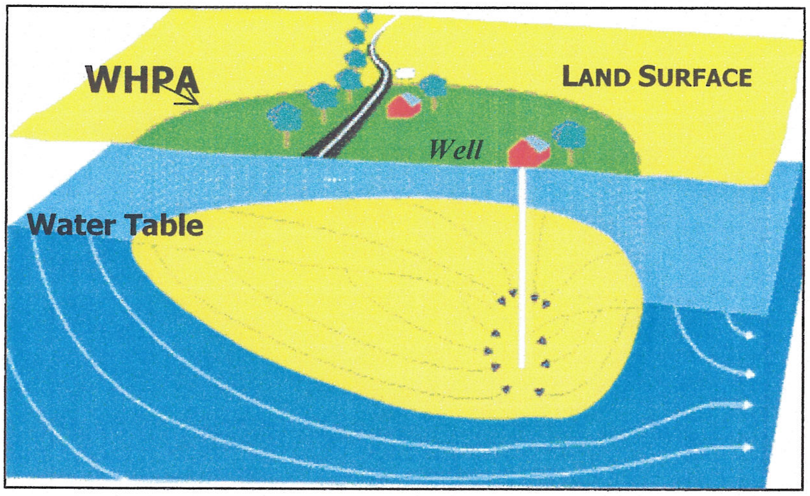
SOURCE WATER ASSESSMENT

for

SAN MAR CHILDRENS HOME

Washington County, MD



Prepared By

WATER MANAGEMENT ADMINISTRATION

Water Supply Program

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MDE

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SUMMARY

The Maryland Department of the Environment's Water Supply Program (WSP) has conducted a Source Water Assessment for the San Mar Childrens Home water system. The required components of this report as described in Maryland's Source Water Assessment Program (SWAP) are 1) delineation of an area that contributes water to the source, 2) identification of potential sources of contamination, and 3) determination of the susceptibility of the water supply to contamination. Recommendations for protecting the drinking water supply conclude this report.

The source of San Mar's water supply is one well in an unconfined fractured-rock aquifer, the Tomstown Dolomite. The Source Water Assessment area was delineated by the WSP using U.S. EPA approved methods specifically designed for this source type.

Point sources of contamination were investigated within the assessment area from field inspections, contaminant inventory databases, and previous studies. The Maryland Department of Planning's 2002 digital land use map for Washington County was used to identify non-point sources of contamination. Well information and water quality data were also reviewed. An aerial photograph and maps of potential contaminant sources and land use within the Source Water Assessment area are included in the report.

The susceptibility analysis is based on a review of the existing water quality data for the San Mar Childrens Home water system, the presence of potential sources of contamination in the source water assessment area, well integrity, and the inherent vulnerability of the aquifer. It was determined that the San Mar Childrens Home water supply is susceptible to microbiological contaminants including *Cryptosporidia* and *Giardia,* This water supply is not susceptible to nitrates, inorganic compounds, volatile organic compounds, synthetic organic compounds, or radionuclides.

INTRODUCTION

The Water Supply Program has conducted a Source Water Assessment for the San Mar Childrens Home water system in Washington County. The San Mar Childrens Home is located approximately 2 miles north of the Town of Boonsboro in Washington County on the west side of Route 66. The water system is owned by San Mar Childrens Home and operated by Maryland Environmental Service (MES). The water system serves a population of approximately 51 persons.

WELL INFORMATION

Well information was obtained from the Water Supply Program's database, site visits, well completion reports, sanitary survey inspection reports, and published reports. San Mar Childrens Home presently obtains its water supply from one well (Figure 1). A review of the well completion reports for the supply well indicates that it was drilled in 2000 and should meet the State's well construction standards, which were implemented in 1973. Well information is shown in Table 1 below. A recent site inspection revealed that the well was in good condition.

PLANT ID	SOURCE ID	SOURCE NAME	PERMIT NO	TOTAL DEPTH (ft)	CASING DEPTH (ft)	YEAR DRILLED
01	01	Production Well	WA942110	160	134	2000

Table 1. San Mar's Well Information.

San Mar Childrens Home has an appropriation permit to pump water from the Tomstown Dolomite for an average use of 7,200 gallons per day (gpd) and an average of 11,000 gpd in the month of maximum use.

HYDROGEOLOGY

San Mar Childrens Home lies within the Hagerstown Valley physiographic province, which is underlain by a sequence of metasedimentary limestones and shales that have eroded away to form the valley bound by South Mountain and the Bear Pond Mountains west of Clear Spring. In some areas the carbonate rock formations have developed into a karst-like aquifer. Duigon (2001) has identified sinkholes, wells that penetrate cavernous zones, and other karst features in the valley. San Mar's well obtains water from the Tomstown Formation, a sequence of interbedded light gray white and pink, thick-bedded limestone, light gray to yellow-gray, thin-bedded to massive dolomite, and thin-bedded calcareous shale (Edwards, 1978). This is a heterogeneous formation and can be very karstic in some areas, and in others much more like a crystalline fractured-rock aquifer. The San Mar well appears to be in an area surrounded by karstic features like sinkholes (Figure 2) and may be influenced by them. Ground water moves principally through secondary porosity, like solution enlarged fractures and sinkholes, and is recharged by precipitation percolating through soil and saprolite.

Source Water Assessment Area Delineation

For ground water systems, a Wellhead Protection Area (WHPA) is considered the source water assessment area for the system. The source water assessment area for public water systems with an average appropriation amount of less than 10,000 gpd and drawing from fractured-rock aquifers is a circle with a 1,000-foot radius (MD SWAP, 1999). San Mar's well was determined to be ground water under the influence of surface water (GWUDI) based on the presence of fecal coliform bacteria in its raw water samples. For those wells that are determined to be GWUDI, the MDE's SWAP (1999) recommends locating and mapping sinkholes and conducting a dye trace study to define the contributing area (WHPA) for the well.

Duigon (2001) conducted a study of the karst hydrogeology of the Hagerstown Valley in which he located and mapped the sinkholes in the area. MDE completed a dye trace study to determine the source of bacterial contamination to several public water systems (including San Mar) in the Boonsboro area (Evans and Holt, 2003). The study can be found at the end of this report (Attachment I). Fluorescent dyes were used to inoculate contamination sources: an unnamed tributary of Little Beaver Creek at the Fahrney-Keedy's WWTP outfall, an intermittent branch of the unnamed tributary flowing south, and San Mar's septic systems. Several sinkholes and potentially losing streams were not evaluated in this study. The results of the study were inconclusive with regard to determine the area contribution to the well. Tracer dyes used to inoculate branches of the unnamed tributary were detected in raw water from the San Mar well using charcoal receptors.

The wellhead protection area (WHPA) includes the drainage area of the intermittent stream and the stream receiving Fahrney-Keedy's outfall. The area of the delineated WHPA is about 570 acres (Figure 2).

Potential Sources of Contamination

Potential sources of contamination are classified as either point or non-point sources. Examples of point sources of contamination are leaking underground storage tanks, landfills, discharge permits, large-scale feeding operations, and CERCLA sites. These sites are generally associated with commercial or industrial facilities that use chemical substances that may, if inappropriately handled, contaminate ground water via a discrete point location. In addition, in karst areas (areas underlain by limestone), sinkholes may be point sources of contamination to the aquifer by receiving contaminated runoff and delivering the contamination directly into the aquifer. Non-point sources of contamination are associated with certain types of land use practices such as use of pesticides, application of fertilizers or animal wastes, or septic systems that may lead to ground water contamination over a larger area.

Point Sources

Sinkholes were identified in the general vicinity of the WHPA (Duigon, 2001). Additional sinkholes not included in the Duigon, 2001 dataset were observed in the area (Evans and Holt, 2003). Potential contaminant point source located within the WHPA include the discharge of wastewater from Fahrney-Keedy, the discharge of wastewater from Central Precision, and the storage of controlled hazardous substances at Fahrney-Keedy. (Figure 2).

Non-Point Sources

The Maryland Office of Planning's 2002 digital land use coverage of Washington County was used to determine the predominant types of land use in the WHPA (Figure 3). The land use summary is shown in Table 1. The majority of the WHPA is made up of agricultural land (cropland and pasture), low-density residential uses, and forested land with a smaller proportion of industrial, and commercial areas.

LAND USE CATEGORIES	TOTAL AREA (acres)	PERCENTAGE OF WHPA
Low Density Residential	143.61	25.18
Commercial	32.51	3.76
Industrial	21.45	5.7
Cropland	149.96	26.29
Pasture	87.58	15.35
Forest	134.54	23.58
Water	0.8	0.14
Total	570.45	100

Table 2. Land Use Summary

Agricultural land is commonly associated with nitrate loading of ground water and also represents a potential source of SOCs depending on use of pesticides. Pasture areas may also be a source of microbiological pathogens from animal wastes.

Residential areas without sewer service can be a source of nitrate from septic systems and microbial pathogens if systems are not constructed in accordance with regulations. Additionally, residential areas may be a source of nitrate and SOCs if fertilizers, pesticides, and herbicides are not used carefully in lawns and gardens.

A review of the Maryland Department of Planning's 2002 Sewer Map for Washington County indicates that 17.2% of the WHPA is served by an existing sewer system (Fahrney-Keedy WWTP). There is no planned sewer service for the remaining 82.8% of the WHPA (Figure 4) WHPA. Other properties in the WHPA also have onsite septic systems. The onsite septic systems are sources of nitrate and microbiological contaminants.

WATER QUALITY DATA

Water Quality data was reviewed from the Water Supply Program's database for Safe Drinking Water Act (SDWA) contaminants. The State's SWAP defines a threshold for reporting water quality data as 50% of the Maximum Contaminant Level (MCL). If a monitoring result is greater than 50% of a MCL, this assessment will describe the sources of such a contaminant and if possible, locate the specific sources that are the cause of the elevated contaminant level. All data reported is from the finished (treated) water unless otherwise noted. The treatment that the

San Mar Childrens Home water system currently uses, include hypochlorination for disinfection, filtration for surface water treatment, and ion exchange for softening.

A review of the monitoring data since 1999 for San Mar Childrens Home water supply indicates that it meets the current drinking water standards. The water quality sampling results are summarized in Table 4. No samples have exceeded our review criteria of 50% of the maximum contaminant levels (MCLs).

	Nitrate		SOCs		VOCs		IOCs (except nitrate)		Radionuclides	
PLANT NO	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL	No. of Samples Collected	No. of samples > 50% MCL
01	6	0	2	0	6	0	6	0	4	0

Table 3. Summary of Water Quality Samples for San Mar Childrens Home Water Supply.

Inorganic Compounds (IOCs)

No IOCs above 50% of the MCL have been detected in San Mar's water supply. Nitrates have been routinely detected. Detected levels range from 3.43 to 4.3 parts per million (ppm). The MCL for nitrate is 10 ppm. Fluoride was measured at very low levels. Fluoride was detected in August 2003 at 0.17 ppm. The MCL for fluoride is 4 ppm. Sodium was reported in July 2001, September 2001, and August 2003 at 112 ppm, 126 ppm, and 114 ppm, respectively. The high sodium levels are a consequence of the softening. The concentration from the well was less than 8 ppm. EPA recommends that people on sodium restricted diets of 500mg/day consume water with 20mg/l or less of sodium. The treated water provided at San Mar is five to six times EPA's guidance and would be a significant source of salt for persons on sodium restricted diets.

Radionuclides

No radionuclides above 50% of the MCL have been detected in San Mar's water supply. Gross alpha and gross beta were detected in February 2001 at 3 picoCuries/Liter (pCi/L) and 4 pCi/L. Gross alpha was also detected in May 2001 and July 2001 at 1 pCi/L and 4 pCi/l, respectively. The MCL for gross alpha is 15 pCi/L and for gross beta is 50 pCi/L. Radon-222 was detected in July 2001 at 50 pCi/L. At present there is no MCL for radon-222, however EPA has proposed an MCL of 300 pCi/L and an alternate MCL of 4000 pCi/L for community water systems if the State has a program to address the more significant risk from radon in indoor air.

Volatile Organic Compounds (VOCs)

A review of the data shows that VOCs have not been detected above 50% of an MCL.

Synthetic Organic Compounds (SOCs)

No SOCs above 50% MCL have been detected in San Mar's water supply. The only contaminant detected on two occasions was di (2-ethylhexyl) phthalate (also known as DEHP). In July 2001 it was detected at 1.2 ppb and in February 2004 it was detected at 1.7 ppb. It must be noted that DEHP was also detected at similar concentrations in the laboratory blank analyzed concurrently with the July 2001 and February 2004 samples. The MCL for this contaminant is 6 ppb.

Microbiological Contaminants

Raw water bacteriological data is available from evaluation for ground water under the direct influence of surface water (GWUDI). A review of the data shows that total coliform and fecal coliform bacteria were detected in the raw water from the well following rainfall (Table 4). Negative numbers in the table indicate absence of coliform bacteria.

SOURCE NAME	RAIN DATE	RAIN AMOUNT (INCHES)	CONDITIONS	SAMPLE DATE	PH	TOTAL COLIFORM (MPN/100ml	FECAL COLIFORM (MPN/100ml)
WELL	18-JAN-99	.55	WET SET	25-JAN-99	7.5	200.7	42.9
WELL	18-JAN-99	.55	WET SET	21-JAN-99	7.45	200.7	1
WELL	18-JAN-99	.55	WET SET	20-JAN-99	7.44	20.7	1
WELL	18-JAN-99	.55	WET SET	19-JAN-99	8.52	165	-1
WELL	04-JAN-99	1	WET SET	11-JAN-99	8.83	>200.5	-1
WELL	04-JAN-99	1	WET SET	07-JAN-99	8.2	>200.5	-1
WELL	04-JAN-99	1	WET SET	06-JAN-99	8.57	>200.5	-1
WELL	04-JAN-99	1	WET SET	05-JAN-99	8.86	>200.5	-1
WELL	15-APR-98	0	DRY	15-APR-98	7.26	73.8	-1
WELL	19-APR-98	.75	WET SET	23-APR-98	7.46	42.9	-1
WELL	19-APR-98	.75	WET SET	22-APR-98	7.44	1	-1
WELL	19-APR-98	.75	WET SET	21-APR-98	7.37	1	-1
WELL	19-APR-98	.75	WET SET	20-APR-98	7.58	1	1

Table 4. Raw Water Bacteriological Test results

SUSCEPTIBILITY ANALYSIS

The well serving the San Mar Childrens Home water supply pumps water from unconfined carbonate, fractured-rock aquifers. Wells in unconfined aquifers especially in carbonate rock, are generally vulnerable to any activity on the land surface that occurs within the wellhead protection area. Therefore, continued monitoring of contaminants is essential in assuring a safe drinking water supply. The *susceptibility* of the source to contamination is determined for each group of contaminants based on the following criteria: 1) the presence of potential contaminant sources within the WHPA, 2) water quality data, 3) well integrity, and 4) the aquifer conditions. Table 5 summarizes the susceptibility of San Mar's water supply to each of the groups of contaminants.

Inorganic Compounds

No IOCs have been detected in San Mar's water supply above 50% of an MCL. Nitrates have been detected with levels ranging from 3.43 ppm to 4.3 ppm. The MCL for nitrate is 10 ppm. Sources of nitrate can generally be traced to land use. Septic systems and the fertilization of cropland and residential properties are all sources of nitrate loading in ground water. Agricultural land (cropland and pasture) comprises a major portion of the WHPA (68%). Fertilization of agricultural fields and residential lawns, and onsite septic systems are all sources of nitrate loading in ground water. The levels of nitrates do not show any trend of increasing over the past four years.

Based on the above analysis, San Mar's water supply **is not** susceptible to nitrate and other inorganic compounds.

Radionuclides

No radionuclides above 50% of the MCL have been detected in San Mar's water supply. Radionuclides are naturally occurring contaminants and are not expected to increase over time.

Based on the above analysis, San Mar's water supply **is not** susceptible to radionuclides.

Volatile Organic Compounds

The water supply **is not** susceptible to volatile organic compounds, based on water quality data and the lack of potential contaminant sources within the WHPA. No VOCs were detected in the water supply.

Synthetic Organic Compounds

No SOCs have been detected in San Mar's water supply above 50% of the MCL. No point sources of SOCs were identified within the source water assessment area. Potential sources of SOCs within the WHPA may be pesticide or herbicide use in the agricultural or residential areas. However, because these contaminants have not been detected, it appears that any chemicals that may be used in the WHPA are degrading or being attenuated in the soil and are not reaching the wells.

Based on the above analysis, San Mar's water supply **is not** susceptible to SOC contamination.

Microbiological Contaminants

Fecal coliform was detected in San Mar's raw water. The system's well was determined to be susceptible to bacteria and protozoans like *Cryptosporidia* and *Giardia*. Based on the raw water quality data, dye study results and aquifer type, San Mar's water supply **is** susceptible to microbiological contaminants.

CONTAMINANT TYPE	Are Contaminant Sources present in the WHPA?	Are Contaminants detected in WQ samples at 50% of the MCL	Is Well Integrity a Factor?	Is the Aquifer Vulnerable?	Is the System Susceptible to the Contaminant
Nitrate	YES	NO	NO	YES	NO
Inorganic Compounds (except nitrate)	NO	NO	NO	YES	NO
Volatile Organic Compounds	YES	NO	NO	YES	NO
Synthetic Organic Compounds	YES	NO	NO	YES	NO
Radionuclides	NO	NO	NO	NO	NO
Microbiological Contaminants	YES	YES	YES	YES	YES

Table 5. Susceptibility Summary for San Mar's water supply.

MANAGEMENT OF THE SOURCE WATER ASSESSMENT AREA

Public Awareness and Outreach

- The Consumer Confidence Report should list that this report is available to the customers through their county library or by contacting the Water Supply Program.

Monitoring

- The system should continue to monitor for all Safe Drinking Water Act contaminants as required by MDE.

Planning/ New Development

- Washington County Department of Planning is encouraged to adopt a wellhead protection ordinance that provides protection for all community water systems relying on ground water. (MDE has a model ordinance that can be used as a starting point. Grant funding is available.)

Land Acquisition/Easements

- Loans are available for the purchase of property or easements for protection of the water supply. Eligible property must lie within the designated WHPA. Loans are currently offered at zero percent interest and zero points. Contact the Water Supply Program for more information.

Nutrient Management

- Agricultural producers within the wellhead protection area should be encouraged to apply for MDA Cost Share money for cover crop implementation. Cover crops have been shown to reduce nitrate levels in ground water.

Inspection of Facilities

- MDE's Underground Injection Program will be conducting an inspection of commercial facilities in the WHPA to determine whether any of the facilities are discharging to ground water.

Contingency Plan

- San Mar Childrens Home should have a Contingency Plan for its water system. COMAR an 26.04.01.22 requires all community water systems to prepare and submit for approval a plan for providing a safe and adequate drinking water supply under emergency conditions.
- Develop a spill response plan in concert with the Fire Department and other emergency response personnel.

Changes in Use

- The San Mar Childrens Home is required to notify MDE if new wells are to be put into service. Drilling a new well outside the current WHPA would modify the area; therefore the Water Supply Program should be notified if a new well is being proposed.

REFERENCES

Bolton, D.W., 1996, *Network Description and Initial Water-Quality Data from a Statewide Ground-Water-Quality Network in Maryland: Maryland Geological Survey Report of Investigations No. 60*, 167 pp.

Duigon, M.T., 2001, *Karst Hydrogeology of the Hagerstown Valley, Maryland*, MGS Report of Investigations 73, 128 pp.

Duigon, M.T., and J.R. Dine, 1991, *Water Resources of Washington County, Maryland*, MGS Bulletin 36, 109 pp.

Evans, W.N. and Holt, J.D., 2003, *An Investigation to Determine the Source and Bacterial Contamination of Multiple Community Drinking Water Systems near Boonsboro, MD, Using Fluoromatic Methods*, report submitted to Water Management Administration, Water Supply Program, 36 pp.

MDE, Water Supply Program, 1999, *Maryland's Source Water Assessment Plan*, 36 p.

U.S. Environmental Protection Agency, 1991, *Delineation of Wellhead Protection Areas in Fractured Rocks: Office of Ground Water and Drinking Water*, EPA/570/9-91-009, 144 pp.

OTHER SOURCES OF DATA

Water Appropriation and Use Permit WA1997G017
Public Water Supply Sanitary Survey Inspection Reports
MDE Water Supply Program Oracle® Database
MDE Waste Management Sites Database
Department of Natural Resources Digital Orthophoto Quarter Quadrangles for Funkstown SE
USGS Topographic 7.5 Minute Quadrangles for Funkstown
Maryland Office of Planning 2002 Washington County Digital Land Use Map
Maryland Office of Planning 2002 Washington County Digital Sewer Map

FIGURES

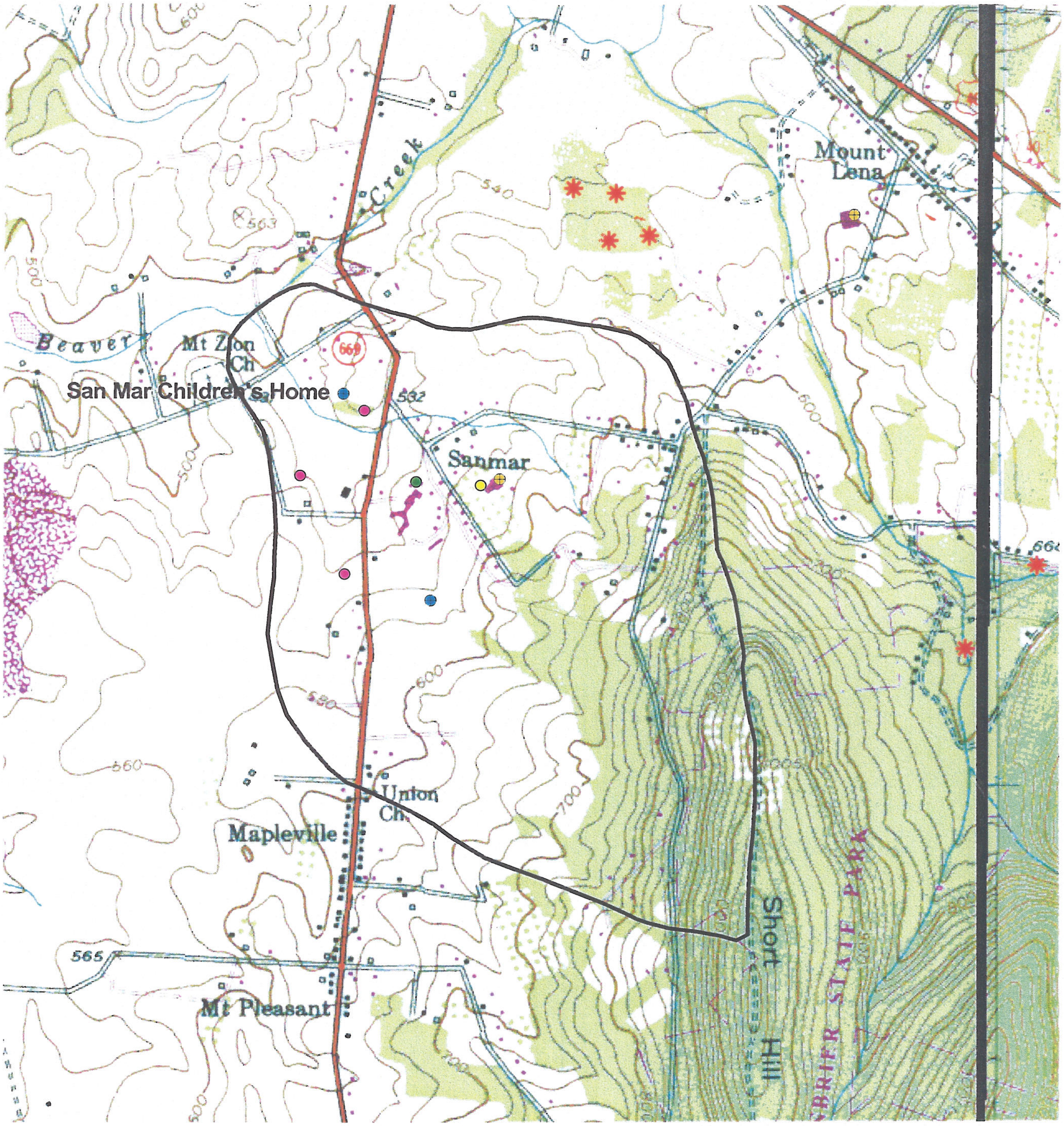
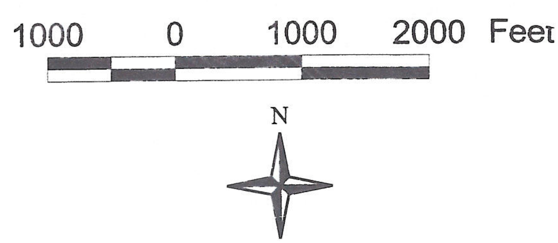


Figure 2. San Mar Children's Home Wellhead Protection Area with Potential Contaminant Sources

Legend

- Community Water System
- Nontransient Noncommunity Water System
- Discharger
- Discharger and CHS Generator
- Wellhead Protection Area
- Sinkholes
- Septic



Base Map: USGS Topographic 7.5 minute quadrangles- Funkstow

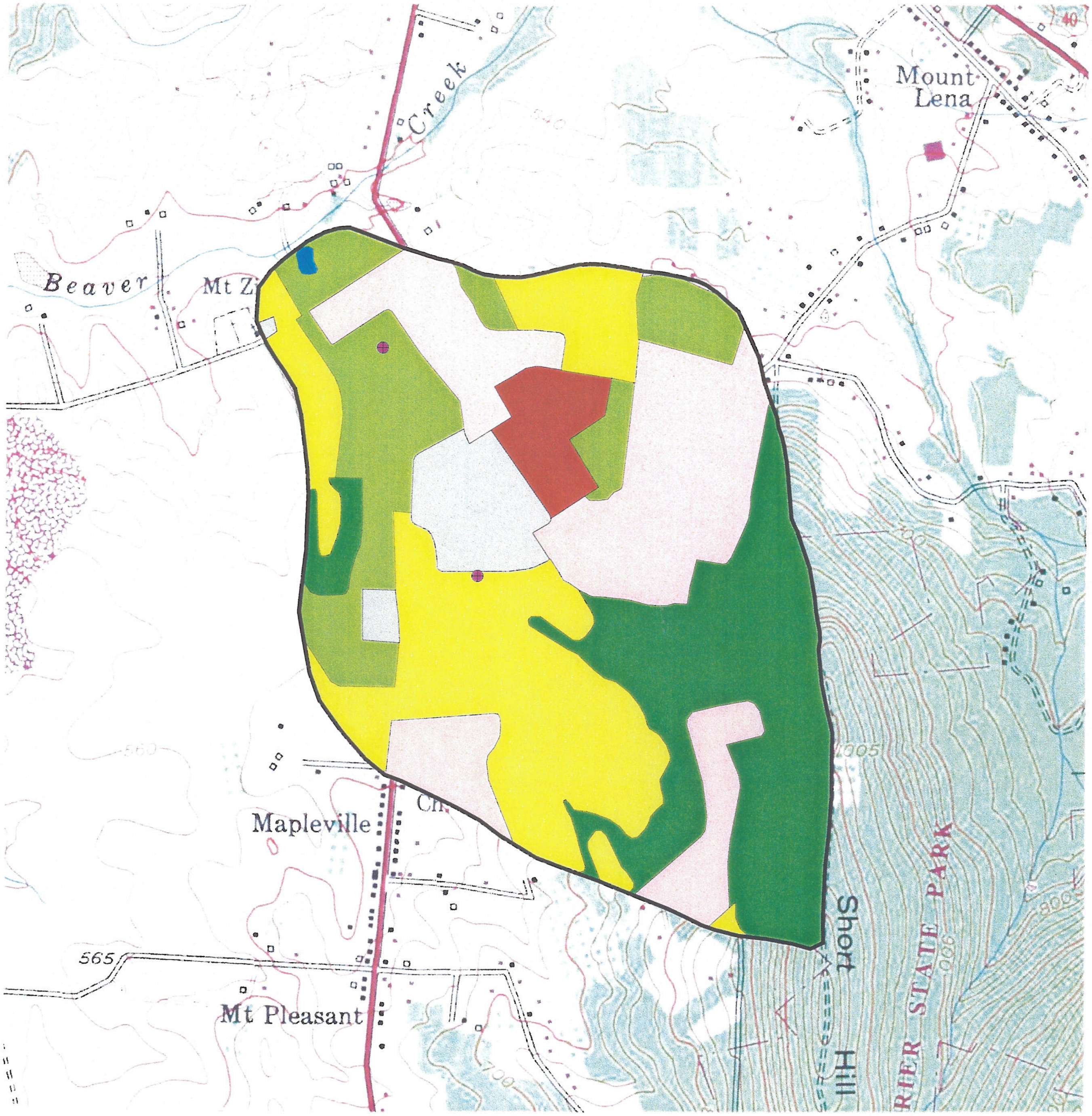
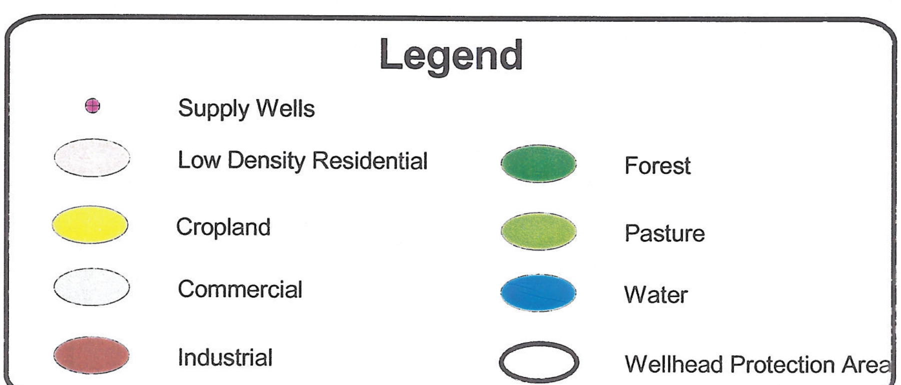
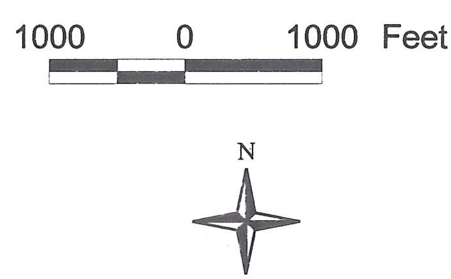


Figure 3. Land Use Map of San Mar Children's Home Wellhead Protection Area





Base Map: USGS Topographic 7.5 minute quadrangles- Funkstown

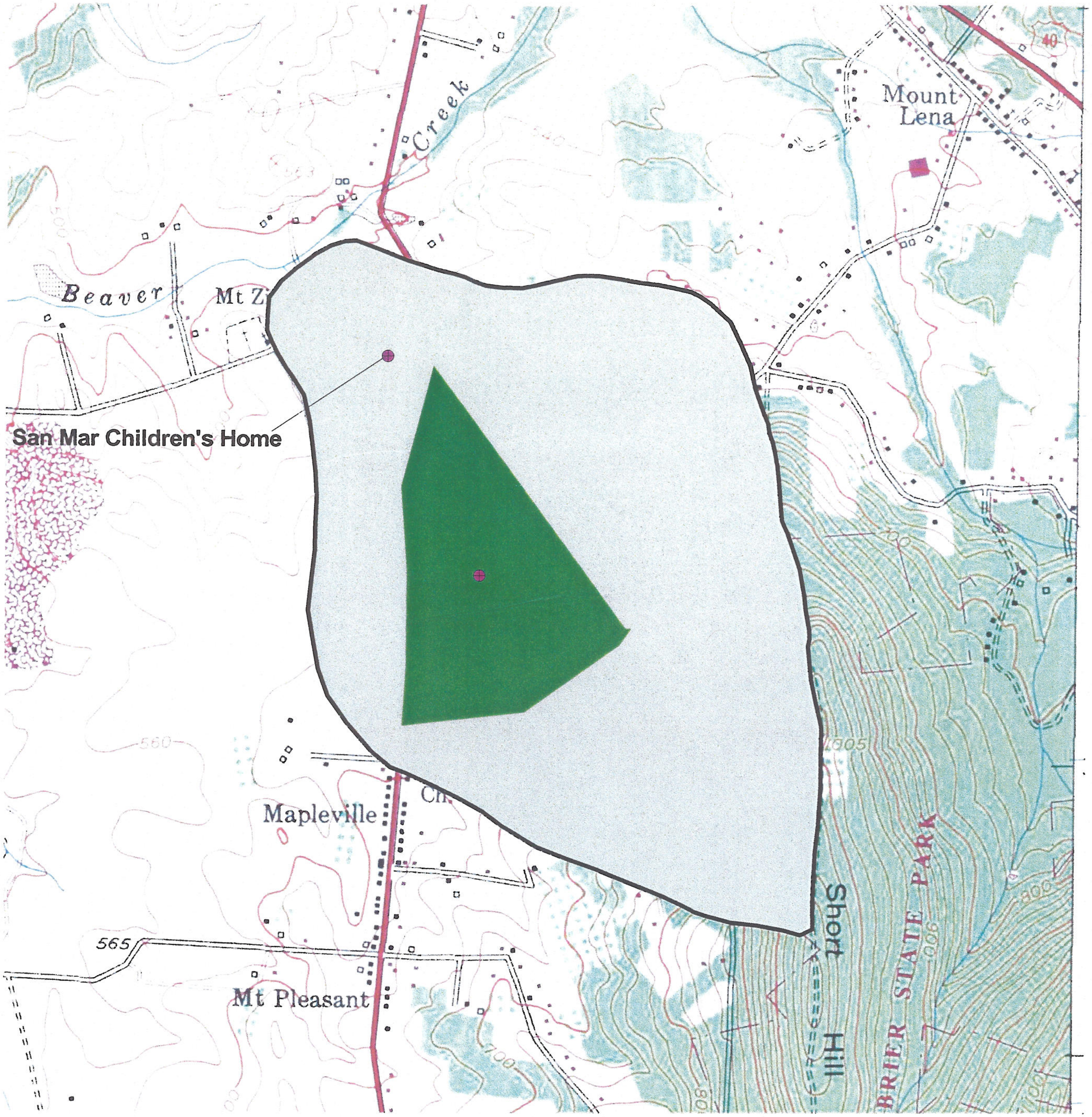
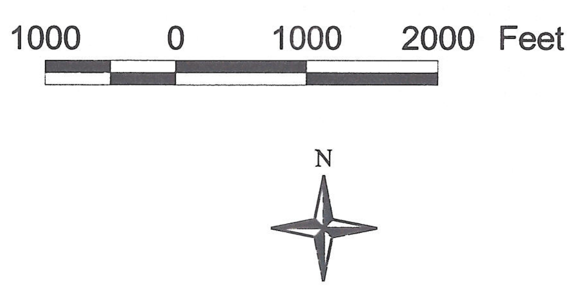


Figure 4. Sewer Map for San Mar Children's Home Wellhead Protection Area

Legend

- Community Water Systems
- Not Planned for Service
- Existing Service or System Under Construction



Base Map: USGS Topographic 7.5 minute quadrangles-Funkstown

REPORT: SAN MAR CHILDRENS HOME
DYE STUDY

San Mar Children's Home
& Fahrney Keedy Home Dye Study

December 2004

Submitted to

Maryland Department of the Environment
Water Management Administration
Water Supply Program

Submitted by

Maryland Department of the Environment
Technical and Regulatory Services Administration
Compliance Monitoring Division
Drinking Water Monitoring Section

MDE

Final Report

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Introduction

The Maryland Department of the Environment (MDE) has administered the wet/ dry weather bacteriological analysis of untreated (raw) water supplying public drinking water systems in Washington County, Maryland. Several drinking water systems within Washington County have exhibited elevated levels of the sanitary indicator organism fecal coliform coincident with precipitation, indicating that groundwater aquifers are under direct surface water influence, referred to as 'GWUDI' (i.e., Ground Water Under Direct Influence). These findings require MDE to conduct detailed investigations designed to evaluate the source(s) of bacterial contamination and to contribute to knowledge about the contribution area for affected ground water aquifers.

This project is designed to investigate and determine the source(s) of fecal coliform contamination of the well (WA-94-2110) supplying the public drinking water system (021-0214) for San Mar Children's Home located approximately 2.5 miles south of Interstate 70 near the eastern boundary of Washington County, MD (see insert Figure 1). The San Mar well was constructed in October 1998 and demonstrated elevated levels of fecal coliform in untreated water collected January 1999 (Appendix 1). This project employed the latest fluorometric techniques to 'tag and capture' potential contamination sources in proximity to San Mar's well. Fluorescent dyes introduced into potential sources including nearby streams and septic systems were

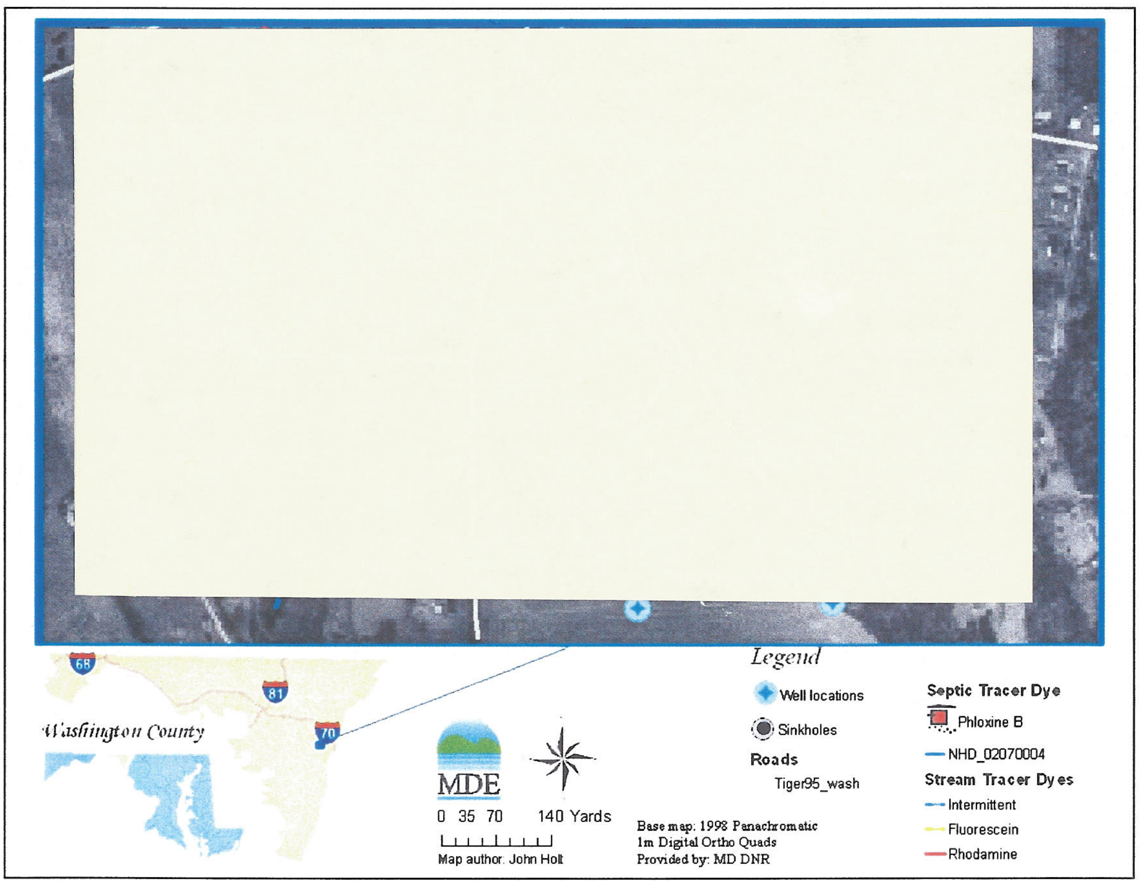

Figure 1. Study area map.

subsequently sought in the subject well using very sensitive fluorometric instrumentation.

The use of tracer dyes provided an opportunity to evaluate the recharge areas and contamination potentials for two additional water sources in proximity to San Mar's well. A natural spring located on San Mar's property and a well (Well 2, WA-04-0855) supplying the nearby Fahrney Keedy Home public drinking water system (021-0213) were monitored during this study (Figure 1). Other wells associated with Fahrney Keedy (Water appropriation permit ID WA1997G003) were not evaluated in this study, including Well 3 (WA-94-3249) constructed in September 2003 and an abandoned well located just south of Well 2 (does not appear in report illustrations).

Site Description

The study area is located on the eastern edge of the Great (Hagerstown) Valley at the foot of South Mountain. The Hagerstown Valley is a unique portion of the Valley and Ridge geological province defined by its wide valley floor underlain by carbonate rock. Carbonate rock is highly susceptible to dissolution by water, resulting in features characteristic to the landscape of the region including closed depressions and disrupted surface drainage.

Many sinkholes identified by the Maryland Geological Survey (Duigon 2001) are within a 1½-mile radius of the San Mar well. Field reconnaissance by MDE personnel failed to locate many of the geo-referenced sinkholes. However, several sinkholes that are not included in the Duigon (2001) dataset were observed during field reconnaissance. One particularly large collapsed sinkhole was observed at the intersection of Greenbriar Road and Swope Road (Figure 2). Several other smaller sinkholes were observed along the south side of Little Beaver Creek south of the intersection of San Mar Road and Mount Lena Road.

Regional land use is predominantly agricultural. The backyards of roadside residences typically end at crop fields or livestock grazing areas. Horse farms are also very common in the region. An unnamed tributary of Little Beaver Creek dissects the San Mar property and represents a probable contamination source (Figure 1). Two conditions elevate the contamination potential for this unnamed tributary. The stream receives treated wastewater effluent from Fahrney Keedy's domestic sewage treatment facility (MD0053066) at the outfall located approximately 120 yards south of the San Mar well. An intermittent branch of the tributary flowing from the south demonstrates loss of flow to groundwater.

Data Usage

The data collected in this study will be forwarded to MDE's Water Supply Program of the Water Management Administration in the form of an analytical report outlining technical results of the field investigation. Analysis of fluorometric data will attempt to determine what the source(s) of bacterial contamination impacting the San Mar Children's Home well. Data generated in this project will assist local, County and State officials in determining system remediation potential, completing a source water assessment, and developing a source water protection program.

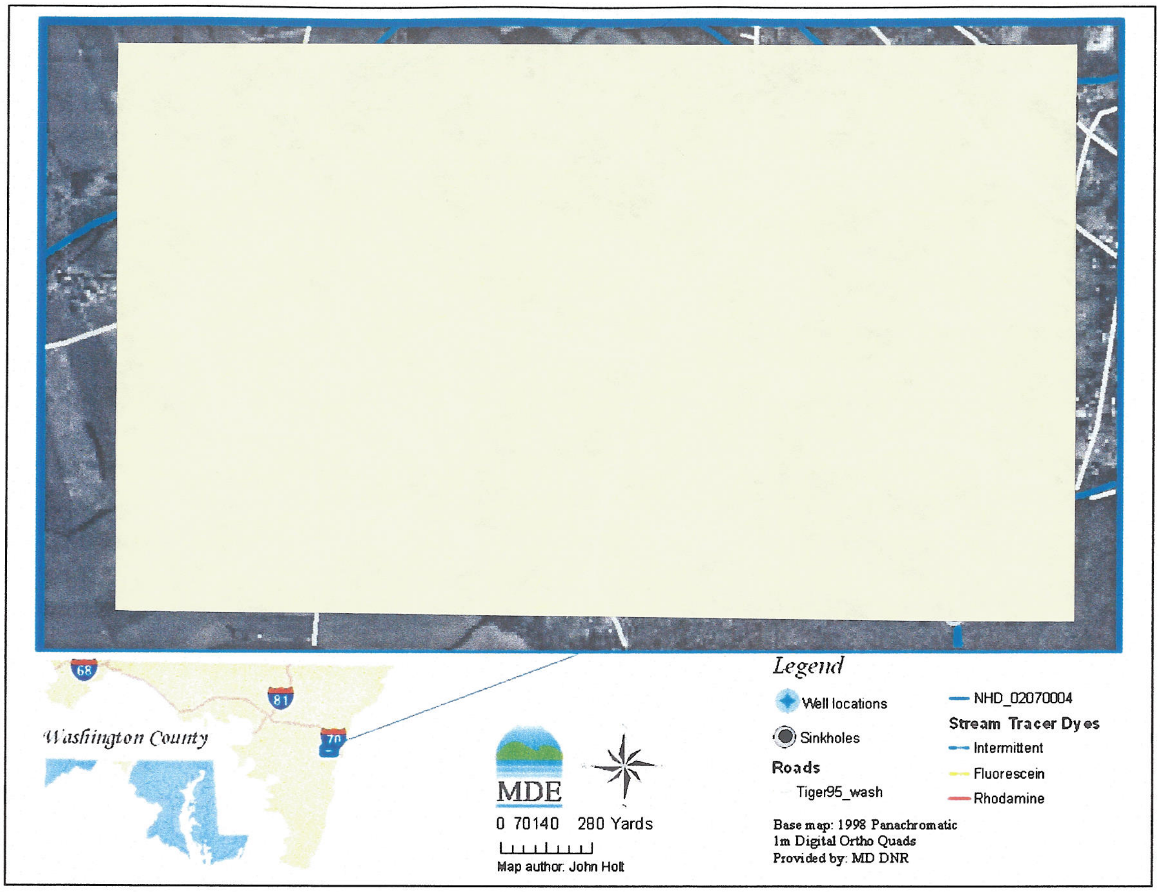

Figure 2. Expanded study area revealing unevaluated potential regional sources.

Methodology

1. Sampling Design

This project has adopted a narrow *scope* and focuses on local sources of contamination, including streams in proximity to San Mar's well and septic systems operated by San Mar. Regional potential sources of contamination, including several sinkholes and potentially losing streams were not evaluated in this investigation (Figure 2). The septic system serving the San Mar complex has two drain fields, one located to the west and the other newer (constructed 1997) drain field located to the south (Figure 1). Although the western drain field is typically used as 'back-up' it was the only operational system during this study due to sewage leak at the pumping station just south of Fahrney Church Road. Furthermore, dye-tracing efforts conducted during this study revealed a direct discharge of sewage into the stream channel between the spring and the outfall for Fahrney Keedy's WWTP. The sewage leak and the direct discharge pipe represent obvious avenues of bacterial loading to the streams, further elevating their contamination potential for the San Mar well. A third drainage field evaluated in this study services a San Mar residence located approximately 200ft east-southeast of the San Mar well.

Three tracer dyes were used to *inoculate contamination sources*. The first, rhodamine WT, also known as acid red 388, was used to inoculate the unnamed tributary of Little Beaver Creek at the Fahrney Keedy WWTP outfall (Figure 1). Uranine dye was used to inoculate the intermittent branch of the unnamed tributary flowing from the south. Using different tracer dyes in stream segments enabled differentiation of segment influences. Phloxine B was used to inoculate San Mar's septic systems.

Recovery points for the tracer dyes were established at the raw taps of the San Mar and Fahrney Keedy systems as well as in the flowing water channel below the San Mar Spring. Continuous flow was maintained through 2½-gallon stainless steel buckets for the duration of collection efforts at each raw tap. Multiple methods of dye recovery were employed to detect dyes, including manual grab water samples, ISCO automatic composite water samples, and charcoal receptors.

Manual grab water samples were collected using new pre-cleaned 1L-glass amber bottles. Grab samples enable detection of relatively large amounts of dye, but manual sampling is very time-consuming. *Automated water samples* using an ISCO robotic sampler enabled more efficient detection of relatively large dye amounts over a longer time period. The ISCO sample program generated 1-hour composite samples by collecting aliquots every 15 minutes into clean discrete 350 milliliter glass bottles, resulting in continuous hourly monitoring for three days following dye inoculation.

Charcoal receptors permit detection of trace dye amounts that would not be measurable in water samples. Receptors absorb and accumulate dyes throughout their deployment. Dyes are subsequently released from charcoal using elution processes (Appendices 2 and 4) and detected using the same instrumentation as used for water samples. Charcoal receptors were deployed into recovery buckets for 5-day time periods to detect the presence of dye in the source water.

All collections were *transported* to the MDE Annapolis Field Office and stored appropriately until analyzed, which usually occurred within one week of collection. Water samples (grab and composite) were maintained at room temperature in an enclosed container to prevent degradation due to ambient light. Charcoal receptors collected using aseptic techniques were placed in plastic ziplock bags and manila envelopes then refrigerated until elution procedures were conducted.

Qualitative analysis of samples occurred at MDE's biological lab using a Shimadzu RF-5301PC spectrofluorophotometer that emits spectra from its synchronous scan. The Shimadzu internally compensates for temperature. Spectrum integration and calibration curves stored in the computer are used in the qualitative analysis for uranine, phloxine B, and rhodamine WT. Charcoal receptors were eluted to release any absorbed dyes using the procedure outlined in Appendix 2 for qualitative analyses. Ranges of emission wavelengths that will be used to identify tracer dyes are listed in Table 1.

Dye	Normal Acceptable Emission Wavelength Range (nm) in water	Normal Acceptable Emission Wavelength Range (nm) in elutant
Uranine	508 to 513	514 to 518
Rhodamine WT	575 to 579	574 to 578
Phloxine B	553 to 560	557 to 563

Table 1. Emission wavelength ranges for tracer dyes.

Quantitative analysis of samples for rhodamine WT dye was conducted using a Turner Designs Model 10 AU outfitted with the appropriate light filters and source lamp to measure constituents which fluoresce at the same wavelength as rhodamine WT. Calibration of the Turner instrument was performed prior to the onset of the investigation according to the recommended manufacturer's instructions and in accord with standardized dilutions of known tracer compound (Appendix 3). Because the Turner instrument does not internally compensate for temperature, measured sample values were manually corrected if sample temperature differed from calibration temperature. Rhodamine WT values were reported at a detection limit of 0.02 parts per billion (ppb) with a manufacturer's claim of sensitivity at the 0.01 ppb level.

Charcoal receptors were eluted using the procedure outlined in Appendix 4 to conduct quantitative analyses. Eluted charcoal samples do not enable quantitative measurement of the amount of dye in the source water. Values are only *semi-quantitative* because many factors influence the quantity of dye absorbed by the charcoal, including dye concentration in the water, water quantity, water velocity, water temperature, duration of exposure, and turbidity. This study adopts categories used by Center for Cave and Karst Studies of Western Kentucky University to interpret charcoal dye concentration rather than ppb (http://www.dyetracing.com/dyetracing/dy04005.html).

	Description	Expanded description for this study
ND	below quantification limit	net fluorescence less than 0.2ppb
B	background levels	net fluorescence less than 2x background value
+	positive	net fluorescence greater than 2x background value
++	very positive	net fluorescence greater than 5x background value
+++	extremely positive	net fluorescence greater than 10x background value
NS	receptor not recovered	

Table 2. Description of categories used to report semi-quantitative rhodamine WT charcoal receptor results.

2. Background Fluorescence Collections

Fluorescence is the luminescence caused by radiation of some wavelength of energy immediately following the absorption of energy by a material. Analyses of ambient water were conducted to account for materials that fluoresce at the same wavelength as tracer dyes used in the investigation. Four to five background water samples were collected between 7/14/03 and 7/23/03 from each recovery point. Two to three background charcoal samples were collected between 6/06/03 and 7/14/03.

3. Dye inoculation

Dye inoculation of septic systems and streams occurred early (7/21/03) in a multiple day precipitation event (see Appendix 5) resulting in over 1.8 inches of rain between 7/21/03 and 7/23/03. Dye inoculation details are illustrated in Figure 3. Septic systems were inoculated by pouring a phloxine B dye solution into a commode at each target system. Streams were inoculated by slowly pouring rhodamine WT dye or uranine dye into stream flow.

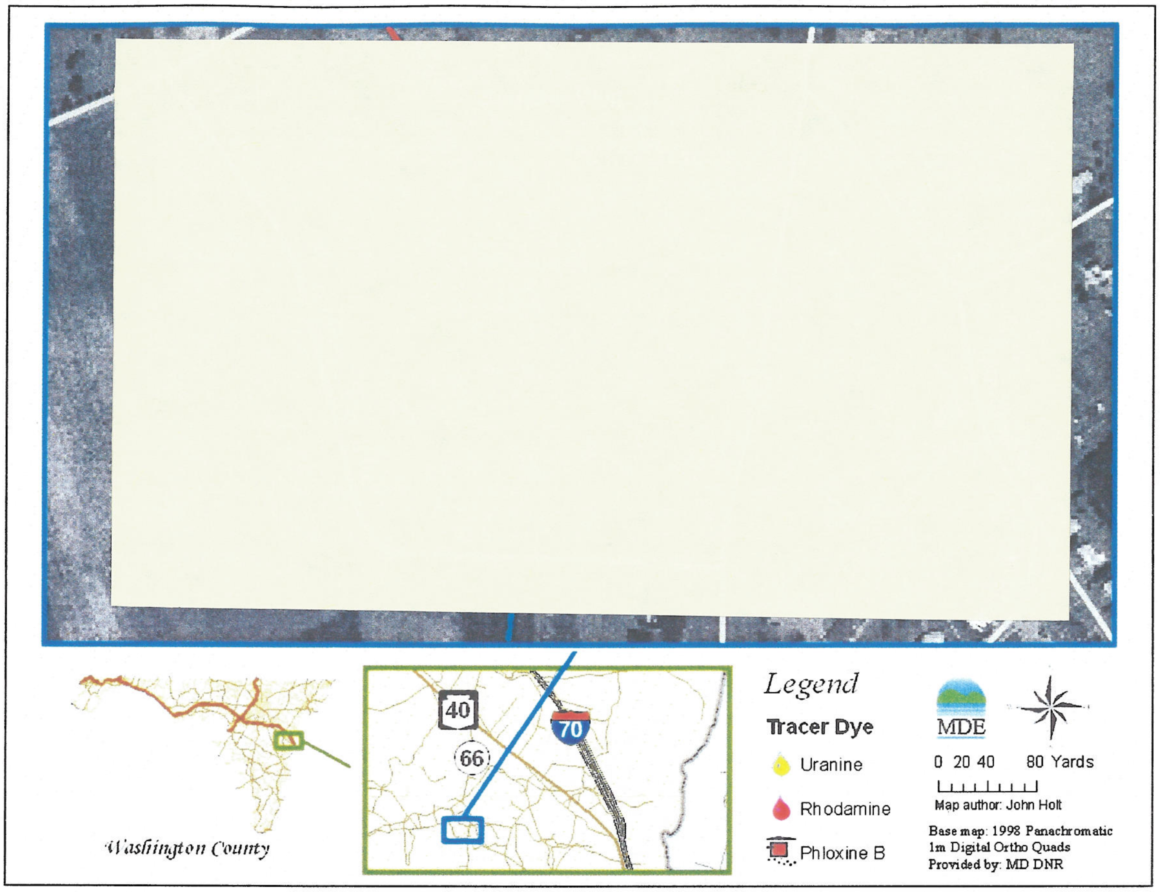

Figure 3. Dye inoculation details.

Results and Discussion

Trace levels of Uranine and Rhodamine, used to inoculate branches of the unnamed tributary of Little Beaver Creek, were detected in raw water from the San Mar Well using charcoal receptors (Figure 5). A number of observations suggest that Uranine was the strongest result of the two dyes detected. Uranine fluorescence intensities were slightly higher than Rhodamine intensities. There was also no background fluorescence detected near the Uranine wavelength range to confound post inoculation results, whereas small increases in background fluorescence with peaks at 568nm and 564nm (near the range for Rhodamine in charcoal elutant [574-578nm]) slightly shadow these Rhodamine post inoculation results. Furthermore, semi-quantitative analyses of charcoal receptors (Table 3) did not corroborate qualitative Rhodamine results because Rhodamine was at 'background' level or 'non-detectable' (Table 2). All tracer dye concentrations were too low to enable detection in water samples from the San Mar well (Figure 4).

The concentration of phloxine B was high enough to enable detection in water samples collected from the spring at San Mar (Figure 6). The presence of phloxine B in water samples was also corroborated by charcoal receptor analyses (Figure 7). Results reveal a connection of local shallow groundwater to the water discharged from the spring because phloxine B was introduced into the septic systems of the San Mar Children's Home. While the Turner Spectrofluorometer was not specifically equipped to detect phloxine B, the wavelength was close enough to that of Rhodamine to enable additional corroboration of phloxine B results using this semi-quantitative analysis that suggest a very positive trace detection (Table 3) because post inoculation levels are more than 10X background levels (Table 2). Fortunately, trace levels of Uranine and Rhodamine were not detected in the San Mar spring (Figure 7). Background charcoal receptor fluorescence at wavelengths similar to each dye would have inhibited detection of dye fluorescence.

ppb	San Mar	Spring	Fahrney
Background 1	0.1	0.2	0.0
Background 2	0.0	0.2	0.0
Background 3		0.2	0.0
Charcoal 1	0.1	0.9	0.0
Charcoal 2	0.1	4.9	0.0
Charcoal 3	0.0	3.7	0.0

Table 3. Semi-quantitative results (ppb) of charcoal receptors using Turner spectrofluorometer.

No tracer dyes were detected in the Fahrney Keedy Well (Figures 8 and 9). As in the San Mar spring charcoal results, background fluorescence confounds detection of trace levels of Uranine and Rhodamine (Figure 9). Semi-quantitative results corroborate the absence of trace levels of Rhodamine (Table 3). Fahrney Keedy's Well 2 is not documented as GWUDI. It was a subject of this study due to the GWUDI status of former (abandoned) Fahrney Keedy drinking water sources. Furthermore, inclusion of the well was a relic of early study design in which more regional sources of contamination were targeted for dye inoculation.

Correction of conditions observed during reconnaissance and sampling efforts at San Mar could reduce potential bacterial loads to the San Mar Well. The leak at the sewage pump station (south of Farhney Church Road) for the new (southern) drain field was a chronic bacteria source for the stream dyed in this study with Uranine because a septic pool formed at the surface could produce overland flow into the stream after significant precipitation events. Trace amounts of dye introduced into this stream entered the San Mar Well, thus bacteria in the stream may also enter the well aquifer. Likewise, the direct sewage discharge into the stream channel between the spring and the WWTP outfall could also contribute bacteria to the San Mar Well because trace amounts of Rhodamine dye introduced just downstream were detected in the well.

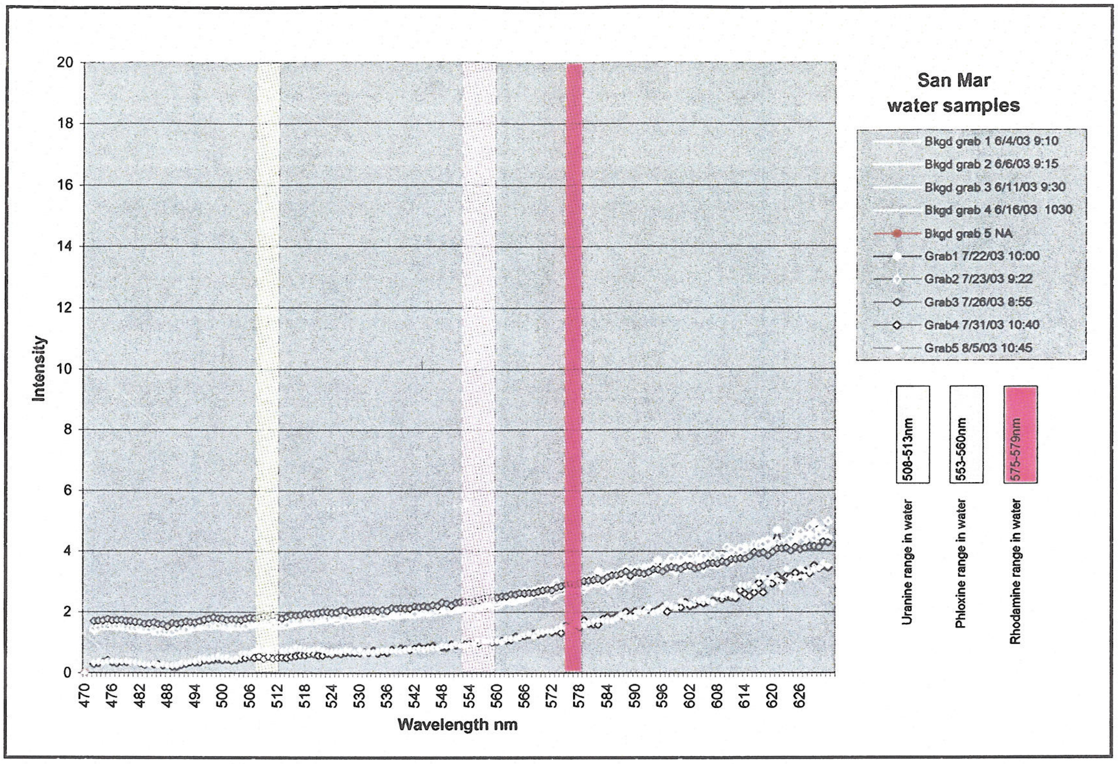

Figure 4. San Mar qualitative water sample results.

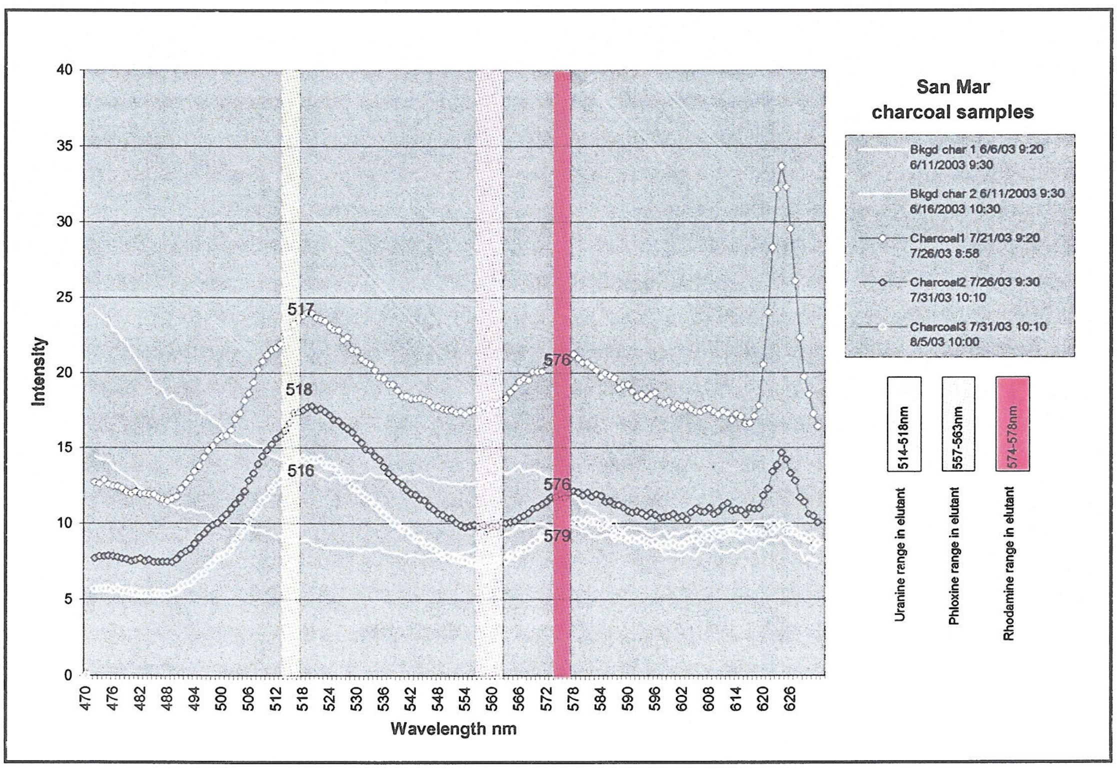

Figure 5. San Mar qualitative charcoal results.

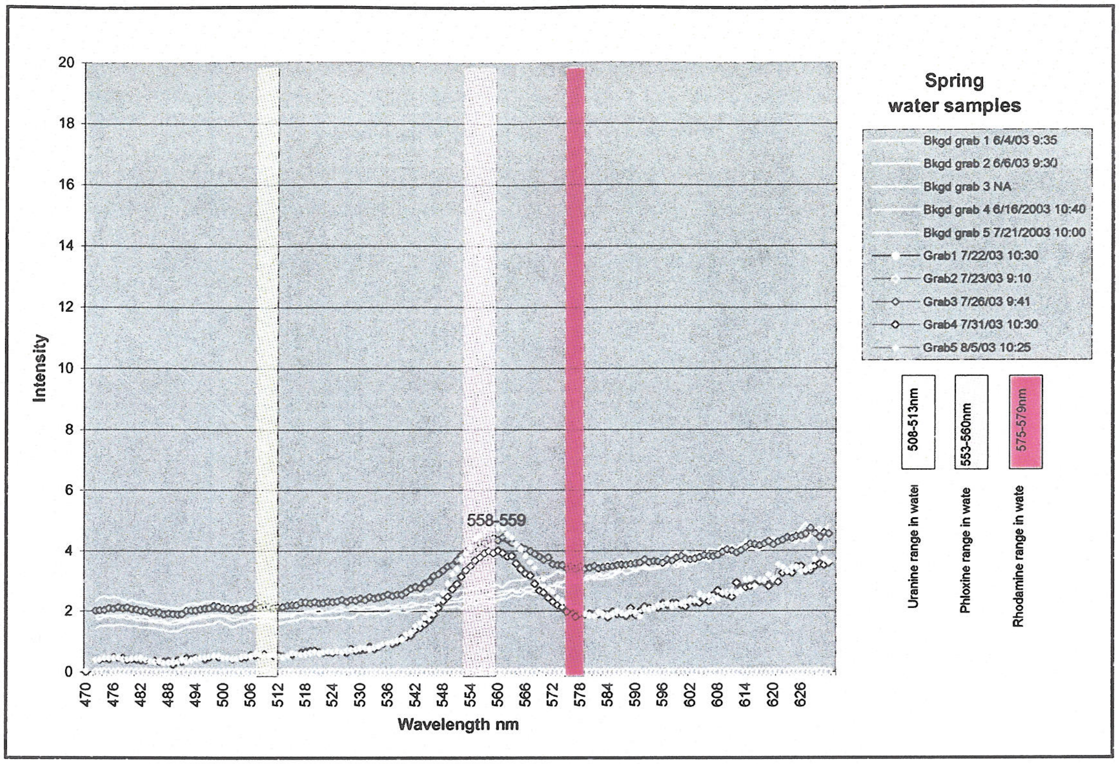

Figure 6. San Mar Spring qualitative water sample results.

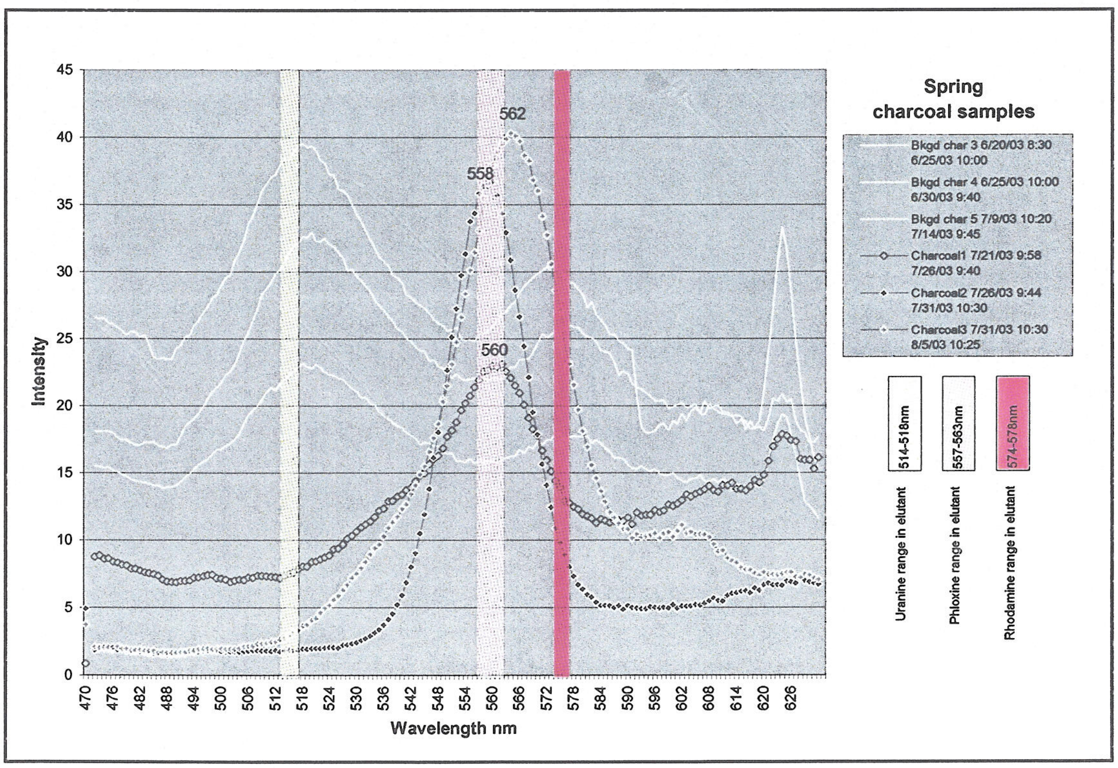

Figure 7. San Mar Spring charcoal receptor results.

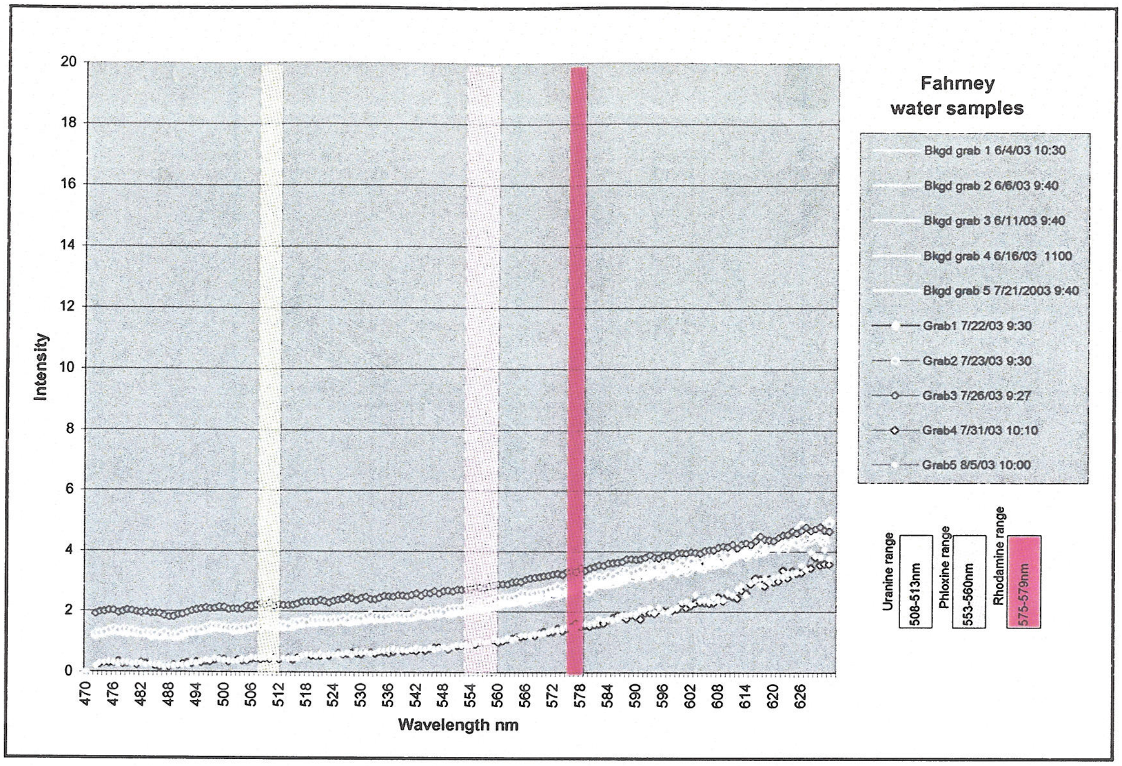

Figure 8. Fahrney Keedy qualitative water sample results.

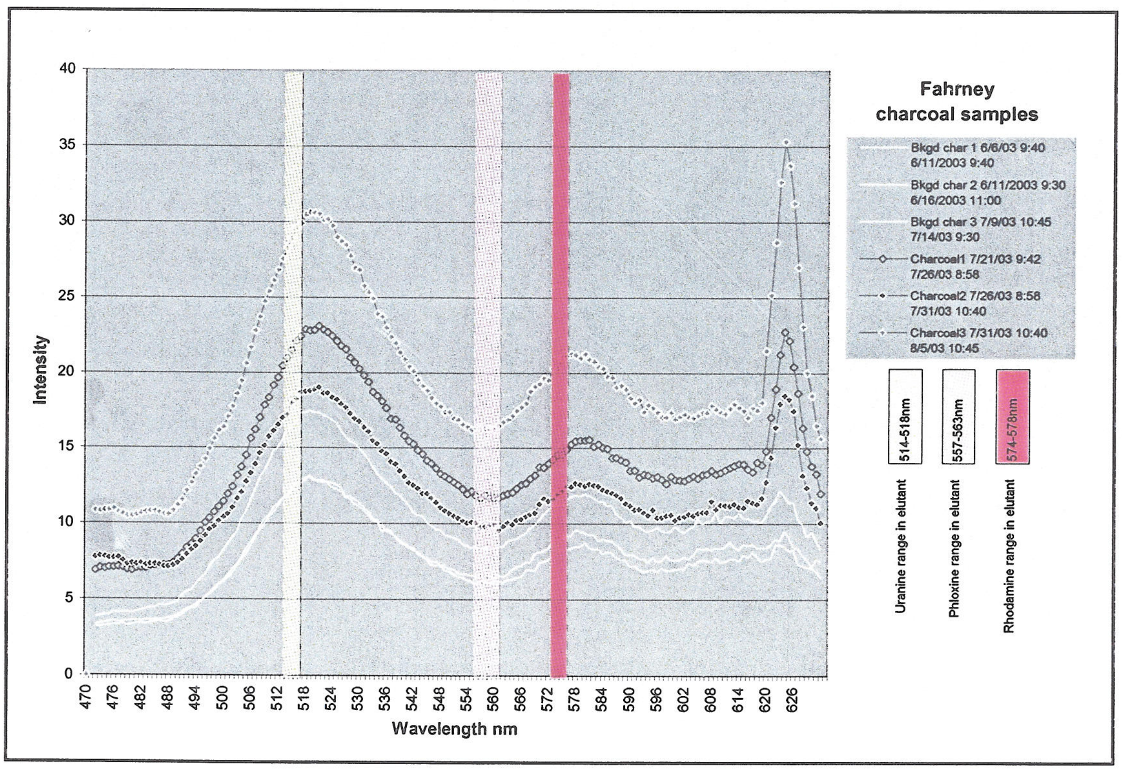

Figure 9. Fahrney Keedy qualitative charcoal sample results.

References

Duigon MT. 2001. Karst Hydrogeology of the Hagerstown Valley, Maryland. Maryland Geological Survey. Report of Investigations No.73. 4 p.

Appendix 1: GWUDI data

Sample Date	Temp (C)	pH	Turbidity (NTU)	Total Coliform (mpn/100ml)	Fecal Coliform (mpn/100ml)
15-Apr-98	13.2	7.26	15.1	73.8	-1
Samples following 0.75 inch rain event on 4/19/98:					
20-Apr-98	13.3	7.58	54.6	Present	Present
21-Apr-98	13	7.37	35.3	Present	Absent
22-Apr-98	13	7.44	18.8	Present	Absent
23-Apr-98	13	7.46	29.8	42.9	-1
Samples following 1 inch rain event on 1/4/99:					
5-Jan-99	11.5	8.86		200.5	-1
6-Jan-99		8.57		200.5	-1
7-Jan-99	11.8	8.2		200.5	-1
11-Jan-99	11.8	8.83		200.5	-1
Samples following 0.55 inch rain event on 1/18/99:					
19-Jan-99	13.5	8.52	0.56	165	-1
20-Jan-99	15	7.44	0.5	20.7	1
21-Jan-99	13	7.45	0.27	200.7	1
25-Jan-99	13	7.5	2.57	200.7	42.9

Appendix 2: Shimadzu elution procedure

MARYLAND DEPARTMENT OF THE ENVIRONMENT
SHIMADZU RF5301 INSTRUCTIONS FOR SAMPLE ANALYSIS
Uranine, rhodamine WT, and phyloxine b elution from activated charcoal

LABEL ELUTION CUPS TO MATCH SITE INFORMATION

MAKE ELUTANT WITH 5% $NH_4(OH)_3$ SOLUTION AND THE REMAINING 95% WITH 70%-ISOPROPAL ALCOHOL.

ADD AMMONIUM HYDROXIDE TO ALCOHOL AND TOP OFF FOR NEEDED VOLUME (12 MILLILITERS OF ELUTANT PER 5 GRAM CHARCOAL PACKET).

ADD KOH FLAKES AND DISSOLVE UNTIL *SUPERSATURATED BOTTOM LAYER* (not used as elutant) DEVELOPS

RINSE CHARCOAL PACKETS THROUGHLY USING DEIONIZED WATER TO REMOVE SILT AND VEGETATION.

ANALYZE ELUTANT SOLUTION (top layer) TO MAKE SURE NO FOREIGN FLUORESCENCE EXISTS

DECANT ELUTANT (top layer) INTO DISPOSIBLE CUVETTE USING A DISPOSABLE PIPETTE. VERIFY OUTER EDGES OF CUVETTE ARE FREE FROM MARKS OR DEBRIS.

PLACE CUVETTE INTO INSTRUMENT AND PRESS START TO ANALYZE ELUTANT SOLUTION.

PRESS START TO ANALZE, MAKING SURE THERE ARE NO PEAKS BETWEEN 500 AND 600 NANOMETERS THAT ARE GREATER THAN 10.

ONCE VERIFIED, ADD ELUTANT TO CHARCOAL. SHAKE NYLON BAG TO REMOVE EXCESS WATER AND GET CHARCOAL TO BOTTOM OF PACKET.

CUT OPEN BAG AND PLACE CHARCOAL IN PLASTIC CUP, MAKING SURE NOT TO GET CHARCOAL IN OTHER CUPS.

USING LARGE GLASS SYRINGE FILLED WITH ELUTANT, PLACE 12 MILLILITERS OF ELUTANT INTO EACH CUP AND COVER.

MAKE SURE ALL CHARCOAL IS WET, AND THEN LET SIT FOR 60 MINUTES.
FOLLOW SAME PROCEDURES AS FOR ANALYZING ELUTANT

Appendix 3: Turner standards preparation

Procedures for rhodamine WT dye standard preparation for use in calibration of Turner Designs Fluorometer

Solution A: Original dye from manufacturer. Concentration 2 x 10^8 ppb (20% Rhodamine WT). Specific Gravity equals 1.19.

Solution B: Concentration equals 2.38 x 10^6 ppb. Pipette 10 ml. of solution A and make up to 1000 ml. in Volumetric with deionized water.

Solution C: Concentration equals 2.5 x 10^4 ppb. Pipette 10 ml. of solution B and mix with 942 ml. of deionized water.

Solution D: Concentration equals 250 ppb. Pipette 10 ml. of solution C and mix with 990 ml. of deionized water. This will be the primary standard.

Solution E: Concentration equals 25 ppb. Pipette 20 ml. of solution D and mix with 180 ml. of deionized water.

Solution F: Concentration equals 10 ppb. Pipette 10 ml. of solution D and mix with 240 ml. of deionized water.

Solution G: Concentration equals 5 ppb. Pipette 20 ml. of solution D and mix with 980 ml. of deionized water.

Solution H: Concentration 2.5 ppb. Pipette 10 ml. of solution D and mix with 990 ml. of deionized water.

Solution I: Concentration equals 1 ppb. Measure 100 ml. of solution G and mix with 400 ml. of deionized water.

Solution J: Concentration equals 0.5 ppb. Measure 50 ml. of solution G and mix with 450 ml. of deionized water.

Solution K: Concentration equals 0.2 ppb. Measure 25 ml. of solution G and mix with 600 ml. of deionized water.

Solution L: Concentration equals 0.1 ppb. Pipette 10 ml. of solution G and mix with 490 ml. of deionized water.

*The above solutions are prepared using strict laboratory techniques. The output of the fluorometer is then compared to the known range of dye concentrations.

Appendix 4: Turner elution procedure

Elution Protocols for Activated Charcoal Dye Receptors

MARYLAND DEPARTMENT OF THE ENVIRONMENT
Turner Designs Model 10AU Fluorometer
Rhodamine WT dye elution from activated charcoal

BACKGROUND INFORMATION:
RHODAMINE WT DYE IS ALSO KNOWN AS (ACID RED 388) OR (XANTHENE) (C28H31N203CL). OPTIMUM STABILITY PH 10.5 – 10.8

(DO NOT MIX WITH ACID) ACIDS, ULTRAVIOLET LIGHT, AND BIOLOGICAL ACTIVITY WILL QUICKLY DEGRADE THIS COMPOUND.

ELUTION FROM 14.8 GMS ACTIVATE COCONUT CHARCOAL EXPOSED TO DILUTED RHODAMINE DYE IN STREAM WATER OR WELL WATER FOR 72 HOURS OR (3 DAY) PERIOD. NOTE: CHARCOAL PACKETS MUST BE STORED IN A FREEZER AND FREE OF ANY LIGHT, ESPECIALLY SUNLIGHT (ULTRAVIOLET RADIATION) UNTIL ELUTION PROCEDURE IS PERFORMED.

CAUTION: MAKE SURE HANDS, AND ALL GLASSWARE, AND CONTAINERS ARE CLEAN AND FREE OF ANY CONTAMINATING DYE BEFORE BEGINNING THIS PROCEDURE. ALSO UTILIZE A TECHNIQUE THAT WILL ELIMINATE THE CHANCE OF CARRY OVER CONTAMINATION FROM ONE SAMPLE TO ANOTHER.

PROCEDURE:

1. DYE ABSORDED CHARCOAL (14.8 GMS) PACKET IS TAKEN FROM THE FREEZER AND ALLOWD TO THAW FOR ABOUT TEN MINUTES. USING SCISSORS THAT ARE CLEAN AND FREE OF DYE CAREFULLY CUT ONE END OFF THE PACKET OVER INTO A LABELLED OPEN 150 ML DISPOSABLE HISTOLOGICAL SCREW CAP CONTAINER. MAKE SURE MOST OF THE CHARCOAL PARTICLES ARE TAPPED OUT OF THE PACKET INTO THE ELUTION CONTAINER.

2. ADD 10 ML OF 50% 1-PROPANOL-DEMINERALIZED WATER SOLUTION TO THE CONTAINER AND CHARCOAL. MAKE SURE THIS SOLUTION COVERSTHE CHARCOAL.

3. ADD 40 ML OF 1:1 AMMONIUM HYDROXIDE, CLOSE THE CONTAINER, THEN GENTLY ROTATE THE CONTAINER 5 TO 10 ROTATIONS.

4. REPLACE FLASK TOP SECURELY AND ROTATE FLASK SLOWLY FOR A MINIMUM OF TEN ROTATIONS.

5. KEEP ELUTION CONTAINER CLOSED WITH GENTLE ROTATIONS EVERY TEN MINUTES FOR A MAXIMUM OF 30 MINUTES. AFTER 30 SIMUTES DYE ACTIVITY WILL BEGIN TO DECREASE.

6. TURN ON FLUOROMETER TEN TO FIFTEEN MINUTES BEFORE TAKING ANY READINGS.

7. CHECK AN UNABSORBED 14.8 GMS OF ACTIVATED CHARCOAL USING THE SAME ELUTING SOLUTION AND USE THIS AS A REFERENCE BLANK.

AT 30 MINUTES POUR 50 ML OF ELUATE FROM THE 150 ML CONTAINERINTO AN 80 ML FLUOROMETER CUVETTE TOCHECK FOR ANY DYE LEVEL ELUTION.

Appendix 5: Precipitation data

(source: http://i4weather.net/br404.gif)