

First Quarterly Report on the
Cooperative Agreement to Determine of Ground Water Quality in the
Colonial National Historical Park, Virginia at Locations Proximal
to Urban and Agricultural Land Uses.

December 3, 1993

Monitoring Well Installation and Initial Sampling

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Well Installation and Initial Sampling

Thirty one groundwater monitoring wells have been installed in eight regions within the Colonial National Historic Park. The regions were selected because of their proximity to potential sources of groundwater contaminants that may affect groundwater quality in the Park. The wells were designed to monitor physical and chemical characteristics of shallow groundwater, and to allow assessment of the effects of land use in areas adjacent to the park boundaries on groundwater within the park.

The wells were installed in boreholes made by hand auger and were constructed of two inch polyvinyl chloride (PVC) well screen and riser. In most cases the wells were installed to intercept the shallowest occurrence of groundwater at the site. Drought conditions during the summer of 1993 have required some modification of the original well installation plan. The unusually low rainfall is indicated by the monthly rainfall data for the nearby Langley AFB shown in Table 1. Wells were initially proposed to be installed in the upper Columbia aquifer to allow collection of samples of shallow, unconfined groundwater, which is particularly likely to contain contaminants from local sources. Because of the low total rainfall in 1993 (20% lower than normal, and 40% lower than normal for May through November), the upper aquifer was dry at most of the monitoring sites.

In order to obtain groundwater, most wells were installed with the screened interval in the underlying confined or semiconfined layer, at the level of the shallowest occurrence of groundwater. Additional wells have been installed with the screened interval in the upper unconfined layer in anticipation of significant groundwater occurrence once the summer drought ends and rainfall increases. These wells are currently dry. Additional wells may be installed if observation of the local conditions suggests that an unconfined groundwater is appearing at a later date. A description of the well installations in each region of the Park is given below. Field drilling logs and rough well site maps are attached. Well depths are referenced to the local ground level. Surveying of well head horizontal positions and elevations by optical and GPS methods has begun recently, since this work is facilitated by the fall leaf drop. Horizontal positions will be reported in reference to NAD (1927) coordinates, and vertical elevations to the NGVD (1929) datum. Conversions to other reference systems can be supplied if needed. The well identification labels used in this report are temporary, and will be converted to an identification code compatible with the STORET and State of Virginia database systems.

Table 1. Monthly Rainfall in Inches Recorded at Langley AFB

	<u>Normal</u>	<u>1993</u>
Jan.	3.72	4.38
Feb.	3.49	1.68
Mar.	4.26	7.32
Apr.	2.84	3.83
May	3.77	3.25
Jun.	3.74	2.59
Jul.	4.80	0.58
Aug.	4.77	2.12
Sep.	4.60	4.48
Oct.	3.39	3.22
Nov.	2.91	1.27
Dec.	3.26	
Total Jan-Nov	42.29	34.72
Total May-Nov	27.98	17.51

Pages Landing region

Two wells identified as PL-1 and PL-2 were installed along the Colonial Parkway adjacent to the Pages Landing Community development. These wells are screened in confined sand at about 4 meters. The upper unconfined layer was dry at the time of drilling. Additional shallow wells may be installed here if future meteorological conditions allow sampling in the upper layer.

Gospel Spreading Farm region

Three wells (GS-2, GS-3 and GS-4) were installed on the south side of the Colonial Parkway across from Gospel Spreading Farm. Wells GS-2 and GS-4 were screened in semi-confined sands at about 3 to 4 meters. Well GS-2 was screened in unconfined sandy fill material at 1.35 meters. A bore hole on the north side of the parkway encountered very fine, running, fill material at a depth of 3.85 meters. This material made it impossible to maintain an open bore hole and precluded installation of a well. The bore hole was backfilled with bentonite and abandoned. Wells GS-2, GS-3 and GS-4 were cut off flush with the ground level and 12 inch diameter manholes were installed to facilitate mowing operations.

Kingsmill region

Four wells (K-1, K-2, K-3 and K-4) were installed on the east side of the Colonial Parkway north of the bridge over College Creek and adjacent to the Kingsmill housing development. Wells K-1 and K-2 are located on the south and north sides of the first gully north of the bridge. Well K-3 is located approximately 30 meters east and upstream of K-2. Well K-4 was installed in the second gully north of the bridge. All wells were screened in a confined, clayey, shelly sands of the upper Yorktown formation at 1-3 meters deep. The overlying unconfined sand layer was dry at the time of drilling. Additional shallow wells may be installed at a later date.

Papermill Creek region

Six wells were installed in the Papermill Creek area. PM-1 was installed downstream from the abandoned landfill near the William and Mary graduate student housing complex. PM-2 and PM-3 are in the gully below the surface water runoff catchment dam between the graduate student housing complex and the law school on the west bank of Papermill creek. Well PM-1 was screened in a confined layer of the upper Yorktown formation at 1-3 meters. PM-2 and PM-3 were also screened in the Yorktown formation but in this area the confining layer was greatly reduced or absent.

Well PM-4 and PM-5 are located off the exit ramp from the Colonial Parkway onto Newport Avenue. PM-4 is in the middle of the ramp. PM-5 is at the base of the ramp on the east side of the small creek which runs along the parkway. PM-4 is screened in the confined clayey, shelly sand of the Yorktown formation at 2.1 to 4.9 meters. PM-5 is also screened in the Yorktown from 0.75 to 2.75 meters.

Well PM-6 was installed across the Colonial Parkway from PM-1 from the 22 kilometer Parkway marker. The well is in the flood plain of the creek and is screened in the confined Yorktown formation at 1.5 to 2.82 meters.

Lackey region

Four wells were installed off the French Loop section of the Washington Springs tour road adjacent to the community of Lackey in York County. Wells L-1, L-2 and L-3 are on a line perpendicular to Great Run on the North side of the stream. These wells are screened at depths of about 2 to 4 meters in a confined layer consisting of a clayey sand with shell hash identified as the upper portion of the Yorktown formation. Well L-4 is one meter to the East of L-1 and is screened in the upper, unconfined sand layer at about 1 meter. L-4 was dry at the time of drilling and later observation. An additional borehole was drilled and abandoned after plugging with bentonite.

Hickory Hill region

Six wells were installed around the perimeter of the Hickory Hill development. Wells HH-1 and HH-2 are located in the tree line across Rt. 639 from the southeast entrance road to the development. The wells are on the west side of the intermittent creek draining the area. HH-1 was screened in the confined upper portion of the Yorktown formation from 4 to 5 meters. HH-2 was screened in the upper unconfined sand layer above the Yorktown at 0.3 to 185 meters. This layer was dry at the time of installation but it is hoped that increase in rainfall will result in significant water in the upper layer. 185?

Well HH-3 was installed across Rt. 639 near the northwest entrance of the development. During drilling no groundwater was encountered before the borehole was terminated at 7.25 meters. Tight clay layers were encountered at 6 to 6.1 and 7.1 meters. Screen was set at 4.45 to 7.25 meters in anticipation of rising water levels during wetter periods.

Wells HH-4 and HH-5 were installed in a deep gully on the

north side of the development. Both were placed on the steep banks of the small stream and were completed in the Yorktown formation. In this area the Yorktown is exposed at the surface in the stream bed. At the well locations the Yorktown is semi-confined and has significant artesian head. HH-4 is located 100 meters upstream and west of the abandoned concrete building. HH-5 is 100 meters downstream and east of the building. HH-4 was screened from 1 to 2.39 meters. HH-5 was screened from 0.5 to 1.0 meters.

When these wells were visited to collect the first samples, HH-4 showed signs of tampering. The lock was missing from the security cap and sticks and other debris had been put down the well. It appears that more effective security measures are needed at this location. Field personnel should be accompanied by Park Service personnel when visiting these wells as a precaution suggested by the observed tampering and by gun shots heard during installation.

Well HH-6 was installed on the northeast side of the development between the Colonial Parkway and the development. This well was also completed in the confined Yorktown formation with screen placed at 5.0 to 7.95 meters.

Trailer Park region

Four wells were installed around the Trailer park at the junction of Rts. 639 and 238. Two wells, TP-1 and TP-2 were located in the woods across Rt. 238 on the south side of the park west of the junction with Rt. 693. TP-1 is across from a red building with the numbers 3103 on the front. TP-1 was drilled to a depth of 7.75 meters. No water table was encountered but screen was set from 4.73 to 7.75 meters in anticipation of higher groundwater levels in the future. TP-2 encountered saturated sand at about 8.30 meters. Screen was set from 5.45 to 8.40 meters.

Wells TP-3 and TP-4 were installed on the banks of a stream in a 20 meter deep gully on the north of the trailer park. In this area, as in the Hickory hill wells HH-4 and HH-5, the Yorktown formation crops out and is overlain only by soil. Well TP-1 was screened from 0.30 to 1.76 meters, and TP-4 was screened from 1.0 to 1.42 meters.

Yorktown region

Two wells, Y-1 and Y-2 were installed in Yorktown. Y-1 is located in the open field southwest of the town across from the Yorktown Baptist Church. This well was cut off flush and fitted with a 12 inch manhole to avoid interfere with mowing operations. The well was completed in the confined sands of the upper Yorktown formation and screened from 3.36 to 6.16 meters. Y-2 was installed in a gully on the northwest side of Rt 17 at the intersection of Rt. 17 and Rt.1001 (Main Street). Y-2 was also screened in the confined Yorktown formation from 2.5 to 5.05 meters. In this location high head in the confined layer resulted in very runny material and in a significant artesian condition.

Results of First Sampling

Data on nutrients, pH, temperature, and water level below ground surface are presented in Table 2. Nitrate and ammonia concentrations were high enough to indicate potential local sources of groundwater contamination in the Gospel Spreading Farm, Yorktown, Papermill Creek, and Trailer Park regions. Nutrient concentrations were low at the Pages Landing and Kingsmill regions. $[\text{NO}_3 + \text{NO}_2]$ concentrations were below the EPA water quality limit of 10 mg $\text{NO}_3\text{-N/L}$. Phosphate concentrations were low or undetectable, and did not indicate contamination sources. Salinity (S) was measured by refractometry for all wells, but was below the level (0.5 ‰) at which the salinity is a valid concept in all cases. There was no indication of sea water intrusion. In the future, electrical conductivity (specific conductance) of all water samples will be determined with a new Orion Model 160 meter. On the basis of the salinity values from the first sampling, all specific conductances are expected to be below $0.001 \text{ ohm}^{-1}/\text{cm}^{-1}$. However, comparison of these conductance values within and between regions may be useful in identifying potential sources of contaminated groundwater. The $[\text{NO}_3 + \text{NO}_2]/[\text{NH}_4]$ ratio is a measure of the redox potential (Eh) of the groundwater, with elevated ammonia indicating reducing conditions. Thus, most groundwater samples were oxygenated. Dissolved gases (oxygen and hydrogen sulfide) measurements were not reliable due to problems with gas exchange with the atmosphere during well purging and sampling. These problems have since been solved by changes in sampling procedures in which down hole probe measurements of O_2 and H_2S are made before and after purging, with minimal disturbance of the water surface. A new YSI model 58 oxygen meter with a model 5739 downhole probe has been obtained for his work. Oxygen and hydrogen sulfide will be reported for all future samples, and related to aquifer pH-Eh environmental conditions.

Table 2. Results of first well sampling.

Well	Water level (cm)	Water Temp Deg.C	NO ₃ ⁻ +NO ₂ ⁻ mgN/L	NH ₄ ⁺ mgN/L	PO ₄ ⁻³ mgP/L	S ppt	pH	Date
PL-1	230	18	0.52	0.03	0.014	<0.5	5.80	08/04/93
PL-2	231	18	0.23	0.05	0.006	<0.5	5.92	08/04/93
GS-2	158	26	1.93	0.04	0.011	<0.5	5.37	08/04/93
GS-3	126	28	0.03	1.34	nd	<0.5	6.55	08/04/93
GS-4	225	19	0.94	0.03	0.006	<0.5	5.36	08/04/93
K-1	145	20	0.03	0.20	nd	<0.5	7.03	08/04/93
K-2	142	19	0.03	0.10	0.026	<0.5	7.03	08/04/93
K-3	192	19	0.08	0.16	nd	<0.5	7.09	08/04/93
K-4	144	19	0.21	0.11	nd	<0.5	7.20	08/04/93
PM-1	116	20	0.04	1.01	nd	<0.5	7.08	08/04/93
PM-2	79	18	0.06	0.04	nd	<0.5	7.30	08/04/93
PM-3	164	19	0.03	0.02	nd	<0.5	7.09	08/04/93
PM-4	376	19	0.95	0.03	nd	<0.5	7.05	08/04/93
PM-5	148	20	0.05	0.53	nd	<0.5	7.02	08/04/93
PM-6	81	19	0.17	0.14	nd	<0.5	7.55	08/04/93
L-1	DRY							08/09/93
L-2	268	18	0.07	0.09	0.002	<0.5	----	08/09/93
L-3	300	18	0.09	0.04	nd	<0.5	7.32	08/09/93
L-4	DRY							08/09/93
HH-1	277	17	0.08	0.03	nd	<0.5	7.35	08/09/93
HH-2	DRY							08/09/93
HH-3	DRY							08/09/93
HH-4	****							08/09/93
HH-5	82	20	0.04	0.06	nd	<0.5	7.3	08/09/93
HH-6	602	20	0.770	0.05	0.006	<0.5	7.2	08/20/93
TP-1	DRY							08/20/93
TP-2	750	20	1.13	0.05	0.001	<0.5	7.6	08/20/93
TP-3	64	20	4.13	0.04	0.001	<0.5	6.9	08/20/93
TP-4	141	18	1.99	0.02	nd	<0.5	6.9	08/20/93
Y-1	552	21	0.61	0.05	0.01	<0.5	6.8	08/04/93
Y-2	332	18	0.44	0.11	nd	<0.5	7.4	08/04/93

Detection limits are: $[\text{NO}_3 + \text{NO}_2] = 0.0008 \text{ mgN/L}$, $[\text{NH}_4] = 0.0015 \text{ mgN/L}$,
 $[\text{PO}_4] = 0.0006 \text{ mgN/L}$

****Well HH-4 was vandalized and damaged.

Locations of organic sampling wells have been selected using information from table 2, and the geohydrology and the potential organic sources for each region. High concentrations of nitrate and ammonia in groundwater are generally associated with agriculture, septic systems and landfills. Concentrations of these nutrients may be associated with organic contaminants from these land use sources, and therefore the primary criterion for location of the organics wells is proximity to wells with high nutrient levels. The suggested organic sampling well locations are shown on the attached well site maps for each region. Installation of these organic sampling wells will be done immediately after these suggested locations are reviewed and approved by the National Park Service.

The second sampling will be done between Decemeber 6 and 17, 1993.

**Report after Third Quarterly Sampling on the
Cooperative Agreement to Determine of Ground Water Quality in the Colonial National
Historical Park, Virginia at Locations Proximal to Urban and Agricultural Land Uses.**

April 4, 1993

*Typo 19942
Incorrect Date
See page 22 Date*

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I Introduction

Thirty one monitoring wells for sampling and analysis of inorganic solutes and five wells for sampling and analysis of organic solutes have been installed in eight local regions within the Colonial National Historic Park. These regions were selected because of their proximity to potential sources of groundwater contaminants that may affect water quality in the Park. The wells were designed to monitor physical and inorganic chemical characteristics of shallow groundwater, and to allow assessment of the effects of land use in areas adjacent to the park boundaries on groundwater within the park.

II Inorganic sampling) Well Installation

The wells were installed in boreholes made by hand auger and were constructed of two inch polyvinyl chloride (PVC) well screen and riser. In most cases the wells were installed to intercept the shallowest occurrence of groundwater at the site.

Therefore, most wells were installed with the screened interval in the underlying confined or semiconfined layer, at the level of the shallowest occurrence of groundwater. Additional wells were installed with the screened interval in the upper unconfined layer in anticipation of groundwater occurrence at the end of the 1993 drought. Descriptions of the inorganics sampling well installations in each region of the Park are listed below. In these descriptions, aquifers overlain by low hydraulic conductivity clay layers are referred to as confined, although the spatial density of wells in each region is not sufficient to firmly establish that these layers form regional aquitards or aquicludes. Field drilling logs and rough well site maps are attached. Well depths are referenced to the local ground level. Well head elevations above local ground level are given on the drilling logs. Dr. Rick Berquist of the Geology Department, College of William and Mary has just examined these logs, and has independently assigned designations for strata in each log that agree closely with our field assignments. He has also requested to re-examine the logs after information on well head position and elevation have been added, in order that he may confirm his assignments using elevation comparisons with local stratigraphic maps. The logs with added elevations will be provided to Dr. Berquist as soon as the well survey data is reduced. Surveying of well head horizontal positions and elevations by optical and GPS methods has been completed and data are now computer processed and transformed to the uncompressed ARCINFO format. In table 1, horizontal positions are reported in reference to NAD (1927) coordinates, and vertical elevations to the NGVD (1929) datum. Conversions to other reference systems can be supplied if needed. The well identification designations used in this report are temporary, and will be converted to a permanent identification code compatible with the STORET and State of Virginia database systems. A source of stamped stainless steel identification labels for the well heads has been selected (Metal Craft, Mason City, IA), and labels will be ordered and installed when their design and necessary information content is approved by the NPS.

Table 1. Survey locations of well head positions.

Well ID #	Y * (Northing)	X * (Easting)	Z **	Location
Y-1	4121615.958	366121.046	8.948	YORKTOWN
Y-2	4122228.316	365918.442	5.562	YORKTOWN
Y-3				YORKTOWN
HH-1	4121148.056	364831.661	15.186	HICKORY HILL
HH-2	4121147.345	364830.244	15.005	HICKORY HILL
HH-3	4121347.795	364580.913	19.949	HICKORY HILL
HH-4	4121746.036	364527.954	8.927	HICKORY HILL
HH-5	4121733.986	364609.962	7.701	HICKORY HILL
HH-6	4121533.050	365014.388	18.674	HICKORY HILL
TP-1	4121870.892	363876.882	21.755	TRAILER PARK
TP-2	4121800.194	364002.925	22.111	TRAILER PARK
TP-3	4122062.691	364099.487	8.098	TRAILER PARK
TP-4	4122052.713	364072.861	9.436	TRAILER PARK
TP-5	4122045.300	364067.990	11.444	TRAILER PARK
L-1	4121475.705	362855.831	19.413	LACKEY
L-2	4121487.486	362857.877	19.449	LACKEY
L-3	4121499.244	362860.692	20.485	LACKEY
L-4	4121474.733	362856.347	18.977	LACKEY
L-5				LACKEY
PM-1	4125417.340	349006.472	8.586	PAPERMILL CREEK
PM-2	4125525.216	348977.828	10.782	PAPERMILL CREEK
PM-3	4125544.837	348985.479	10.604	PAPERMILL CREEK
PM-4	4125759.353	348967.663	16.381	PAPERMILL CREEK
PM-5	4125696.254	349018.208	10.840	PAPERMILL CREEK
PM-6	4125368.917	349065.912	6.526	PAPERMILL CREEK
PM-7	4125415.252	349004.574	8.908	PAPERMILL CREEK

K-1	4121462.076	349697.651	3.252	KINGSMILL
K-2	4121474.290	349695.884	3.023	KINGSMILL
K-3	4121475.722	349710.414	3.640	KINGSMILL
K-4	4121521.785	349700.225	2.912	KINGSMILL
GS-2	4119956.285	346837.217	0.539	GOSPEL SPREADING FARM
GS-3	4119984.176	346878.831	0.427	GOSPEL SPREADING FARM
GS-4	4119999.798	346974.545	0.683	GOSPEL SPREADING FARM
GS-5				GOSPEL SPREADING FARM
PL-1	4120381.402	344419.911	3.408	PAGES LANDING
PL-2	4120374.299	344389.540	3.080	PAGES LANDING
PL-3				PAGES LANDING

* Coordinates (UTM) in meters

** Elevation (NGVD 1929) in meters

a)Pages Landing region

Two wells identified as PL-1 and PL-2 were installed along the Colonial Parkway adjacent to the Pages Landing Community development. These wells are screened in confined sand at about 4 meters. The upper unconfined layer was dry at the time of drilling.

b)Gospel Spreading Farm region

Three wells (GS-2, GS-3 and GS-4) were installed on the south side of the Colonial Parkway across from Gospel Spreading Farm. Wells GS-2 and GS-4 were screened in semi-confined sands at about 3 to 4 meters. Well GS-2 was screened in unconfined sandy fill material at 1.35 meters. A bore hole on the north side of the parkway encountered very fine, running, fill material at a depth of 3.85 meters. This material made it impossible to maintain an open bore hole and precluded installation of a well. The bore hole was backfilled with bentonite and abandoned. Wells GS-2, GS-3 and GS-4 were cut off flush with the ground level and 12 inch diameter manholes were installed to facilitate mowing operations.

c)Kingsmill region

Four wells (K-1, K-2, K-3 and K-4) were installed on the east side of the Colonial Parkway north of the bridge over College Creek and adjacent to the Kingsmill housing development. Wells K-1 and K-2 are located on the south and north sides of the first gully north of the bridge. Well K-3 is located approximately 30 meters east and upstream of K-2. Well K-4 was installed in the second gully north of the bridge. All wells were screened in a confined, clayey, shelly sands of the upper Yorktown formation at 1-3 meters deep. The overlying unconfined sand layer was dry at the time of drilling.

d) Papermill Creek region

Six wells were installed in the Papermill Creek area. PM-1 was installed downstream from the abandoned landfill near the William and Mary graduate student housing complex. PM-2 and PM-3 are in the gully below the surface water runoff catchment dam between the graduate student housing complex and the law school on the west bank of Papermill creek. Well PM-1 was screened in a confined layer of the upper Yorktown formation at 1-3 meters. PM-2 and PM-3 were also screened in the Yorktown formation but in this area the confining layer was greatly reduced or absent.

Well PM-4 and PM-5 are located off the exit ramp from the Colonial Parkway onto Newport Avenue. PM-4 is in the middle of the ramp. PM-5 is at the base of the ramp on the east side of the small creek which runs along the parkway. PM-4 is screened in the confined clayey, shelly sand of the Yorktown formation at 2.1 to 4.9 meters. PM-5 is also screened in the Yorktown from 0.75 to 2.75 meters.

Well PM-6 was installed across the Colonial Parkway from PM-1 from the 22 kilometer Parkway marker. The well is in the flood plain of the creek and is screened in the confined Yorktown formation at 1.5 to 2.82 meters.

e) Lackey region

Four wells were installed off the French Loop section of the Washington Springs tour road adjacent to the community of Lackey in York County. Wells L-1, L-2 and L-3 are on a line perpendicular to Great Run on the North side of the stream. These wells are screened at depths of about 2 to 4 meters in a confined layer consisting of a clayey sand with shell hash identified as the upper portion of the Yorktown formation. Well L-4 is one meter to the East of L-1 and is screened in the upper, unconfined sand layer at about 1 meter. L-4 was dry at the time of drilling and later observation.

f) Hickory Hill region

Six wells were installed around the perimeter of the Hickory Hill development. Wells HH-1 and HH-2 are located in the tree line across Rt. 639 from the southeast entrance road to the development. The wells are on the west side of the intermittent creek draining the area. HH-1 was screened in the confined upper portion of the Yorktown formation from 4 to 5 meters. HH-2 was screened in the upper unconfined sand layer above the Yorktown at 0.3 to 185 meters. This layer was dry at the time of installation but it is hoped that increase in rainfall will result in significant water in the upper layer.

Well HH-3 was installed across Rt. 639 near the northwest entrance of the development. During drilling no groundwater was encountered before the borehole was terminated at 7.25 meters. Tight clay layers were encountered at 6 to 6.1 and 7.1 meters. Screen was set at 4.45 to 7.25 meters in anticipation of rising water levels during wetter periods.

Wells HH-4 and HH-5 were installed in a deep gully on the north side of the development. Both were placed on the steep banks of the small stream and were completed in the Yorktown formation. In this area the Yorktown is exposed at the surface in the stream bed. At the well locations the Yorktown is semi-confined and has significant artesian head. HH-4 is located 100 meters upstream and west of the abandoned concrete building. HH-5 is 100 meters downstream and east of the building. HH-4 was screened from 1 to 2.39 meters. HH-5 was screened from 0.5 to 1.0 meters.

When these wells were visited to collect the first samples, HH-4 showed signs of tampering. The lock was missing from the security cap and sticks and other debris had been put down the well. This tampering was repeated prior to the third sampling, and this time the entire cap assembly was taken.

Well HH-6 was installed on the northeast side of the development near the Colonial Parkway. This well was also completed in the confined Yorktown formation with screen placed at 5.0 to 7.95 meters.

g)Trailer Park region

Four wells were installed around the Trailer park at the junction of Rts. 639 and 238. Two wells, TP-1 and TP-2 were located in the woods across Rt. 238 on the south side of the park west of the junction with Rt. 693. TP-1 is across from a red building with the numbers 3103 on the front. TP-1 was drilled to a depth of 7.75 meters. No water table was encountered but screen was set from 4.73 to 7.75 meters in anticipation of higher groundwater levels in the future. TP-2 encountered saturated sand at about 8.30 meters. Screen was set from 5.45 to 8.40 meters.

Wells TP-3 and TP-4 were installed on the banks of a stream in a 20 meter deep gully on the north of the trailer park. In this area, as in the Hickory hill wells HH-4 and HH-5, the Yorktown formation crops out and is overlain only by soil. Well TP-1 was screened from 0.30 to 1.76 meters, and TP-4 was screened from 1.0 to 1.42 meters.

h)Yorktown region

Two wells, Y-1 and Y-2, were installed in Yorktown. Y-1 is located in the open field southwest of the town across from the Yorktown Baptist Church. This well was cut off flush and fitted with a 12 inch manhole to avoid interference with mowing operations. The well was completed in the confined sands of the upper Yorktown formation and screened from 3.36 to 6.16 meters. Y-2 was installed in a gully on the northwest side of Rt 17 at the intersection of Rt. 17 and Rt. 1001 (Main Street). Y-2 was also screened in the confined Yorktown formation from 2.5 to 5.05 meters. At this location, high head in the confined layer resulted in very runny material and in a significant artesian condition.

III Results of Sampling of Inorganics Wells

Data on nutrients, pH, temperature, and water level depth below the well head elevation in the first sampling are presented in Table 1. Nitrate and ammonia concentrations were high enough to indicate potential local sources of groundwater contamination in the Gospel Spreading Farm, Yorktown, Papermill Creek, and Trailer Park regions. Nutrient concentrations were low at the Pages Landing and Kingsmill regions. $[\text{NO}_3 + \text{NO}_2]$ concentrations were below the EPA water quality limit of 10 mg $\text{NO}_3\text{-N/L}$. Phosphate concentrations were low or undetectable, and did not indicate contamination sources. Salinity (S) was measured by refractometry for all wells, but was below the level (0.5 ‰) at which the salinity is a valid concept in all cases. There was no indication of sea water intrusion. In the future, electrical conductivity (specific conductance) of all water samples will be determined with a new Orion Model 160 meter. On the basis of the salinity values from the first sampling, all specific conductances are expected to be below $0.001 \text{ ohm}^{-1}/\text{cm}^{-1}$. However, comparison of these conductance values within and between regions may be useful in identifying potential sources of contaminated groundwater. The $[\text{NO}_3 + \text{NO}_2]/[\text{NH}_4]$ ratio is a measure of the redox potential (Eh) of the groundwater, with elevated ammonia indicating reducing conditions. Thus, most groundwater samples were oxygenated. Dissolved gases (oxygen and hydrogen sulfide) measurements were not reliable due to problems with gas exchange with the atmosphere during well purging and sampling. These problems have since been solved by changes in sampling procedures in which down hole probe measurements of O_2 and H_2S are made before and after purging, with minimal disturbance of the water surface. A new YSI model 58 oxygen meter

with a model 5739 downhole probe has been obtained for his work. Oxygen and hydrogen sulfide will be reported for all future samples, and related to aquifer pH-Eh environmental conditions.

Table 2. Results of first well sampling.

Well	Water level (m)	Water Temp Deg.C	NO ₃ ⁻ + NO ₂ ⁻ mgN/L	NH ₄ ⁺ mgN/L	PO ₄ ⁻³ mgP/L	S ppt	pH	Date
PL-1	1.11	18	0.52	0.03	0.014	<0.5	5.80	08/04/93
PL-2	0.77	18	0.23	0.05	0.006	<0.5	5.92	08/04/93
GS-2	-1.04	26	1.93	0.04	0.011	<0.5	5.37	08/04/93
GS-3	-0.83	28	0.03	1.34	nd	<0.5	6.55	08/04/93
GS-4	-1.57	19	0.94	0.03	0.006	<0.5	5.36	08/04/93
K-1	1.80	20	0.03	0.20	nd	<0.5	7.03	08/04/93
K-2	1.60	19	0.03	0.10	0.026	<0.5	7.03	08/04/93
K-3	1.72	19	0.08	0.16	nd	<0.5	7.09	08/04/93
K-4	1.47	19	0.21	0.11	nd	<0.5	7.20	08/04/93
PM-1	7.43	20	0.04	1.01	nd	<0.5	7.08	08/04/93
PM-2	9.99	18	0.06	0.04	nd	<0.5	7.30	08/04/93
PM-3	8.96	19	0.03	0.02	nd	<0.5	7.09	08/04/93
PM-4	12.62	19	0.95	0.03	nd	<0.5	7.05	08/04/93
PM-5	9.36	20	0.05	0.53	nd	<0.5	7.02	08/04/93
PM-6	5.72	19	0.17	0.14	nd	<0.5	7.55	08/04/93
L-1	DRY							08/09/93
L-2	16.77	18	0.07	0.09	0.002	<0.5	----	08/09/93
L-3	17.49	18	0.09	0.04	nd	<0.5	7.32	08/09/93
L-4	DRY							08/09/93
HH-1	12.42	17	0.08	0.03	nd	<0.5	7.35	08/09/93
HH-2	DRY							08/09/93
HH-3	DRY							08/09/93
HH-4	****							08/09/93
HH-5	6.88	20	0.04	0.06	nd	<0.5	7.3	08/09/93
HH-6	12.65	20	0.770	0.05	0.006	<0.5	7.2	08/20/93
TP-1	DRY							08/20/93
TP-2	14.61	20	1.13	0.05	0.001	<0.5	7.6	08/20/93
TP-3	7.46	20	4.13	0.04	0.001	<0.5	6.9	08/20/93
TP-4	8.03	18	1.99	0.02	nd	<0.5	6.9	08/20/93

Y-1	3.43	21	0.61	0.05	0.01	<0.5	6.8	08/04/93
Y-2	2.24	18	0.44	0.11	nd	<0.5	7.4	08/04/93

Table 3. Results of second well sampling.
December 1993

Well	Water level (m)	Water Temp Deg.C	NO ₃ ⁻ + NO ₂ ⁻ mgN/L	NH ₄ ⁺ mgN/L	PO ₄ ⁻³ mgP/L	DO mg/L	cond	pH	Date
PL-1	0.14	16.3	0.618	0.022	0.004	2.8	0.07	7.21	12/08/93
PL-2	0.14	16.0	0.378	0.026	0.004	1.7	0.07	7.20	12/08/93
GS-2	-1.15	15.7	0.336	0.025	0.005	5.4	0.14	6.74	12/08/93
GS-3	-0.64	15.7	2.302	0.840	0.002	0.4	0.37	6.74	12/08/93
GS-4	-1.67	15.7	2.490	0.022	0.004	4.7	0.11	6.21	12/08/93
K-1	1.08	15.2	0.039	0.162	0.000	0.9	0.37	6.86	12/08/93
K-2	1.26	15.3	0.025	0.023	0.025	0.5	0.68	6.97	12/08/93
K-3	1.34	15.3	0.079	0.036	0.003	3.4	0.40	7.07	12/08/93
K-4	1.05	15.2	0.050	0.036	0.004	1.0	0.63	6.77	12/08/93
PM-1	6.98	14.5	0.021	0.981	0.001	0.2	0.87	6.98	12/08/93
PM-2	8.47	14.5	0.027	0.023	0.001	0.8	0.55	7.14	12/08/93
PM-3	7.90	14.5	0.022	0.023	0.001	0.6	0.83	7.16	12/08/93
PM-4	11.43	17.2	1.597	0.012	0.002	1.9	0.81	7.01	12/08/93
PM-5	8.58	15.2	0.064	0.671	0.001	3.7	0.59	7.12	12/08/93
PM-6	5.30	15.4	0.021	0.175	0.002	0.6	0.49	7.38	12/08/93
L-1	16.70	14.8	0.058	0.131	0.001	2.3	0.49	6.45	12/07/93
L-2	16.71	15.4	2.498	0.047	0.006	0.4	0.39	6.48	12/07/93
L-3	16.66	15.2	0.118	0.510	0.000	3.0	0.61	6.40	12/07/93
L-4	DRY								12/07/93
HH-1	12.31	14.9	0.018	0.021	0.004	3.0	0.30	7.08	12/16/93
HH-2	DRY								12/16/93
HH-3	DRY								12/16/93
HH-4	8.72	14.7	0.006	0.033	0.003	0.7	0.29	7.55	12/16/93
HH-5	6.61	12.6	0.011	0.022	0.002	3.5	0.30	7.48	12/16/93
HH-6	11.40	14.6	0.021	0.025	0.008	0.5	0.31	7.06	12/16/93

TP-1	DRY								12/09/93
TP-2	13.87	14.9	0.234	0.073	0.003	1.5	0.97	5.83	12/09/93
TP-3	7.06	13.9	3.350	0.030	0.002	3.2	0.95	6.97	12/09/93
TP-4	7.75	14.5	3.597	0.017	0.002	0.4	0.76	6.83	12/09/93
Y-1	2.99	16.9	0.564	0.032	0.005	5.0	0.59	6.52	12/07/93
Y-2	1.85	16.0				3.6	0.37	6.61	12/07/93

Surface water samples were taken from streams during the third well sampling. An unusually heavy rainfall of about 3 to 4 inches occurred in the two days prior to stream sampling, which was initiated to observe this event. These stream samples are identified by single letters in Table 4. Descriptions of the sampling locations are:

- A -- Stream at point perpendicular to, and about 8 meters from, well PM-6.
- B -- Stream at point perpendicular to, and about 10 meters from, well PM-1.
- C -- Stream at point perpendicular to, and about 5 meters from, well TP-3.
- D -- Stream near well PM-1, immediately at west end of culvert under the parkway.
- E -- Stream at point perpendicular to, and about 4 meters from, well TP-4.
- F -- Stream at point perpendicular to, and about 3 meters from, well L-1.
- G -- Stream at point 70 meters downstream from sample F location.
- H -- North side opening of Culvert under Parkway apparently draining feedlot and barns of Gospel Spreading Farm.
- I -- Stream (Beaver Dam Creek) at point under wooden bridge carrying tour road.
- J -- Stream flowing north from Hickory hill development at the abandoned concrete blockhouse.
- K -- Stream flowing west from Hickory Hill development area at the abandoned concrete blockhouse (The blockhouse is at the confluence of streams sampled in J and K).
- L -- Drain directly across Rt. 638 (Goosley Rd.) from the Yorktown sewage pump house at Hickory Hill.

Table 4. Results of third well and surface water sampling.
March 1994

Well	Water level (m)	Water Temp Deg.C	NO ₃ ⁻ + NO ₂ ⁻ mgN/L	NH ₄ ⁺ mgN/L	PO ₄ ⁻³ mgP/L	DO mg/L	cond	pH	Date
PL-1	0.38	13.4	0.668	0.029	0.007	5.05	0.064	5.75	3/6/94
PL-2	0.37	13.0	0.138	0.021	0.004	1.31	0.069	6.09	3/6/94
G-2	-0.74	10.4	0.091	0.039	0.003	6.14	0.098	5.67	3/6/94
G-3	0.05	10.2	1.965	0.349	0.002	7.57	0.337	6.97	3/6/94
G-4	-1.29	12.5	0.305	0.143	0.002	6.25	0.090	5.90	3/6/94
K-1	1.47	11.7	0.043	0.074	0.006	2.76	0.077	5.78	3/6/94
K-2	1.82	10.4	0.026	0.012	0.072	1.06	0.527	7.25	3/6/94
K-3	1.93	11.4	0.049	0.023	0.002	1.49	0.410	7.23	3/6/94
K-4	1.38	9.7	0.057	0.022	0.002	8.66	0.235	7.50	3/6/94
PM-1	7.33	8.1	0.011	0.518	0.001	1.21	0.798	7.17	3/6/94
PM-2	8.68	10.8	0.013	0.022	0.001	0.70	0.566	7.36	3/6/94
PM-3	8.45	8.7	0.015	0.011	0.001	6.30	0.638	7.35	3/6/94
PM-4*	11.77	14.0	.4-.8	0.013	0.002	5.19	0.708	7.05	3/6/94
PM-5*	8.61	11.1	<0.15	0.047	0.001	0.58	0.575	7.25	3/6/94
PM-6	5.20	11.4	0.021	0.155	0.001	0.00	0.493	7.62	3/6/94
L-1	17.30	10.6	0.278	0.053	0.001	7.0	0.119	6.14	3/5/94
L-2	17.50	10.9	1.428	0.044	0.019	6.5	0.368	6.70	3/5/94
L-3	18.09	12.1	0.104	0.158	0.002	5.3	0.574	7.51	3/5/94
L-4	Dry								3/5/94
HH-1	14.33	12.3	0.006	0.008	0.008	0.74	0.704	7.15	3/8/94
HH-2	14.53	10.8	0.089	0.056	0.002	6.85	0.130	5.96	3/8/94
HH-3	DRY								3/8/94
HH-4	8.70	13.4	0.003	0.032	0.000	0.68	0.444	7.53	3/8/94
HH-5	6.66	11.1	0.016	0.017	0.001	1.29	0.496	7.41	3/8/94
HH-6	13.28	13.9	0.078	0.028	0.013	4.35	0.425	7.28	3/8/94
TP-1	DRY								3/5/94
TP-2	14.29	10.8	0.032	0.041	0.000	4.8	0.061	5.46	3/5/94
TP-3	7.19	10.3	0.343	0.042	0.005	3.9	0.650	7.34	3/5/94

TP-4	7.95	11.5	3.081	0.023	0.009	4.9	0.699	7.15	3/5/94
Y-1	3.35	10.2	0.496	0.030	0.033	6.9	0.525	7.35	3/5/94
Y-2	2.23	10.3	0.514	0.016	0.001	4.3	0.895	6.13	3/5/94
A	SW	----	0.606	0.076	0.025	----	0.918	8.11	3/6/94
B	SW	----	0.266	0.813	0.001	----	0.825	7.42	3/6/94
C	SW	----	4.262	0.014	0.010	----	0.894	6.90	3/5/94
D	SW	----	0.554	0.111	0.017	----	0.952	7.97	3/6/94
E	SW	----	2.424	0.086	0.017	----	0.874	6.92	3/5/94
F	SW	----	1.803	0.029	0.012	----	0.126	6.65	3/5/94
G	SW	----	0.505	0.047	0.009	----	0.120	6.53	3/5/94
H	SW	----	0.154	2.542	0.073	----	0.532	7.43	3/6/94
I	SW	----	0.136	0.025	0.007	----	0.234	7.48	3/7/94
J	SW	----	0.367	0.012	0.074	----	0.491	7.40	3/8/94
K	SW	----	0.010	0.015	0.038	----	0.461	7.81	3/8/94
L	SW	----	0.266	0.093	0.005	----	0.195	6.50	3/9/93

Detection limits are: $[\text{NO}_3 + \text{NO}_2] = 0.0008 \text{ mgN/L}$, $[\text{NH}_4] = 0.0015 \text{ mgN/L}$, $[\text{PO}_4] = 0.0006 \text{ mgN/L}$

****Well HH-4 was vandalized and damaged.

Discussion of Results of first three samplings.

Nutrient concentrations in groundwater showed little variation over the period. Stream samples taken during the third sampling period gave results that appear to be related to local groundwater sources. High nitrogen species concentrations were found in streams at the Trailer Park, Lackey, and Gospel Spreading Farm, with slightly elevated values in Papermill Creek. Surface water will be sampled again during the fourth well sampling. Results from these samples are required for more complete correlations of groundwater with surface water compositions. Also, we wish to obtain samples in a period without an immediate prior rainfall, because the stream is supplied by groundwater seepage rather than a combination of surface runoff and groundwater seepage.

Water table levels decreased from August to December, and this decrease may be unusually large due to the unusually low rainfall in the summer and fall of 1993 which is indicated by the monthly rainfall data for the nearby Langley AFB shown in Table 1. Rainfall was 20% lower than normal for January to November, and 40% lower than normal for May through November. Water table levels had partially recovered by March of 1994.

Table 5. Monthly Rainfall in Inches Recorded at Langley AFB

	<u>Normal</u>	<u>1993</u>
Jan.	3.72	4.38
Feb.	3.49	1.68
Mar.	4.26	7.32
Apr.	2.84	3.83
May	3.77	3.25
Jun.	3.74	2.59
Jul.	4.80	0.58
Aug.	4.77	2.12
Sep.	4.60	4.48
Oct.	3.39	3.22
Nov.	2.91	1.27
Dec.	3.26	
Total Jan-Nov	42.29	34.72
Total May-Nov	27.98	17.51

All results obtained to date are being entered into D-BASE for distribution to users. Complete STORET manuals have been obtained from EPA and files containing the location and water quality data collected for each well will be prepared in a format compatible with the STORET system for later submission to that system.

Installation of Organics Sampling Wells

Organics sampling wells were installed in boreholes made by hand augering, and were constructed of two inch polyvinyl chloride (PVC) well screen and riser, with threaded connections. No PVC cements were used. The wells were screened to intercept the shallowest occurrence of groundwater. Drilling logs and well emplacement information for these wells are given in the Appendix.

Organics sampling wells have been placed at locations selected based on dissolved nutrient information given in Tables 2, 3 and 4, and on inferences regarding the geohydrology and the potential organic sources for each region. High concentrations of nitrate and ammonia in groundwater are generally related to agriculture, septic systems, and landfills, and these nutrients may be associated with organic contaminants from these land use sources. Therefore the primary criterion for location of the organics wells was proximity to wells with high nutrient levels at positions, and also situation downgradient from potential sources of organic contaminants. Organic sampling wells have been installed in five regions that displayed elevated nutrient concentrations (Pages Landing, Gospel Spreading Farm, Papermill Creek, Lackey, and the Trailer Park).

Designations and approximate positions of these organics wells follow.

a) Well PL-3 is perpendicular to ,and 18 meters north of the center of a line joining wells PL-1 and PL-2. It is screened at a depth of 3 to 4 meters in a fine sand confined by a clay layer at about 2.5 meters depth.

b) Well G-5 is 10 meters northwest of well G-3, and is screened at a depth of about 0.5 to 2 meters in an unconfined sand.

c) Well PM-7 is about 5 meters southwest of well PM-1 on a ground surface that slopes upward towards a closed landfill, and is screened in a confined layer of the upper Yorktown formation at 1-3 meters depth.

d) Well TP-5 is about 20 yards up the drainage gully from (and on the same side of the gully as) well TP-4, and is screened at depth of 3.5 to 4.5 meters in a confined sand with shell fragments that is probably the upper Yorktown formation.

e) Well L-5 is about 5 yards toward the nearest house from well L-2, and is screened at a depth of about 3 to 4 meters in a confined layer consisting of a clayey sand with shell hash identified as the upper portion of the Yorktown formation.

A sixth organic sampling well will be placed in the Yorktown region, but the exact location must be agreed upon by the cooperating investigators prior to installation of this last organics well. Immediately after all the wells are installed, they will be sampled and analyzed for dissolved organic compounds as described in the study proposal.