HEAD ON BASE OF COVER	24.1	
HEAD ON BASE OF LANDFILL	.0	
SNOW WATER	.00	.0

MAXIMUM VEG. SOIL WATER (VOL/VOL) .4580

MINIMUM VEG. SOIL WATER (VOL/VOL) .0920

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123456789012345678901234567890123456789012345678901234567890123456789012345678

ORIGINAL
(Red)

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ARMY CREEK LANDFILL
NEW CASTLE COUNTY
10/28/85

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GOOD GRASS

LAYER 1

VERTICAL PERCOLATION LAYER
THICKNESS = 24.00 INCHES
EVAPORATION COEFFICIENT = 4.500 MM/DAY**0.5
POROSITY = .4580 VOL/VOL
FIELD CAPACITY = .2230 VOL/VOL
WILTING POINT = .0920 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY = 2.30999997 INCHES/HR

LAYER 2

LATERAL DRAINAGE LAYER
SLOPE = 5.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET
THICKNESS = 12.00 INCHES
EVAPORATION COEFFICIENT = 3.300 MM/DAY**0.5
POROSITY = .3510 VOL/VOL
FIELD CAPACITY = .1740 VOL/VOL
WILTING POINT = .1070 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY = [illegible]

AR302159

ORIGINAL
(Red)

LAYER 3

BARRIER SOIL LAYER		
THICKNESS	=	24.00 INCHES
EVAPORATION COEFFICIENT	=	3.100 MM/DAY**0.5
POROSITY	=	.5200 VOL/VOL
FIELD CAPACITY	=	.4500 VOL/VOL
WILTING POINT	=	.3600 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	.00014200 INCHES/HR

LAYER 4

WASTE LAYER		
THICKNESS	=	300.00 INCHES
EVAPORATION COEFFICIENT	=	3.300 MM/DAY**0.5
POROSITY	=	.5200 VOL/VOL
FIELD CAPACITY	=	.3200 VOL/VOL
WILTING POINT	=	.1900 VOL/VOL
EFFECTIVE HYDRAULIC CONDUCTIVITY	=	.28300000 INCHES/HR

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	77.42
TOTAL AREA OF COVER	=	2110000. SQ. FT
EVAPORATIVE ZONE DEPTH	=	12.00 INCHES
EFFECTIVE EVAPORATION COEFFICIENT	=	4.500 MM/DAY**0.5
UPPER LIMIT VEG. STORAGE	=	5.4960 INCHES
INITIAL VEG. STORAGE	=	1.8900 INCHES

CLIMATOLOGIC DATA FOR PHILADELPHIA PENNSYLVANIA

MONTHLY MEAN TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
32.31	34.10	41.37	52.19	63.65	72.68

ORIGINAL
(Red)

76.86	75.07	67.79	55.96	45.52	36.49

MONTHLY MEANS SOLAR RADIATION, LANGLEYS PER DAY

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
131.61	191.10	284.66	387.22	471.30	514.37
504.89	445.40	351.84	249.28	165.20	122.13

LEAF AREA INDEX TABLE

DATE	LAI
1	.00
123	.00
139	1.23
154	2.01
170	2.01
185	2.01
201	2.01
217	2.01
232	1.81
248	1.31
263	.64
279	.34
366	.00

GOOD GRASS

WINTER COVER FACTOR = 1.20

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MONTHLY TOTALS FOR 74

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	2.95	2.14	4.91	2.77	3.21	4.43
	2.08	3.83	4.68	1.93	.81	4.04
RUNOFF (INCHES)	.000	.000	.003	.000	.000	.000
	.000	.035	.000	.020	.000	.035
EVAPOTRANSPIRATION	.896	1.126	2.246	2.542	2.615	3.066

ORIGINAL
(Red)

(INCHES)	1.545	2.372	2.975	1.139	.591	.958
PERCOLATION FROM BASE OF COVER (INCHES)	.1149	.1063	.1316	.1227	.1173	.1207
	.1232	.1243	.1199	.1279	.1159	.1356
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.0826	.1055	.1250	.1271	.1180	.1196
	.1238	.1232	.1223	.1255	.1183	.1320
DRAINAGE FROM BASE OF COVER (INCHES)	1.155	.879	1.665	2.123	.785	.864
	.682	.837	1.741	1.069	.212	1.605
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000	.000	.000	.000	.000	.000
	.000	.000	.000	.000	.000	.000

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ANNUAL TOTALS FOR 74

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	37.78	6642982.	100.00
RUNOFF	.094	16456.	.25
EVAPOTRANSPIRATION	22.071	3880760.	58.42
PERCOLATION FROM BASE OF COVER	1.4602	256751.	3.86
PERCOLATION FROM BASE OF LANDFILL	1.4230	250214.	3.77
DRAINAGE FROM BASE OF COVER	13.617	2394360.	36.04
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	113.45	19948995.	

SOIL WATER AT END OF YEAR	114.03	20050187.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	-1.	.00

****

SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 74

SEGMENT	INCHES
1	.035
2	.204
3	.325
4	.363
5	.374
6	.372
7	.364
8	2.685
9	2.471
10	10.800
11	96.037

****

MONTHLY TOTALS FOR 75

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	4.00 6.32	2.91 2.21	4.68 7.21	2.97 3.24	4.99 3.14	7.57 2.89
RUNOFF (INCHES)	.000 .206	.000 .000	.226 .449	.002 .000	.000 .107	.114 .000
EVAPOTRANSPIRATION	.915	1.117	2.101	2.335	3.284	4.508

ORIGINAL
(Red)

(INCHES)	3.508	1.622	1.819	1.977	1.231	.970
PERCOLATION FROM BASE OF COVER (INCHES)	.1252	.1129	.1303	.1190	.1247	.1291
	.1324	.1201	.1312	.1338	.1213	.1361
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1253	.1142	.1276	.1226	.1236	.1283
	.1311	.1234	.1263	.1360	.1230	.1286
DRAINAGE FROM BASE OF COVER (INCHES)	2.202	1.734	2.384	1.414	1.753	2.892
	2.498	.962	1.612	3.041	1.868	.786
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000	.000	.000	.000	.000	.000
	.000	.000	.000	.000	.000	.000

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ANNUAL TOTALS FOR 75

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	52.13	9166189.	100.00
RUNOFF	1.103	193969.	2.12
EVAPOTRANSPIRATION	25.489	4481730.	48.89
PERCOLATION FROM BASE OF COVER	1.5160	266564.	2.91
PERCOLATION FROM BASE OF LANDFILL	1.5100	265511.	2.90
DRAINAGE FROM BASE OF COVER	23.146	4069920.	44.40
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	114.03	20050187.	

ORIGINAL
(Red)

SOIL WATER AT END OF YEAR	114.91	20205245.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	2.	.00

****

SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 75

SEGMENT	INCHES
1	.058
2	.288
3	.343
4	.336
5	.327
6	.450
7	.450
8	2.701
9	3.115
10	10.800
11	96.043

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MONTHLY TOTALS FOR 76

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	4.50	1.66	2.38	2.06	4.35	3.42
	4.04	2.17	2.44	4.30	.32	1.63
RUNOFF (INCHES)	.121	.000	.000	.000	.040	.000
	.000	.000	.000	.001	.000	.000
EVAPOTRANSPIRATION	.848	1.118	2.037	1.669	2.825	2.240

ORIGINAL (Red)

(INCHES)	2.705	1.465	1.151	2.245	.812	.827
PERCOLATION FROM BASE OF COVER (INCHES)	.1309 .1237	.1173 .1223	.1194 .1049	.1168 .1246	.1260 .1181	.1165 .1220
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1364 .1222	.1206 .1214	.1196 .1067	.1165 .1209	.1259 .1180	.1185 .1259
DRAINAGE FROM BASE OF COVER (INCHES)	2.805 1.096	1.864 .905	1.015 .318	.677 1.412	1.363 .637	.927 .593
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ANNUAL TOTALS FOR 76

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	33.27	5849973.	100.00
RUNOFF	.161	28379.	.49
EVAPOTRANSPIRATION	19.964	3510397.	60.01
PERCOLATION FROM BASE OF COVER	1.4426	253651.	4.34
PERCOLATION FROM BASE OF LANDFILL	1.4525	255402.	4.37
DRAINAGE FROM BASE OF COVER	13.613	2393586.	40.92
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	114.91	20205245.	

ORIGINAL
(Red)

SOIL WATER AT END OF YEAR	112.99	19867449.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	7.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 76

SEGMENT	INCHES
1	.031
2	.153
3	.184
4	.184
5	.216
6	.252
7	.251
8	2.676
9	2.210
10	10.800
11	96.033

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MONTHLY TOTALS FOR 77

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	2.61	1.33	4.19	5.59	.70	5.33
	1.47	7.65	4.49	3.11	6.95	5.96
RUNOFF (INCHES)	.000	.000	.090	.252	.000	.011
	.000	.053	.000	.000	1.042	.176
EVAPOTRANSPIRATION	.883	1.014	2.023	2.507	1.455	2.799

AR302167

ORIGINAL
(Red)

(INCHES)	1.703	4.588	2.637	2.145	1.344	.881
PERCOLATION FROM BASE OF COVER (INCHES)	.1331 .1233	.1053 .1274	.1297 .1187	.1228 .1204	.1271 .1291	.1180 .1436
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1311 .1235	.1067 .1241	.1256 .1215	.1235 .1213	.1274 .1258	.1209 .1385
DRAINAGE FROM BASE OF COVER (INCHES)	1.109 .967	.318 2.278	1.616 1.573	1.833 1.289	.975 2.446	1.010 4.368
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000	.000 .000

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ANNUAL TOTALS FOR 77

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	49.38	8682648.	100.00
RUNOFF	1.623	285412.	3.29
EVAPOTRANSPIRATION	23.978	4216206.	48.56
PERCOLATION FROM BASE OF COVER	1.4986	263497.	3.03
PERCOLATION FROM BASE OF LANDFILL	1.4898	261962.	3.02
DRAINAGE FROM BASE OF COVER	19.780	3477909.	40.06
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	112.99	19867449.	

ORIGINAL
(Red)

SOIL WATER AT END OF YEAR	115.50	20308608.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	0.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 77

SEGMENT	INCHES
1	.063
2	.334
3	.429
4	.441
5	.445
6	.447
7	.447
8	2.679
9	3.373
10	10.800
11	96.042

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MONTHLY TOTALS FOR 78

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	8.90	1.35	4.31	1.76	6.00	1.76
	4.45	6.43	2.02	1.20	2.19	5.42
RUNOFF (INCHES)	.730	.000	.021	.000	.232	.000
	.795	.197	.000	.000	.000	.201
EVAPOTRANSPIRATION	.856	1.038	2.105	2.131	3.513	1.558

AR302169

ORIGINAL
(Red)

(INCHES)	2.237	3.358	2.093	.802	.848	.904
PERCOLATION FROM BASE OF COVER (INCHES)	.1547	.1295	.1203	.1187	.1213	.1158
	.1289	.1254	.1167	.1026	.1080	.1334
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1480	.1403	.1229	.1192	.1201	.1188
	.1274	.1233	.1201	.1064	.1023	.1311
DRAINAGE FROM BASE OF COVER (INCHES)	5.164	3.645	1.362	1.284	1.536	.348
	1.415	1.328	1.091	.224	.317	2.757
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000	.000	.000	.000	.000	.000
	.000	.000	.000	.000	.000	.000

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ANNUAL TOTALS FOR 78

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	45.79	8051406.	100.00
RUNOFF	2.177	382706.	4.75
EVAPOTRANSPIRATION	21.443	3770479.	46.83
PERCOLATION FROM BASE OF COVER	1.4762	259559.	3.22
PERCOLATION FROM BASE OF LANDFILL	1.4798	260207.	3.23
DRAINAGE FROM BASE OF COVER	20.971	3687366.	45.80
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00
SOIL WATER AT START OF YEAR	115.50	20308608.	

ORIGINAL (Red)

SOIL WATER AT END OF YEAR	115.22	20259251.	
SNOW WATER AT START OF YEAR	.00	0.	
SNOW WATER AT END OF YEAR	.00	0.	
ANNUAL WATER BUDGET BALANCE	.00	5.	.00

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SOIL WATER CONTENTS OF SEGMENTS
AT THE END OF YEAR 78

SEGMENT	INCHES
1	.062
2	.334
3	.422
4	.434
5	.440
6	.443
7	.445
8	2.676
9	3.124
10	10.800
11	96.038

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AVERAGE MONTHLY TOTALS FOR 74 THROUGH 78

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION (INCHES)	4.59	1.88	4.09	3.03	3.85	4.50
	3.67	4.46	4.17	2.76	2.68	3.99
RUNOFF (INCHES)	.170	.000	.068	.051	.054	.025
	.200	.057	.090	.004	.230	.082
EVAPOTRANSPIRATION (INCHES)	.880	1.083	2.102	2.237	2.739	2.834
	2.360	2.665	2.135	1.661	.965	.908

ORIGINAL (Red)

PERCOLATION FROM BASE OF COVER (INCHES)	.1318	.1143	.1263	.1200	.1233	.1202
	.1263	.1239	.1183	.1219	.1185	.1341
PERCOLATION FROM BASE OF LANDFILL (INCHES)	.1247	.1175	.1241	.1218	.1230	.1212
	.1256	.1231	.1194	.1220	.1175	.1312
DRAINAGE FROM BASE OF COVER (INCHES)	2.487	1.668	1.608	1.466	1.282	1.308
	1.331	1.262	1.267	1.407	1.096	2.021
DRAINAGE FROM BASE OF LANDFILL (INCHES)	.000	.000	.000	.000	.000	.000
	.000	.000	.000	.000	.000	.000

****

****

AVERAGE ANNUAL TOTALS FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	43.67	7678639.	100.00
RUNOFF	1.032	181384.	2.36
EVAPOTRANSPIRATION	22.589	3971914.	51.73
PERCOLATION FROM BASE OF COVER	1.4787	260004.	3.39
PERCOLATION FROM BASE OF LANDFILL	1.4710	258659.	3.37
DRAINAGE FROM BASE OF COVER	18.225	3204628.	41.73
DRAINAGE FROM BASE OF LANDFILL	.000	0.	.00

****

ORIGINAL
(Red)

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PEAK DAILY VALUES FOR 74 THROUGH 78

	(INCHES)	(CU. FT.)
PRECIPITATION	3.99	701575.0
RUNOFF	1.042	183261.7
PERCOLATION FROM BASE OF COVER	.0118	2068.7
PERCOLATION FROM BASE OF LANDFILL	.0079	1385.7
DRAINAGE FROM BASE OF COVER	.372	65323.3
DRAINAGE FROM BASE OF LANDFILL	.000	.0
HEAD ON BASE OF COVER	21.9	
HEAD ON BASE OF LANDFILL	.0	
SNOW WATER	.00	.0

MAXIMUM VEG. SOIL WATER (VOL/VOL) .2304

MINIMUM VEG. SOIL WATER (VOL/VOL) .0920

****
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AR302173

ORIGINAL
(Red)

APPENDIX Q

AR302174

ORIGINAL
(Red)

STATEMENT OF DETERMINATION

I, Thomas P. Eichler, have reviewed the facts, including the Endangerment Assessment for the Army Creek Landfill attached to this Statement, supporting the Administrative Order on Consent between the United States Environmental Protection Agency and New Castle County, Delaware, which Order is issued pursuant to Section 106(a) of the Comprehensive Environmental, Response, Compensation and Liability Act, 42 U.S.C. §9606(a), and I hereby determine that the presence of hazardous substances at the Army Creek Landfill facility located in New Castle County, Delaware and the potential release of hazardous substance from that facility may present a substantial hazard to human health and the environment.

Thomas P. Eichler
THOMAS P. EICHLER
Regional Administrator
U.S. Environmental Protection Agency
Region III

August 1, 1984
DATE

AR302175

ORIGINAL (Red)

ENDANGERMENT ASSESSMENT

Army Creek Landfill

By Richard L. Zambito

ENGINEER, CERCLA ENFORCEMENT SECTION INTRODUCTION

The Army Creek landfill was an abandoned sand and gravel quarry which was used by Newcastle County as a landfill for the disposal of various wastes including some unknown chemical materials. Ground water contamination emanating from the landfill was discovered in 1971 and has been the object of numerous studies and investigations since that time.

The RAMP report prepared by NUS provides the most comprehensive summation of site conditions and data and was used extensively for this assessment. The USGS performed a more extensive review of reports currently on the site. This report is included for the readers information.

The major hazard posed by the Army Creek landfill is posed by contamination of ground water resources by the landfill. In light of the extensive ground water use in area this contamination represents the most serious threat to public health. Of secondary concern is the threat to surface water posed by discharge from recovery wells and leachate seeps. Sampling of wells in the area by EPA, DNREC, and New Castle County has revealed the presence of several toxic and carcinogenic compounds.

PHYSICAL DESCRIPTION

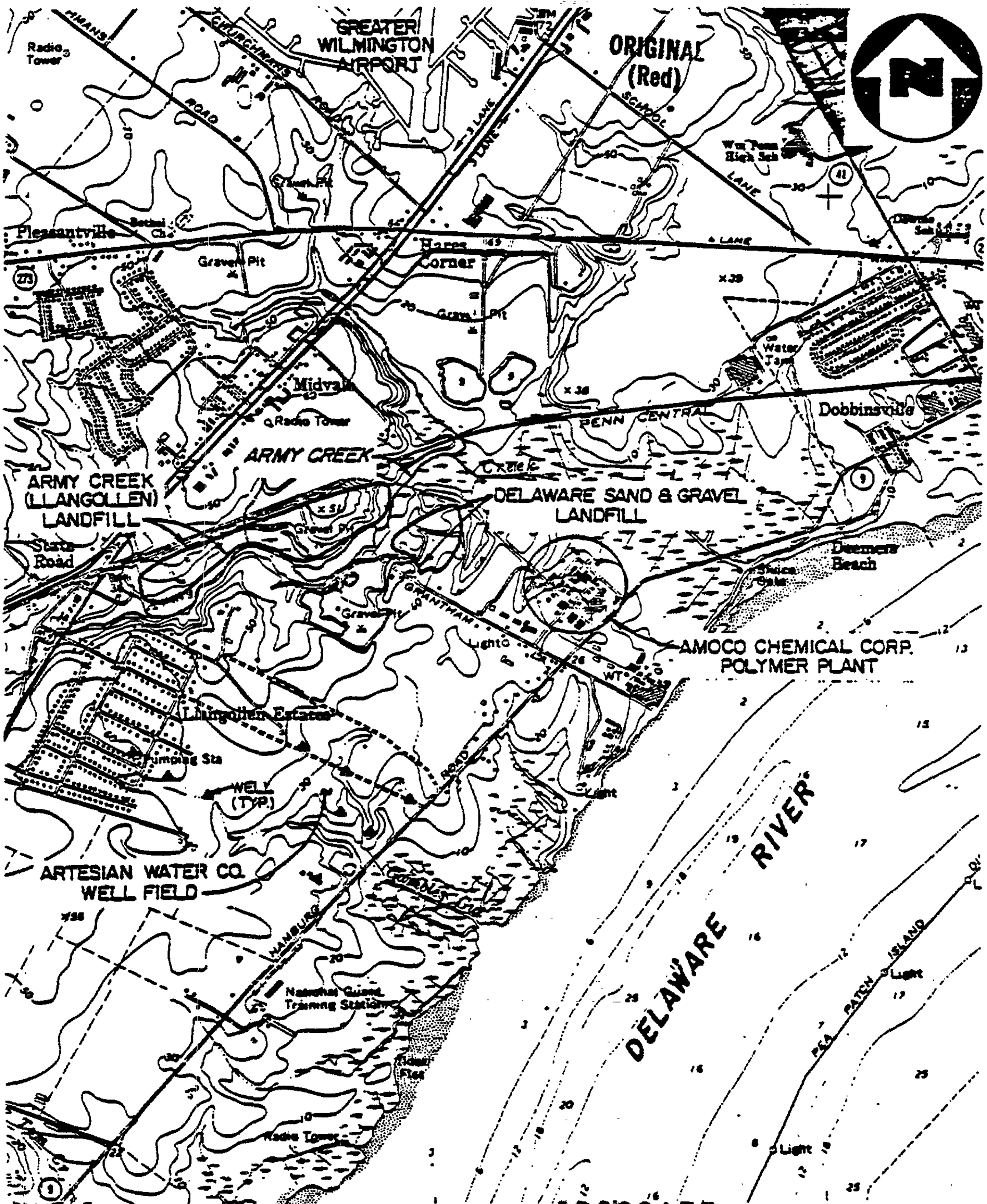
Location

The Army Creek (Llangollen) landfill is an abandoned sand and gravel pit which was used by New Castle County, Delaware, as a primary disposal site for municipal and industrial wastes between 1960 and 1968. The site is located on the northwest bank of Army Creek, which discharges into the Delaware River one mile east of the site as shown in Figure 1.

The landfill is bordered on the west by U.S. Routes 13 and 40 and on the east by State Route 9, located at distances of one-fourth and one-half miles from the site respectively.

Army Creek landfill is approximately two miles southwest of New Castle, Delaware, lying at 30°39'12 north latitude and 75°36'35" west longitude (USGS, 1967).

The site is bordered on the northwest by railroad tracks owned by Penn Central Company, as shown in Figure 2. The Amoco Chemical Corporation Polymer Plant, which was closed in 1980 due to fire, is located one-half mile to the east. Llangollen Estates, a residential development, is one-fourth mile to the south, as is the Artesian Water Company's well field.



BASE MAP IS A PORTION OF THE U.S.G.S. WILMINGTON SOUTH, DEL.-N.J. QUADRANGLE (7.5 MINUTE SERIES, 1967) CONTOUR INTERVAL = 10'

AR302177

FIGURE 1

LOCATION OF ARMY CREEK LANDFILL
NEW CASTLE COUNTY, DELAWARE

SCALE 1" = 2000'

NUS CORPORATION

ORIGINAL
(Red)

Site Description

The Army Creek Landfill is adjacent to the Delaware Sand and Gravel Landfill, which lies just southeast of the site. The sites are topographically separated by Army Creek.

Many types of wastes have been dumped at the site, including liquid waste chemicals and oils. Ponds and pits from the previous sand and gravel operation were filled with refuse, and the compaction of the refuse was generally poor. Due to the lack of sufficient cover material and inadequate compaction, significant differential settlement occurred, resulting in an uneven finished surface when the landfill was closed in 1968. This uneven surface allowed rainwater to accumulate on and infiltrate into the site. The Army Creek Landfill contains refuse ranging from 6 feet to over 35 feet in depth and covers an area of 44 acres. It is approximately 4,400 feet long and 200 feet to 900 feet wide, with a volume of approximately 2 million cubic yards.

Site Use History

The Army Creek Landfill was operated as a sand and gravel pit by Saienni Brothers until the pit was depleted. Supposedly, no clay was removed during this time because it would have interfered with the gravel-washing operation. Near its final stages, the pit had large pools of standing water in both eastern and western sections, as was seen in an aerial photograph in Saienni's office.

When landfilling operations began, refuse was reported to have been dumped rather haphazardly, beginning from the eastern end of the pit and proceeding toward the western portion, as shown in Figure 3. Existing ponds were filled with refuse, and compaction and covering were poor. Daily and intermittent cover material was obtained almost entirely from within the pit, reportedly using the pit's floor of red clay and perhaps the Potomac sand beneath it. When the county became pressed for landfill space, it is not unlikely that additional volume for disposal may have been created by excavation of the floor on the eastern end. Unfortunately, all surface traces of the intermittent cover were obliterated when the final cover of Pleistocene sand and gravel was hauled in from the Greggo and Ferrara quarry north of the railroad tracks in 1968.

The Army Creek property was turned over to the New Castle County Division of Parks and Recreation for intended use as a public park, although further improvement of the property has not yet been made.

ORIGINAL
(Red)

Permit and Regulatory History

The Army Creek Landfill, which operated from 1960 to 1968, was permitted to accept industrial and municipal wastes (Weston, 1972). The permitting agencies within the state of Delaware were not specific. The landfill reached capacity and was closed in 1968.

Remedial Actions to Date

In January 1971, a domestic well owned by Mrs. Mary Renni of Llangollen Estates, adjacent to the landfill, became contaminated. New Castle County and its consultant, Roy F. Weston, Inc. of West Chester, Pennsylvania began a multi-year field investigation to assess the problem. Results from that investigation showed that leachate, most likely originating from the Army Creek and Delaware Sand and Gravel Landfills, was contaminating local aquifiers. Since 1971, all but about 14 residences in Llangollen Estates abandoned their private ground water wells and are now serviced by the Artesian Water Company.

Weston's remedial investigation has led to the installation of a ground-water recovery system designed to maintain a ground water divide between the landfills and the Artesian Water Company well field. Contaminated ground water obtained from the recovery well system is discharged untreated into Army Creek. The overall focus of the multi-year study is to restore the aquifiers to their pre-landfill coditions. In the interim, however, remedial measures have been directed toward the preservation of the Artesian Water Company well field which serves a population of about 100,000.

SITE CONTAMINATION/OFF-SITE CONTAMINATION

Air

Ambient air quality measurements have not been performed at the landfill. Air quality measurements were taken from well head space by the FIT Region III on November 12, 1981. The results are shown in Table 1 and indicate high concentrations of organic vapors, some within explosive ranges. None of the well casings tested were deficient in oxygen.

Soil

Soils have not been sampled at Army Creek Landfill. However, five sediment samples were taken from Army Creek by FIT on November 11, 1981. The analyses generally show inorganics at concentrations well below 1 ppm (except for iron, maximum concentration = 6430 ppb). The highest levels of zinc (54 ppb), aluminum (605 ppb), vanadium (10 ppb), magnesium (370 ppb) and sodium (1000 ppb) were found downstream of the landfill, while the maximum concentrations of barium (74 ppb), iron (6430 ppb), lead (16 ppb), manganese (282 ppb) and calcium 510 ppb) were found in the creek adjacent to the south edge of the western portion of the landfill (see Figure 2). Organics detected in the sediments are listed in Table 2 and 5.

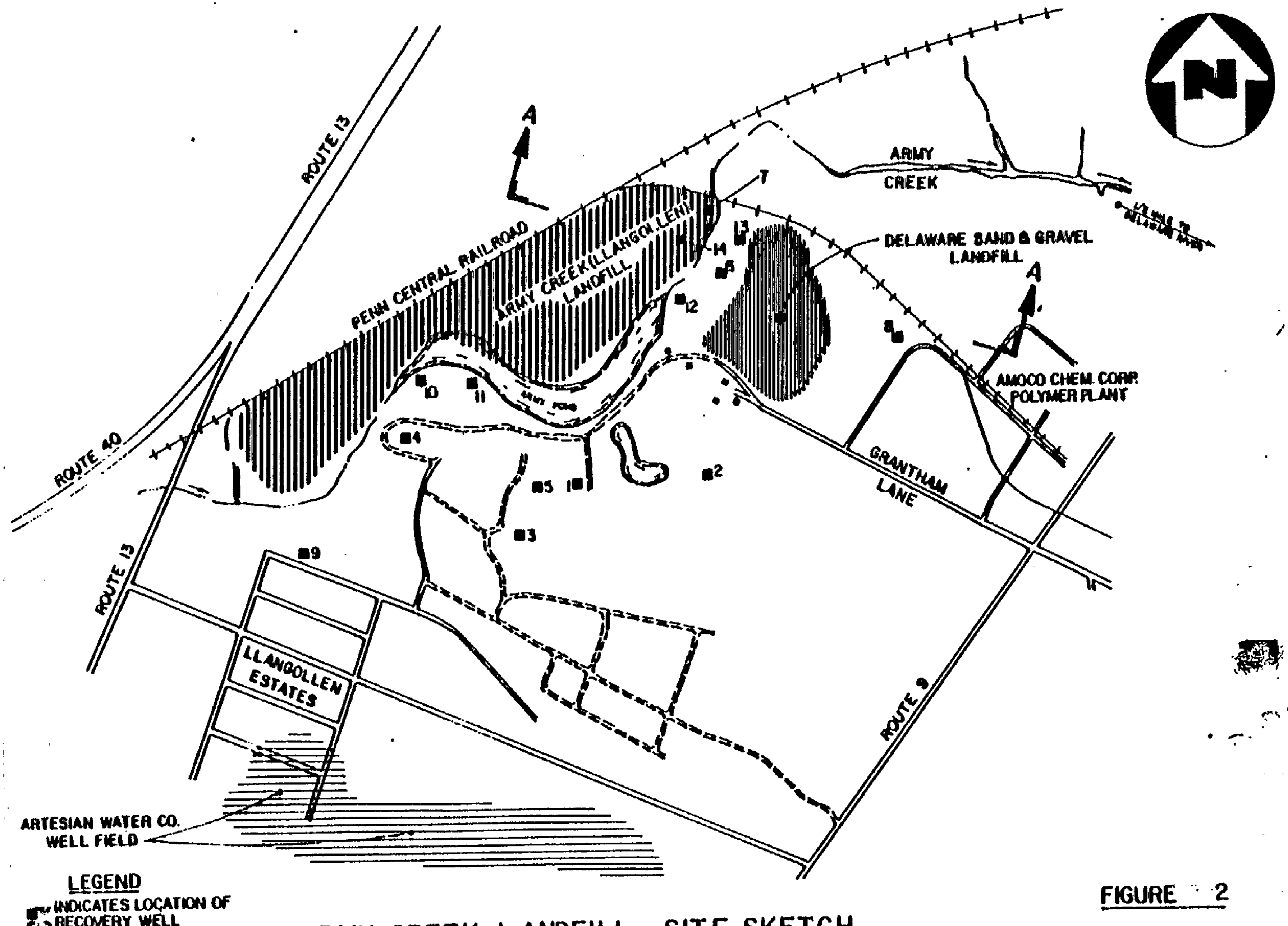
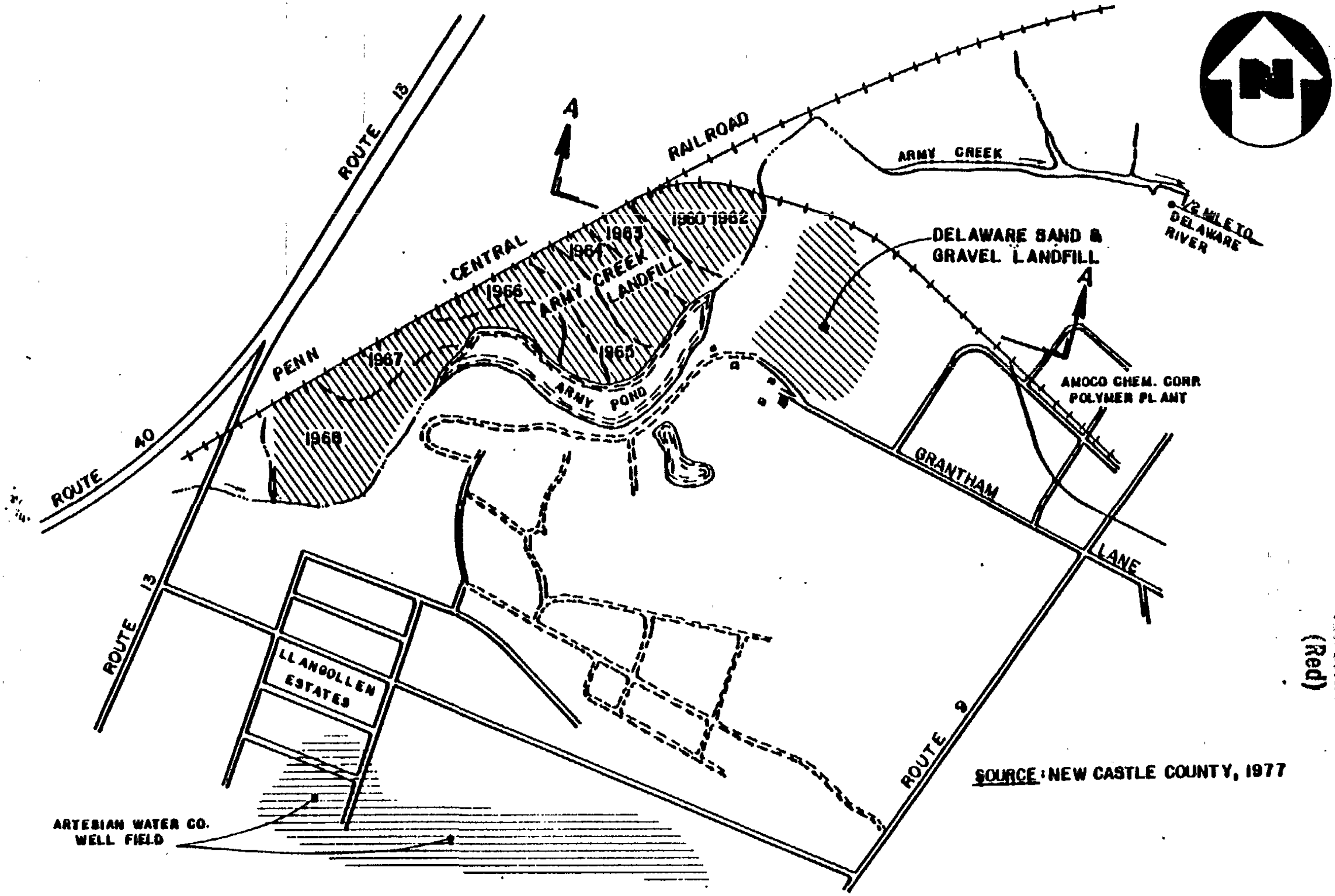


FIGURE 2

ARMY CREEK LANDFILL - SITE SKETCH
NEW CASTLE COUNTY, DELAWARE
SCALE: 1" = 1000'

NUS CORPORATION

AR302180



SOURCE: NEW CASTLE COUNTY, 1977

ORIGINAL (Red)

FIGURE . 3

NUS CORPORATION

APPROXIMATE DATES OF REFUSE EMPLACEMENT
AT THE ARMY CREEK LANDFILL
NEW CASTLE COUNTY, DELAWARE
SCALE : 1" = 1000'

AR302181

Groundwater

After the discovery of the leachate problem (in private wells) in 1971 by the Delaware Geological Survey and New Castle County Department of Public Works, the county implementated a monitoring program to determine the extent and area of leachate migration. Since then, wells in and around the landfill have been sampled extensively, primarily for inorganic water quality indicators such as COD, total iron, manganese, and chlorides. The available data typically show higher concentrations of contaminant indicators in the landfill and recovery wells than in off-site wells. Iron encrustation on recovery well casings has led to costly periodic well rehabilitation efforts. A similar trend exists in the data for organic analyses of wells and around the site. The most recent data are shown in Tables 2 and 3.

Surface Water

Limited surface water aalyses have been performed for the Army Creed Landfill. The most recent data indicate high levels of inorganic water quality indicators such as iron and manganese as well as several priority organic pollutants such as phenol, bis(2-ethyl hexyl) phthalate, butyl benzyl phthalate, and di-n-butyl phthalate.

Biota

Recent photographs taken during an NUS REMPO site visit (March 2, 1983) show normal vegetative cover with no signs of environmental stress. However, the FIT site inspection report (November 1981) noted damage to flora where leachate seeps from the landfill.

ORIGINAL (Red)

TABLE 1

SUMMARY OF FIELD MEASUREMENTS
ON NOVEMBER 9-11, 1981
E&E FIT REGION III

Wall Number	OVA (ppm)	HNU (ppm)	explosimiter (%)	O2 Meter
5A	0	0	Sight	Sufficient
A2	0	0	0	Sufficient
S1	30	5	0	Sufficient
70	200	200	0	Sufficient
A6	Off-scale	50	Off-scale	Sufficient
B12	Off-scale	3	Off-scale	NA
B11	0	0	0	Sufficient
A8	40	0	45	Sufficient
RW14	Off-scale	5	0	Sufficient
57	0	0	0	Sufficient
56	0	1	0	Sufficient
55	0	0	0	Sufficient
54	0	0	0	Sufficient
B21	0	0	0	Sufficient
B18	0	0	0	Sufficient
45	0	0	0	Sufficient
53	500	0	10	Sufficient
39	40	0	0	Sufficient
RWG	0	0	0	Sufficient
29	0	0	NA	NA
RW4	0	0	NA	NA
42	0	0	0	Sufficient
RW11	0	0	0	Sufficient
31	0	0	NA	NA
48	0	0	0	Sufficient
RW5	0	0	0	Sufficient

Chemical Compounds

Records and/or analyses of the wastes are non-existent. Analyses of groundwaters, surface waters, and sediments give the best indication of compounds and elements contained in the wastes. Generally, the data show inorganic and organic contamination on-site. The specific compounds found are summarized in Tables 2 and 3.

Hazardous Characteristics

A listing of the flammable and/or toxic characteristics of hazardous substances found in water and sediment samples is shown in Tables 4 and 5. As can be seen from the tables 24 hazardous organics and 9 inorganics, some in concentrations above Federal Drinking Water Standards and Water Quality Criteria were found in groundwater beneath the sites.

ENVIRONMENTAL SETTING

Landforms

The Army Creek Landfill, located in New Castle County, Delaware is within the Atlantic Coastal Plain geologic province.

In general, the coastal plain slopes are level to gently rolling with flat lowlands with many marshes. Elevations range from sea level to approximately 100 feet above sea level. Near the site, the slopes are gently rolling with elevations ranging from approximately 20 to 50 feet above sea level.

New Castle County Delaware, is drained mainly by streams that flow eastward into the Delaware River. The area surrounding the Army Creek Landfill is drained by Army Creek, which flows past the site to the Delaware River approximately two miles downstream.

Surface Waters

Army Creek flows between the Army Creek (Llangollen) landfill and the Delaware Sand and Gravel Landfill. It discharges into the Delaware River one mile downstream and east of the site.

Geology and Soils

In general, the landfill is underlain by stream-deposited unconsolidated sediments in excess of 600 feet thick, which overlie crystalline rocks. The unconsolidated materials comprise two geologic formations. The lowermost formation is the Potomac Formation of Cretaceous age. This formation is overlain by the Columbia Formation of the Pleistocene age.

The Columbia Formation consists of orange, tan, and yellow, medium to coarse sands and gravels that vary in grain size and degree of sorting, both vertically and horizontally within the formation. This upper geologic layer forms a nearby continuous surficial cover, ranging from 10 to 60 feet in thickness. The base of the formation ranges from about 10 feet above to 20 feet below the mean sea level in the vicinity of the landfill. The dip of the formation is toward the southeast.

TABLE 2

SUMMARY OF INORGANIC WATER QUALITY ANALYSES OF WELLS IN THE
VICINITY OF ARMY CREEK LANDFILL
FIT REGION III, NOVEMBER 9-11, 1981

PARAMETER (ppb)

Sample	Al	Cr	Ba	Be	Cd	Co	Cu	Fe	Pb	Ni
Criteria 1*	-	0.3	-	100-600	0.012	-	5.6	1.0	0.75	0.56
Criteria 2*	-	-	-	-	-	-	-	-	-	-
Criteria 3*	-	50	1000	0.037	10	-	1000	300	50	13.4
5A	300	<10	20	<2	<5	<10	<20	4560	<40	<20
51	20,700	50	160	<2	<20	20	80	87,600	80	120
70	2,000	20	50	<2	<5	20	<20	19,000	<40	<20
54	19,400	80	190	4	<5	20	80	100,000	80	40
56	100	<10	60	<2	<5	<10	<20	340	<40	<20
57	21,300	20	80	<2	<5	10	<20	20,600	<40	<20
48	5750	10	290	<2	10	30	100	106,000	<40	60
B11	6200	70	700	<2	<5	20	400	24,200	960	40
29	<50	<10	500	<2	<5	40	<20	34,600	<40	<20
45	300	<10	60	<2	<5	<10	<20	720	<40	<20
39	315,000	200	520	4	30	70	100	22,400	600	120
31	50	<10	220	<2	<5	20	<20	9280	<40	<20
RW4	4500	10	330	<2	<5	80	60	172,000	<40	20
RW5	<50	<10	100	<2	<5	30	<20	10,400	<40	<20
42	<50	<10	300	<2	<5	30	<20	21,300	<40	<20
AWC Midvale #1	100	<10	100	<2	<5	<10	<20	40	<40	<20
AWC Midvale #2	100	20	70	<2	<5	20	20	40	200	<20
AWC 03	<50	<10	70	<2	<5	<10	<20	40	<40	<20
Amoco PW2	50	<10	50	<2	<5	<10	20	260	<40	<20
Streamflow										
I	350	<10	60	<2	<5	<10	<20	1760	<40	<20
II	400	10	170	<2	<5	10	<20	2160	<40	<20
III	300	<10	270	<2	<5	20	<20	25,000	<40	<20
IV	150	<10	80	<2	<5	<10	<20	880	<40	<20
V	400	10	210	<2	<5	50	200	167,000	<40	<20

Streamflow Locations
- I Army Creek Near U.S. 13 Bridge
- II Near Well #48
- III Near Well #42
- IV Near Well #RW4
- V U.S. Rt. 9 Bridge

AR302185

ORIGINAL
(Red)

TABLE 2
SUMMARY OF INORGANIC WATER QUALITY ANALYSES OF WELLS IN THE
VICINITY OF ARMY CREEK LANDFILL
FIT REGION III, NOVEMBER 9-11, 1981
PAGE TWO

PARAMETER (ppb)

Sample	Mn	Zn	B	V	Ca	Mg	Na	As	Th	Sn
Criteria 1	-	47	-	-	-	-	-	440	40	-
Criteria 2	-	-	-	-	-	-	-	0.022	-	-
Criteria 3	50	5000	1000	-	-	-	-	50	13	-
5A	40	90	10	<10	2800	600	2300	<10	<10	<20
51	450	500	150	40	86,000	96,800	327,000	10	<40	20
70	170	180	20	10	12,700	3900	17,600	<10	<10	<20
54	140	210	<10	160	10,300	7300	5200	20	<10	<20
56	30	140	<10	<10	7800	2700	6300	<10	<10	<20
57	80	100	<10	40	8800	1700	3200	<10	<10	<20
48	3220	8630	230	<10	35,600	10,800	27,900	<10	<10	<20
B11	460	800	430	40	48,200	2030	26,800	60	<10	200
29	1130	10	320	<10	11,400	9400	52,000	<10	<10	<20
45	100	40	<10	<10	8200	3400	5500	<10	<10	70
39	2600	600	<10	400	19,800	9500	9000	50	<10	<20
31	1150	10	60	<10	8400	4700	15,700	<10	<10	<20
RW4	900	450	<10	<10	12,800	5800	12,500	<10	<10	<20
RW5	490	40	20	<10	7600	3600	11,600	<10	<10	<20
42	1220	20	<10	<10	20,100	7400	36,100	<10	<10	<20
AWC Midvale #1	<10	10	<10	<10	8600	5500	6600	<10	<10	<20
AWC Midvale #2	<10	40	10	10	8100	3600	5300	<10	<10	<20
AWC 03	<10	30	<10	<10	8500	3500	23,800	<10	<10	<20
Amoco PW2	10	70	<10	<10	7400	2400	10,100	<10	<10	<20
Streamflow										
I	290	50	50	<10	21,800	7700	17,900	<10	<10	<20
II	590	50	80	<10	13,600	4700	28,300	<10	<10	<20
III	830	20	<10	<10	20,100	7500	38,500	<10	<10	<20
IV	130	20	30	<10	20,700	7800	26,700	<10	<10	<20
V	470	150	<10	<10	11,600	5400	13,000	<10	<10	<20

Antimony <20 ppb for all samples
Mercury <1 ppb for all samples
Selenium <10 ppb for all samples
Silver <20 ppb for all samples

*Maximum values for the protection of:
Criteria 1 Fresh water aquatic life
Criteria 2 Potable water Supply (10^{-6} cancer risk)
Criteria 3 Potable water supply (toxicity)

Abstracted from Federal Register, November 28, 1980 and "Quality Criteria for Water," EPA. July, 1976.

ORIGINAL (Red)

AR302186

TABLE 3

SUMMAY OF ORGANIC ANALYSIS OF GROUNDWATER, SURFACE WATER, AND SEDIMENTS IN THE VICINITY OF THE ARMY CREEK LANDFILL (FIT REGION III, NOVEMBER 9-11, 1981)

PARAMETER (ppb)

Location	p-chloro-m-cresol	2,4-di-methyl phenol	pentachlorophenol	phenol	Bis (2-chloroethyl) ether	dieldrin	PCB-12
Well #5A							
Well #51	<10	32		<10	<10		
Well #70							
Well #54						<10	
Well #56							
Well #57							
Well #48							
Well #B11						0.35	
Well #29				<10			
Well #45							
Well #39			<10	<10			
Well #31							
Well RW4							
Well RW5							
Well #42							
AWC Mid-vale #1							
AWC #2							
AWC #3							
Amoco PW2				<10			
Streamflow							
I							
II							
III				<10			
IV							
V							
Stream Sediments							
I							
II							
III							
IV							
V							0.35 µg/g

TABLE ' 3
SUMMAY OF ORGANIC ANALYSIS OF GROUNDWATER, SURFACE WATER, AND SEDIMENTS IN THE VICINITY OF THE ARMY CREEK LANDFILL
(FIT REGION III, NOVEMBER 9-11, 1981)
PAGE TWO

Location	PARAMETER (ppb) fluoranthene	naphthalene	Bis (2-ethyl-hexyl) phthalate	Butyl benzyl phthalate	Diethyl phthalate	Dimethyl phthalate	Di-n-butyl phthalate
Well #5A			<10				<10
Well #51		<10	<10			<10	<10
Well #70			<10				<10
Well #54			<10	<10			<1[illegible]
Well #56			<10		<10		<1[illegible]
Well #57			<10				
Well #48			<10	<10			<10
Well #B11		14	10				
Well #29			<10				
Well #45			<10				<10
Well #39	<10		<10	<10			<10
Well #31			<10	<10			<10
Well RW4			<10	<10			<10
Well RW5			<10				<10
Well #42			<10				<10
AWC Mid-vale #1			<10				<10
AWC #2			<10				<10
AWC #3			<10				<10
Amoco PW2			<10				
Streamflow							
I			<10				<[illegible]
II			<10				<[illegible]
III			<10				
IV			<10				
V			<10	<10			<10
Stream Sediments							
I			*				*
II	*		*				*
III	*		*				*
IV	*		*				*
V	*		*				*

AR302188

TABLE 2-3
SUMMAY OF ORGANIC ANALYSIS OF GROUNDWATER, SURFACE WATER, AND SEDIMENTS IN THE VICINITY OF THE ARMY CREEK LANDFILL
(FIT REGION III, NOVEMBER 9-11, 1981)
PAGE THREE

	PARAMETER (ppb)						
Location	Trichloro-fluoromethane	1,2-Trans-dichloroethylene	methylene chloride	chlorobenzene	benzene	1,4-Dichloro-robenzene	Benzo (a) anthracene
Well #5A					100	<10	
Well #51							
Well #70		16	<10				
Well #54							
Well #56							
Well #57							
Well #48					<10	<10	
Well #B11				<10		<10	
Well #29							
Well #45							
Well #39				<10			
Well #31							
Well RW4	<10	31					
Well RW5					<10		
Well #42							
AWC Mid-vale #1							
AWC #2			<10				
AWC #3							
Amoco PW2							
Streamflow							
I							
II							
III							
IV							
V							
Stream Sediments							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							

AR 302189

TABLE 3
SUMMAY OF ORGANIC ANALYSIS OF GROUNDWATER, SURFACE WATER, AND SEDIMENTS IN THE VICINITY OF THE ARMY CREEK LANDFILL
(FIT REGION III, NOVEMBER 9-11, 1981)
PAGE FOUR

PARAMETER (ppb)

Location	chrysene	anthracene	phenathrene	pyrene	benzo (a) pyrene	Benzo (a) fluoranthene	Benzo (k) fluoranthene	Benzo (ghi) perylene
Well #5A								
Well #S1								
Well #70								
Well #54								
Well #56								
Well #57								
Well #48								
Well #B11								
Well #29								
Well #45								
Well #39								
Well #31								
Well RW4								
Well RW5								
Well #42								
AWC Mid-vale #1								
AWC #2								
AWC #3								
Amoco PW2								
Streamflow								
I								
II								
III								
IV								
V								
Stream Sediments								
I								
II	*	*	*	*				
III	*	*	*	*				
IV	*	*	*	*	*	*	*	*
V		*	*					

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TABLE 3
SUMMAY OF ORGANIC ANALYSIS OF GROUNDWATER, SURFACE WATER, AND SEDIMENTS IN THE VICINITY OF THE ARMY CREEK LANDFILL
(FIT REGION III, NOVEMBER 9-11, 1981)
PAGE FIVE

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*Indicates that the chemical was detected below the detection limit.

Streamflow and Sediment Locations

I	U.S. Route 13 Bridge
II	Near Well #48
III	Near Well #42
IV	Near Well #RW4
V	U.S. Route 9 Bridge

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AR 302192

The Potomac Formation, which is approximately 600 feet thick, consists of variegated red, gray, purple, yellow, and white, frequently lignitic silts and clays containing interbedded white gray, and rust-brown sands and some gravel. This formation thickens and dips toward the southeast at approximately 40 to 140 feet per mile. The Potomac Formation is divided into the Upper Potomac and the Lower Potomac Formations, separated by a thick confining clay layer.

In the upper Potomac Formation the relatively impermeable silts and clays are discontinuous and not uniform, with the sands of the Columbia, and Potomac Formations coming in direct contact in some areas. A hydrogeologic cross section (Section A-A in Figure 2 is shown in Figure 4 (Lee, 1982).

Since the discovery of contamination in the aquifers below the landfill, numerous wells have been drilled in and around the landfill. A review of logs of borings reveals that sediments described in and around the landfill correlate adequately with the general geologic description above. The logs list what could be identified as the fine and coarse sediments of the Columbia and/or upper Potomac formations. The locations of selected wells in the vicinity of the landfills are shown in Figure 5.

The Eastern portion of the landfill has been mapped in the USDA-SCS Soil Survey of New Castle County, Delaware as a gravel pit or quarry. The western portion of the landfill has been mapped as Matapeake silt loam soil that has been moderately eroded. Soil survey information was gathered before the western portion was used as a landfill as indicated by Figure 3. Today the western portion would be considered and mapped as gravel pit or quarry also.

In the vicinity of the landfill the soil survey has mapped Matapeake silt loam, Matapeake-Sassafras-Urban Land Complex, and Woodstown loam. The slopes on these mappings Units range from 0-10 percent.

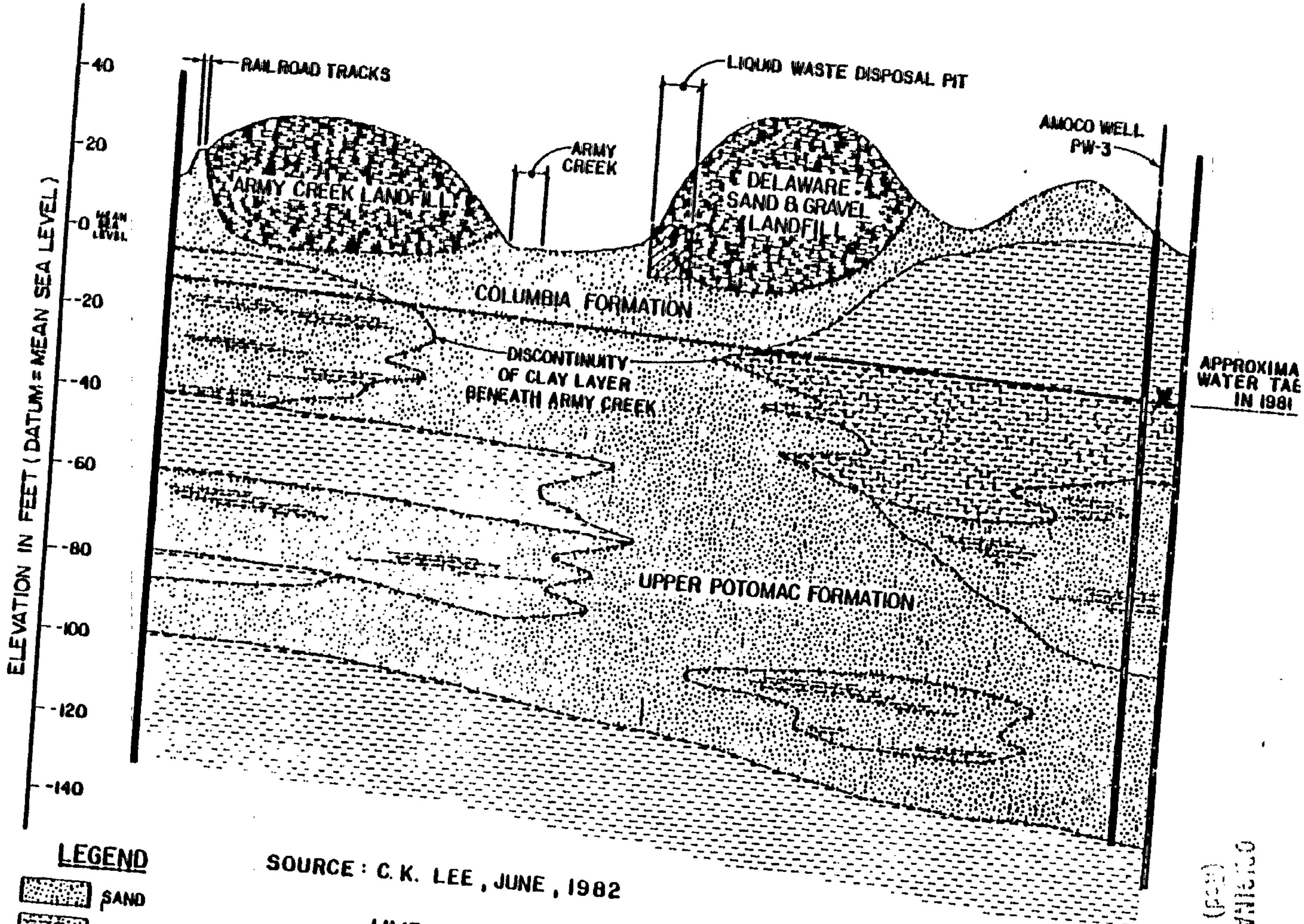
The Matapeake soil series consists of deep, well-drained soils that occur on uplands of the Coastal Plain. The permeability in this soil ranges from 0.63 to 2.0 inches per hour.

The Woodstown series consists of deep, moderately well-drained soils that occupy uplands of the Coastal Plain. These soils develop on old deposits of sandy material that contain a moderate amount of slit and clay. Permeability in this soil ranges from 2.0 to 6.3 inches per hour.

Groundwater

The three aquifers which occur in and/or around the landfill site are the:

- Shallow, unconfined Columbia Aquifer
- Confined, Upper Potomac Aquifer
- Confined, Lower Potomac Aquifer



SOURCE : C. K. LEE , JUNE , 1982

HYDROGEOLOGIC SECTION A-A
ARMY CREEK LANDFILL
NEW CASTLE COUNTY, DEL
HORIZONTAL [illegible]ALE: 1"≈500'
NOT TO VE[illegible]AL SCALE

FIGURE 4

TABLE 4.

HAZARDOUS CHARACTERISTIC OF PRIMARY ORGANIC POLLUTANTS DETECTED IN WATER AND SEDIMENT SAMPLES AT THE ARMY CREEK LANDFILL

Pollutant	Aqueous Concentration Range	Flammability/Reactivity	Toxicity/Carcinogenicity
p-chloro-m-cresol	<10 μg/l	Moderately flammable when exposed to heat or flame. Slight explosion hazard when vapors are exposed to heat or flame. Emits highly toxic fumes when heated to decomposition.	Highly toxic via oral and subcutaneous routes. An allergen.
2,4-dimethyl-phenol	32 μg/l	No information available.	Moderately toxic via oral route. An experimental carcinogen.
Pentachloro-phenol	<10 μg/l	No information available, but emits highly toxic chloride fumes when heated to decomposition.	Highly toxic via oral, dermal, intraperitoneal and subcutaneous routes.
Phenol	<10 μg/l	Moderately flammable when exposed to heat, flame or oxidizers. When heated, evolves toxic and flammable vapors which can form explosive mixtures with air.	Highly toxic via oral and dermal routes. Acute toxic effect is on central nervous system. Rapid death through dermal exposure can occur. Chronic poisoning leads to digestive disturbances, nervous disorders, and skin eruptions. Extensive damage to kidney and liver may cause death. It is a cocarcinogen and experimental carcinogen via dermal route.

TABLE 4
HAZARDOUS CHARACTERISTIC OF PRIMARY ORGANIC
POLLUTANTS DETECTED IN WATER AND SEDIMENT SAMPLES
AT THE ARMY CREEK LANDFILL
PAGE TWO

Pollutant	Aqueous Concentration Range	Flammability/Reactivity	Toxicity/Carcinogenicity
Fluoranthene	<10 µg/l and present in sediment	Slight fire hazard when exposed to heat or flame.	No information available.
Naphthalene	<10-14 µg/l	Moderately flammable. Reacts with oxidizing materials, reacts violently with CrO_3. Dust is a moderate explosion hazard when exposed to heat or flame.	Moderately toxic via oral route. Highly toxic via intraperitoneal route.
Butyl benzyl phthalate	<10 µg/l	Slight fire hazard when exposed to heat or flame. Can react with oxidizing materials.	Moderately toxic via intraperitoneal route. An irritant to mucous membrane. Narcotic at high concentrations.
Diethyl-p-phthalate	<10 µg/l	Low flammability.	Moderately toxic via intraperitoneal route. An irritant to mucous membranes, a narcotic at high concentrations.
Fluorotrichloromethane	<10 µg/l	Dangerous when heated to decompostion, emits highly toxic fumes of fluorides and chlorides. Reactions violently with aluminum and lithium.	Mild irritant. Low toxicity via inhalation route. High concentrations cause narcosis and anesthesia.
Di-n-Butyl Phthalate	<10 µg/l and present in sediment	Moderately flammable. Vapor may decompose into toxic and corrosive substances (chlorides and/or phosgene) at high temperatures.	Moderately toxic via inhalation oral route. Causes narcosis and anesthesia. Severe acute exposure may be fatal. Chronic exposure may lead to liver damage. A suspected carcinogen.

AR 302195

TABLE . 4.
HAZARDOUS CHARACTERISTIC OF PRIMARY ORGANIC
POLLUTANTS DETECTED IN WATER AND SEDIMENT SAMPLES
AT THE ARMY CREEK LANDFILL
PAGE THREE

Pollutant	Aqueous Concentration Range	Flammability/Reactivity	Toxicity/Carcinogenicity
Trans-dichloroethylene	16-31 µg/l	Highly flammable when exposed to heat, flame or oxidizers. Moderate explosion hazard in vapor form when exposed to flame. Can react vigorously with oxidizing materials, emits highly toxic chlorides.	Low toxicity via inhalation route. Moderately toxic via oral route. Exposure to high concentrations of vapor may cause nausea, vomiting, weakness, tremors, and cramps.
Methylene chloride	<10 µg/l	Non-flammable but forms flammable vapor and air mixture at about 100°C or higher. Emits highly toxic phosgene fumes when heated to decomposition.	Moderately toxic via oral, subcutaneous, intraperitoneal and inhalation routes. Very dangerous to the eyes. Induces narcosis. An experimental carcinogen.
Chlorobenzene	<10 µg/l	Highly flammable. Moderately explosive when exposed to heat or flame. Can react vigorously with oxidizing materials.	Moderately toxic via oral, inhalation and subcutaneous routes. Strong narcotic. Chronic exposure may cause liver and kidney damage.
Benzene	<10-100 µg/l	Highly flammable. Vapor may travel considerable distances to a source of ignition and flash back. Can react violently with oxidizing materials. Vapors pose a moderate explosion hazard when exposed to flame.	Acute and chronic toxicity via inhalation and dermal routes. Acute poisoning (≤3000 ppm) characterized by narcotic effect on central nervous system,

ORIGINAL
(Red)

TABLE 4.
HAZARDOUS CHARACTERISTIC OF PRIMARY ORGANIC POLLUTANTS DETECTED IN WATER AND SEDIMENT SAMPLES AT THE ARMY CREEK LANDFILL
PAGE FOUR

Pollutant	Aqueous Concentration Range	Flammability/Reactivity	Toxicity/Carcinogenicity
Benzene (continued)			followed by death through respiratory failure (prolonged exposure). Chronic toxicity characterized by a variety of symptoms which vary widely from person to person. It is a recognized leukemogen.
1,4 dichlorobenzene	<10 µg/l	Moderately flammable when exposed to heat, flame or oxidizers. Emits highly toxic chloride fumes when heated to decomposition.	Moderately toxic via intraperitoneal and inhalation routes. High toxic via oral. Reported to cause liver damage in humans. It is an experimental carcinogen.
Benz(a)anthracene	present in sediment	No information available	Highly toxic via many routes and an experimental carcinogen.
Chrysene	present in sediment	No information available	Highly toxic via subcutaneous, dermal and probably inhalation routes. An experimental carcinogen and neoplasm former.

AR 302197

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TABLE 4 :
HAZARDOUS CHARACTERISTIC OF PRIMARY ORGANIC POLLUTANTS DETECTED IN WATER AND SEDIMENT SAMPLES AT THE ARMY CREEK LANDFILL
PAGE FIVE

Pollutant	Aqueous Concentration Range	Flammability/Reactivity	Toxicity/Carcinogenicity
Anthracene	present in sediment	Low flammability when exposed to heat or flame. Reacts with oxidizers. Moderate explosion hazard when exposed to heat, flame, $Ca(OCl)_2$ or chromic acid.	An allergen and mild irritant. A recognized carcinogen of the skin, hands, forearms and scrotum. An experimental carcinogen of the bladder.
Phenanthrene	present in sediment	Low flammability when exposed to heat or flame. Can react with oxidizing materials.	Moderately toxic via oral route. A skin photosensitizer. An experimental carcinogen via dermal route.
Pyrene	present in sediment	No information available	An experimental neoplasm former via dermal route.
Benzo(a)Pyrene	present in sediment	No information available	An experimental carcinogen, neoplasm former and mutagen.
Benzo(a)Fluroanthene	present in sediment	No information available	An experimental carcinogen.
Benzo(k)Fluoranthene	present in sediment	No information available	An experimental carcinogen.
Benzo(ghi)perylene	present in sediment	No information available	An experimental carcinogen.

NOTE: <10 µg/l = detected but not quantified

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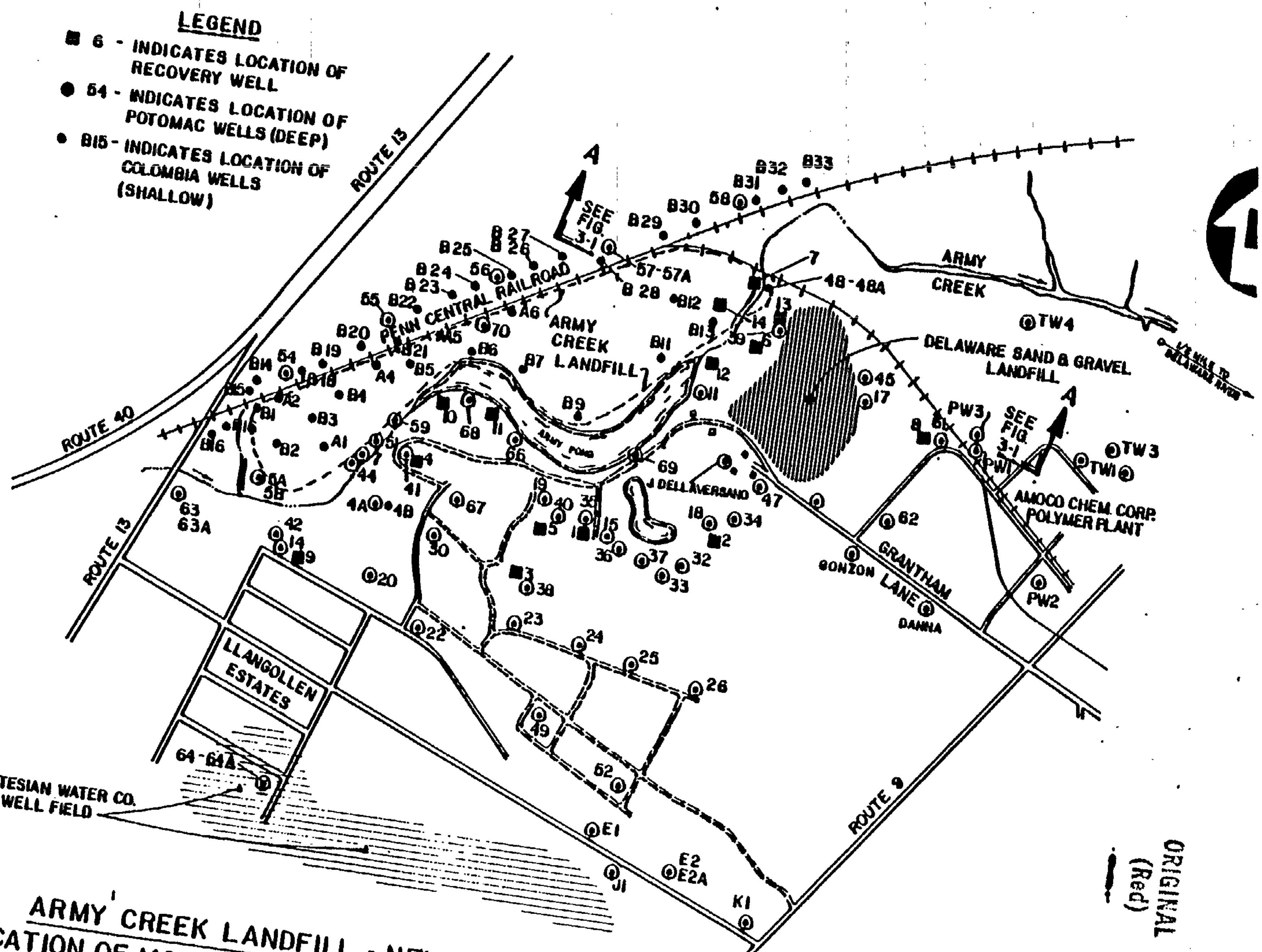
ORIGINAL (Red)

TABLE 5

INORGANIC POLLUTANT DETECTED IN WATER AND SEDIMENT SAMPLES
AT THE ARMY CREEK LANDFILL
(VARIOUS DATES)

Pollutant	Aqueous Concentration Range ug/l	Sediment Concentration Range ug/kg	Maximum Contaminant Limit for the Protection of Potable Water Supplies ug/l
Arsenic	<10 - 60	-	50
Beryllium	<2 - 4	0.2	0.037
Cadmium	<5 - 30	-	10
Chromium	<10 - 200	<1 - 3	50
Iron	40 - 224,000	106 - 6430	300
Lead	<40 - 960	<4 - 16	50
Manganese	<10 - 3220	47 - 282	50
Nickel	<20 - 120	<2 - 4	13.4
Zinc	10 - 8630	2 - 54	5000



ARMY CREEK LANDFILL - NEW CASTLE COUNTY, DELAWARE
LOCATION OF MONITORING, PRODUCTION AND RECO…

FIGURE

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(Red)

The shallow, unconfined Columbia Aquifer appears in the sands and gravels of the Columbia Formation above the confining clay and silt sediments of the Potomac Formation, where present. Where these clays are not present, the aquifer is unconfined. The water table in the Columbia Aquifer (deposits) is changed by seasonal fluctuation up to 10 feet, generally rising from mid-October to early April and declining from mid-April to mid-October. The general groundwater flow in this aquifer is toward Army Creek.

The Upper Potomac Aquifer is one of the most productive groundwater zones of New Castle County. This aquifer is a principal source of drinking water in the county. Most large industrial groundwater supplies and almost all groundwater withdrawls for municipal and land uses, obtain their water from the coarse grained deposits of this aquifer.

This confined aquifer ranges in thickness from 2 to 80 feet. Pump tests have shown the hydraulic conductivity to be 500 gpd/sq. ft, however these results may be suspect (Altomari, 1983). Transmissivity ranges from 45,000 to 70,000 gpd/ft (DeWalle 1981, Lee 1982). Regional accounts show transmissivity values in the Upper Potomac for this area of Delaware range from 40,000 to 50,000 gpd/ft.

The groundwater flow is generally from north to south toward the Delaware River, with an approximate natural hydraulic gradient of 0.005 ft per foot (Lee 1982).

Climate and Meteorology

Delaware, as part of the Atlantic Coastal Plain, consists mainly of flat lowlands with many marshes. The Army Creek Landfill is located approximately seven miles south of Wilmington, Delaware, in the northern end of the state. This area is marked by low, rolling hills which extend northward and northwestward into Pennsylvania.

Characteristic of this region are warm,humid summers and winters which are usually mild. Because of the close proximity of large water bodies and the inflow of southerly winds, this region experiences high relative humidity year-round.

The rainfall distribution is fairly uniform throughout the year with the summer normally experiencing the largest amount. Winds from the Northwest prevail at an average of 9.2 mph in this area. A summary of average monthly temperatures and rainfall for Wilmington is listed Table 6.

Land Use

Land within one mile of the Army Creek Landfill is used for residential, commercial, and industrial purposes.

The Amoco Chemical Corporation Polymer Plant is located approximately one-half mile east of the site. The plant had operated its own well field until 1973, producing between 1.3 mgd and 2.5 mgd, until the wells became contaminated and were closed. This contamination was probably caused by leachate from the Army Creek and Delaware Sand and Gravel Landfills (Lee, 1982). The plant has been inactive since 1980.

Commercial development is extensive along Interstate Route 40, located northwest of the site. Most of these establishments, especially those in the Midvale area, are located within one mile of the site.

The Artesian Water Company's well field is located one-half mile south of the site and currently provides the potable water supply for a population of approximately 100,000. During the early 1970's the company produced as much as 5.3 mgd from its well system. However, since the start-up of the recovery well system installed by New Castle County, pumping has been curtailed to a maximum of 2 mgd, with an average of approximately 1.8 mgd.

Also located within one half mile south of the site is Llangollen Estates, a major residential center of approximately two hundred single family dwellings. Light industrial development is located within one mile of the site, along Grantham Lane and Hamburg Road, as shown in Figure 1. There are about thirty single-family dwellings located in these areas.

Another land use within the vicinity of the site is the Delaware Sand and Gravel Landfill, located across Army Creek to the east. This site was used as a municipal and industrial landfill from 1968 until it was closed in 1976.

POTENTIAL RECEPTORS

Population Distributions

The largest population center within a ten-mile radius of the Army Creek Landfill is Wilmington, Delaware. Located seven miles north of the site, Wilmington has a population of 70,195 according to the 1980 census. Delaware City lies seven miles to the southwest and has a population of 1,858. Two miles northeast of the site is New Castle, Delaware, which has a population of 4,907. A residential development of approximately 200 single-family dwellings, Llangollen Estates, lies one-half mile to the south.

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TABLE 6
AVERAGE MONTHLY TEMPERATURES AND
RAINFALL FOR WILMINGTON, DELAWARE

Month	Temperature (°F)	Rainfall (In.)
January	32.0	2.85
February	33.6	2.75
March	41.6	3.74
April	52.3	3.20
May	62.4	3.35
June	71.4	3.24
July	75.8	4.31
August	74.1	3.98
September	67.9	3.42
October	57.2	2.60
November	45.7	3.49
December	34.7	3.32
TOTAL	54.0°F(ave.)	40.25" (annual)

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Water Users

Surface Waters

Currently the waters of Army Creek and Army Pond are not used for water supply, recreational or industrial purposes.

Groundwater

The major user of groundwater in the area is the Artesian Water Company, located near Llangollen Estates. In 1973, New Castle County installed its groundwater containment program to temporarily prevent leachate from contaminating the Artesian well field. This program involved installing numerous monitoring and leachate recovery wells between the landfills and the Artesian well field. The effort resulted in a production limit of 2.0 mgd by the Artesian Water Company.

Currently, all but 14 residences of Llangollen Estates are served by the Artesian Water Company (Altomari, 1983). These residents continue to acquire their potable water from private wells, as did the other residents until aquifer contamination was detected.

The Amoco Chemical Corporation Polymer Plant was the only other user of groundwater in the area. Well water production ceased in 1973 when the production wells became contaminated.

Land Users

Local residents are the primary land users of the areas adjoining the Army Creek Landfill. The residential areas of Llangollen Estates and Midvale are located within one half mile of the landfill to the south and north, respectively.

Even though they are graphically removed from the site, customers of the Artesian Water Company must also be considered when identifying potential land users in the vicinity of the landfills.

PUBLIC HEALTH CONCERN

Air Pollution

During the November, 1981 site inspection conducted by FIT Region III, air pollution readings were obtained using an inorganic vapor analyzer (OVA) monitoring instrument which detects certain organic vapors and gases. The readings, in well casings in which organic vapors were detected, ranged from 40 ppm in Monitoring Well A8 to off-scale readings in Recovery Well 14 and Monitoring Well A6. The majority of the wells showed no organic vapors. It is difficult to assess the significance of the off-scale readings for the air quality in the vicinity of these wells. However, at the concentrations found in other wells in the area (500 ppm), natural dispersion of organic vapors is expected to be sufficient to decrease concentrations below detectable and harmful levels except in the immediate vicinity of the wells. In view of the off-scale readings it will be necessary to evaluate each area by additional monitoring of ambient air. The hazard to surrounding populations presented by air pollution from this site, however, appears to be minimal.

From another viewpoint, since the landfill was operated as a sanitary landfill without a gas venting system, the potential exists for the release of methane gas as a result of anaerobic decomposition. Again this does not appear to be of great concern for off-site exposures.

Soil Contamination

Soils have not been sampled at the Army Creek Landfill. Wastes are not apparent over the surface of the landfill and surface contamination would not be expected since the wastes have been covered by several feet of uncontaminated soils. However, soil contamination should be expected in areas where leachate seeps from the landfill. Direct contact with these areas should be avoided.

Groundwater Contamination

The contamination of the Columbia and Potomac aquifers, which serve as the potable water supply for a population in excess of 10,000, is a major public health concern. The hydrogeologic connection between the Army Creek and Delaware Sand and Gravel Landfills has been documented in previous reports by the county's consultants and FIT Region III. The evaluation below addresses the contribution to the groundwater quality degradation by the Army Creek Landfill.

The presence of groundwater contamination in private wells was confirmed by the Delaware Geological Survey and the New Castle County Department of Public Works in 1971. Since then, extensive monitoring has defined the area and extent of contaminant migration. Both inorganic and organic contaminants have been detected in wells on and around the landfill.

The most recent data resulting from the FIT site inspection in November 1981, indicate levels of several contaminants greater than the Federal Drinking Water Standards. These include iron, manganese, chromium, beryllium, cadmium, lead, nickel, zinc, and arsenic. The Artesian Water Company Well #2, a source of potable water supply, contained four times the maximum contaminant limit of lead.

Nineteen priority organic pollutants were detected in the samples but only four were quantified. Also, DNREC sampled private drinking water wells in the vicinity of the landfill and found low levels (generally 1 ppb) of chloroform, trichlorothylene, perchloroethylene, and 1,2-dichloroethane. These compounds are also moderately to highly toxic, with three of the four considered carcinogenic.

Surface Water Contamination

Army Creek receives surface water runoff and recovery well discharges from the groundwater recovery system. However, Army Creek is not used for municipal, industrial, or recreational purposes prior to its discharge to the Delaware River, one mile downstream. The effect of the creek on the Delaware River is expected to be minimal due to dilutio

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It can not be determined at this time if discharges from the recovery wells affect fish, wildlife, and other casual users of Army Creek.

Fire and Explosion

Explosive vapor mixtures were detected in several of the well casings during the FIT site inspection in November, 1981. Also, the nature of the landfill (i.e., sanitary) would lend itself to the generation of methane gas. Thus, the potential for fire or explosion exists, but the probability of explosion appears to be small due to normal dilution and dispersion of the vapors and gases.

General Risk Assessment

Air and soil contamination present minimal threat to the public so long as access to the site is limited.

Groundwater contamination in the vicinity of the site presents the most serious threat to the public health. Analytical investigations show that toxic and carcinogenic organic compounds as well as toxic levels of some inorganics are present in the groundwater.

Surface waters could possibly pose some threat due to use of Army Creek by presently unidentified casual users. The impact of Army Creek on the Delaware River should be minimal due to dilution.

Specific Toxicological Assessment

EPA-Region III toxicologist, Dick Brunker, has reviewed the chemical data presented in Tables 2 and 3. A copy of Brunker's report is attached.

United States Department of the Interior

GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
208 Carroll Building
8600 La Salle Road
Towson, Maryland 21204

Roy

ORIGINAL (Red)

November 3, 1983

Ms. Stephanie Del Re'
U.S. Environmental Protection Agency
Office of Waste Programs
Enforcement
Washington, D.C. 20460

Re: Army Creek Landfill

Dear Ms. Del Re':

Don Vroblesky has completed his review and discussion of the existing data concerning Army Creek (Llangollen) landfill, New Castle County, Delaware, as part of the U.S. Geological Survey hydrogeologic support for the U.S. Environmental Protection Agency. The report is attached. As requested by Roy Shrock, his packet also contains xerox copies of most of the cited references.

Herbert J. Freiberger

Enclosure

cc: Roy Shrock
Philadelphia, Pennsylvania

AR 302207

REVIEW AND DISCUSSION OF EXISTING DATA

CONCERNING ARMY CREEK (LLANGOLLEN) LANDFILL

AND DELAWARE SAND AND GRAVEL LANDFILL,

NEW CASTLE COUNTY, DELAWARE

ORIGINAL (Red)

Don Vroblesky, Hydrologist
U.S. Geological Survey, Towson, Maryland

A. INTRODUCTION

This review has been prepared by the U.S. Geological Survey as part of the cooperative hydrogeologic support for the U.S. Environmental Protection Agency (EPA) Enforcement investigation and alternatives assessment. The purpose is to summarize previous efforts and to list any additional tasks related to hydrogeology which need to be performed to fully assess the contamination of the soil, surface-water, and ground-water at the Army Creek Landfill and the Delaware Sand and Gravel Landfill for the purpose of selecting optimum remedial actions. Cost analyses and political opposition to specific options are not addressed here.

B. PREVIOUS INVESTIGATIONS

Several reports have been published on the ground-water hydrology in the general area of the Army Creek Landfill. These reports include:

1. Water level measurements (Boggess and Coskery, 1956, Coskery, 1957, 1960, 1961a, 1961b; Coskery and Rasmussen, 1958; Marine, 1955; Marine and Rasmussen, 1954; Martin and Denver, 1982).

2. A hydrologic atlas of the Wilmington area by the U.S. Geological Survey for the period 1950-1961 (Adams and Boggess, 1964).

3. Reports on the ground-water resources of Delaware (Marine and Rasmussen, 1955; Sundstrom, Pickett, and Varrin, 1975; Roy F. Weston, Inc., 1970; Woodruff, 1969, 1970) and of northern Delaware specifically (Martin, in review; Rasmussen and others, 1957; Sundstrom and Pickett, 1971; Sundstrom and others, 1967).

4. A report on the water resources of the Delmarva Peninsula (Cushing and others, 1973).

Additional reports have been published on the specific

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hydrology of the Army Creek Landfill since ground-water contamination was first detected in 1971. These reports include: Apgar (1975, 1976); Apgar and Langmuir (1971); Baedecker and Apgar (in press); Baedecker and Back (1979a, 1979b); Clark (1979); DeWalle and Chian (1981), Fiore and Satterthwaite (1973); Geraghty and Miller, Inc. (1982); Lee (1981, 1982); Lee and McGovern (1982a, 1982b); Leis and others (1976); Miller (1982); Miller and Silka (1981); New Castle County (1979); Niesen (1974); NUS Corporation (1983); Roy F. Weston, Inc. (1972, 1973a, 1973b, 1973c, 1973d, 1973e, 1974a, 1974b, 1974c, 1975a, 1975b, 1976, 1977a, 1977b, 1978, 1980a, 1980b, 1980c, 1981); Webb (1974), and Satterthwaite and Apgar (1972). Some of the consulting reports by Roy F. Weston, Inc., and by Ecology and Environment, Inc., have been published by specific authors. These references are cited under the author's name. Specific contents of the above reports are discussed where appropriate in the following sections. Complete references are cited at the end of this report.

C. SOURCE CONTROL MEASURES IDENTIFIED IN THE RAMP:

1. Closure of hazardous waste landfill to include measures designed to minimize infiltration and prevent contaminant migration.

   a. Surface capping (synthetic or natural cover materials)
   b. Regrading to control surface-water runoff
   c. Revegetation

Requirements:

1) Estimate of the contribution of vertical infiltration to leachate generation.
2) Estimate of the amount of water that will enter the refuse after reduction of infiltration.

Available data:

Based on hydrologic mass balance calculations, Lee and McGovern (1982a, p. 4.3) has estimated that only 0.4% of the water moving through Army Creek landfill is from vertical infiltration. This figure is probably low because the data used in the mass balance calculation appear to be for the aquifer thickness and not for the saturated landfill thickness. A more correct statement would be that only 0.4% of the combined ground-water flow through the fill and through the aquifer immediately beneath the fill is derived from vertical infiltration of precipitation through the fill. Baedecker and Apgar (in press, p.5) estimate that 70% of the leachate generation originates as infiltrating percolation and only 30% from lateral inflow.

Thicknesses of saturated refuse are shown Niessen (1974), New Castle County (1979), and DeWalle and Chian (1981). The contribution of infiltration to generation of landfill leachate can be calculated based on these figures. An estimate of the amount of precipitation infiltration and ground-water infiltration to the fill is also given in Roy F. Weston(1974). Papers by Clark (1979), Roy F. Weston (1974), and Niesen (1974) contain estimates o. the amount of water t. t will enter the refuse after reduction of infiltration.

ORIGINAL (Red)

Data deficiencies:
None.

2. <u>Partial excavation and disposal of wastes (those below the seasonal water-table).</u>
 a. On-site in a newly constructed landfill
 b. Off-site in a suitable facility

Requirements:
1) Suitable location to receive the wastes
2) Evaluation of the possibility of releasing contaminants during handling and transport.
3) Location of areas within the fill containing wastes disposed of below the seasonal water-table.

Available data:

Of primary hydrogeologic importance in determining possible locations for a new onsite landfill is the configuration of the clay layers and the water table. The thickness of the red clay confining unit at the Army Creek Landfill site is shown in a report by Roy F. Weston (1973a). Geologic conditions elsewhere in New Castle County are discussed in reports cited in B3 above.

The potential for release of contaminants during handling and transport depends on the chemical stability of waste material. Although leachate tests have not been done on the waste material, the presence of a plume of contaminated ground-water indicates that the material is highly leachable. Excavation and handling techniques would have to include rainwater diversion and control of surface-water runoff.

A paper by Niessen (1974) contains maps showing the bottom of the fill, the thickness of the fill, the thickness of saturated refuse in January, 1974, and the elevation of the water table. Most of these maps can also be found in New Castle County (1979), and DeWalle and Chian (1981). These data can be used along with water-table elevation maps of the wet season to determine the location of areas within the fill containing wastes disposed of below the seasonal water-table.

Data deficiencies:
None. An alternative apparently not considered is removal of the waste buried beneath the seasonal water-table to a hydrogeologically sound, temporary storage area. The excavations could then be backfilled to above the seasonal water-table, and the waste material could be returned to the original fill and reburied. The same requirements and available data as above pertain to this alternative.

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Requirements:

1) Evaluation of the degree of treatment required to bring such presumably high concentrations to within acceptable limits for discharge.

2) Evaluation of the possibility of releasing contaminants during the well installation process.

3) Evaluation of the effects of mixing of the leachate with uncontaminated, oxygenated ground-water induced to move into and through the fill material as a result of the pumping.

Available data:

This option has been discussed briefly by Clark (1979), suggesting that the leachate could be discharged into a county sewer. It has also been discussed indirectly by Roy F. Weston (1974) in relation to drainlines. The report discusses options of what to do with the leachate, including recirculation and spray irrigation. Treatability studies of the leachate collected from down-gradient wells has been done (Fiore and Satterthwaite, 1973). The determination was that the only interim treatment feasible would be lime addition, filtration, and final pH adjustment. This treatment would substantially reduce the amount of metals in solution, but would not effectively reduce COD and ammonia contamination. The study determined that if water quality suitable for recharge of an aquifer used for public supply is desired, then additional treatment must be used, such as activated carbon, ion exchange, and reverse osmosis. These methods all concentrate contaminants in the spent carbon or brine solution rather chemical or biological degradation of them, creating a problem of residue disposal. Leachate collected directly from the fill will be more highly concentrated that the samples for the treatability study. Extraction analyses done on leachate taken directly from the fill (letter to Harry Otto, DNREC, from USEPA Southeast Research Lab., 5/18/74) show large amounts of organic acids and industrial chemicals, particularly phenols, relative to the other site wells. The amount of treatment required for the leachate will therefore be greater than indicated by the study.

The possibility of releasing contaminants during the well installation process depends on the leachability of the material, which has been discussed in "C2" above. Well installation methods must be chosen which utilize as little water as possible in order to minimize leachate generation.

The effects of mixing oxygenated water with oxygen-deficient leachate on organic chemistry is discussed in Baedecker and Apgar (in press) and Baedecker and Back (1979a, 1979b). If most of the iron in the existing leachate plume is due to dissolution of aquifer matrix by leachate, as suggested by Baedecker and Apgar(in press), then water flowing into the fill, mixing with leachate, and being removed by wells in the fill would be expected to contain substantially less iron than found in wells pumping leachate from the aqui...r.

ORIGINAL (Red)

Data deficiencies:

Treatability studies of leachate immediately adjacent to or preferably in the fill material are needed to evaluate this option. Suitable methods of disposal of the contaminants concentrated by the additional treatment methods must be determined.

4. Gas venting

Requirements:

1) Indications that gasses are present in sufficient amount to be hazardous.

Available data:

OVA readings at the well heads in November, 1981 (Ecology and Environment, 1982) show high values at the Army Creek landfill, indicating that methane and other volatile organic gasses are present in explosive concentrations at several wells.

Data deficiencies:

None concerning hydrogeology, although a risk assessment should be determined before initiating additional drilling, grading, or excavation at the fill.

5. No action

Requirements:

Assessment of the time neccessary to deplete the landfill of leachable material.

Available data:

The available data is largely qualitative. The time to restore the aquifer has been estimated at 25 years (New Castle County, 1977), but it has been observed, for example, that some landfills from the days of the Roman Empire are still producing leachate (Freeze and Cherry, 1979, p. 437). Baedecker and Apgar (in press, p.24) point out that the refractory nature of many organic compounds and their tendency to remain coated on aquifer materials may cause contamination problems long after the concentrations of major inorganic constituents return to pre-landfill conditions.

Data deficiencies:

The amount of leachate to be generated and the time neccessary to deplete the landfill of leachable material are unknown and possibly unknowable factors. If this option is chosen, it must be assumed that the aquifer will be unusable for at least several generations.

AR302212

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D. OFF-SITE CONTROL MEASURES IDENTIFIED IN THE RAMP:

I. No action.

Requirements:
1) Rate of ground-water movement
2) Rate of leachate input to ground-water system
3) Rate of attenuation of pollutants
4) Rate of mechanical dispersion of pollutants
5) General behavior of contaminants in ground-water system.

Available data:

This option relys on natural attenuation and dispersion of the leachate by the aquifer. The rate of ground-water movement depends on aquifer hydraulic conductivity (k) and on the head gradient (I): velocity=KI. Ground-water flow velocities and travel times between the Llangollen landfill and nearby major production wells have been calculated (Roy F. Weston, 1973a); however, they were based on head gradients for 1972 and probably need to be reevaluated based on more recent head data and updated transmissivity values. The head gradient can be determined from water table and piezometric maps. Limiting the data to those wells screened at approximately the same depth below the water table will reduce the effects of vertical flow on the head gradient calculation. Water table or piezometric maps can be found for specific years in almost all of the reports on the site. The hydraulic conductivity is a factor related to the aquifer matrix. It can be computed from transmissity by dividing transmissivity by the thickness of the aquifer. Transmissivities based on pumping and recovery tests have been calculated for the study area (Roy F. Weston, 1973b). The thickness of the aquifer can be found in boring logs (in EPA files, Philadelphia) or can be estimated if necessary.

The rate of leachate input to the ground-water is a function of the amount of water entering the fill and of the leachability of the refuse. The amount of water(Q) entering the fill from horizontal flow can be calculated from Darcy's Law: Q=KIA, where A= a cross-sectional area of the saturated waste through which water flows. K and I are calculated as above. The area (A) can be determined from maps of the thickness of saturated refuse (found in Niessen, 1974; New Castle Co., 1979, DeWalle and Chian, 1981). The amount of vertical infiltration can be calculated as discussed in C-1 above.

Although the leachability of the waste is an unknown factor, a qualitative measure of the amount of leachate being generated can be determined based on the amount of water entering the fill and the known concentration of contaminants in the ground water. This is probably adequate for purposes of determining the impact of a "no-action" decision.

The rate of attenuation of organic compounds in leachate moving through the aquifer at Llangollen landfill has been estimated by Webb (1974) and DeWalle and Chian (1981). Th[e] degree of dilution due to dispersion can be computed usin[g] chloride as the conservative species. Chloride analyses from wells at the site are available for calibration for each year from 1973 to 1983. A summary of chloride analyses for four wells at the site can be found in Baedecker and Apgar (in press, Fig. 6). A cross-section of the chloride plume in mid 1973 showing movement through the punctured clay is shown in DeWalle and Chian (1981).

The general behavior of the organic contaminants in the aquifer at Llangollen landfill is discussed in papers by Baedecker and Apgar (in press) and Baedecker and Back (1979a, 1979b).

Data deficiencies:
None

2. Expansion of present ground-water recovery system.

Requirements:
1) Determination of optimum pumping rates and well spacing.
2) Evalution of the effects of increased pumping on the amount of uncontaminated water wasted.

Available data:
Appropriate hydrogeologic parameters can be calculated as in "D1" above. The parameters can be used to calculate drawdown curves. An alternative approach is to use an existing 2-D (Miller, 1982) or quasi 3-D (Martin, in review) ground-water flow model of the area to simulate the various pumping scenarios.

Data deficiencies:
If one of the existing flow-models is used, then it would be neccessary to reduce the grid size and to improve the calibration. Stream bed leakance is a factor that is not well defined and may have to be manipulated to facilitate calibration.

3. Treatment of ground-water recovery well discharges in a newly-constructed package treatment plant or the Wilmington WWTP.

Requirements:
Treatability tests on the leachate.

Available data:
Treatability tests of the Llangollen landfill leahate, as extracted from discharge wells, have been done (Fiore and Satterthwaite, 1973). The conclusions are cited in C3 above. The study was based on analyses from 1973. More recent analyses (Baedecker and Apgar, in press) show that although the major inorganic constituents have changed little, the number of organic compounds and the organic carbon content of the leachate have greatly decreased.

Data deficiencies:
Updated treatability tests need to be done to

ORIGINAL (Red)

adequately evaluate the leachate treatment options. If additional treatment is deemed neccessary, such as activated carbon, ion exchange, or reverse osmosis, then a suitable method of disposal of the contaminants concentrated by such treatment must be decided on.

4. Treatment of municipal, industrial, and private well water supplies affected by contaminant releases from the Delaware Sand and Gravel and Army Creek Landfills.

Requirements:
Same as "D3" above.

Available data:
Same as "D3" above.

Data deficiencies:
Same as "D3" above.

5. Reuse of recovery well discharges for industrial purposes or aquifer reinjection following treatment.

Requirements:
Same as "D3" above.

Available data:
Same as "D3" above.

Data deficiencies:
Same as "D3" above regarding aquifer reinjection. Industrial use will depend on the specific industrial tolerance to the type of water and on the quality of the resulting wastewater.

6. Minimizing off-site ground-water pumpage to minimize off-site degradation.

Requirements:
Determination of the optimum pumping balance between ground-water interception wells and supply wells required to maintain maximum supply with minimal withdrawal for diversion of contamination.

Available data:
This option can be addressed in the same manner as "D2" above.

Data deficiencies:
Same as "D2" above.

AR302215

[illegible] industrial, and private well water supplies affected by contaminant releases from the Delaware Sand and Gravel and Army Creek Landfills.

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Requirements:

1) The potential for contamination of these supplies
2) The availability of an alternate water supply source

Available data:

The potential for contamination can be qualitatively determined as described in "D1" above. The availability of an alternate ground-water supply can be addressed using the ground-water flow model by Martin (in review). The modeled area is divided into vertical layers, so individual layers can be stressed and the resulting effects of the stress on the other layers can be seen. One scenario tested by the model was the effects over a 25-year period of the decrease in pumpage by Amoco in October, 1980. The simulation predicted a head recovery of 120 feet in the lower aquifer.

Data deficiencies:

If the model by Martin (in review) is used, then the grid should be reduced and the effects of local geology should be incorporated.

8. Recharge barrier by gravity injection from the water table to the Potomac Aquifer south of the existing recovery wells.

Requirements:

1) Areal distribution of head differences between the water table aquifer and the Potomac Aquifer.
2) Chemical analyses from both aquifers in the area of the proposed recharge barrier in order to determine the effects of mixing of the two types of water on precipitation of solids and well clogging.
3) Evaluation of the drawdown in the water-table aquifer as related to possible changes in the direction of flow and the transport of contaminants in the water-table aquifer.
4) Amount of recharge required to attain the desired head distribution.

Available data:

The available data on the water-table aquifer appear to be limited to the northwest of the fill (upgradient). The FIT report (Lee and McGovern, 1982a) shows some wells south of the fill which have no counterpart in the legend, such as wells R-2, R-3, D1, D2, etc., but apparently these wells are either filled in or nothing is known about the depth.

Data deficiencies

If R-2, R-3, D1, D2, etc. are of unknown depth or are deep, then additional data must be obtained south of the recovery well system. This involves installation of water-table "piezometers" and at least one or two wells from which water-table samples can be obtained for analysis.

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9. Restoration of Army Creek and Army Pond (by dredging, etc.) if significant impact has occurred as a result of contaminant releases from the landfills.

Requirements:

1. Evaluation of leachate impact on surface-water bodies,
2. Evaluation of methodology of restoration

Available data:

The limited data available indicate that stream-water concentrations of iron and manganese increase significantly due to discharge from recovery wells and that concentrations of iron, cadmium, chromium, lead, copper, nickel, zinc, and silver are over the maximum value for protection of fresh-water aquatic life (Lee and McGovern, 1982a).

Data Deficiencies:

Stream-sediment samples need to be collected and analyzed in order to determine the value of this option. If the results indicate that significant contamination has occurred, then restoration options need to be addressed, such as determining whether dredging will release more contaminants than no-action. If dredging is decided on, then a suitable method of disposal of the waste is needed.

E. CONCLUSIONS

In order to evaluate any of the options requiring waste treatment, updated treatability tests need to be done. If it is found that treatment methods such as activated carbon, ion exchange, or reverse osmosis are neccessary, then a suitable method of disposal of treatment residue must be determined. If existing ground-water flow models are used to evaluate options, the grid size will have to be reduced and the framework will have to be updated to account for localized geology; however this can be done without additional field work.

Additional fieldwork is neccessary to determine the effect of landfill and leachate recovery operations on surface-water bodies. Stream-sediment samples need to be collected and analyzed. If the results indicate that significant contamination has occurred, then restoration options need to be addressed, such as determining whether dredging will release more contaminants than no-action. If dredging is decided on, then a suitable method of disposal of the waste is needed.

The amount of information known about wells R-3, R-4, D1, etc. is not clear from the literature. If these are not usable wells sampling the water-table aquifer, then additional information has to be gathered in order to evaluate the option of creating a ground-water divide by gravity injection recharge water. This re. ires the installati of additional "piezometers" and well(s) in the area soutn of the leachate recovery wells.

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AR302218

APPENDIX - ANNOTATION OF SELECTED LITERATURE

Preliminary Investigation of Ground-Water Contamination Associated With The Llangollen Landfill, New Castle County, Delaware (Satterwaite and Apgar, 1972).

The report contains maps showing the bottom of the upper Potomac confining beds in the landfill vicinity, the bottom of the Columbia Formation in the landfill vicinity, an isopach of the upper Potomac confining bed, the piezometric levels for Sept., 1972, the theoretical ground-water flow pattern in Sept., 1972, and the known extent of contamination in Sept., 1972. Also presented are presumed background water quality analyses.

Two papers by M. A. Apgar (1975, 1976) suggesting that the underlying clays of the Potomac Group were probably removed in places during development of the landfill.

Ground Water Contamination Associated with the Llangollen Landfill, New Castle County, Delware, Extent of Contamination and Proposed Corrective Procedures, January 1973 (Weston, 1973a).

This report contains maps of the thickness of the red confining unit at the top of the Potomac Formation in the vicinity of Llangollen landfill, and ground-water flow directions and water quality (9/72) in the Upper Potomac aquifer. Ground-water flow velocities and travel times between the Llangollen landfill and major production wells in the vicinity are calculated based on head gradients for 1972. Chemical analyses include chloride. The proposed corrective measures were to install wells and piezometers to determine aquifer characteristics and to intercept the contamination.

Evaluation of Ground Water Availability and Pumping Capacity, Llongollen Area. (Weston, 1973b)

The report contains aquifer transmissivities and storage coefficients calculated from pumping and recovery tests and a map showing the contaminated area. The recommendation was to reduce the pumping rates in existing wells.

Inter-office memorandum to Haley and others from W. B. Satterthwaite, Roy F. Weston, Inc., 31 July, 1973.

The memorandum discusses the positive and negative impacts of several alternatives: leachate pumping and discharge with no treatment; pumping and treating to remove metals only; pumping and treating for metals and ammonia; supplying deficit water quantity to the Artesian Water Company from other water systems; utilizing retrieval system with various options; treating leachate in the aquifer and landfill; planning to pump from existing wells for either treatment and discharge or for drinking water; no action, condemning aquifer.

Inter-office memorandum to Project Files from J.A. Weaver regarding the Llangollen landfill treatment alternatives, 30 October, 1973.

The memorandum presents economic and technical rationale fo[r] initial reduction of the number of potential alternatives for treating the Llangollen landfill in ord to prevent its contamination of a major portable water aquifer. Total haulage of landfill materials to new site, as well as lining the landfill bottom are ruled out as viable solutions. Certain options of controlling water infiltration are discussed.

Preliminary Treatability Study Report. (Fiore and Satterthwaite, 1973).

The report concluded that the only interim treatment feasible would be lime addition, filtration, and final pH adjustment. this treatment would substantially reduce the amount of metals in solution, but would not effectively reduce COD and ammonia contamination. The study determined that if water quality suitable for public supply of aquifer recharge is desired, then additional treatment must be used, such activated carbon, ion exchange, and reverse osmosis.

Preliminary Feasibility Study. Leachate Control Strategies for Llangollen Landfill (Niessen, 1974).

The report contains maps showing the elevations of the landfill floor, the contours of refuse thickness, the elevations of the top of the clay beneath the fill, approximate dates of refuse emplacement, thickness of saturated refuse, and the elevation of the water table as of Jan., 1974. The report examines hydrogeolgic control alternatives for isolating the landfill and incineration alternatives for the ultimate disposal of the refuse. It concludes that it is uncertain whether the hydrogeologic isolation of the leachate would be effective enough to restore the aquifer to its previous purity, and that uncertainty remains as to the technical feasibility of certain types of incinerators.

Letter to Dr. Harry W. Otto. Technical Services Section. Delaware Department of Natural Resources. from the USEPA. Southeast Environmental Research Laboratory. April 18. 1974.

The letter contains the results of analyses of leachate samples by an extraction method designed to separate the leachate into portions containing neutral, acidic, and basic compounds. The samples were from a well directly in the fill, Recovery Well-3, Well #29, and one of the Artesian Wells. The landfill leachate contained large amounts of organic acids and industrial chemicals. Recovery Well-3 and Well #29 were less contaminated. The Artesian Well Company well was uncontaminated. The water in the landfill was found to be strongly buffered near a neutral pH, so the landfill materials did not constitute an odor problem; however, if they were to escape the landfill and encounter an acid environment, as in some cooking, gasses would be released.

Water Resources in the Vicinity of a Solid Waste Landfill in the Midvale-Llangollen Estates Area. New Castle County. Delaware (Sundstrom, 1974).

This report concluded that (1) the Lower Potomac aquifer was completely developed or nearly completely developed by existing

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wells in the area; (2) there appeared to be little or no danger of leachate contamination from the Llangollen landfill to the Lower Potomac aquifer in the Midvale-Llangollen Estates area: (3)salt-water contamination from the Delaware River had not occurred in the Lower Potomac aquifer in the Midvale-Llangollen Estates area; (4) the limit of development of water from the wells in the Upper Potomac aquifer on a sustained basis was estimated to be about 6,500,000 gpd or less in the study area; (5) as of January 1, 1974, the Upper Potomac aquifer had received leachate contamination in much of a 310-acre area in the study area; (6) the Pleistocene and subcropping Potomac aquifer beneath and south of the landfill had received leachate contamination and was passing the contamination to the Upper Potomac aquifer in places; (7) Army Creek had received leachate contamination by discharge from the Pleistocene aquifer to the creek in places; and (8) a small rise in chlorides in the water from the Amoco Polymer Plant well field wells PW-2 and PW-3 located in the northeastern part of the area was caused by slight leachate contamination rather than salt-water from the Delaware River.

Preparatory Paper for Army Creek (Llangollen) Landfill Roundtable, November 17-18, 1977 (New Castle County, 1977).

The paper discusses various remedial action scenarios. These are attenuation; hydrogeologic controls (precipitation infiltration reduction, interception of ground-water inflow, and collection of leachate within the landfill); removal of the source (transport to another landfill or incineration); hasten decomposition (spray-irrigation or annelidic consumption. Leachate treatment and incineration are examined in detail.

Army Creek Landfill Technical Rountable, November 17-18, 1978, Summary Proceedings (Draft) (New Castle County, 1979).

A number of possible solutions were discussed at the rountable meeting. Attenuation, a no-action alternative, was the least costly and appeared to have some degree of technical merit, but was rejected because of the degree of risk associated with Artesian Water Company's well field. Removal of the source was also considered. Moving the landfill was considered to be just transporting the problem compounded by the costs of excavation, transportation, and relandfilling. Incineration was rejected because of high cost and technical complications. Recycling of the leachate through the landfill was eliminated because Delaware's humid climate would result in an ever-increasing amount of leachate generation. Annelidic decomposition was rejected because it would only be applicable to 10% of the landfill mass. Hydrogeologic control was the alternative recommended, which included relocation of recovery wells closer to the source, applying a relatively impermeable cover to the landfill surface, and diverting ground-water flow around the landfill.

Remedial Action Activities for Army Creek Landfill (Clark, 1979)

The report contains maps showing the potentiometric surfac[e] of the Upper Potomac aquifer prior to installation of contr[ol] measures and in March, 1976 and the extent of contamination migration as of August, 1973, and May, 1978. Hydrologic controls (precipitation infiltration reduction, interception of ground-water inflow, and collection of leachate within the fill) and removal of the source are discussed. Spray irrigation, recycling, and annelidic consumption are examined as well as pressure maintenance and landfill aeration. The recommendations are to minimize leachate production by surface capping and upgradient trenching, and maximize leachate recovery by construction of new recovery wells within or closer to the landfill and phasing out the existing recovery system.

Papers discussing the chemical behaviour of the leachate.

The general behavior of the organic contaminants in the aquifer at Llangollen landfill is discussed in papers by Baedecker and Apgar (in press) and Baedecker and Back (1979a, 1979b). The reports conclude that beneath the landifll and immediately downgradientof the landifll large amounts iron and manganese are dissolved, organic matter is oxidized and reduced, oxygen is consumed, ammonia is adsorbed and nitrate is reduced. Farther downgradient, iron and manganese precipitate, less organic matter is oxidized and reduced, and additional ammonia is removed by ion exchange. Farther downgradient, the water chemistry is predominantly controlled by mixing. The ratio of reduced nitrogen to nitrate can be used to indicate the location of reducing fronts as the leachate migrates. One report (Baedecker and Back, 1979a) suggests that ethylene may act as a conservative species at this site and may therefore be useful as a tracer in transport modeling. The paper by Baedecker and Apgar (in press) is a conceptual chemical model using chloride as a conservative tracer.

Feasibility Study for the Discharge of Contaminated Groundwater from Army Creek Landfill Recovery Wells, New Castle County, Delaware (Roy F. Weston, 1980).

The report concludes that the State Road Pump Station had insufficient capacity to receive all recover well flows; that introduction of all or any recovery well flows to the Wilmington WWTP would have minimal impact on effluent quality, unit operation, or sludge disposal; that the Delaware River would be minimally affected in terms of water qualtity by discharge of recovery well flows to either the Wilmington WWTP or Army Creek; and that selective pretreatment facilities were not necessary.

Detection of Trace Organics in Well Water Near a Solid Waste Landfill (Dewalle and Chian, 1981).

The most significant aspect of this paper is a discussion of attenuation of organics in the soil at Army Creek Landfill. Notably, attenuation tends to decrease with decreasing molecular weight, possibly because of the decreasing adsorptive capacity that lower molecular weight compounds have with respect to the soil adsorptive complex. The limited data indicate that most of the biological degradation of the leachate occurs during the first few hundred meters of permeation. Trace organics showed a 90 % concentration reduction for every 200 meters permeated through the aquifer.

Field Investigations of Uncontrolled Hazardous Waste Sites. A Hydrologic Survey of Army Creek Landfill and Delaware Sand and Gravel Landfill (Lee and McGovern, 1982a)

The report contains ground-water elevation maps for 9/72, 6/75, 3/76, 7/77, 1978, 2/81, and 11/81. The report also contains a hydrologic mass balance in Army Creek and Delaware Sand and Gravel landfills, chemical analyses for 11/81, and a graph showing the relationship between pumpage and influence distance.

Field Investigations of Uncontrolled Hazardous Waste Sites. Well Drilling at Delaware Sand and Gravel Landfill (Lee and McGovern, 1982b).

This report discusses the ground-water conditions at the Delaware Sand and Gravel Landfill based on three monitoring wells and two boreholes in the area. The report contains boring logs, chemical analyses, and water levels for specific wells, as well as the results of a magnetometer study which was unsuccessful in delineating buried magnetic objects in the drum-pit area.

Evaluation of the Recovery-Well System for the Llangollen Landfill, New Castle County, Delaware. (Geraghty and Miller, 1982)

The report used a linear gradient model to predict the effects of the then "proposed" relocation of the recovery-well system to a site closer to the fill. The conclusions were (1) the ground-water divide created by the existing recovery-well system appeared to allow two significant segments of the plume to continue to drift toward the Artesion well field; (2) the proposed new recovery-well program could expose the aquifer to more extensive contamination; (3) a larger number of wells closer to the fill would be more effective; (4) a recharge program could provide additional dilution and diversion.

Simulated Ground-Water Flow in the Potomac Aquifers, New Castle County, Delaware (Martin, in review).

The quasi 3-d model used simulates flow in three aquifers and intervening confining units of the Potomac Formation in New Castle County. The calibrated model was used to evaluate changes in water levels resulting from five possible scenarios of future pumpage. One of the scenarios was based on the assumption of no change in pumping rates for the next 25 years. The results indicate that the reduction of pumpage at Amoco that occurred in October, 1980, should produce a head recovery of 120 ft. Other scenarios are: (1) assume that Amoco pumpage did not decrease, (2) redistribute pumpage, (3) include expected increases in pumpage, (4) reduction of ground-water use by substitution of other supplies, such as surface-water or ground-water outside the study area.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region III - 6th & Walnut Sts.
Philadelphia, Pa. 19106

SUBJECT: Toxicological Assessment of the Army Creek Landfill

DATE: JUN 13 1984

FROM: Dick Brunker, Toxicologist
Site Investigation and Support Section RB

TO: Richard Zambito, Environmental Engineer
CERCLA Enforcement Section (3HW12)

The Army Creek landfill analyses revealed the presence of numerous toxic pollutants at concentrations that would cause considerable risks to to affected individuals and would be very damaging to an impacted aquatic environment. There are at least three areas of concern regarding the hazards that exist at this drum site. These are; I) the threat of leachates to the nearby aquatic ecosystem; II) the considerable long term cancer threat to those who drink water containing these pollutants; and III) the threat of physical damage caused by the toxic nature of these substances to those who drink water containing these contaminants.

The data cited in the streamflow samples indicate that the Army Creek watershed is currently being polluted by leachates from the drumsite. These leachates can be expected to increase in concentration and complexity as more drums corrode releasing their contents. The toxic heavy metals have a strong propensity to bioaccumulate in aquatic plants, insect larva, benthic fauna, fish, and most particularly in shellfish causing a health hazard to the consumers of these organisms.

In aquatic ecosystems these toxic substances cause a loss of the less tolerant (and usually more desirable) species and cause severe perturbations in the ecological balance of the affected biomes, usually resulting in their domination by less desirable species of fish and other organisms. Dangerous concentrations of copper were detected in the streamflow sample number V (Table 1). Copper is particularly toxic to algae in these systems causing the cessation of photosynthetic reactions in these primary producers. Reductions in the amounts of this important food source are felt all along the food chain and can have a severe impact on fish populations.

The concentrations of the six toxic metals listed on Table 1 are well above those established by the EPA as maximum values for the protection of aquatic life and published in the Ambient Water Quality Criteria for the respective metals and published in 1980. The drum site has contaminated water containing copper concentrations that are two orders higher than the maximum values allowed. Concentrations of lead were found that were three orders too high.

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There are at least 45 assays of six toxic heavy metals that reveal concentrations that would produce deliterious effects in an aquatic environment. This threat becomes more evident when it is appreciated that current laboratory detection levels for cadmium, copper, chromium, lead, and nickel are not nearly as low as the maximum allowable values for these elements in aquatic systems. It is reasonable to assume that numerous other well and stream samples contained concentrations of these toxic elements that are harmful to the biota but were below detection limits.

At least six of the pollutants are carcinogens (Table 2). Some of these carcinogens were found in concentrations that were about four orders (10,000x) higher than the concentration necessary to cause an additional incidence of cancer in a population of one million. These included arsenic, cadmium, beryllium, Dieldrin, and PCBs. Benzene was detected at a concentration that was over two orders higher than a level that would cause a 10^{-6} risk of a cancer increase.

Again it must be stressed that the calculated individual 10^{-6} cancer risk levels are all at least two orders lower, and for one element (beryllium), it is three orders lower than labortory detection levels. Again we should assume that numerous other samples contained concentrations of carcinogens that represent an unsatisfactory cancer risk but these concentrations were below detection levels.

Many of the samples contained concentrations of heavy metals that are so high that they are considered to be toxic according to data published in the Ambient Water Quality Criteria for the specific metals (Table 3). The physical damages caused by these toxic elements are insidious and take place slowly and over an extended period of time. Organs and physical systems affected include the circulatory system, reproductive system, kidneys, liver, lungs, peripheral nervous system, reproductive system including the brain, the bones, inner ear, the eyes and the teeth. They are also alleged to cause personality changes and a loss of intelligence. Much of the physical damage is not reversible, even with the use of chelation therapy. Children have been determined to be particularly susceptible to these damaging affects.

Concentrations of nickel and lead are particulary dangerous at the concentrations detected. Nickel is suspected to be a factor in stillbirths and has been linked to heart and liver damage of affected individuals. The effects of the chronic ingestion of lead have been widely studied and have revealed deliterious effects to all of the systems and organs previously mentioned. It has also been determined to cause blockages of at least four reactions concerned with the formation of hemoglobin.

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References

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2. Ambient Water Quality Criteria for Beryllium, EPA 440/5-80-24, October 1980.
3. Ambient Water Quality Criteria for Cadmium, EPA 440/5-80-25, October 1980.
4. Ambient Water Quality Criteria for Chromium, EPA 440/5-80-035, October 1980.
5. Ambient Water Quality Criteria for Copper, EPA 440/5-80-037, October 1980.
6. Ambient Water Quality Criteria for Lead, EPA 440/5-80-057, October 1980.
7. Ambient Water Quality Criteria for Nickel, EPA 440/5-80-060, October 1980.
8. Ambient Water Quality Criteria for Polychlorinated Biphenyls, EPA 440/5-80-068.
9. EPA Water Quality Criteria (Federal Register, Vol. 45., No. 231, November 28, 1980) and our Quality Limits.

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CONCENTRATIONS THAT WOULD CONSTITUTE A THREAT TO FRESHWATER AQUATIC ECOSYSTEMS.

Copper (5.6); Chromium(0.3); Cadmium (0.012); Lead (0.75); Nickel (0.056); Zinc (47)

5A						90
51	80	50		80	120	500
70		20				180
54	80	80		80	40	210
56						140
57		20				100
48	100	10	10		60	8630
B11	400	70		960	40	800
29						
45						
39	100	200	30	600	120	600
31						
RW4	60	10			20	
RW5						450
[illegible]C/MV#1						
AWC/MW#2	20	20	20	200		
[illegible]OCO/PW2	20					20

SF

I						50
II		10				50
III						
IV						
V	200	10				150

(all variables are in ug/l)

Table 1

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INCREASED CANCER RISK

Concentrations that would cause a cancer risk causing more than one additional incidence in a population of one million (>10^{-6} risk) if 2 liters were consumed per day for 70 years.

	Arsenic	Cadmium	Beryllium	Dieldrin	Benzene	PCBs
-6 risk->	2.2ng/l	2.6 ng/l	3.7 ng/l	71 pg/l*	0.66 ug/l	79 pg/
all #						
					100	
51	10					
54	20		40			
48		10				
B11	60			0.35		
	50	39	4			
V**						

unlabled concentrations (pollutants) are ug/l.
* pg/l = picograms per liter (10^{-12} grams per liter)
** S.F. V = stream flow collection number V.

Table 2

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CONCENTRATIONS THAT COULD ILLICIT TOXIC EFFECTS IN DRINKING WATER.

Arsenic (50)*, Chromium (50), Cadmium (10), Lead (50), Nickel (13.4), Zinc (5000).

Well	Arsenic	Chromium	Cadmium	Lead	Nickel	Zinc
51				80	120	
54		80		80	40	
48					60	8630
B11	60	70		960	40	
39		200	30	600	120	
31					20	
AWCMV#2				200		

units are in ug/l amounts
*Figures in brackets indicate Ambient Water Quality criteria for drinking water.

Table 3

ADDENDUM

TO

APPENDIX O

AND

APPENDIX R

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
Division of Water Resources
Water Management Section
89 KINGS HIGHWAY
P.O. BOX 1401
DOVER, DELAWARE 19903

TELEPHONE: (302) 736-4761

November 5, 1985

Mr. Lawrence Benning (3WM53)
Chief, DE/WV Section
Water Permits Branch
U. S. Environmental Protection Agency
Region III
841 Chestnut Building
Philadelphia, PA 19107

Re: Army Creek Wellfield Draft
NPDES Permit No. DE 0050741

Dear Mr. Benning:

Enclosed is a November 1, 1985 draft permit for the Army Creek Wellfield discharge to Army Creek. This draft is being forwarded to you for your comments prior to sending it to the permittee. Normally, in accordance with the 1983 M.O.A. you are expected to provide comments within 30 days. Due to the urgency you have placed on the issuance of a permit to this particular permittee you are requested to provide comments as early as possible, hopefully within 15 days.

Also enclosed is the information relative to this facility you requested in your letter to me dated September 5, 1985. Specifically you requested us to provide:

(1) Flow information on Army Creek (Q7-10)

(2) Any instream aquatic biological data for Army Creek

(3) Our rationale on how this data supports our decision for the location of the point of discharge in accordance with the August 27, 1982 "State of Delaware Water Quality Standards for Streams" and Addendums

Flow Information

An excerpt of a U.S.G.S. report entitled "Water Resource Data - Maryland and Delaware - Water Year 1981" has been enclosed. Specifically, this excerpt is data for USGS gaging station 0182200

Army Creek located at State Road (U.S. Rt. 13), Delaware. The data indicates that a low flow of .01 cfs was encountered for 14 consecutive days during August and September 1981. As such the (Q7-10) low flow is interpreted as being much less than .1 cfs.

Aquatic Biological Data

Enclosed is a October 29, 1985 memo from Mr. Gregory M. Mitchell to Dr. Harry W. Otto. This memo is a report on the results of a June 11, 1985 biosurvey conducted at Army Creek. Also enclosed are two memos that recount a finfish sampling effort of May 31, 1983. One of these memos is dated June 17, 1983 and is again from Mr. Mitchell to Dr. Otto. The second is dated June 2, 1983 and is from Mr. Mark F. Boller to Ramesh J. Shah and Marilyn P. LaRiccia.

In addition to the above information we are awaiting the formal results of a static bioassay that was performed by EPA (at our request) in the Deluth Laboratory. I have enclosed a copy of the results that were relayed over the telephone. The written results will be forwarded as soon as they are received.

Finally, additional biological data is available in Appendix L of the feasibility study for this site. A copy has not been enclosed, however, this document should be available in the Region III offices.

Rationale

As has been previously pointed out, the Q7-10 low flow of Army Creek is naturally less than .1 cfs. It is currently higher solely as a result of the recovery well discharges being pumped to the creek. As such when the recovery well discharges are eliminated the stream will be intermittent and therefore will not support fishlife. The pond will be smaller but will probably still exist.

The creek downstream of the pond currently supports freshwater aquatic species, in spite of the fact that the well discharges have been pumped to the creek for the last decade or so. It is anticipated that by continuing to pump these discharges to the pond for the next 5 years or so will have no significant negative impact on the present or future uses of the pond. This is especially true when one considers permit special conditions 6 and 7. These conditions state that it is assumed the discharges will be discontinued as a result of the landfill closure plan. Further, the permittee will be required to decommission the facility (pond) and may be required to return the pond back to its natural condition if certain, yet to be determined, conditions exist. Therefore by allowing the permittee to use the pond as the treatment facility for a limited time we will be able to get the pond "cleaned up" or restored to its natural condition if necessary.

After investigating the issue of using the pond as the treatment facility I have come to the conclusion that this is an unusual situation. However, by allowing them to use the pond in this manner we will eventually get the pond cleaned up. If we don't give some in this area we do not have an alternative mechanism for getting the pond cleaned up.

If you have any questions on the draft permit or the information supplied herein, please contact me.

Sincerely,

J. Paul Jones

J. Paul Jones
Environmental Engineer
Water Pollution Branch

V 01 1985

State Permit Number WPCC 3028/77
NPDES Permit Number DE 0050741
Effective Date
Expiration Date

AUTHORIZATION TO DISCHARGE UNDER THE

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

AND THE LAWS OF THE

STATE OF DELAWARE

In compliance with the provisions of the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (33 U.S.C. 1251 et seq.) (hereinafter referred to as "the Act"), and pursuant to the provisions of 7 Del. C., §6003

New Castle County Department of Public Works
2701 Capitol Trail
Newark, Delaware 19711

is authorized to discharge from the facility
(Point Sources 001) located at

Army Creek Wellfield, parts of which are located on Llangollen Landfill and Delaware Sand and Gravel Landfill

to receiving waters named

Army Creek, a tributary of the Delaware River

The effluent limitations, monitoring requirements and other permit conditions are set forth in Part I, II and III hereof.

R. Wayne Ashbee, Director
Division of Water Resources
Department of Natural Resources
and Environmental Control

Date Signed

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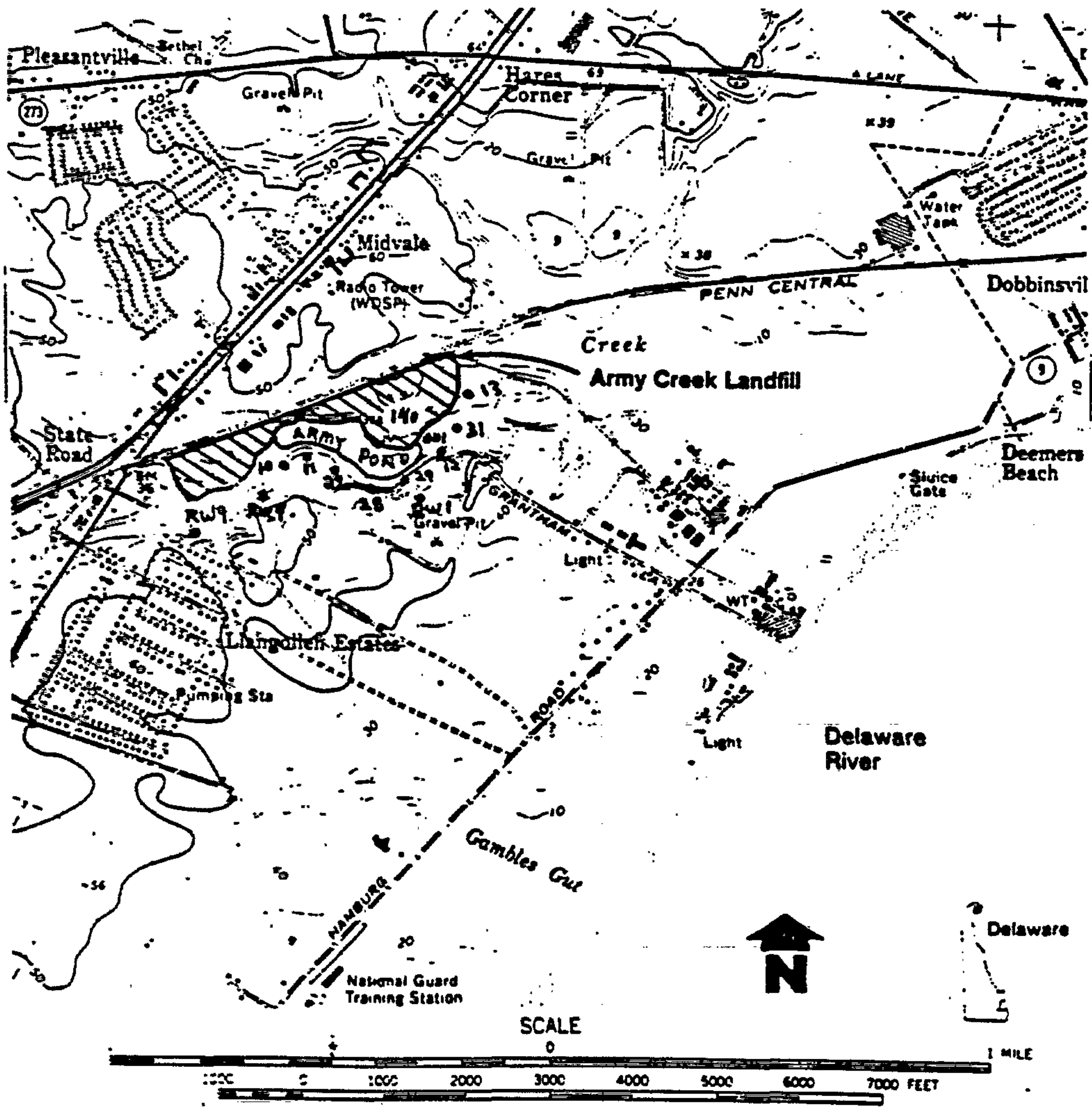
A. General Description of Discharges and Facilities

Discharge 001 is the outfall of Army Pond and consists of treated groundwater that is pumped from 11 different groundwater recovery wells located at Llangollen and Delaware Sand and Gravel Landfills. The recovery wells are labeled as follows and are shown on the location map below: RW-4; 27; RW-1; 28; 29; 31; 10; 11; 12; 13; 14.



From U.S.G.S. Wilmington South, Del.-N.J. 7½ Min. Quadrangle

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NOV 01 1985

B. EFFLUENT LIMITATIONS

During the period beginning effective date and lasting through the expiration date the permittee is authorized to discharge from point source(s) 001* the quantity and quality of effluent specified below:

The average quantity of effluent discharged from the wastewater treatment facility shall not exceed 3.25 million gallons per day (mgd) or 12,301 cubic meters per day.**

	Daily Average ***			Daily Maximum ***		Maximum Instantaneous Concentration
Parameter	lbs/day	kg/day	Concentration	lbs/day	kg/day	
Total Suspended Solids	813	370	30 mg/L	1220	370	45 mg/L
Fluoride	81	37	3 mg/L	122	55	4.5 mg/L
Iron (Total)	54	25	2 mg/L	81	37	3 mg/L
Chromium (Total)	4.1	1.8	.150 mg/L	6.1	2.8	.230 mg/L
Mercury	0.14	0.06	0.005 mg/L	0.20	0.09	0.007 mg/L
Nickel	27	12	1.0 mg/L	41	18	1.5 mg/L
Selenium	0.5	1.2	0.020 mg/L	0.8	0.4	0.030 mg/L

The pH shall not be less than 6.0 standard units nor greater than 9.0 standard units. The discharge shall be free from floating solids, sludge deposits, debris, oil and scum.

*Discharge from the abatement facility for treating all well discharges.
**Flow determination is to be made from pumping records.
***Loadings are to be calculated using actual discharge flows. See Special Condition A.2 on page

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NOV 01 1985

C. MONITORING REQUIREMENTS

During the period beginning effective date and lasting through expiration date the permittee is authorized to discharge from outfall(s) 001

Such discharge(s) shall be monitored by the permittee as specified below:

Effluent Parameter	Monitoring Requirement: Measurement Frequency	Monitoring Requirement: Sample Type
Flow	Ongoing	Pump records
Total Suspended Solids	Once/week	Grab
Fluoride	Once/month	Grab
Iron (Total)	Once/week	Grab
Chromium (Total)	Once/month	Grab
Mercury	Once/month	Grab
Nickel	Once/month	Grab
Selenium	Once/month	Grab
pH	Once/week	Grab

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location: At the discharge from the abatement facility for treating all well discharges. Flow monitoring will be done using pump records.

DRAFT NOV 01 1985

D. SCHEDULE OF COMPLIANCE

1. The permittee shall achieve compliance with the effluent limitations specified for discharges in accordance with the following schedule:

Within 6 months of the effective date:

a. Install a primary measuring device for flow at the outfall of the pond.

2. No later than 14 calendar days following a date identified in the above schedule of compliance, the permittee shall submit either a report of progress or, in the case of specific actions being required by identified dates, a written notice of compliance or noncompliance. In the latter case, the notice shall include the cause of noncompliance, any remedial actions taken, and the probability of meeting the next scheduled requirement.

E. Monitoring and Reporting

1. Representative Sampling

Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

2. Reporting

Monitoring results obtained during the previous one (1) month shall be summarized for each month and reported on a Discharge Monitoring Report Form (EPA No. 3320-1), postmarked no later than the 28th day of the month following the completed reporting period. The first report is due on . Signed copies of these, and all other reports required herein, shall be submitted to the State at the following address:

DELAWARE DEPT. OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL, DIVISION OF WATER RESOURCES, R & R BUILDING, P. O. BOX 1401, DOVER, DELAWARE 19903, TELEPHONE (302) 736-4761

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NOV 01 1985

3. Definitions

a. The daily average discharge - The total discharge by weight during a calendar month divided by the number of days in the month that the production or commercial facility was operating. Where less than daily sampling is required by this permit, the daily average discharge shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar month when the measurements were made.

b. The daily maximum discharge - The total discharge by weight during any calendar day.

c. Maximum instantaneous concentration - The concentration of a pollutant in terms of milligrams per liter which represents the value obtained from a grab sample of an effluent. The maximum instantaneous concentration shall be based on a review of the degree of fluctuation experienced in comparable systems. For purposes of compliance, the maximum instantaneous concentration shall be based on the actual analysis of the grab sample.

d. Bypass - The intentional diversion of wastes from any portion of a treatment facility.

e. Upset - An exceptional incident in which there is unintentional and temporary noncompliance with technology-based permit effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facility, inadequate treatment facilities, lack of preventive maintenance or careless or improper operation.

f. Composite sample - A combination of individual samples obtained at intervals over a time period. Either the volume of each individual sample is proportional to discharge flow rates or the sampling interval (for constant volume samples) is proportional to the flow rates over the time period used to produce the composite. For a continuous discharge, a minimum of 24 individual grab samples shall be collected and combined to constitute a 24 hour composite sample. For intermittent discharges of 4-8 hours duration, a minimum of 12 grab samples shall be collected and combined to constitute the composite sample for the discharge. For intermittent discharges of less than 4 hours, a minimum of individual grab samples shall be collected and combined to constitute the composite sample equal to the duration of the discharge in hours times 3 but not less than 3 samples.

g. Grab sample - An individual sample collected in less than 15 minutes.

h. I/S (immersion stabilization) - A calibrated device is immersed in the effluent stream until the reading is stabilized.

i. The monthly average temperature - The arithmetic mean of temperature measurements made on an hourly basis, or the mean value plot of the record of a continuous automated temperature recording instrument, either during a calendar month, or during the operating month if flows are of shorter duration.

j. The daily maximum temperature - The highest arithmetic mean of the temperature observed for any two (2) consecutive hours during a 24-hour day, or during the operating day if flows are of shorter duration.

k. Measured flow - Any method of liquid volume measurement the accuracy of which has been previously demonstrated in engineering practice, or for which a relationship to absolute volume has been obtained.

l. Estimate - To be based on a technical evaluation of the sources contributing to the discharge including, but not limited to, pump capabilities, water meters and batch discharge volumes.

m. Non-contact cooling water - The water that is contained in a leak-f·ee system, i.e., no contact with any gas, liquid, or solid other than he container for transport; the water shall have no net poundage addi on of any pollutant over intake water levels.

4. Test Procedures

Test procedures for the analysis of pollutants shall conform to the : plicabl test procedures identified in 40 C.F.R., Part 136, unless otherwise ecified in this permit.

5. Quality Assurance Practices

The permittee is required to show the validity of all data by requir ng its laboratory to adhere to the following minimum quality assurance prac.ices:

a. Duplicate(1) and spiked(2) samples must be run for each constituent in the permit on 5% of the samples, or at least on one sample per month, whichever is greater. If the analysis frequency is less than one sample per month, duplicate and/or spiked samples must be run for each analysis.

b. For spiked samples, a known amount of each constituent is to be added to the discharge sample. The amount of constituent added should be approximately the same amount present in the unspiked sample, or must be approximately that stated as maximum or average in the discharge permit.

(1) Duplicate samples are not required for the following parameters: Color, Temperature, Turbidity.

(2) Spiked samples are not required for the following parameters: Acidity, Alkalinity, Bacteriological, Benzidine, Chlorine, Color, Dissolved Oxygen, Hardness, pH, Oil & Grease, Radiological, Residues, Temperature, Turbidity, BOD_5 and Total Suspended Solids. Procedures for spiking samples are available through the Regional Quality Assurance Coordinator.

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NOV 01 1985

c. The data obtained in a and b shall be summarized in an annual report submitted at the end of the fourth quarter of reporting in terms of precision, percent recovery, and the number of duplicate and spiked samples run, date and laboratory log no. of samples run and name of analyst.

d. Precision shall be calculated by the formula, standard deviation $s = (\sum d^2/k)^{1/2}$, where d is the difference between duplicate results, and k is the number of duplicate pairs used in the calculations.

e. Percent recovery shall be reported on the basis of the formula $R = 100\ (F-I)/A$, where F is the analytical result of the spiked sample, I is the result before spiking of the sample, and A is the amount of constituent added to the sample.

f. The percent recovery, R, in e above shall be summarized yearly in terms of mean recovery and standard deviation from the mean. The formula, $s = (\sum(x-\bar{x})^2/\ (n-1)\ )^{1/2}$, where s is the standard deviation around the mean $\bar{x}$, x is an individual recovery value, and n is the number of data points, shall be applied.

g. The permittee or his contract laboratory is required to annually analyze an external quality control reference sample for each pollutant. These are available through the EPA regional quality assurance coordinator. Results shall be included in the annual report, c above.

h. The permittee and/or his contract laboratory is required to maintain an up-to-date and continuous record of the method used, of any deviations from the method or options employed in the reference method, of reagent standardization, of equipment calibration and of the data obtained in a, b and f above.

i. If a contract laboratory is utilized, the permittee shall report the name and address of the laboratory and the parameters analyzed together with the monitoring data required.

6. Records

a. For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information:

(1) The date, exact place and time of sampling or measurements;

(2) The person(s) who performed the sampling or measurements;

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NOV 01 1985

(3) The dates analyses were performed;

(4) The person(s) who performed each analysis;

(5) The analytical techniques or methods used;

(6) The results of each analyses; and

(7) The quality assurance information as stated above.

b. An operator log must be kept on site at all times. This log should include time spent at the treatment facility on any date, and the nature of operation and maintenance performed.

7. Additional Monitoring by Permittee

If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in the calculation and reporting of the values required in the Discharge Monitoring Report form (EPA No. 3320-1). Such increased frequency shall also be indicated.

8. Records Retention

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation and recording from continuous monitoring instrumentation shall be retained for three (3) years. This period of retention shall be extended automatically during the course of any unresolved litigation regarding the regulated activity or regarding control standards applicable to the permittee, or as requested by the Department.

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NOV 01 1985

A. MANAGEMENT REQUIREMENTS

1. Change in Discharge

All discharges authorized herein shall be consistent with the terms and conditions of this permit. The discharge of any pollutant identified in this permit at a level in excess of that authorized shall constitute a violation of the permit. Any anticipated facility expansions, production increase, or process modifications which will result in new, different or increased discharge of pollutants must be reported by submission of a new NPDES application at least 180 days prior to commencement of the changed discharge. Any other activity which would constitute cause for modification or revocation and reissuance of this permit, as described in Part II, B-5 of this permit, shall be reported to the Department. Following such notice, the permit may be modified to specify and limit any pollutants not previously limited.

2. Noncompliance Notification

a. If, for any reason, the permittee does not comply with or will be unable to comply with any daily maximum effluent limitations or maximum instantaneous concentration specified in this permit, the permittee shall provide the Department with the following information, in writing, within five (5) days of becoming aware of such conditions:

(1) A description of the discharge and cause of noncompliance;

(2) The period of noncompliance, including exact dates and times and the anticipated time when the discharge will return to compliance;

(3) Steps being taken to reduce, eliminate and prevent recurrence of the noncomplying discharge.

b. In the case of any upset or discharge subject to any toxic pollutant effluent standard under Section 307(a) of the Act, the Department shall be notified within 24 hours of the time the permittee becomes aware of the noncomplying discharge. Notification shall include information as described in paragraph 2(a) above. If such notification is made orally, a written submission must follow within five (5) days of the time the permittee becomes aware of the noncomplying discharge.

3. Facilities Operation

The permittee shall at all times maintain in good working order and operate as efficiently as possible all collection and treatment facilities and systems (and related appurtenances) installed or used by the permittee to achieve compliance with the terms and conditions of this permit. Proper operation and maintenance includes, but is not limited to, effective performance based on designed facility removals.

DRAFT
NOV 1 1985

adequate funding, effective management, adequate operator staffing and training and adequate laboratory and process controls including appropriate quality assurance procedures.

4. Adverse Impact

The permittee shall take all reasonable steps to minimize any adverse impact to the waters of the State or the United States resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge.

5. Bypassing

Any bypass of treatment facilities necessary to maintain compliance with the terms and conditions of this permit is prohibited unless:

a. The bypass is unavoidable to prevent loss of life, personal injury or severe property damage; and

b. There are no alternatives; and

c. The Department is notified within 24 hours (if orally notified, then followed by a written submission, within five (5) days of the permittee's becoming aware of the bypass. Where the need for a bypass is known (or should have been known) in advance, this notification shall be submitted to the Department for approval at least ten (10) days before the date of bypass; and

d. The bypass is allowed under conditions determined by the Department to be necessary to minimize adverse effect as provided under 7 Del. C., Chapter 60, §6011.

6. Conditions Necessary for Demonstration of an Upset

An upset shall constitute an affirmative defense to an action brought for noncompliance with technology-based effluent limitations only if the permittee demonstrates, through properly signed contemporaneous operating logs, or other relevant evidence, that:

a. An upset occurred and that the permittee can identify the specific cause(s) of the upset; and

b. The permitted facility was at the time being operated in a prudent and workman-like manner and in compliance with proper operation and maintenance procedures; and

c. The permittee submitted a notification of noncompliance as required by Part II, A.2.b.

d. The permittee has taken all remedial measures required to minimize adverse impact.

DRAFT

NOV 01 1985

7. Removed Substances

Solids, sludges, filter backwash, or other pollutants removed in the course of collection or treatment of wastewaters shall be disposed of in a manner such as to prevent any pollutant from such materials from entering surface waters or groundwaters.

8. Failure

The permittee, in order to maintain compliance with its permit, shall control production and all discharges upon reduction, loss or failure of the treatment facility until the facility is restored or an alternative method of treatment is provided.

9. Alternative Power Source

In order to insure compliance with the effluent limitations and all other terms and conditions of this permit, the Department may require that the permittee shall provide an alternative power sufficient to operate the wastewater collection and treatment facilities in accordance with the Schedule of Compliance contained in Part I of this permit.

B. RESPONSIBILITY

1. Right of Entry

The permittee shall allow the Secretary of the Department of Natura Resources and Environmental Control, the Regional Administrator, an their authorized representatives, jointly and severally, upon the presentation of credentials and such other documents as may be required by law:

a. To enter upon the permittee's premises where a point source is located or where any records are required to be kept under the terms and conditions of this permit; and

b. At reasonable times to have access to and copy any records required to be kept under the terms and conditions of this permit; to inspect any monitoring equipment or monitoring method required in this permit; to inspect any collection, treatment, pollution management, or discharge facilities required under this permit; and to sample any discharge of pollutants.

2. Transfer of Ownership and Control

In the event of any change in ownership or control of facilities from which the authorized discharge emanates, the permit may be transferred to another person if the permittee:

a. Notifies the Department, in writing, of the proposed transfer; and

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NOV 01 [illegible]

b. A written agreement between the transferrer and the transferree, indicating the specific date of proposed transfer of permit coverage and acknowledging responsiblities of current and new permittees for compliance with and liability for the terms and conditions of this permit, is submitted to the Department; and

c. The Department within thirty (30) days of receipt of the notification of the proposed transfer does not notify the current permittee and the new permittee of intent to modify, revoke and reissue, or terminate the permit and require that a new application be submitted.

3. Reapplication for a Permit

At least 180 days before the expiration date of this permit, the permitte shall submit a new application for a permit or notify the Department of i intent to cease discharging by the expiration date. In the event that a timely and sufficient reapplication has been submitted and the Departmen is unable, through no fault of the permittee, to issue a new permit befo the expiration date of this permit, the terms and conditions of this per are automatically continued and remain fully effective and enforceable.

4. Availability of Reports

Except for data determined to be confidential under Section 308 of the A all reports prepared in accordance with the terms of this permit shall b available for public inspection at the offices of the Department of Natu Resources and Environmental Control. As required by the Act, effluent d shall not be considered confidential. Knowingly making any false statem on any such report may result in the imposition of criminal penalties as provided for under 7 Del. C., §6013.

5. Permit Modification, revocation and Reissuance and Termination

a. After notice and opportunity for a hearing, this permit may be modified, terminated, or revoked and reissued in whole or in part during its term for cause including, but not limited to, the following:

(1) Violation of any terms or conditions of this permit;

(2) Obtaining this permit by misrepresentation or failure to disclose fully all relevant facts;

(3) A change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge; or

(4) Information that the permitted discharge poses a threat to human health or welfare.

DRAFT
NOV 01 1985

b. In addition to the provisions of paragraph 5.a. above, this permit may be modified, revoked and reissued in whole or in part, but not terminated, after notice and opportunity for a hearing, for cause including, but not limited to, the following:

(1) Material and substantial alterations or additions to the discharger's operation which were not covered in the effective permit provided that such alterations do not constitute total replacement of the process or production equipment causing the discharge which converts it into a new source;

(2) The existence of a factor or factors which, if properly and timely brought to the attention of the Department, would have justified the application of limitations or other requirements different from those required by applicable standards or limitations but only if the requestor shows that such factor or factors arose after the final permit was issued;

(3) Revision, withdrawal or modification of State water quality standards or Environmental Protection Agency promulgated effluent limitations guidelines, but only when:

(a) The permit term or condition requested to be modified revoked was based on a promulgated effluent limitations guideline or an Environmental Protection Agency approved State water quality standards.

(b) The U.S. Environmental Protection Agency has:

(i) Revised, withdrawn or modified that portion of the effluent limitations guidelines on which the permit term or condition was based; or

(ii) Approved a State action with regard to a water quality standard on which the permit term or condition was based and

(c) A request for modification or revocation and reissuance is filed within ninety (90) days after Federal Register notice of:

(i) Revision, withdrawal or modification of that portion of the effluent limitations guidelines; or

(ii) The U.S. Environmental Protection Agency approval of State action regarding a water quality standard;

(4) Judicial remand of Environmental Protection Agency promul[illegible] effluent limitations guidelines, if the remand concerns th[illegible] portion of the guidelines on which the permit term or conditio[illegible] was based and the request is filed within ninety (90) days of the judicial remand;

NOV 01 1985

(5) Any modification or revocation and reissuance of permits specifically authorized by the Act;

(6) To comply with any applicable standard or limitation promulgated or approved under sections 301(b) (2) (C) and (D), 304 (b) (2) and 307(a) (2) of the Clean Water Act, if the effluent standard or limitation so issued or approved:

(a) Contains different conditions or is otherwise more stringent than any effluent limitations in the permit; or

(b) Controls any pollutant not limited in the permit.

The permit as modified or reissued under this paragraph shall also contain any other requirements of the Act then applicable.

(7) To contain a schedule of compliance leading to termination of the direct discharge by a date which is no later than the statutory deadline;

(8) To modify a schedule of compliance in an issued permit for good and valid cause by a date which is no later than the statutory deadline.

(9) To modify a schedule of compliance of a POTW which has received a grant, under section 202(a) (3) of the Act, to reflect the amount of time lost during construction of the innovative and alternative facilities by a date which is no later than the statutory deadline.

6. Oil and Hazardous Substance Liability

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under 7 Del. C., Chapter 60.

7. State Laws

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation.

8. Discharge of Pollutants

Any person who causes or contributes to the discharge of a pollutant into waters of the State or the United States either in excess of any conditions specified in this permit or in absence of a specific permit condition shall report such an incident to the Department as required under 7 Del. C., §6028.

DRAFT

NOV 01 1985

9. Property Rights

The issuance of this permit neither conveys any property rights in either real or personal property, or any exclusive privileges, nor authorizes any injury to private property or any invasion of personal rights, or any infringement of Federal, State or local laws or regulations.

10. Construction Authorizations

This permit does not authorize or approve the construction of any onshore or offshore physical structures or facilities or the undertaking of any work in any navigable waters.

11. Severability

The provisions of this permit are severable. If any provision of this permit is held invalid, the remainder of this permit shall not be affected. If the application of any provision of this permit to any circumstance is held invalid, its application to other circumstances shall not be affected.

NOV 01 1985

A. Special Conditions

1. This permit supersedes NPDES Permit DE 0050741 as issued on October 11, 1977.

2. For the purpose of determining compliance with the flow limitation, pump records shall be used. For the purpose of determining compliance with loading limitations the flow, leaving the treatment facility at the time the sample is collected, shall be used.

3. The necessary state and federal permits for the installation of the primary flow measuring device must be obtained. Additionally, the primary flow measuring device shall be designed, installed and maintai according to accepted engineering principles and practices.

4. There shall be no leaks at the recovery wells or in the piping between the recovery wells and the treatment facility.

5. Bioassay tests shall be conducted quarterly on discharge 001 usin "Daphnia" in accordance with the testing procedures outlined in "Methods for Measuring the Acute Toxicity of Effluents to Aquati Organisms" EPA-600/4-78-012, revised July 1978 and the followinc minimum requirements:

   i. Prepare effluent water by collecting representative composi e samples of the discharge. During the sampling day, if the instantaneous flow rate does not vary by more than + 15 pe ent of the average flow rate, then a time-intervaled composite will be an acceptable representative sample. Otherwise, flow weighted composite samples will have to be collected.

   ii. Perform aseries of three 24-hour static toxicity tests. A low a 24-hour lag period between each test. These tests must be initiated as soon as possible, but no later than 24 hours after collection of the effluent samples (as specified in i.). A survival rate of 80% or greater as an average of three tests indicates low toxicity. In these tests the control samples must have a survival rate of 80% or greater for the tests results to be valid. If the control sample has a survival rate of less than 80%, then the tests must be conducted again. Test results must be reported to the Department within 15 days of completion of these tests. This report must include the individual and average survival rates for the three tests.

   iii. Upon completion of the static toxicity tests, if the average survival rate (in the discharge) is less than 80%, the permittee shall:

      a. Perform a flow through LC_{50}-96 hours test according to EPA's approved methods (Ref: Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms EPA-600/4-78-012 revised July 1978).

DRAFT

NOV 01 1985

b. Characterize wastewater by appropriate EPA approved analytical procedures.

c. Report to the Department the LC_{50}-96 hours of the effluent and the wastewater characterization results within 15 days of test completion.

iv. If LC_{50}-96 hours is less than 50% whole waste, submit a plan, within 30 days of test completion, for reducing the effluent toxicity.

v. The permittee shall notify the Department in writing at least 30 days before the planned day for conducting the bioassays. The permittee shall also split the composite samples used to perform the static bioassay tests with Department personnel.

vi. All documentation pertaining to these toxicity tests must be maintained at the facility and must be made available for inspection, upon request, by the Department.

vii. After the completion of 4 bioassays, the permittee may request the Department to review the data from these tests to modify the monitoring frequencies of the bioassays.

6. This permit is for discharges contaminated groundwater from recovery wells identified on page 2. It is issued on the assumption that all contaminated groundwater recovery wells will be eliminated as part of the Army Creek Landfill closure plan.

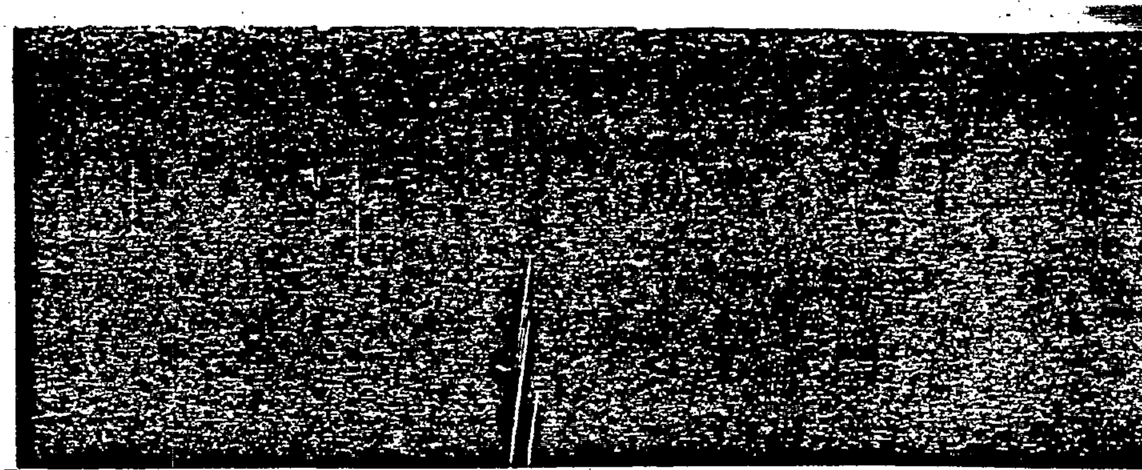
7. Within 6 months the permittee shall develop and submit for approval a plan to decommission the treatment facility. The plan is to be implemented within 3 months of the discharges from contaminated groundwater recovery wells being eliminated. The plan shall address at least the following:

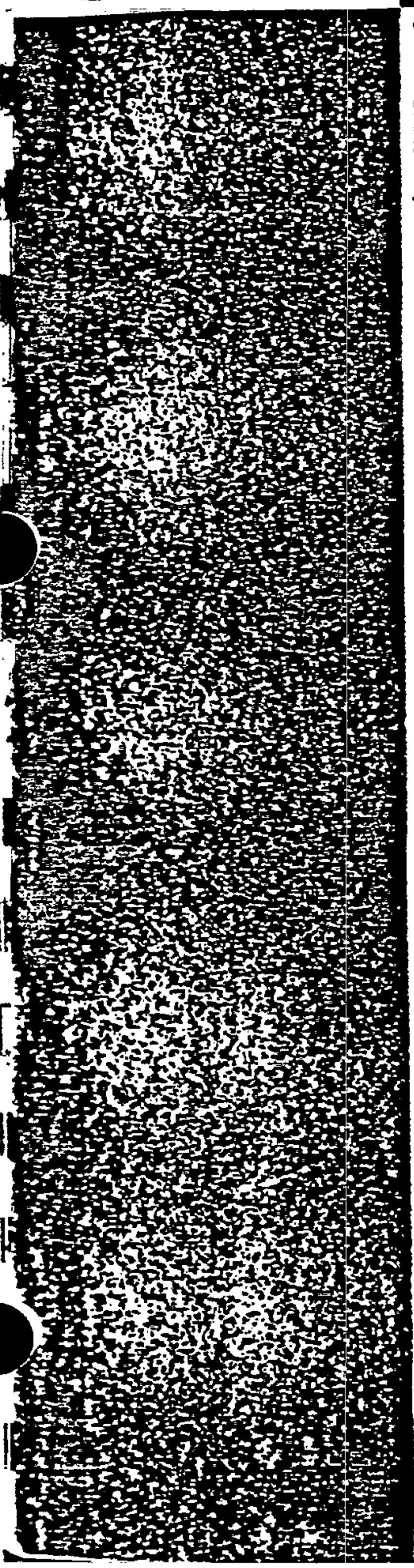
a. The necessary methodology to return Army Pond back to its natural condition.

b. The necessary state and/or federal permits required to implement the methodology outlined as a result of a. above.

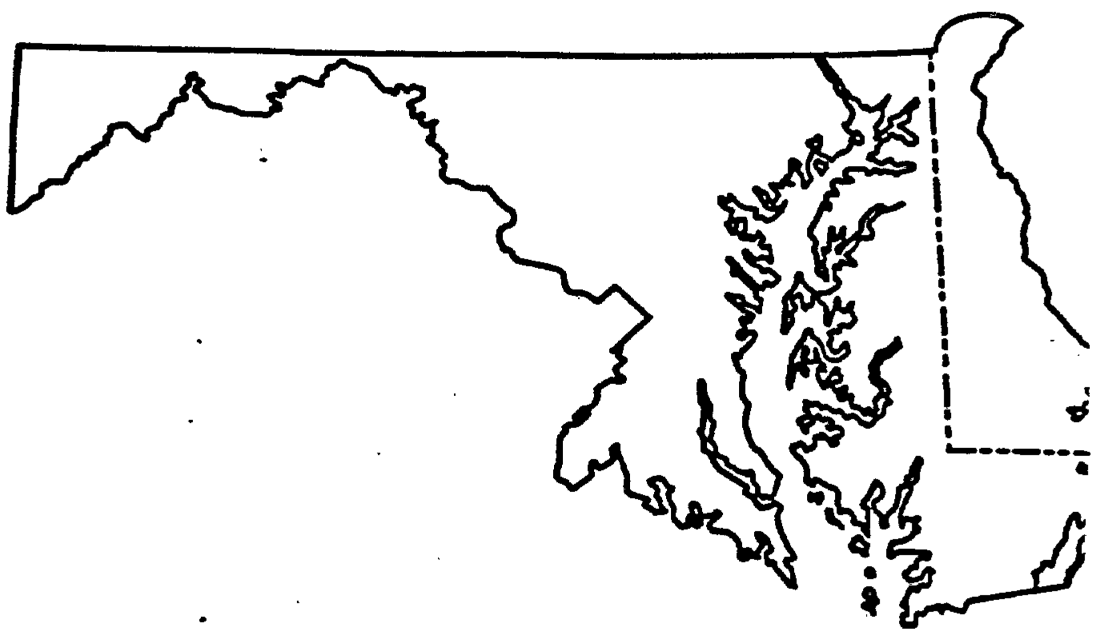
c. A schedule for obtaining the required permits as well as for implementing the methodology.

d. The necessary criteria and testing to determine prior to the implementation of the methodology the advisability of implementing the proposal.





Water Resources Data Maryland and Delaware Water Year 1981



U.S. GEOLOGICAL SURVEY WATER-DATA REPORT MD-DE-81-1

Prepared in cooperation with the States of Maryland and Delaware and with other agencies

01482200 ARMY CREEK AT STATE ROAD, DE

LOCATION.--Lat 39°38'56", long 75°37'18", New Castle County, Hydrologic Unit 02040205, on left bank at downstream end of culvert on U.S. Highway 13, 0.2 mi (0.3 km) south of State Road, and 2.3 mi (3.7 km) upstream from mouth.

DRAINAGE AREA.--2.42 mi² (6.27 km²).

PERIOD OF RECORD.--October 1978 to September 1981 (discontinued).

GAGE.--Water-stage recorder. Concrete control since Sept. 24, 1979. Altitude of gage is 10 ft (3.0 m), from topographic map.

REMARKS.--Records poor. Several observations of water temperature were made during the year.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge known, 184 ft³/s (5.21 m³/s) Jan. 21, 1979, gage height, 4.09 ft (1.247 m); minimum daily discharge, 0.01 ft³/s (<0.001 m³/s) many days during August, September, October 1980, and August, September 1981.

EXTREMES FOR CURRENT YEAR.--Peak discharges above base of 65 ft³/s (1.8 m³/s) and maximum (*):

Date	Time	Discharge (ft³/s)	Discharge (m³/s)	Gage height (ft)	Gage height (m)	Date	Time	Discharge (ft³/s)	Discharge (m³/s)	Gage height (ft)	Gage height (m)
May 15	1615	129	3.65	3.81	1.161	July 21	Unknown	Unknown		Unknown	
June 20	1415	79	2.24	3.25	0.991	Aug. 8	Unknown	*Unknown		Unknown	

Minimum daily discharge, 0.01 ft³/s (<0.001 m³/s) many days during October, August, and September.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1980 TO SEPTEMBER 1981
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.02	.09	.11	.12	.07	.19	2.4	.80	.06	.18	.02	.01
2	.05	.08	.11	.13	3.6	.14	.80	4.2	1.6	.40	.02	.01
3	.04	.06	.09	.10	.46	.11	.27	.54	.19	.15	.10	.02
4	.65	.53	.06	.07	.14	.09	.21	.30	.16	1.5	.06	.02
5	.06	.28	.06	.04	.08	1.2	1.4	.21	.15	.50	.04	.02
6	.03	.07	.06	.04	.07	.78	.60	.16	.08	.10	.03	.02
7	.02	.07	.07	.09	.09	.41	.27	.14	.06	.05	.03	.02
8	.02	.08	.07	.07	1.0	.27	.21	.09	.04	.03	35	.21
9	.02	.14	.10	.04	.33	.21	.34	.09	.16	.03	3.0	.13
10	.02	.07	.20	.04	.17	.17	.21	.09	.27	.03	2.0	.01
11	.06	.06	.11	.04	9.1	.34	.21	17	.07	.03	.15	.01
12	.02	.06	.16	.04	1.5	.21	1.7	2.7	.04	.03	.10	.09
13	.01	.06	.09	.04	.20	.14	.51	.57	.46	.03	.05	.16
14	.02	.06	.09	.03	.21	.12	5.4	.30	.53	.05	.06	.17
15	.02	.08	.11	.05	.10	.17	1.1	23	.08	.02	.20	1.2
16	.02	.06	.24	.07	.18	.20	.30	1.0	.03	.02	4.7	5.4
17	.02	.04	.14	.07	.21	.15	.34	.43	3.1	.02	.08	.26
18	.48	2.0	.08	.07	.22	.10	.22	.27	.10	.02	.03	9.9
19	.40	.25	.09	.16	.22	.09	.22	.56	.07	.30	.02	1.4
20	.06	.17	.06	.26	1.3	.09	.34	.24	3.0	1.2	.01	.19
21	.04	.14	.04	.28	.78	.09	.19	.19	.50	25	.01	.10
22	.02	.13	.03	.32	.34	.08	.17	.17	.30	.20	.01	.06
23	.02	.10	.22	.31	1.4	.10	.31	.12	.20	.02	.01	.04
24	.02	3.9	.51	.28	1.1	.08	.72	.10	.14	.02	.01	.03
25	15	1.4	.23	.26	.20	.07	.21	.09	1.6	.02	.01	.02
26	1.6	.20	.06	.22	.20	.08	.18	.08	.15	.02	.01	.03
27	.24	.16	.06	.23	.16	.09	.17	.07	.10	.02	.01	.05
28	.22	.76	.12	.19	.10	.09	.91	.62	.07	.04	.01	.02
29	.18	.20	.24	.16	---	.09	.90	.19	.05	.08	.01	.02
30	.10	.13	.21	.10	---	.71	.20	.12	.04	.04	.01	.01
31	.09	---	.13	.07	---	.25	---	.08	---	.03	.01	---
TOTAL	20.37	12.95	4.06	3.97	23.79	6.96	21.27	55.30	13.60	30.10	45.89	19.63
MEAN	.66	.43	.13	.13	.85	.22	.71	1.78	.46	.97	1.48	.65
MAX	15	3.9	.51	.32	9.1	1.2	5.4	23	3.1	25	35	9.9
MIN	.01	.06	.03	.03	.07	.07	.17	.07	.03	.02	.01	.01
CFSM	.27	.18	.05	.05	.35	.09	.29	.74	.19	.40	.61	.27
IN.	.31	.20	.06	.06	.37	.11	.33	.85	.21	.46	.71	.30

CAL YR 1980 TOTAL 300.95 MEAN .82 MAX 16 MIN .01 CFSM .34 IN 4.62
WTR YR 1981 TOTAL 257.97 MEAN .71 MAX 35 MIN .01 CFSM .29 IN 3.96

AR 302258

M E M O R A N D U M

TO: Harry W. Otto

FROM: Gregory M. Mitchell G.M.M.

DATE: October 29, 1985

SUBJECT: Bio-Survey at Army Creek

On June 11, 1985, a qualitative biological survey was conducted at Army Creek. Survey objectives were to determine what kinds of macroinvertebrates existed above and below Army Pond. Sample locations were Rt. 13 Brd. - east side (Storet No. 114021) and Army Pond effluent (No Storet No.). Also, a set of water quality samples (routine parameters) and water samples for acute toxic bioassays were collected. This report only discusses the bio-survey results.

General Description of Sample Sites

The sample station at Rt. 13 was a stream, but flow velocity was extremely slow. The stream channel with noticeable flow was less than 2 ft. wide. Even in the channel, flow velocity was slow. Below this area was a large pool approximately 10 ft. wide and 1 ft. deep. Biota collections were taken from the small channel and pool. The substrate was hard with scattered cobbles, pebbles, gravel and sand.

The sample location at Army Pond effluent was in the stream just below pond discharge. This station had moderate flow velocity, a riffle and a large deep pool. The stream was about 12 ft. wide, the riffle shallow and the pool 4 ft. deep. The substrate was hard pack clay and sand with scattered cobbles and boulders. Biological sampling was done in the riffle and pool.

Sample timing was ideal because of low flow (spring drought) in Army Creek and Army Pond. During the spring season, there had been very little rain water dilution to minimize pollution impacts.

Materials and Methods

At both stations, qualitative sampling was conducted by three people for 30 minutes. The sampling protocol is outlined below:

1. Kick samples - the D-shaped net (0.5 mm mesh) was held upright and the sediment was kicked several times in front of the net. Dislodged benthos drifted into the net. This could only be done at the Army Creek effluent station because stream flow was adequate.

2. Sweep samples - the D-shaped net was swept across the bottom, around the stream banks and through aquatic vegetation. Sweeps through vegetation were very productive.

3. Random hand-picked cobbles - 15 cobbles were examined closely for clinging invertebrates.

4. Sieve sediments - sediments in pools and next to stream bank were sieved with the 0.5 mm mesh sieve. Several oligochaetes, pea clams and chironomids were collected.

5. Dip net samples - a 3/8 inch mesh hand dip net was swept through pools and aquatic vegetation for finfish and very large macroinvertebrates. A few fish, dragonfly nymphs and large snails were collected.

This qualitative technique does not permit collected organisms to be enumerated as number of individuals per unit sample area (e.g. - 50 mayflies per square foot). Densities are listed as abundant (>25 individuals), common (>10 individuals) and present (<10 individuals).

Advantages of qualitative sampling are less sample time and laboratory time. Also, a variety of habitats are surveyed instead of just the riffle habitat when using the quantitative Surber sampler. The more habitats sampled will increase species wealth. Species wealth is the strongest and simplest biological parameter for assessing water quality impacts.

Results

Chemical and physical data are presented in Table 1. The identification and relative abundancies of macroinvertebrates are listed in Table 2.

Chironomids were lumped under one taxon (Chironomidae) on the Benthic Data Sheet (Table 2). If all midge larvae were collected and identified, several species would probably be present. This would raise the total number of taxa. Field observations noted a lot of red chironomids at both sample sites.

Table I
Chemical and Physical Data

Station	Water Temp., C°	D.O.; mg/l	pH	Flow Vel.	Bottom Type
Rt. 13 Brd.	20	5.9	6.68	None	Hard: cobble, pebble, gravel, sand
Army Pond Eff.	22	8.2	6.60	Moderate	Hard: cobble, sand, clay pack

Discussion - Rt. 13 Brd. Station

At this sample site invertebrate densities were very high. The most abundant organisms were Chironomidae larvae, snails (Physa), pea clams (Musculium), Tubificidae worms and leeches. Feeding habits of these dominant organisms are scavengers and filter feeders. These feeding habits and the high standing crop indicated organic enrichment.

Several other different kinds of invertebrates were collected. These included mayflies, damselflies, dragonflies, beetles, crayfish and other snail species. A total of 13 taxa were identified which was fair species wealth.

Environmental tolerances of the organisms sampled range from facultative to tolerant. The one exception may be the mayflies (Centroptilum) but a literature search was fruitless.

A small effort was made to see what finfish were residing. After dip netting in a pool and around aquatic plants, one small carp and bluegill were captured and released.

Negative responses indicated by the invertebrate community were the high standing crop, dominance of hardy species, plus scavengers and filter feeders. Species richness was fair (positive response). Overall stream health appeared to be fair, but moderate organic enrichment was strongly suggested. Fortunately, toxicity did not appear to be a problem.

Discussion - Army Pond Effluent

At this sample location invertebrate densities were high. Although the standing crop would still be considered high, it was not as enormous as the other sample site. Most abundant species were Chironomidae larvae, caddisflies (Hydropsyche), and snails (Physa). Like the other sample station, these invertebrates were scavengers and filter feeders. Hydropsychid caddisflies not collected at the Rt. 13 Brd. Station were abundant at this location because of adequate flow velocity. These species build nets and depend on swift flow to wash food stuffs into the nets. I strongly believe they were not nutritionally or water quality limited, but limited by nearly no flow at the other station. Also, net spinning caddisflies were indicative of high levels of suspended organic particulates.

Many other different types of invertebrates were collected. These included blackflies (Simulium), mayflies (Caenis), damselflies, dragonflies, shrimp, Planorbidae snails (Helisoma), Tubificidae worms, leeches and flatworms. The total number of taxa was 12 which indicated fair species richness.

Environmental tolerances of the organisms ranged from facultative to tolerant. Only the caddisflies were sensitive types. The mayflies (Caenis) are considered faculative by most authors.

One hugh carp and several small fish were seen, but not identified. One bluegill was collected and released.

The high invertebrate densities, abundance of hardy species and feeding habits (filter feeders and scavengers) indicated environmental impacts. Positive signs were the sensitive Hydropsychidae larvae and fair species richness. Moderate organic enrichment and high levels of suspended particulates were strongly suggested. There was no indication of toxicity.

Conclusions

Species composition and species richness at both sample sites were similar. Macroinvertebrate densities were high, but the Rt. 13 Brd. Station appeared to have greater biomass. Also common to both stations were the preponderance of facultative and tolerant organisms. These community responses strongly suggested moderate organic enrichment.

Table 2
Army Creek 1985
Benthic Data

Organisms	Stations Rt. 13 Brd.	Stations Army Pond Eff.
Diptera		
Chironomidae	A	A
Simuliidae		
Simulium sp.	--	P
Trichoptera		
Hydropsyche sp.	--	A
Ephemeroptera		
Centroptilum sp.	P	--
Caenis sp.	--	P
Odonata		
Zygoptera		
Ischnura sp.	P	--
Argia sp.	C	C
Anisoptera	P	P
Coleoptera		
Dytiscidae		
Agabus sp.	P	--
Decapoda		
Palaemonidae		
Palaemonetes sp.	--	P
Astacidae		
Cambarus sp.	P	--
Gastropoda		
Helisoma sp.	C	P
Physa sp.	A	A
Lymnaea sp.	P	--
Pelecypoda		
Sphaeriidae		
Musculium sp.	A	--
Annelida		
Oligochaeta		
Tubificidae	A	P
Hirudinea	A	C
Turbellaria	--	P
Total No. of Taxa	13	12

GMM:dlh

MEMORANDUM

TO: Harry W. Otto

FROM: Gregory Mitchell, Robert Garrow

DATE: June 17, 1983

SUBJECT: Finfish Collections at Red Lion Creek, Army Creek and St. Jones River

---

On May 31, 1983, the Red Lion Creek and Army Creek surveys were finally accomplished. The following day, June 2, 1983, the St. Jones River survey was completed. Survey objectives were to collect ambient water and finfish samples at all selected sample sites. At Red Lion Creek, sample sites were Route 13 Bridge (Storet 107021) and Route 9 Bridge (Storet 107031). The Army Creek sample site was the railroad bridge below Llangollen Landfill (no storet number). At St. Jones River, the sample site was next to the Wildcat Landfill (R.M. 7.75, no storet number).

Chemical analyses for the ambient water samples were PCB's and chlorobenzenes. Fish tissue analyses were PCB's, chlorobenzenes and the heavy metals arsenic, cadmium, chromium, copper, mercury, lead and zinc.

Water samples were collected in the special prepared bottles for organic chemicals and vials for synthetic organic chemicals. All samples were grab samples. At Red Lion and Army Creeks, finfish were collected with standard fish collection equipment such as gill nets and haul sieves. An abundance of fish were captured. All samples preserved for tissue analyses were composed of several individuals. The large channel catfish was the only single fish sample. At the St. Jones River, a gill net was set three times and collections were sparse. Two channel catfish and two small white perch were packaged for samples.

AR302264

Listed below are the fish species collected and preserved fish samples selected for tissue analyses.

Stations	Fish Collected	Fish Samples for Analyses
Red Lion Creek, Rt. 13 Brd. Station	brown bullheads, white perch	brown bullheads, white perch
Red Lion Creek, Rt. 9 Brd. Station	brown bullheads, carp, white perch, gizzard shad, channel catfish, eels, pumpkinseed sunfish	brown bullheads, channel catfish, carp, white perch
Army Creek, RR. Brd. Station	brown bullheads, redfin pickerels, pumpkinseed sunfish, blue gill sunfish, blue spot sunfish, black crappie, golden shiners, white perch, eels	brown bullheads
St. Jones River, next to Wildcat Landfill	channel catfish, white perch, black crappie	channel catfish, white perch

Extra fish that Technical Services Section did not need for analysis were given to Diamond Shamrock upon their request (Joe Viaren). At Red Lion Creek, Route 13 Bridge Station, they were given white perch. At the Route 9 Bridge Station, they were given brown bullheads, carp, gizzard shad and white perch.

Several DNREC personnel participated in the Red Lion and Army Creek's survey. Roy Miller, Cathy Martin and Joe Kamper (Fish and Wildlife Div.) were responsible for collecting fish at all three sample stations. Special thanks to them for their cooperation and expertise in fish collections for making this survey a success. Mark Blosser (Water Resources Section) and Greg Mitchell (Technical Services Section) collected ambient water samples (organics and SOC's) at all stations. Bob Garrow, Ellen Lynch, and Greg Mitchell (Technical Services Section) were responsible for quality control in the field. Identifications, weights and lengths of all fish species collected were recorded. All fish samples were packaged in acetone rinsed aluminium foil and immediately placed in ice chests. They also completed and proofread all analytical request sheets and legal custody sheets. Mark Boller (Water Supply Section) observed fish collections and preservations for possible fish collections by Water Supply Section. Mark Blosser and Mark Boller also did field reconnaissance at Army Creek.

Sample collections for the single station at St. Jones River was a much simpler effort. Water samples (organics and SOC's) and fish collections were carried out by Cathy Martin, Joe Kamper and Greg Mitchell. Special thanks to conservation aids (Fish and Wildlife Division) for removing mud from the Barker's Landing boat ramp.

The overall project was completed with a minimal amount of the customary problems that plague field collection.

However in the future we strongly recommend that all interested parties participate in meetings from planning to execution.

Analytical results are pending.

GM:RG:dp

cc: Thomas P. Eichler
Robert J. Touhey
Roy Miller
Cathy Martin

STATE OF DELAWARE

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

ORGANIC ANALYTICAL REQUEST JUL 05 1983

DATE SAMPLED 5/31/83 SAMPLE BY Martin Miller RESULTS TO H.Otto

COMPLETION DATE 6-29-83 ANALYST J Teagle / S Robinson APPROVED [illegible]

PROGRAM - CORE

SAMPLE LOG NO.	SAMPLE SITE	SAMPLE TYPE	LENGTH CM ~~(inches)~~	WEIGHT (grams)
1897	Army Creek (near RR Brdg)	* Brown Bullhead	26	224
		"	19	92
		"	20.5	130
		"	20.5	130
		Redfin Pickerel	22	68
			17	32
			15	20
		Pumkinseed	8	12
		"	9	15
		"	11	25
		"	9	16
		"	8	11
		"	8	12
		"	10	18
		"	8	12

COMMENTS

Analize for PCB's, Chlorobenzene, Metals + Zinc

Metals - As - Cd, Cu, Cr, Hg, Pb, Zn

* Representative samples to be ~~[illegible]~~ Analyzed.

Instructions from G Mitchell to analyze Brown bullhead other species are not to be analyzed. [illegible]

AR302267

CODE PARAMETER	UNITS	SAMPLE NUMBER
		1897
No. of Fish Analyzed		4
Whole Fish		✓
Filleted		
Chlorobenzene		None detected
PCB		1.2 ug/g
Aldrin		
Dieldrin		
pp DDE		
op DDE		
op DDD		
pp DDD		
op DDT		
pp DDT		
cis - Chlordane		
trans - Chlordane		
cis - Nonachlor		
trans - Nonachlor		
Endrin		
Methoxychlor		
Hexachlorobenzene		
Pentachlorophenol		
alpha BHC		
~~Lindane~~ Zinc	ug/g	18.
Arsenic	ug/g	<0.60
Cadmium	ug/g	<2.0
Chromium	ug/g	5.2
Copper	ug/g	5.2
Mercury	ug/g	<0.10

No evidence of contamination by purgeable synthetic organic compounds. [illegible] 6/29/83

STATE OF DELAWARE

JUN 28 1983

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

SPECIAL ANALYTICAL REQUEST

DATE SAMPLED: May 31, 1983 SAMPLED BY: Mitchell - Blosser RESULTS TO:

COMPLETION DATE: 28 June 83 ANALYST: Teagle / S Robinson APPROVED: C [illegible]

ANALYTICAL REQUEST: PCB's, SOC's (especially Chlorobenzenes) ~~and Metals~~

~~Metals – As, Cd, Co, Cr, Hg, Pb, Zn~~ DO NOT RUN METALS

LOG NO.	SAMPLE DESCRIPTION	Temp	pH	Spec. Con
1896	Army Creek, Rt. 9 114011 Surface Water	19	6.0	110
	Tide ebbing, Salinity 0‰			

DATA REPORT:

AR302269

SYNTHETIC ORGANIC COMPOUNDS	ug/1.	COMPOUND SAMPLE NO.
	1896	
Chloromethane, ug/1.	< 10	
Bromomethane, ug/1.	< 10	
Vinyl Chloride, ug/1.	< 10	
Chloroethane, ug/1.	< 10	
Methylene Chloride, ug/1.	< 10	
Trichlorofluoromethane, ug/1	<	
1,1- Dichloroethane, ug/1.	< 10	
trans -1,2- Dichloroethylene, ug/1.	< 10	
Chloroform, ug/1.	< 10	
1,2 - Dichloroethane, ug/1.	< 10	
1,1,1-Trichloroethane, ug/1	< 10	
Carbon Tetrachloride, ug/1.	< 10	
Bromodichloromethane, ug/1.	< 10	
1,2-Dichloropropane, ug/1.	< 10	
trans-1,3-Dichloropropene ug/1.	< 10	
Trichloroethylene, ug/1.	< 10	
Dibromochloromethane, ug/1.	< 10	
cis -1,3-Dichloropropene ug/1	< 10	
1,1,2-Trichloroethane, ug/1	< 10	
Benzene, ug/1	< 10	
2-Chloroethylvinyl Ether ug/1	< 10	
Bromoform, ug/1.	< 10	
Tetrachloroethylene, ug/1.	< 10	
1,1,2,2-Tetrachloroethane ug/1	< 10	
Toluene, ug/1	< 10	
Chlorobenzene, ug/1	< 10	
Ethylbenzene, ug/1.	< 10	

CHLORINATED PESTICIDES	ug/1	COMPOUND SAMPLE NO.
	1894	
Polychlorinated biphenyls (PCB's), ug/1	<1 ug/l	(GC)
Aldrin, ug/1.		
Dieldrin, ug/1.		
DDE-o,p, ug/1.		
DDE-p,p, ug/1.		
DDD-o,p, ug/1.		
DDD-p,p, ug/1.		
DDT-o,p, ug/1.		
DDT-p,p, ug/1.		
Chlordane-cis isomer, ug/1.		
Chlordane-trans isomer, ug/1		
cis isomer of nonchlor, ug/1		
trans isomer of nonchlor, ug/		
Endrin, ug/1		
Methoxychlor, ug/1		
Hexachlorobenzene, ug/1.		
BHC- A isomer, ug/1.		
BHC-B isomer, ug/1		
Lindane, ug/1.		
Heptachlor, ug/1.		
Heptachlor epoxide, ug/1.		
Mirex, ug/1.		
Arsenic		
Cadmium		
Copper		
Chromium		
Mercury		

AR302270

M E M O R A N D U M

TO: Harry W. Otto

THRU: Robert F. Garrow RG

FROM: Gregory M. Mitchell GMM
Ellen E. Lynch EEL

DATE: March 28, 1985

SUBJECT: Sampling Quality Control at Army Creek (Delaware Sand and Gravel - Superfund)

Surface water and stream sediment samples were collected at Army Creek on March 26, 1985. All samples were collected except for Station 8 (intermittent stream east of inert disposal area). After walking most of this segment, it was apparent there was no stream flow. Only a few tiny pools approximately one inch deep were observed.

Water and sediment sampling at Army Creek began at the lower station 6 (tidal gate east of Rt. 9) and samples were consistently collected going upstream.

Upon arrival at each station, water samples were hand dipped first. No collection devices were used such as buckets, scoops, etc. Since all sample sites were shallow, sediments were also hand dipped. One hand with a thoroughly rinsed latex glove (clean glove at each station) held the sediment sample jar. The jar was pushed 3-4 inches into the sediment and swept across the bottom until filled. Sticky, muddy sediments were rinsed off the outside of the jar with stream water.

An attempt at each station was made to get muddy or oozy sediments and not sand, gravel and pebbles. Sediment characteristics at some stations were dominated by fine sand, silt or clay. At those stations (No. 1, 2, 4, 7), that was the best sample we could collect.

Duplicate samples were collected at Station 1 (west side of Rt. 13 behind Dairy Queen). All samples and blank samples were kept chilled in an ice chest during the day. Legal custody sheets were also submitted to the laboratory.

Stream observations at a biological and physical point of view indicated stresses. Luxurious growths of long filamentous algae, heavy iron precipitate (orange substrate) and gassing, bubbling sediments (when penetrated) were observed at most locations, except Station 6.

Station 8 (intermittent stream east of inert disposal area) will be inspected the first week of April 1985. If flow is adequate, water samples will be collected. A sediment sample will be collected regardless of flow.

GMM:EEL:dlh

Surface Water Summary

INORGANIC ANALYTICAL RESULTS
OF APRIL 1985
DELAWARE SAND AND GRAVEL RI/FS SURFACE WATER SAMPLING (1)

Sampling Location	Iron	Manganese	Zinc	Barium	PH	BOD	Chloride	Ammonia-N	Sulfate	TDS	TOC
1*	0.530	0.150	<.100	<0.100	6.96	<2.4	27.	0.10	23.5	151.	7.
2	0.555	0.155	<.100	<0.100	6.91	<2.4	29.	<0.10	28	161.	8.
3	1.810	0.400	<.100	0.120	7.15	<2.4	37.	2.80	10.	156	16.
4	4.850	0.600	<.100	0.110	7.02	<2.4	43.	2.55	14.5	192.	24.
5	4.640	0.580	<.100	0.110	6.61	<2.4	39.	0.70	14.5	180.	23.
6	4.000	0.390	<.100	<0.100	6.64	<2.4	330.	<0.10	64.5	733.	12.
7	0.435	<.100	<.100	<0.100	6.94	<2.4	6.	<0.10	14.5	49.	< 5.

1. Army Creek, West of Route 13
2. Army Creek, East of Route 13, Upstream of Weir
3. Army Creek, Pond Entrance
4. Army Creek, Pond Effluent
5. Army Creek, Under Railroad Bridge
6. Army Creek, Tidal Gate, East of Route 9
7. Gravel Pit Pond

*Duplicate analysis was performed on this sample. The results presented are the highest values between the duplicates.

(1) Units in ppm except specific conductance (umhos/cm) and pH (dimensionless).

AR302273

STATE OF DELAWARE

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

SPECIAL ANALYTICAL REQUEST

DATE SAMPLED: March 23, 1985 SAMPLED BY: Lynch & Mitchell RESULTS TO: Young

COMPLETION DATE: 5/8/85 ANALYST: J [illegible] APPROVED: [illegible]

ANALYTICAL REQUEST: See attached Sheet for Parameters

Delaware Sand & Gravel Project

LOG NO.	SAMPLE DESCRIPTION
873	# 1 Army Creek - west side of Rt 13
874	2 " " - upstream of weir east of Rt 13
875	3 " " - at the pond entrance
876	4 " " - at the pond effluent
877	5 " " - under RR Brd.

DATA REPORT: There is no evidence of contamination by PCBs, chlorinated pesticides, halogenated or Aromatic volatiles, acid/base/neutral extractable compounds [illegible] 5/8/85

Harry W. Otto

AR302274

STATE OF DELAWARE

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

SPECIAL ANALYTICAL REQUEST

DATE SAMPLED: March 23, 1985 SAMPLED BY: Lynch & Mitchell RESULTS TO: Young

COMPLETION DATE: 5/8/85 ANALYST: S. Robinson APPROVED: [illegible]

ANALYTICAL REQUEST: See attached Sheet for Parameters

Delaware Sand & Gravel Project

LOG NO.	SAMPLE DESCRIPTION (Water)
878	#6 Army Creek - Tidal gate east of Rt. 9
879	7 Gravel Pit Pond
880	8 intermittent stream [illegible] #1
881	Blank

DATA REPORT: There is no evidence of contamination by PCBs,

chlorinated pesticides, halogenated or aromatic VOAs or

acid / base / neutral extractable compounds CA 5/8/85

[illegible]

AR302275

TECHNICAL SERVICES SECTION
DIVISION OF ENVIRONMENTAL CONTROL
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
REQUEST FOR LABORATORY ANALYSIS

DATE SAMPLED March ~~25~~ 26, 1985 SAMPLER Lynch/Mitchell CAR /✓/ BOAT / / SPLIT

REQUESTER H.O. RESULTS TO [redacted] Steve Young

SAMPLE TYPE: STREAM ✓ WELL ___ DOMESTIC WASTE ___ INDUSTRIAL ___ AIR ___

BIOLOGICAL ___ SLUDGE ___ BORING ___ STP ___ OTHER SEDIMENT

SOURCE NAME Army Creek NPDES DE - ___

ADDRESS Delaware Sand and Gravel Project *

SAMPLING MODE GRAB /✓/ COMPOSITE MFG. ___ S/N ___
FROM: YR ___ MO ___ DAY ___ HR ___
BASIN ___ TO: YR ___ MO ___ DAY ___ HR ___

TIDE LW Station box THIO ADDED TO ___

COMMENTS/INSTRUCTION Note - sample # 889 results confirmed twice.
Station 7 - sandy sediments - no mud or ooze
Station 8 - No samples - No flow, few little pools ≈ 1" deep
pools had orange color bottom

LOG. NO.	SAMPLE IDENTIFICATION	TIME	TEMP., °C. WTR	TEMP., °C. AIR	Cl_2 Res.	SECCHI IN.	FLOW	DEPTH FT.
882	#1 west of Rt 13	1329	9	8				
883	#2 East of Rt 13	1304	8	7				
884	#3 Pond ent.	1156	11.5	6				
885	#4 Pond eff.	1110	10	6				
886	#5 under RR.	1037	9.5	5				
887	#6 Tidal Gate	1007	5.5	6				
889	#7 Gravel pit	1211	10	7				
	#10	NO SAMPLES						

DATE & TIME ACCEPTED 3/26/85 1330 ACCEPTED BY S. Robinson

APPROVED BY C. S. Williams
(Laboratory Supervisor)

APPROVED BY Larry C. Wilts
(Laboratory Manager)

COST CENTER				
AP	RC	PE	FF	
WP ✓	DSW		FW	
WS	DR			

DATE 5/6/85

DOCUMENT NO 40-08-81 10 01

AR302276

ANALYSIS REQUEST

LABORATORY LOG NO.								
% SATURATION								
DIS. OXYGEN, mg/l								
BOD, mg/l								
COD, mg/l								
COLOR, UNITS								
TURBIDITY, FTU								
SPEC. COND., umhos/cm								
pH	6.96	6.91	7.15	7.02	6.61	6.64	6.94	NS
ALK., mg/l $CaCO_3$								
ACIDITY, mg/l $CaCO_3$								
HARDNESS, mg/l								
CHLORIDE, mg/l								
T. NITROGEN, mg/l								
ORGANIC N., mg/l								
AMMONIA N., mg/l								
NITRITE N., mg/l								
NITRATE N., mg/l								
SULFATE, mg/l SO_4								
TOTAL PHOSPHORUS, mg/l								
SET. SOLIDS, ml/l								
T. SUSP. SLDS., mg/l								
N.V. SUSP. SLDS., mg/l								
V. SUSP. SLDS., mg/l								
TOTAL SOLIDS, mg/l								
N. V. T. SLDS., mg/l								
VOL. TOT. SLDS., mg/l								
T. DIS. SLDS., mg/l								
% MOISTURE								
MBAS, mg/l								
GREASE, mg/l								
PHENOL, ug/l								
TOC, mg/l								
IRON, ug/g Total	17909	9505	44010	18530	45175	27962	2867	
COPPER, ug/l								
MANGANESE, ug/g	167	190	274	398	845	1320	24.26	
CHROMIUM, ug/g	18.49	10.21	25.54	<10	14.92	14.93	<10	
SILVER, ug/g	<10	<10	<10	<10	<10	<10	<10	
CALCIUM, ug/l								
ZINC, ug/g	87.27	90.92	274	70.75	143	240	22.24	
LEAD, ug/g	17.07	142	175	25.41	70.63	56.75	10.11	
NICKEL, ug/l								
CADMIUM, ug/g	<10	<10	<10	<10	<10	<10	<10	
MERCURY, ug/g	<0.50	<0.50	<0.50	<0.50	<0.50	0.63	<0.50	
ARSENIC, ug/g	<3.0	<3.0	9.26	<3.0	5.47	13.54	<3.0	
SELENIUM, ug/g	<0.50	<0.50	0.71	<0.50	<0.50	<0.50	<0.50	
[illegible], ug/g	26.56	38.31	234	79.72	145	76.66	<10	
T. COLIFORM, #/100 ml								
F. COLIFORM, #/100 ml								
F. STREP. #/100 ml								

AR302277

ANALYSIS REQUEST

LABORATORY LOG NO.									
% SATURATION									
DIS. OXYGEN, mg/l									
BOD, mg/l									
COD, mg/l									
COLOR, UNITS									
TURBIDITY, FTU									
SPEC. COND., umhos/cm									
pH	6.46								
ALK., mg/l $CaCO_3$									
ACIDITY, mg/l $CaCO_3$									
HARDNESS, mg/l									
CHLORIDE, mg/l									
T. NITROGEN, mg/l									
ORGANIC N., mg/l									
AMMONIA N., mg/l									
NITRITE N., mg/l									
NITRATE N., mg/l									
SULFATE, mg/l SO_4									
TOTAL PHOSPHORUS, mg/l									
SET. SOLIDS, ml/l									
T. SUSP. SLDS., mg/l									
N.V. SUSP. SLDS., mg/l									
V. SUSP. SLDS., mg/l									
TOTAL SOLIDS, mg/l									
N. V. T. SLDS., mg/l									
VOL. TOT. SLDS., mg/l									
T. DIS. SLDS., mg/l									
% MOISTURE									
MBAS, mg/l									
GREASE, mg/l									
PHENOL, ug/l									
TOC, mg/l									
IRON, ug/g	21902								
COPPER, ug/l									
MANGANESE, ug/g	148								
CHROMIUM, ug/g	15.28								
SILVER, ug/g	<10								
CALCIUM, ug/l									
ZINC, ug/g	28.53								
LEAD, ug/g	21.40								
NICKEL, ug/l									
CADMIUM, ug/g	<10								
MERCURY, ug/g	<0.50								
ARSENIC, ug/g	<3.0								
SELENIUM, ug/g	<0.50								
Barium, ug/g	42.80								
T. COLIFORM, #/100 ml									
F. COLIFORM, #/100 ml									
F. STREP. #/100 ml									

AR 302278

STATE OF DELAWARE

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL

ORGANIC ANALYTICAL REQUEST

DATE SAMPLED 3/26/85 SAMPLED BY Lynch Mitchell SAMPLE TYPE Sediment RESULTS TO S. Young

COMPLETION DATE 5/13/85 ANALYST J. Robinson COST CENTER DSG APPROVED Cfr

PROJECT LOCATION Army Creek
Delaware Sand & Gravel Project

APPROVED [illegible]

SAMPLE LOG NO.	SAMPLE DESCRIPTION
882	#1 West of Rte 13
883	#2 East of Rte 13
884	#3 Pond Ent.
885	#4 Pond Eff.
886	#5 Under RR
887	#6 Tidal Gate
888	#7 Gravel Pit
889	Duplicate #1
890	Blank

ANALSIS REQUEST Chlorinated Pesticide/✓/ Insecticide/_/ Herbicide/_/ Fungicide/_/

PCB/✓/ VOA/✓/ Acid Extractables/✓/ Base/Neutral Extractables/✓/

BTX /_/ OTHER________________

COMMENTS

AR302279

There is no evidence of contamination by PCBs, chlorinated pesticides, halogenated or aromatic VOCs, acid/base/neutral extractable compounds.

TECHNICAL SERVICES SECTION
DIVISION OF ENVIRONMENTAL CONTROL
DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
REQUEST FOR LABORATORY ANALYSIS

DATE SAMPLED April 2, 1985 SAMPLER Mitchell / Smith CAR /✓/ BOAT /__/ S

REQUESTER HO RESULTS TO HO

SAMPLE TYPE: STREAM ✓ WELL____ DOMESTIC WASTE____ INDUSTRIAL____ AIR____

BIOLOGICAL____ SLUDGE____ BORING____ STP____ OTHER____

SOURCE NAME Army Creek NPDES DE - ____

ADDRESS Del. Sand and Gravel Project

SAMPLING MODE GRAB /✓/ COMPOSITE MFG.____ S/N____
FROM: YR____ MO____ DAY____ HR____
BASIN____ TO: YR____ MO____ DAY____ HR____

TIDE____ THIO ADDED TO____

COMMENTS/INSTRUCTION Sediment

LOG. NO.	SAMPLE IDENTIFICATION	TIME	TEMP., °C. WTR	AIR	Cl_2 Res.	SECCHI IN.	FLOW	
921	# X intermittent stream		6.5	2.5				

RECEIVED
MAY 13 1985
STATE OF DELAWARE
OFFICE OF SOLID WASTE

DATE & TIME ACCEPTED 4/2/85 1:20 ACCEPTED BY J. Robinson

APPROVED BY C. Anthony
(Laboratory Supervisor)

APPROVED BY Larry W. Etter
(Laboratory Manager)

DATE 5/6/85

COST CENTER				
AP	RC	PE	FF	
WP ✓	DSW		FW	
WS	DR			

[illegible]

AR302280

ANALYSIS REQUEST

LABORATORY LOG NO.	922							
% SATURATION								
DIS. OXYGEN, mg/l								
BOD, mg/l								
COD, mg/l								
COLOR, UNITS								
TURBIDITY, FTU								
SPEC. COND., umhos/cm								
pH	6.11							
ALK., mg/l $CaCO_3$								
ACIDITY, mg/l $CaCO_3$								
HARDNESS, mg/l								
CHLORIDE, mg/l								
T. NITROGEN, mg/l								
ORGANIC N., mg/l								
AMMONIA N., mg/l								
NITRITE N., mg/l								
NITRATE N., mg/l								
SULFATE, mg/l SO_4								
TOTAL PHOSPHORUS, mg/l								
SET. SOLIDS, ml/l								
T. SUSP. SLDS., mg/l								
N.V. SUSP. SLDS., mg/l								
V. SUSP. SLDS., mg/l								
TOTAL SOLIDS, mg/l								
N. V. T. SLDS., mg/l								
VOL. TOT. SLDS., mg/l								
T. DIS. SLDS., mg/l								
% MOISTURE								
MBAS, mg/l								
GREASE, mg/l								
PHENOL, ug/l								
TOC, mg/l								
IRON, ug/g	18254							
COPPER, ug/l								
MANGANESE, ug/g	87.02							
CHROMIUM, ug/g	11.57							
SILVER, ug/g	<10							
CALCIUM, ug/l								
ZINC, ug/g	73.06							
LEAD, ug/g	31.69							
NICKEL, ug/l								
CADMIUM, ug/g	<10							
MERCURY, ug/g	<0.50							
ARSENIC, ug/g	<3.0							
SELENIUM, ug/g	<0.50							
Barium, ug/g	57.34							
T. COLIFORM, #/100 ml								
F. COLIFORM, #/100 ml								
F. STREP. #/100 ml								

AR302281

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF ENVIRONMENTAL CONTROL
WATER RESOURCES SECTION
89 KINGS HIGHWAY
PO BOX 1401
DOVER, DELAWARE 19903

TELEPHONE: (302) 736 - 4761

MEMORANDUM

TO: Ramesh J. Shah
Marilyn P. LaRiccia

FROM: Mark F. Boller

SUBJ: Red Lion Creek Fish Sampling

DATE: June 2, 1983

On May 31, 1983, I went to Red Lion Creek to observe the Division of Fish and Wildlife and Tech. Services collect fish samples. My trip was planned so I could watch sampling procedures and processing of the sample.

Bob Garrow, Ellen Lynch, and Gregg Mitchell from Tech. Services; Mark Blosser and myself from Water Resources; Roy Miller, Cathy Martin and Dave Camper of Fish and Wildlife and Joe Morone of Diamond Shamrock were all present.

Fish were collected with 50' X 6' gill nets with ¼" to 1¼" mesh. The gill net was set across the creek at the Red Lion Rt. 9 bridge and left for approximately 1¼ hours. A haul seine 25' X 4' X ¼" was pulled along the bank of the Red Lion. In all, 6 species of fish were caught.

Cyprinus carpio	Carp	15 fish - from 1 to 8 lbs.
Ictalurus nebulosis	Brown Bullhead	8 fish - from 1 to 2 lbs.
Ictalurus punctatus	Channel Catfish	1 fish - approx. 8 lbs.
Lepomis gibbosus	Pumpkinseed Sunfish	4 fish - all less than 1 lb.
Morone Americana	White Perch	10 fish - all less than 1 lb.
Dorosoma cepedianum	Gizzard Shad	4 fish - up to 3 lbs.

Diamond Shamrock and Tech Services divided up the fish they needed to analyze so both had enough samples. The fish kept for the analysis were carp, bullhead, catfish, gizzard shad, and white perch. This way bottom feeders and predator fish were analyzed along with the gizzard shad which is a plankton and invertibrate feeder. After being measured and weighed, the fish were wrapped in acetone rinsed aluminum foil and put on ice.

At Rt. 13 Red Lion Creek, a gill net was set across the creek for 30 min. and a haul seine was pulled along the bank, I might add unsuccessfully, due to deep water. Fifty (50) white perch, 3 to 5 inches and 4 brown bullheads up to 10 inches were collected in the gill net. No other species were collected. These fish were divided with Diamond Shamrock for a split sample.

The Army Creek sample station at Rt. 9 was changed to Army Creek near the railroad bridge by Mark Blosser. He decided that if the fish were going to have any contamination from the landfill, that they would have it there since this station is directly adjacent to the landfill and the recovery system feeds the creek a large amount of water. Also the tidal influence was minimal. He thought that the fish at the Rt. 9 station were more or less Delaware River fish and that the volume of Delaware River Water flowing in and out of the creek greatly diluted any influence of Army Creek. Sampling at Rt. 9, however, should be done because these fish are large and are a recreational and food source which could be a threat to human health. Sampling should definitely be done if the Army Creek fish are contaminated.

In all, 9 species of fish were collected at Army Creek:

Lepomis macrochirus	Bluegill	8 fish - .5 to 3 inches
Enneacanthus gloriosus	Blue spotted sunfish	4 fish - .5 to 2 inches
Lepomis gibbosis	Pumpkinseed sunfish	35 fish - .5 to 3 inches
Pomoxis annularis	White crappie	4 fish - .5 to 1.5 inches
Esox americanus	Redfin pickeral	7 fish - .7 to 9 inches
Ictalurus nebulosis	Brown bullhead	4 fish - 4 to 6 inches
Notemigonus crysoleucas	Golden shiner	1 fish - 4 inches
Anguilla rostrata	American eel	4 fish - 3 to 6 inches
Morone americana	White perch	5 fish - 2.5 to 3 inches

This diversity of species indicates to me that the fish population is in a healthy state. The fish were small but healthy. They did not appear stunted or sick. There were no signs of stress and no fish were deformed. The small size of the fish is due to the small body of water sampled, plus, these fish were sampled in a rocky area where the net hung up frequently making escape possible for larger fish.

Invertibrates collected consisted of numerous grass shrimp and mayfly larvae. These also appear to be healthy. It appears that if toxic substances are present, they are at levels low enough not to endanger aquatic life. These fish were at various stages in their life cycles with some fish being very small and some fish filled with eggs and milt ready to spawn at any time.

The fish to be analyzed at Army Creek are Pumpkinseed sunfish, Redfin pickeral, and Brown bullhead. These fish also were weighed and measured and wrapped in acetone rinsed aluminum foil.

The analyses should be completed within two (2) weeks and results sent shortly thereafter.

/tj

No statistical diff. young prod among 3 sites

ARMY CREEK BIOSURVEY
TELEPHONE RESULTS (DAPHNIA)

Red Lion Creek - OK
Pond in OK
Pond out OK - repro OK
RR bridge 80% mort.
Rt. 13 40% mort.

* Significant compared to Les River control

	Sample	Mean Young →	95% intervals Low	High	% survival w/o last day	w/last
Red Lion	100%	21.6	18	25.2	~~100~~	100
Pond in	100%	16.8	13.3	20.2	~~90~~	90
Pond out	100%	17.7*	16.6	18.8	100	100
	30%	16.7*	12.7	20.7	90	
	10%	13.5*	8.5	18.3	50	50
	3%	11.4*	4.7	18	40	30
	1%	14.2*	10	18.4	80	40
Control (Lester River)		21.1	19.7	22.5	90	90
Rt. 13		14.3	8.0	20.6		60
RR bridge		16.5*	0	69.9	8 died 2 did well	20

lower in young production significant (10%, 3%, 1%)

Gave birth to 1-2 broods and died on last obs. day
May or may not mean toxicity. % survivals based on w/o last day. Output of bootstrap program

AR302284

State of Delaware
Department of Natural Resources
& Environmental Control
Division of Water Resources
Water Management Section
89 Kings Highway
P.O. Box 1401
Dover, Delaware 19903

Telephone: (302) 736 - 4761

November 14, 1985

Ms. Elaine Harbold
U.S. Environmental Protection Agency
Region III
841 Chestnut Building
Philadelphia, PA 19107

Re: Army Creek Wellfield
Rehoboth Summertime Performance
Georgetown Cease and Desist Order

Dear Ms. Harbold:

Enclosed is a letter from Teresa J. Norberg-King to Rick Greene. The letter and attachment confirm the bioassay results for Army Creek that were provided to us over the telephone. The telephone results were submitted to you as part of the permit package sent to Mr. Larry Benning on November 5, 1985.

It is not clear from the results presentaiton, however we have determined that the sample for which dilutions were run was for the effluent of Army Pond.

Additionally, I have enclosed all recent correspondence relative to the recent Cease and Desist Order issued to the Town of Georgetown. A package that constitutes our evaluation of the Rehoboth Beach STP summertime performance has also been included.

Sincerely,

J. Paul Jones
Environmental Engineer
Water Pollution Branch

Enclosure

JPJ/dlp

AR302285

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ENVIRONMENTAL RESEARCH LABORATORY – DULUTH
6201 CONGDON BOULEVARD
DULUTH, MINNESOTA 55804

7 November 1985

Rick Green
Environmental Engineering
Water Pollution Branch DNREC
89 Kings Highway
PO Box 1401
Dover DE 19903

Dear Rick:

Here is the data on Army Creek. I did not provide any methods information with this except for the following. The test used Ceriodaphnia dubia. It used 15 mls of test solution and one animal per 15 ml. We use 10 animals per concentration. Test was renewed twice after it was initiated. Young were counted at each renewal. Animals were fed a mixture of yeast/trout chow/Cerophyl® at 13 mg/l final concentration. Test began with <6 hr old young. They are fed daily. The test temperature is 25°C. Young production was in the normal ranges of our expected production.

This is brief in order to provide the results. If you need more information let us know, or if you need a more final report, let us know.

Sincerely,

Teresa J. Norberg-King
Biologist

6 Nov 1985
Joe Amato

Ceriodaphnia Chronic Tests Run 6/12/85

ARMY CREEK DELAWARE

% Sample	$\bar{X}$ Number of Young Female	95% Confidence Interval	7-day Percent Survival
Control	21.1	(19.7 - 22.5)	90
1%	*14.2	(10.0 - 18.4)	80
3%	*11.4	(4.8 - 18.0)	*40
10%	*13.5	(8.5 - 18.3)	50
30%	16.7	(12.7 - 20.7)	90
100%	*17.7	(16.6 - 18.8)	100
Ambient Site			
Red Lion	21.6	(18.0 - 25.2)	100
R.R. Bridge	16.5	(0 - 64.9)	*20
Pond Influent	16.8	(13.3 - 20.2)	90
Route 13	14.3	(8.0 - 20.6)	60

Routine Water Chemistries

pH Range	Initial Dissolved Oxygen Range	Final Dissolved Oxygen Range
6.7 - 7.0	8.0 - 8.8 mg/l	7.5 - 7.8 mg/l

* Significantly different from the control

AR302287

APPENDIX R

PLUME3D

1 YEAR

```
*****************************************
*                                       *
*   SOLUTE TRANSPORT FROM POINT SOURCES *
*   IN THREE-DIMENSIONAL UNIFORM FLOW   *
*                                       *
*   MODEL: PLUME3D                      *
*                                       *
*****************************************
```

USER: EFS

LOCATION: ARMY CRK

DATE: 2/26/86

INPUT DATA:

DARCY VELOCITY.........................:	1.00	ft/d
EFFECTIVE POROSITY.....................:	.15	
LONGITUDINAL DISPERSIVITY..............:	30.00	ft
LATERAL DISPERSIVITY...................:	10.00	ft
VERTICAL DISPERSIVITY..................:	3.00	ft
DECAY CONSTANT (lambda)................:	0	1/d
NUMBER OF POINT SOURCES................:	5	

SOURCE DATA:

SOURCE NO. 1

X-COORDINATE OF THE SOURCE............:	1000.00	ft
Y-COORDINATE OF THE SOURCE............:	3000.00	ft
Y-COORDINATE OF THE SOURCE............:	70.00	ft
THE SOURCE STRENGTH...................:	0.00	lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...:	365.00	d

SOURCE NO. 2

X-COORDINATE OF THE SOURCE............:	500.00	ft
Y-COORDINATE OF THE SOURCE............:	2500.00	ft
Y-COORDINATE OF THE SOURCE............:	70.00	ft
THE SOURCE STRENGTH...................:	0.00	lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...:	365.00	d

AR 302290

SOURCE NO. 3

X-COORDINATE OF THE SOURCE............: 500.00 ft
Y-COORDINATE OF THE SOURCE............: 2000.00 ft
Y-COORDINATE OF THE SOURCE............: 70.00 ft
THE SOURCE STRENGTH..................: 0.00 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...: 365.00 d

SOURCE NO. 4

X-COORDINATE OF THE SOURCE............: 1000.00 ft
Y-COORDINATE OF THE SOURCE............: 1500.00 ft
Y-COORDINATE OF THE SOURCE............: 70.00 ft
THE SOURCE STRENGTH..................: 0.00 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...: 365.00 d

SOURCE NO. 5

X-COORDINATE OF THE SOURCE............: 500.00 ft
Y-COORDINATE OF THE SOURCE............: 1000.00 ft
Y-COORDINATE OF THE SOURCE............: 70.00 ft
THE SOURCE STRENGTH..................: 0.00 lb/d
ELAPSED TIME OF THE SOURCE ACTIVITY...: 365.00 d

GRID DATA:

X-COORDINATE OF THE GRID ORIGIN.......: 0.00 ft
Y-COORDINATE OF THE GRID ORIGIN.......: 0.00 ft
Z-COORDINATE OF THE GRID ORIGIN.......: 0.00 ft
DISTANCE INCREMENT DELX...............: 500.00 ft
DISTANCE INCREMENT DELY...............: 500.00 ft
DISTANCE INCREMENT DELZ...............: 10.00 ft
NUMBER OF NODES IN X-DIRECTION........: 10

```
********************************* RESULTS ***********************************
+-------> X-direction      CONCENTRATION in mg/l (ppm)
|
v Y
                              Z =  0  ft
```

	0.00 ft	500.00 ft	1000.00 ft	1500.00 ft	2000.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0000	0.0000	0.0002	0.0002	0.0001
1500.00 ft	0.0000	0.0000	0.0000	0.0002	0.0002
2000.00 ft	0.0000	0.0000	0.0002	0.0002	0.0001
2500.00 ft	0.0000	0.0000	0.0002	0.0002	0.0001
3000.00 ft	0.0000	0.0000	0.0000	0.0002	0.0002
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	2500.00 ft	3000.00 ft	3500.00 ft	4000.00 ft	4500.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
1500.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
2000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
2500.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
3000.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

```
********************************* RESULTS ************************************

+-------> X-direction      CONCENTRATION in mg/l (ppm)
|
v Y

                                Z =   10  ft
```

	0.00 ft	500.00 ft	1000.00 ft	1500.00 ft	2000.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0000	0.0001	0.0002	0.0002	0.0001
1500.00 ft	0.0000	0.0000	0.0001	0.0002	0.0002
2000.00 ft	0.0000	0.0001	0.0002	0.0002	0.0001
2500.00 ft	0.0000	0.0001	0.0002	0.0002	0.0001
3000.00 ft	0.0000	0.0000	0.0001	0.0002	0.0002
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	2500.00 ft	3000.00 ft	3500.00 ft	4000.00 ft	4500.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
1500.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
2000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
2500.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
3000.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

********************************* RESULTS ************************************

+------> X-direction CONCENTRATION in mg/l (ppm)
|
v Y

Z = 20 ft

	0.00 ft	500.00 ft	1000.00 ft	1500.00 ft	2000.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0000	0.0001	0.0003	0.0002	0.0001
1500.00 ft	0.0000	0.0000	0.0001	0.0003	0.0002
2000.00 ft	0.0000	0.0001	0.0003	0.0002	0.0001
2500.00 ft	0.0000	0.0001	0.0003	0.0002	0.0001
3000.00 ft	0.0000	0.0000	0.0001	0.0003	0.0002
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	2500.00 ft	3000.00 ft	3500.00 ft	4000.00 ft	4500.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
1500.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
2000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
2500.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
3000.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

AR 302294

``` 
******************************** RESULTS ***********************************
+------> X-direction      CONCENTRATION in mg/l (ppm)
|
v Y
                          Z =   30  ft
```

	0.00 ft	500.00 ft	1000.00 ft	1500.00 ft	2000.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0000	0.0002	0.0003	0.0002	0.0001
1500.00 ft	0.0000	0.0000	0.0002	0.0003	0.0002
2000.00 ft	0.0000	0.0002	0.0003	0.0002	0.0001
2500.00 ft	0.0000	0.0002	0.0003	0.0002	0.0001
3000.00 ft	0.0000	0.0000	0.0002	0.0003	0.0002
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	2500.00 ft	3000.00 ft	3500.00 ft	4000.00 ft	4500.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
1500.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
2000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
2500.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
3000.00 ft	0.0001	0.0001	0.0000	0.0000	0.0000
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

******************************** RESULTS ***********************************

+-------> X-direction CONCENTRATION in mg/l (ppm)
|
v Y

Z = 40 ft

	0.00 ft	500.00 ft	1000.00 ft	1500.00 ft	2000.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0000	0.0005	0.0004	0.0002	0.0001
1500.00 ft	0.0000	0.0000	0.0005	0.0004	0.0002
2000.00 ft	0.0000	0.0005	0.0004	0.0002	0.0001
2500.00 ft	0.0000	0.0005	0.0004	0.0002	0.0001
3000.00 ft	0.0000	0.0000	0.0005	0.0004	0.0002
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	2500.00 ft	3000.00 ft	3500.00 ft	4000.00 ft	4500.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
1500.00 ft	0.0002	0.0001	0.0000	0.0000	0.0000
2000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
2500.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
3000.00 ft	0.0002	0.0001	0.0000	0.0000	0.0000
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

AR 302296

```
********************************* RESULTS ***********************************

+------> X-direction      CONCENTRATION in mg/l (ppm)
!
v Y

                          Z =  50  ft
```

Y	0.00 ft	500.00 ft	1000.00 ft	1500.00 ft	2000.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0000	0.0013	0.0004	0.0002	0.0002
1500.00 ft	0.0000	0.0000	0.0013	0.0004	0.0002
2000.00 ft	0.0000	0.0013	0.0004	0.0002	0.0002
2500.00 ft	0.0000	0.0013	0.0004	0.0002	0.0002
3000.00 ft	0.0000	0.0000	0.0013	0.0004	0.0002
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

Y	2500.00 ft	3000.00 ft	3500.00 ft	4000.00 ft	4500.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
1500.00 ft	0.0002	0.0001	0.0000	0.0000	0.0000
2000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
2500.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
3000.00 ft	0.0002	0.0001	0.0000	0.0000	0.0000
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

******************************** RESULTS ***********************************

```
+-------> X-direction      CONCENTRATION in mg/l (ppm)
|
v Y
                          Z =   60  ft
```

	0.00 ft	500.00 ft	1000.00 ft	1500.00 ft	2000.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0000	0.0043	0.0005	0.0002	0.0002
1500.00 ft	0.0000	0.0000	0.0043	0.0005	0.0002
2000.00 ft	0.0000	0.0043	0.0005	0.0002	0.0002
2500.00 ft	0.0000	0.0043	0.0005	0.0002	0.0002
3000.00 ft	0.0000	0.0000	0.0043	0.0005	0.0002
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

	2500.00 ft	3000.00 ft	3500.00 ft	4000.00 ft	4500.00 ft
0.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000
1000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
1500.00 ft	0.0002	0.0001	0.0000	0.0000	0.0000
2000.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
2500.00 ft	0.0001	0.0000	0.0000	0.0000	0.0000
3000.00 ft	0.0002	0.0001	0.0000	0.0000	0.0000
3500.00 ft	0.0000	0.0000	0.0000	0.0000	0.0000

AR 302298