SOURCE WATER PROTECTION PROGRAM
BENEFITING THE TOWN OF SHARPTOWN (PWSID 022-0005)
WICOMICO COUNTY, MARYLAND

ALWI Project No. MD7S075

1.0 INTRODUCTION

Advanced Land and Water, Inc. (ALWI) was engaged by the Maryland Department of the Environment (MDE) to assist 12 community groundwater systems, including Sharptown, in developing and implementing Source Water Protection Programs (SWPPs). These programs will help protect public health by identifying implementable measures to address existing and potential contaminant threats to groundwater supplies of safe drinking water.

In 2001, ALWI developed a Source Water Assessment and wellhead protection plan for the Town of Sharptown (Town). The Town was and remains served by four supply wells clustered at the previous Town Hall location, approximately 0.4 miles north of the intersection of MD Routes 313 and 348, in northern Wicomico County, Maryland (Figure 1).

We reviewed the previous source water assessments for currency, following technical guidance and advice received from the Water Supply Program of MDE. Notwithstanding this, source water assessment is an intrinsically dynamic process. The currency of this assessment continuously is affected by new data, changing regulations and the evolving experience and professional judgment of those involved in developing and implementing this assessment and the recommendations herein.

1.1 PURPOSE

Maryland's Source Water Assessment Program (SWAP) was approved by the U.S. Environmental Protection Agency (EPA) in November 1999, and the initial Source Water Assessment for the Town was completed in 2001 (Appendix A). The 2001 SWAP included recommendations for ongoing management and protection, as well as periodic updates to reflect changes to the water system, appropriation permit and/or land uses within Source Water Protection Areas (SWPAs) as they may periodically occur. In 2011, the Maryland Rural Water Association completed a further update of the 2001 Source Water Assessment (Appendix B).

Past efforts recommended source protection in concept and supported the implementation of some initial protective measures including the removal of acutely proximal point-source nitrate hazards which already had occurred. However, the previous Source Water Assessments and budgets did not support implementation of ongoing protective measures in full. Accordingly, the overall purpose of this contract is to assist the Town in developing a more refined and ongoing SWPP, which includes specific guidance on implementing feasible source protection measures.

1.2 REGULATORY FRAMEWORK FOR SOURCE WATER ASSESSMENT

ALWI followed MDE's source water assessment guidelines, which stem from The Safe Drinking Water Act (SDWA) of 1974 and its later amendments, which established wellhead protection programs for each state under the oversight of the EPA. The 1996 Amendments to the SDWA mandated the State of Maryland to develop a Source Water Assessment Program.

In September of 2011, ALWI was awarded the SWPP contract. The Town's participation in the SWPP was voluntary and not a regulatory requirement under the SDWA.

1.3 BACKGROUND INFORMATION

The Town's municipal water system (PWSID 022-0005) has an overall, combined MDE Water Appropriation Permit of 80,000 gallons per day (gpd) and serves nearly 650 residents. The Town was and remains served by four closely spaced production wells, three of which are in regular service:

- **Wells 4 and 5** - These two wells withdraw water from the shallow, unconfined Columbia Aquifer of probable Miocene age.

- **Well 6** - This well is completed in the confined Frederica Aquifer, a deeper, silty sand layer within the Atlantic Coastal Plain. In the 2001 report, the Frederica Aquifer was referred to as the Nanticoke Aquifer.

- **Well 1** - This well is used as a backup supply in case of emergency. Reportedly, this well was installed in 1936, which makes it of vintage age predating regulatory grouting requirements. Available well completion data suggest that the bottom of the well extends into, and is screened in, the Frederica Aquifer (Appendix C). However, uncertainty exists as to whether Well 1 also may be open to more shallow aquifers (probably due to lack of adequate grout or the presence of multiple screens). In this report, we evaluate raw water quality as a tool to substantiate the hypothesis that Well 1 also is open to the unconfined Columbia Aquifer. Careful consideration of raw water quality data trends allowed us to interpret plausible water source(s) to this well and the extent to which they mix.

In 2001, ALWI recommended that periodic revisions be made to SWPAs reflecting changes in the magnitude and distribution of groundwater withdrawals, both from the system's production wells and from other nearby wells. Further, we recommended that the contaminant hazard inventory developed in 2001 be updated triennially. Finally, we concluded that local ordinances and protective covenants, combined with community awareness and public outreach measures could afford a measure of ongoing SWPA management. This SWPP is intended to implement many of these recommendations.

1.4 DELINEATIONS REMAIN UNCHANGED FROM 2001 SWAP

Updates to SWPAs were not necessary since no new sources were added to the system. System pumpage distribution was not altered, and there has been no change to the Town's water appropriation permit. SWPAs are depicted on Figure 1. Delineation methods, parameters and uncertainties are summarized in Appendix A and are not repeated herein for brevity.

1.5 Special MDE Concerns at Outset of This Update Effort

During the course of this assessment, ALWI gradually came to understand that water quality concerns at Sharptown supported the MDE decision to pursue and secure funding for this assessment. MDE's concerns arose from a combination of the following factors:

- High nitrate concentrations in the shallow, unconfined Columbia Aquifer;
- Elevated concentrations of Disinfection Byproducts (DBPs) in the finished water, the cause of which is assumed to be the presence of DBP precursors in the raw water;
- The unavailability of deeper freshwater aquifers because of interpreted brackish or saline conditions; and
- Limited financial means to afford the capital and operational cost of conventional denitrification.

These factors and their bases are discussed in later sections of this report.

2.0 CONTAMINANT THREATS ASSESSMENT

ALWI performed regulatory database reviews, field reconnaissances and limited interviews to update the 2001 inventory of potential sources of contamination within the SWPAs. Both point and non-point sources of contamination were considered.

2.1 State Environmental Database Review

MDE provided ALWI the following state-maintained environmental databases to incorporate into point-source hazard inventories:

- Municipal and Industrial Groundwater Discharge Permits (12/21/2011)
- Pesticide Dealers (1/12/2012)
- Land Restoration Program Sites (Voluntary Cleanup Program and Comprehensive Environmental Response, Comprehensive, and Liability Act) (1/16/2012)
- Oil Control Program Underground Storage Tank and Leaking Underground Storage Tank Database (10/14/2011)
- Supplemental database listings of solid waste facilities, wood waste disposal sites and other hazardous waste generators (2/2012).

The databases helped with interpretations of groundwater susceptibility, in that the listed facilities may be generators of hazardous materials, petroleum products and/or other drinking water contaminants. Results of this review are integrated with the susceptibility discussion in Chapter 3.0 of this report.

2.2 FIELD RECONNAISSANCE WITHIN SWPAS

ALWI supplemented the database review with a visual reconnaissance within the four SWPA Zones on December 21, 2011. Results of this updated inventory are displayed on Figure 1 and summarized in Table 1.

During this reconnaissance, local land use conditions were observed with emphasis on the potential use, storage and disposal practices of hazardous materials and petroleum products in such a location where Town wells potentially could entrain related contaminants. Such conditions may have included visual evidence of present or former spills, stained or discolored ground surfaces, stressed vegetation, unusual odors or visible underground storage tank (UST) appurtenances.

Adjacent and nearby properties were visually scanned to the degree practicable from public rights-of-way[1].

2.3 FIELD RECONNAISSANCE NEAR WELLHEADS

ALWI's December 21, 2011 field reconnaissance indicated that all four municipal production wells appeared to possess good physical integrity, though no subsurface or invasive work was performed. Staff revisited the area surrounding the well field on March 12 and April 10, 2012, following receipt and analysis of additional water quality data supplied by the Town (Section 3.1).

No confirmed sources of existing, direct contamination to the wells within SWPAs were observed. No visible changes in well physical integrity, compared with observations ALWI made in 2001, were noted. Photographs of each wellhead are provided in Appendix D.

2.4 SPECIAL CONCERN ABOUT WELL 1 CONSTRUCTION AND INTEGRITY

Prior to the outset of this update effort, MDE hypothesized that Well 1 possibly was open to both the unconfined and confined aquifer systems. In the course of this effort, we came to support this hypothesis (see Chapter 3.0) and share this concern. Many source water protection and water quality improvement strategies depend on aquifer isolation. The possible commingling of waters through a well open to both freshwater aquifers could complicate and lessen the efficacy of certain protective measures (in addition to being a circumstance prohibited under applicable regulations).

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[1] ALWI did not observe specific contamination occurrences warranting immediate investigation or corrective action. However, (1) contaminant hazards may exist that remain undetected because of limitations in the methods employed (concealed visual evidence, etc.) and/or (2) new contamination hazards may develop in the future. For these reasons, the measures employed herein for identifying contaminant hazards should be revisited periodically for this assessment to remain current.

In an effort to help confirm this suspicion of commingling groundwater through the Well 1 bore, MDE was helping the Town develop a plan to perform a downhole camera survey prior to our involvement. Records of the 1936 construction of Well 1 reflect 8-inch diameter casing installed to 256 feet (Appendix C). Based on this, ALWI became concerned that the planned downhole camera would reveal Well 1 to be open to the unconfined aquifer only if the well casing were either:

- Perforated shallowly in a manner not reflected in the 1936 drilling report; and/or

- Installed differently than reflected on the available drilling records.

Based on experience, we judged both of these explanations to be improbable. A more likely explanation involved the possible absence of adequate well grout outside the main casing, whereupon effective short-circuiting could cross-connect the two aquifers.

ALWI contacted MDE and expressed a concern that the planned downhole camera survey would not identify openness to both aquifers (or not) with certainty. Since downhole camera surveys cannot record conditions outside well casings, the aquifer interconnection through the annulus (our hypothesis) would remain undetected and unverified. Performing a sonic bond log, which would allow acoustical verification of the presence of grout, would be far more costly than the planned camera survey. We understand that plans for the expenditure on the downhole camera survey were suspended.

Instead, ALWI used existing water quality data to interpret a probable condition of Well 1 being open to both the unconfined Columbia and Frederica Aquifers, as presented and discussed in Chapter 3.0 herein. Thus, the MDE hypothesis is supported, and we share the concern. Our assessment of its nitrate susceptibility is summarized in Section 4.1 and its abandonment is recommended in Section 8.2.

2.5 POTENTIAL POINT SOURCE CONTAMINATION HAZARDS (OBSERVED)

ALWI observed the following potential point source hazards:

A. **Apparent Concentrated Animal Feeding Operations (CAFOs) -** CAFOs can be point sources of nutrients derived from organic compounds, which involve the conversion of animal wastes into nitrate. Nitrates and associated organic compounds generally are soluble in water, can infiltrate the soil surface and can percolate into unconfined aquifers as recharge. One apparent CAFO exists southeast of the well field, near the edge of Zone 2A. A second apparent CAFO exists outside Zone 2A but within a few hundred feet of its delineated perimeter.

B. **Municipal Sewage Sludge Application Area -** In 2001, ALWI observed a small area of Zone 2A approved for use for the disposal of municipal sewage sludge. At the time, this area displayed verdant vegetation but otherwise did not possess visual indication of contaminant releases or environmental stress. We understand that municipal sludge application in this area continues to be permitted by MDE, but we performed no confirmatory file reviews or other assessments of the composition, transport or specific fate of the sludge and compounds therein.

C. **Farm Dump** - In 2001, ALWI observed an informal refuse disposal area near the far southeastern boundary of Zone 2A. Most of the disposed materials consisted of building debris, junked vehicle parts and components of old machinery. ALWI also observed 55-gallon drums, 275-gallon tanks and oil-stained soil in this location. No stressed vegetation was observed and no other information was available. A 2011 aerial photograph confirmed the continued existence of this informal dump.

2.6 POTENTIAL POINT SOURCE CONTAMINATION HAZARDS (INFERRED)

Based on research but only indirectly supported by field observations, ALWI came to infer the possible existence of potential sources of nutrient contamination of the surficial aquifer in or near the delineated areas. The following four inferred sources are presented in decreasing order of likelihood of continuing effect:

1. **Sewer System Leakage -** We came to appreciate the potential for one or more discrete leaks from the municipal sewer collection system. ALWI observed sewer system manhole covers along streets within and near the delineated areas. As explained in Section 4.3, such leaks and potential leaks are thought to exist (generally, in Town).

2. **Relict / Continuing Domestic Septic Discharges** - Any septic system (relict or still existing) within the SWPA may leach nitrate-laden effluent into the unconfined surficial aquifer. The 2008 Town Comprehensive Plan references two properties within the Town that use septic systems. The Town advises that they are unaware of any properties within the Town or SWPAs that use septic systems.

3. **Private Wells** - Based on historically allowable practices, privately owned wells may exist in the SWPAs, in Town or otherwise. Any possible private wells in Town may act as a conduit for surface contamination into one or both water supply aquifers.

4. **Residual Effect of Past Fertilizer Emplacement** - In 2001, ALWI learned of a past practice (i.e., predating 2001) of on-ground, natural fertilizer storage to support truck farming of the tract immediately southeast of the well-field. At the time, we were informed that MDE and Maryland Rural Water Association personnel observed both the accumulation and its later removal. While we judge that sufficient time probably has elapsed for a water quality effect to dissipate (given typical processes of natural attenuation, dilution and migration), we believe that some level of residual effect or condition is possible.

2.7 NON-POINT SOURCE CONTAMINATION HAZARDS AS SUGGESTED BY LAND USE

MDE guidance suggests consideration and mapping of the municipal sewer service area and the following classifications of land use within the wellhead protection delineated areas: agriculture, forest, residential, industrial, commercial, public lands and mined lands.

ALWI obtained 2010 land use Geographic Information System data for the SWPAs for these and other related land uses, as well as the municipal sewer service area (Figure 2) from the Maryland

Department of Planning. Land use information for 12% of Zone 2A was unavailable, as that portion represents the area of Zone 2A that extends into Delaware. Based on a reconnaissance performed from public roads and highways, we believe the Delaware portion of Zone 2A is agricultural land.

Pertinent land use acreages and percentages by SWPA (for the areas in Maryland) are listed in Table 2. Dominant land uses within the SWPAs are agricultural lands (Zone 2A), low to medium density residential (Zones 1, 2B and 3) and publicly/institutionally owned lands (Zone 1). Relatively small areas are in commercial, institutional and forested uses (Table 2).

Considerations and implications of the land use review include:

- **Agricultural Land Use Practices** - Agricultural land may be fertilized or treated with herbicides. Agricultural lands within the SWPAs (particularly Zone 2A) may act as potential non-point sources of nitrate contamination to the Town well field.

- **Inappropriate Domestic Waste Discharges** - Liquid petroleum products commonly are used as a heating fuel. If residents in unsewered areas discharge waste into their septic systems, such discharges are more likely to enter the groundwater and contaminate the water source.

3.0 CONTAMINANT SUSCEPTIBILITY

ALWI completed a review of available groundwater quality records, integrated with other findings herein, to support an assessment of groundwater susceptibility. MDE guidance defines a threshold for regarding a water source being “susceptible” to a given contaminant as being either:

- When the concentrations exceed 50% of the Maximum Contaminant Level (MCL); and/or

- When a persistent but lower concentration is either increasing or chemically appears associated with an unknown or unexpected source.

In addition to these water quality data considerations, ALWI also considered the following factors in evaluating overall susceptibility:

1. The spatial position of sources of potential contamination relative to the wells;

2. Observed conditions of wellhead integrity and housekeeping; and

3. The natural chemical properties of the source water within contributing aquifers.

3.1 WATER QUALITY DATA REVIEW PROCEDURES

ALWI completed the susceptibility assessment in accordance with the following step-wise procedure:

1. **Obtain and Filter Water Quality Databases -** ALWI reviewed available electronic databases of water quality analyses provided by MDE for the period 2001 to 2011. These databases were filtered to isolate only contaminants affecting Town groundwater supplies.

2. **MDE Compliance Database Review** - The furnished databases were developed by MDE as an incidence of operational compliance record-keeping. They contained analytical records for inorganic compounds (including radiological species), and volatile and synthetic organic compounds. The electronic water quality databases reflect post-treatment, composite water samples and not raw groundwater sources, unless otherwise noted herein. As such, mixing, blending and treatment efficacy hampered correlating specific water quality findings to specific wells, aquifers and contributing SWPAs, with the exception of nitrate and DBP precursors.

3. **Raw Well Water Quality Review** - To gain a more thorough understanding of raw water quality by well, ALWI supplemented the MDE databases with laboratory reports available in MDE and Town paper files. We obtained well-specific nitrate sampling results from 2006, 2009, 2011 and 2012. Additionally, we obtained some raw water analyses from 2009 and 2011 for chloride, fluoride, Total Organic Carbon (TOC), total dissolved solids and pH.

4. **Identify "Exceedance" Instances** - To identify water quality sample exceedances, we compared each specific analytical result to published MCLs (in COMAR 26.04.01 as of September 2011). Guided by MDE, we judged a concentration of greater than or equal to 50% of a given MCL to be an "exceedance." Procedurally, this was accomplished by sorting the data by analyte and concentration and by well (to the degree possible).

5. **Assess Frequency and Relative Percentage of Exceedance Instances** - The number of times that a given analyte was detected in a concentration greater than 50% of its respective MCL was discerned in terms of overall frequency, percentage of total number of samples and date range of exceedance. Contaminants with results equaling or exceeding 50% of the MCL more than 10% of the time were considered *prima facie* susceptible. ALWI also identified changes in contaminant trends over time, even for those that did not equal or exceed 50% of the MCL more than 10% of the time.

6. **End-Member Mixing Analysis -** ALWI used End-Member Mixing Analysis (Koh and others, 2012) to help correlate the available water quality results from Well 1 (possibly open to both the Columbia and Frederica Aquifers) to water quality data sets considered to represent exclusively unconfined (Wells 4 and 5) or confined (Well 6) conditions. Our End-Member Mixing Analysis is detailed in Section 3.3. This technique is widely used to assess relative contributions made by multiple source waters within a possibly-mixed sampling source of interest.

7. **Integration -** ALWI then considered these identified exceedances in the context of the results of the contamination hazard reconnaissance to correlate water quality results to specific field observations suggestive of a condition of susceptibility.

3.2 RESULTS

By applying the procedures set forth in Section 3.1, we found the Town's system susceptible to the following contaminants:

- **Nitrate** - Nitrates are present in the unconfined Columbia Aquifer (i.e., Wells 4 and 5) at concentrations up to 10.2 mg/L and 19.7 mg/L, respectively, which is above the established MCL of 10 mg/L. Even after blending, distribution system nitrate concentrations generally are above 50% of the MCL. Accordingly, ALWI interpreted continuing nitrate susceptibility, similar to 2001. This condition remains due to the presence of contaminant sources in the SWPA (Figures 1 and 2) and the presence of elevated nitrate concentrations in recent samples (Figure E1 in Appendix E). We further discuss nitrate susceptibility in Chapter 4.0.

- **Disinfection By-Product (DBP) Precursors** - DBPs are present in the Town distribution system at concentrations up to 139.6 µg/L (of total trihalomethanes), which exceeds the established MCL of 80 µg/L. DBPs are not naturally-occurring groundwater constituents themselves, but instead form as a consequence of mixing chlorine (used for water disinfection in the treatment system) and naturally-occurring DBP precursors in groundwater, measured as TOC. EPA (Definition No. 415.3) defines TOC as "the gross amount of organic matter found in natural water, [including] suspended particulate, colloidal, and dissolved organic matter…" MDE interpreted that TOC, detected in the Frederica Aquifer at concentrations up to 4.8 mg/L (in 2009), is the likely cause (i.e., precursor) of the DBP condition. Other hypotheses regarding the root cause of the DBP exist, but no other hypotheses seem to possess equal support. We further discuss DBP precursor susceptibility in Chapter 5.0.

Using post-treatment composite water quality data provided by MDE, we did not find the Town's system susceptible to other groundwater contaminants (Table 3). Salient interpretations include:

- **Other Inorganic Compounds -** Barium (in composite samples) and fluoride (in raw samples) were detected at very low concentrations, not exceeding the 50% MCL threshold (1 mg/L and 2 mg/L, respectively). Fluoride was only detected in Wells 6 & 1. Concentrations in Well 6 ranged from 0.72 mg/L to 1.06 mg/L (2009) without an increasing trend. Fluoride was not detected in Well 1 until 2011, when it had a concentration of only 0.16 mg/L. Fluoride in these deeper wells is likely of natural origin.

- **Radionuclides –** Radionuclides, measured as Gross Alpha and Gross Beta radiation, were not detected above 50% of their MCLs. Gross Alpha and Gross Beta were detected in low concentrations, and these are believed to have originated from the natural radioactive decay of subsurface deposits.

- **MTBE -** Methyl Tertiary-butyl Ether (MTBE), a gasoline additive that aids in combustion, was not detected above 50% of the current action level of 20 µg/L. Trace amounts of MTBE were detected in 2006 and 2007, but MTBE has not been detected in three subsequent samples since then.

- **Vinyl Chloride** - This volatile organic compound exceeded the 50% MCL threshold in one of the 18 samples, but has not been detected in ten subsequent samples since its detection in 2005. Vinyl Chloride primarily is used to manufacture a variety of construction, automotive and other products (EPA, n.d.).

3.3 END-MEMBER MIXING ANALYSIS

To evaluate the hypothesis that Well 1 is open to both aquifers, ALWI employed the following step-wise procedures for developing an end-member mixing analysis (selecting constituents typically sampled by the Town for compliance purposes and having source-specific data dating back to 2009):

1. **Selection of Chemical Constituents** - The first chemical constituent selected was chloride, a conservative ion, commonly used as a tracer, because it is not readily adsorbed, and for its resistance to oxidation-reduction reactions. The second chemical constituent was nitrate, which can be used as a conservative ion, while acting as an indicator for additional sources of contamination. It stands to reason that elevated nitrate concentrations typify unconfined, surficial aquifers more so than deeper, confined aquifers (like the Frederica) in this hydrogeologic setting. Agricultural practices and the existence of septic/sewer systems commonly are contributors of elevated nitrate concentrations in the surficial aquifer. Conversely, chloride concentrations tend to increase with depth (i.e., in the Frederica Aquifer) due to a regional tendency for more brackish groundwater to be present (Cushing and others, 1973).

2. **Selection of Representative Wells** - We first selected wells to represent the end-members, or most representative wells of the unconfined and confined aquifers. We selected Well 4 to represent the unconfined Columbia Aquifer because nitrate concentrations remained relatively constant over time, compared to Well 5, the only other Town well in the surficial aquifer (Figure E1). Nitrate concentrations in Well 4 are also closer to concentrations typical of these aquifers compared to Well 5 (Cushing and others, 1973). Well 6 was the only available Town well known to be screened only in the confined, Frederica Aquifer. We noted that Well 4 water quality data plotted in a manner indicative of an unconfined, surficial aquifer (relatively high nitrate and low chloride). Conversely, Well 6 water quality data plotted in a manner indicative of a deeper, confined aquifer (no nitrate and relatively high chloride). These findings are supported by available well construction information and first-hand knowledge of Town officials.

3. **Construction of "Mixing Line"** - Once the data for Wells 4 and 6 were plotted, we extended a "mixing line" connecting the points representing each of these wells (Figure E2). This mixing line illustrates the range of expected nitrate and chloride concentrations for a hypothetical well or wells in which water may represent the commingling of the two end-member aquifers, in various proportions. For example, water from a well that falls on the line halfway between the two end-members would be interpreted as having received 50% of its water from each aquifer.

4. **Relation of Mixing Line to Well 1** - We found that Well 1 fell close to (but slightly above) the mixing line between Wells 4 and 6, but was chemically closer to Well 4 than to Well 6.

Despite its reported depth of casing and screen, the mixing plot suggests that Well 1 is more similar (chemically) to the unconfined aquifer than the confined aquifer.

Section 4.2 presents the use of the end-member mixing plot to infer a point-source of nitrate contamination affecting Well 5, and likely Well 1.

3.4 SUSCEPTIBILITY MANAGEMENT THROUGH SOURCE BLENDING

Sharptown relies on blending Wells 4, 5 and 6 to meet drinking water standards.

- **Nitrate Management** - By mixing these sources, the average concentration of nitrate in the distribution system is less than the concentration in either of the shallow wells.

- **DBP Management** - Water withdrawn from the Frederica Aquifer contains elevated concentrations of organic matter (measured as TOC). This organic matter, when mixed with the chlorine used for disinfection, forms DBPs in the distribution system. The Town balances this circumstance by relying as heavily on Wells 4 and 5 as nitrate concentrations will allow.

ALWI provides recommendations to help address these circumstances in Chapter 8.0.

4.0 DISCUSSION OF NITRATE SUSCEPTIBILITY

ALWI believes that both point and non-point sources contribute to the continuing condition of nitrate susceptibility. To us, this finding was unexpected because earlier assessments only identified non-point agricultural land uses as a continuing concern. In the following sections, we:

- Review nitrate findings on a well-by-well basis;

- Discuss evidence for the presence of a point-source(s) that previously was not present or not appreciated; and

- Discuss non-point nitrate susceptibility.

4.1 NITRATE SUSCEPTIBILITY BY WELL

Our findings for nitrate susceptibility, by well, are as follows:

- **Unconfined Well 4 (Plant ID 01, Source 04) -** Well 4 is susceptible to nitrate contamination. Raw nitrate samples indicate that concentrations of nitrate in this well remain relatively constant over time, slightly below or above the MCL of 10 mg/L (Figure E1).

- **Unconfined Well 5 (Plant ID 01, Source 05)** - Well 5 is susceptible to nitrate contamination. Raw nitrate results from 2006 (15.7 mg/L) and 2009 (19.7 mg/L) indicate that concentrations of nitrate in this well were increasing over time through 2009. The two samples both exceeded the MCL of 10 mg/L. An additional sample collected from this well in 2011 had a concentration of 13.8 mg/L. Despite the apparent decrease in nitrate concentration, we judge the well to remain susceptible since the sample result still exceeds the MCL. The most recent sample, collected in July 2012, had a concentration of 14.8 mg/L.

- **Confined Well 6 (Plant ID 01, Source 06)** - Nitrate was not detected in the raw water samples provided for this well. We concluded that Well 6 is not susceptible to contamination by local (point or non-point) nitrate sources. Despite this favorable finding, ALWI nevertheless recommends that the Town continue to sample Well 6 for nitrate. We deem this a wise precaution given the possibility of cross-contamination of the deeper aquifer through Well 1, which available evidence suggests is open to both the confined and unconfined aquifers. Notwithstanding this possibility of cross-contamination, and based on available data, Well 6 is not susceptible to nitrate until water quality data prove otherwise.

- **Well 1 (Plant ID 01, Source 01)** - Well 1 is susceptible to nitrate contamination, further suggesting its hydrologic connection to the shallow, unconfined aquifer. Raw water samples from 2009 and 2011 reflected concentrations of 10.9 mg/L and 10.7 mg/L, respectively. We hypothesize that during non-pumping conditions, improper or absent grouting, a leak in the well casing, or the existence of additional shallow screen, allows groundwater from the surficial aquifer to enter the well. A sub-parallel shift along the mixing line between 2009 and 2011 (Figure E2) suggests that this leaked water may be diluted under pumping conditions by nitrate-free water from the confined Frederica Aquifer. The most recent sample, collected in July 2012, had a concentration of 12.2 mg/L, the highest concentration in the limited raw water quality records for this well.

4.2 MIXING ZONE INTERPRETATION SUPPORTS NITRATE POINT SOURCE(S)

We displayed Well 5 on the mixing plot, which allowed graphical interpretation of the probable presence of a previously unknown nitrate point source affecting the surficial aquifer near Well 5, based on:

- **Wells 4 and 5 Having Dissimilar Nitrate Trends Through Time -** If the nitrate were exclusively non-point (and thus, regional) in origin, Wells 4 and 5 should have similar nitrate concentrations and likely would display similar variations in nitrate concentrations over time. Wells 4 and 5 possessed considerably different nitrate concentrations in 2009, with Well 5 having approximately twice the nitrate concentration of Well 4. Well 4 nitrate concentrations remained essentially unchanged, and probably represent a background level of susceptibility to non-point sources. By comparison, over the same four-year span, Well 5 nitrate concentrations were higher and variable.

- **Higher Well 5 Nitrates Suggesting Proximal Point Source -** The oval on Figure E2 represents nitrate outliers, with respect to the mixing line defined by Wells 4 and 6. The substantially higher nitrate concentrations without a corresponding change in chloride concentrations in Well 5, compared to Well 4, suggest that an additional source (likely a proximal point source) is contributing nitrate contamination to Well 5 (and likely Well 1). Well 4's chemistry probably reflects non-point agricultural sources. The comparatively increased nitrate concentrations in Well 5 likely are attributed to a point source of contamination positioned proximal to Well 5.

4.3 LEAKING SEWER SYSTEM AS POTENTIAL POINT SOURCE FOR NITRATE

Based on the information developed for this update, consultations with MDE and our field observations, we interpreted that Well 5 is affected by a nitrate point source. ALWI believes that the most plausible point source of nitrate is a leak in a nearby Town sewer line. This hypothesis was supported by the following three concepts:

1. **Relationship of Nitrate Concentrations and Groundwater Levels** - We analyzed a groundwater hydrograph from USGS Groundwater Monitoring Well No. 383225075565002, which is located approximately 11 miles west of Sharptown (in Linkwood). Figure E3 shows that nitrate concentrations in unconfined Town Well 5 rose when Linkwood water levels were deepest (2009) and declined when Linkwood groundwater elevations were shallowest (2006 and 2011).

    - Nitrate concentrations in Well 5 were highest when the water table descended presumably to a depth below the nearest gravity sewer main(s). Because of the absence of natural hydrostatic pressure in the unsaturated soil during such times, nitrate-laden sewage effluent could cascade from a leaking sewer main into the water table below (Figure E4). Conversely, during periods when the water table is elevated, hydrostatic pressure would inhibit such leakage and cause the nitrate concentrations in groundwater to decline (Figure E5).

    - ALWI performed a statistical correlation between groundwater table depth and nitrate concentration in Wells 4 and 5. We found a near-perfect, positive correlation ($R^2 = 0.99$) between depth-to-groundwater and nitrate concentration in Well 5, while Well 4 remained essentially unchanged (Figure E6). These statistics suggest that Well 5 water level fluctuations govern nitrate concentrations, whereas Well 4 nitrates are independent of water level changes, though this hypothesis was based on limited data from 2009 to 2011. This evaluation has since been updated to incorporate the results of our recommended July 2012 sampling sweep, and is further discussed in Section 7.5.

2. **Geochemical Considerations** - We considered that nitrates in sanitary sewer systems are derived from a biochemical process, in which urea (i.e., waste from humans) is converted to ammonium in low pH environments. Well 5 had a pH of 5.14 in 2011.

3. **Infiltration and Inflow Records** - The 2008 Sharptown Comprehensive Plan developed by Davis, Bowen & Friedel, Inc. (DBF) indicates that the municipal sewer system is prone to infiltration and exfiltration based on historic leaks, as evidenced by high wastewater treatment volumes during wet periods (when groundwater elevations are high). The report documented that tree roots have entered the pipes at various locations over the years, causing joint failures and cracks. ALWI observed sewer system manholes near Wells 1 & 5. This is supported by increased flows to the Town’s wastewater treatment plant, when groundwater levels were shallow enough to infiltrate the sewer system (Figure E5).

In Chapter 8.0 we recommend sampling of Wells 4 and 5 for ammonium and nitrite. A higher concentration of these in Well 5 than in Well 4 could further support the sewer system leak hypothesis. This is because of the probable proximity (and quicker inferred travel times) of the leak location(s). The depth below ground surface of the hypothesized sewer system leak may be sufficient to impede the complete oxidization-to-nitrate process. Ammonium and/or nitrite persisting from agricultural uses are less likely the source because these locations are further from Well 5 and sufficient time would likely exist for the nitrogen cycle to convert these into nitrate. However, due to uncertainties related to travel time, potential effluent spill location and well entrainment, it is possible that sewage effluent is oxidized to nitrate before reaching the well-field, potentially resulting in non-detects for ammonium and nitrite.

4.4 OTHER POTENTIAL NITRATE POINT SOURCES

Less plausible point sources for the nitrates in Well 5 include but are not necessarily restricted to the following:

1. **Septic Systems** - Any septic system (existing or relict) outside of the sewer service area, but within the SWPA may leach nitrate-laden septic effluent into the unconfined surficial aquifer. The 2008 Town Comprehensive Plan references two properties within the Town that use septic systems. The Town advises that they are unaware of any properties within the Town or SWPAs that use septic systems. If this information is inaccurate or mistaken, and if one or more of the buildings near Well 5 possesses an active septic system (or even a leaking sewer system connection), the difference in nitrates between Wells 4 and 5 could be readily explained.

2. **Local (to Well 5) Fertilization** - In spite of typically being categorized non-point sources of contamination, ALWI considered relatively small-scale fertilized lands immediately surrounding the well field (e.g., gardens) to act as identifiable point sources. We did not observe evidence of over-fertilization on plots immediately surrounding Well 5. Had this been observed, the elevated nitrate concentrations in Well 5 could be explained by the excessive fertilization on nearby residential or agricultural plots. However, during the Steering Committee Meeting (Chapter 6.0), Town officials indicated that the only (previously) agricultural land within the 1-year time of travel zone was converted into a garden many years ago. MDP labeled this parcel of land as public land (Figure 2). To the recollection of Town officials, there are no large fertilizer users within Zone 1. However, some level of fertilization practice within Zone 1 remains a possibility.

4.5 NON-POINT NITRATE CONTAMINATION SOURCES

Agriculture dominates land use in the Sharptown area and likely has for centuries. Nitrates are a common fertilizer and farms and farm tracts are ubiquitous throughout and surrounding the SWPA.

In addition to agricultural application of nitrate-based fertilizers as a generalized, regional farming practice, the potential exists for nitrate to originate from animal waste at Confined Animal Feeding Operation (CAFO) facilities located in and near the SWPA (Figure 1). While a CAFO proximal to the well-field could constitute a point-source hazard, distance (the CAFOs are located over 1,500 feet from the well-field), dispersion and dilution make it less likely that CAFO practices affect one unconfined Town well more than another. During the Steering Committee Meeting (Chapter 6.0) MDE officials suggested that nutrients derived from CAFOs generally would be of greater concern if applied to adjacent agricultural fields than when merely stored on premises.

Note that ALWI did not directly observe accumulations or storage of such wastes from public rights-of-way. We did not otherwise observe indications of over-fertilization or animal waste leachate mismanagement at the CAFOs. We presumed but did not verify the active enforcement and appropriateness of nutrient management plans for CAFOs within the SWPAs.

4.6 NITRATES AS CHEMICAL BYPRODUCT OF DISINFECTION

Sources indicate the possibility that nitrate concentrations (in the distribution system) may increase as an inadvertent byproduct of required water disinfection. Yang and Cheng (2007) suggest that nitrite oxidizes to nitrate when exposed to chlorine. The study found that a residual chlorination level of only 0.3 mg/L can cause more than 99% nitrite oxidation under typical drinking water treatment conditions.

If nitrite is detected in raw system water, consideration could be given to a disinfection process less reliant on chlorine. Ozonation and ultraviolet radiation are two such processes; the feasibility of their use in Sharptown is a question left as a future recommendation.

5.0 DISCUSSION OF DBP PRECURSOR SUSCEPTIBILITY

ALWI found that Well 6 probably is susceptible to DBPs, given that it maintains a high level of TOC, which MDE regards as a potential precursor to the formation of DBPs in the distribution system. DBPs do not themselves occur in groundwater, naturally or otherwise (except in the rare circumstance of a distribution system leak). DBPs form as a consequence of mixing chlorine with organic matter-enriched water (indicated by TOC).

5.1 INTER-RELATION OF DBPS, TTHMS AND TOC

One of the most common measures of DBPs is Total Trihalomethanes (TTHM), which is the sum of several closely related chlorinated methane compounds. TTHM exceeded the 50% MCL threshold in 52 of the 60 post-treatment, composite samples, with 35 samples at or above the MCL of 80 µg/L (Table 3).

Based on limited sampling in 2009, TOC concentrations of 1.2 mg/L and 4.8 mg/L were detected in Wells 1 and 6, respectively. In 2011, TOC concentrations were 1.6 mg/L and 4.8 mg/L in Wells 1 and 6. In 2012, TOC decreased in both of these wells, to a concentration of 1.31 mg/L in Well 1 and 4.5 mg/L in Well 6. TOC was not detected in either Well 4 or 5 in 2009 or 2011. As further discussed in Section 7.4, TOC was detected for the first time (to our knowledge) in Wells 4 (0.923 mg/L) and 5 (1.55 mg/L).

5.2 TOCS OF LIKELY NATURAL ORIGIN

Elevated TOC results can originate both from natural organic matter and from synthetic sources. Synthetic sources may include fertilizers, pesticides and herbicides. The consistent presence of TOC in the confined aquifer during a time predating the presence of TOC in the shallower, unconfined aquifer suggests a natural origin in the confined aquifer at Sharptown.

5.3 INCREASED CHLORINATION INCREASES DBP CONCENTRATIONS

Organic compounds, such as urea from human waste, break down into ammonium. In turn, ammonium interferes with chlorination processes, reducing the effectiveness of treatment and increasing the need for additional chlorination. Relict ammonium originating from the breakdown of organic compounds (such as waste) that has not been converted to nitrite or nitrate could further increase DBP concentrations.

6.0 STEERING COMMITTEE INTERACTIONS

ALWI, along with MDE representatives from the Water Supply Program, met with the Sharptown Steering Committee on Wednesday, June 28, 2012. The Steering Committee was comprised of Town and Wicomico County Health Department officials and its contracted utility engineering firm of DBF.

ALWI presented a slide show summarizing its source protection findings and recommendations at that time. Salient topics of discussion included:

1. **Groundwater Susceptibility as Suggested by Water Quality Data** - We discussed data limitations supporting definitive interpretations of raw groundwater susceptibility. At the time of our meeting we identified nitrate in the unconfined aquifer as a primary concern, with concentrations above the MCL in Wells 5 and 1 and close to the MCL in Well 4. Blending with water from the confined Frederica Aquifer appears to help reduce the concentration of nitrate in the finished water. However, the presence of likely naturally occurring organic matter (indicated by high TOC in Well 6) reacts with chlorine to form disinfection byproducts at concentrations approaching and sometimes exceeding the MCL for TTHM. We recommended additional raw source groundwater sampling to support more definitive susceptibility interpretations.

2. **Further Discussion of Nitrate Susceptibility -** From a land use perspective the groundwater sources in the unconfined Columbia Aquifer are susceptible to contaminants arising from agricultural and residential land uses. We discussed how agricultural land uses likely contribute nitrate at concentrations within Well 4 close to the MCL, as evidenced by our analysis of nitrate and chloride data. We then discussed how Well 5 and Well 1 appear further impacted by a more proximate nitrate point source. As explained in Section 4.3, we believe that elevated nitrate concentrations in these wells could result from a sewer leak that is controlled by a fluctuating seasonal water table. For the entire well field, Town officials ruled out the possibility of nitrate contamination from septic systems, stating that no septic systems or large-scale fertilization practices exist within Town limits.

3. **Additional Water Quality Sampling Recommendation -** During the meeting, we recommended that the Town consider additional water quality sampling using the existing set of required parameters (e.g., nitrate, chloride, etc.) to build upon the existing database, but with the addition of Methylene Blue Active Substance (MBAS) testing. This test typically is used to verify the presence of optical brightening dyes found in most commercially-available

laundry detergents. The presence of MBAS can indicate that the water is contaminated by domestic sewage (presumably from sewer lines in this case).

4. **Abandonment of Well 1 and Future Replacement With New Well 7** - We discussed how the chemistry of Well 1 suggests the well is open to both aquifers, potentially lessening the efficacy of any aquifer-specific protective strategy (in addition to being prohibited under current regulations). ALWI came to recommend (and MDE agreed) that Well 1 should be abandoned and sealed, as reconstruction would likely cost more than replacement. The discussion turned to assessing whether relevant yield and capacity requirements (i.e., the “Best Well Out Scenario”) can be met with a three-well system (Wells 4, 5 and 6). We also discussed the benefit of commissioning a hydrogeologic evaluation focused on verifying the present sustainable capacities of each well and/or choosing the site of a prospective “Well 7,” preferably elsewhere in the Frederica Aquifer.

5. **Grants as Funding Mechanism for Capital Improvements -** We discussed ALWI’s research into federal grants for funding source water protection measures, including our conclusion that they were not applicable or feasible. We researched the potential availability of grant support from the Conservation Reserve Enhancement Program (CREP), but found the specific terms of CREP funding to be too onerous on participating farmers for the Town to embrace and champion.

6. **Public Workshop** - We discussed the prospect of a public workshop, and its benefit in garnering proactive neighbor and citizen buy-in regarding non-proscriptive source water protection. Town officials expressed interest in holding such a workshop, with the intent on inviting local farmers and landowners to discuss ways to reduce non-point nitrate contamination in the unconfined aquifer.

7.0 SUPPLEMENTAL DATA COLLECTON AND ANALYSIS

As per our recommendation during the Steering Committee Meeting, the Town collected raw water samples from all four wells on July 12, 2012. The Town arranged for laboratory testing of each collected sample for our recommended constituents, including MBAS to assess possible sewer line leaks. Appropriate updates have already been made to our end-member mixing analysis (Figure E2) and nitrate versus time analysis (Figure E1). Our updated findings are presented below.

7.1 NITRATE SUSCEPTIBILITY

We continued to observe elevated nitrate concentrations in the unconfined Columbia Aquifer. In July 2012, Well 5 had a nitrate concentration of 14.8 mg/L, one milligram higher than the sample collected in the previous April. Well 1 had a nitrate concentration of 12.2 mg/L, the highest we have seen in the limited data available for this well. Well 4 continued to show relatively little change in nitrate concentration over time, with a recent sample at 10.2 mg/L. Nitrate was not detected in Well 6.

Based on the above nitrate sampling results, we found that the wells previously determined to be susceptible to nitrate contamination (Wells 1, 4 and 5) remain susceptible. Well 6, which did not have a nitrate detection in the July 2012 sample, remains not susceptible.

7.2 Nitrate to Chloride Ratios

Both Wells 1 and 5 exhibited fluctuations in their nitrate to chloride ratios, with both wells showing an increase in nitrate to chloride ratios since the 2011 sampling event. The nitrate to chloride ratio in Well 4 remained much the same as in previous sampling events, suggesting that Wells 1 and 5 continue to be impacted by proximate nitrate point source(s) whereas Well 4 is not impacted.

Since nitrate has not been detected in Well 6, we cannot generate a simplified nitrate to chloride ratio for this well. However, the concentration of chloride in this well increased by approximately 23 mg/L compared to previous sampling events, resulting in a horizontal shift to the right on the end-member mixing plot (Figure E2).

7.3 MBAS Sampling Results

To test our hypothesis that a leaky municipal sewer system was acting as a point source(s) of nitrates detected in Wells 1 and 5, we asked the Town to have their four wells sampled for MBAS. Positive MBAS findings, particularly in Wells 1 and 5 would support our hypothesis[2]. The confined aquifer well (Well 6) was our control well. With no nitrates detected in Well 6, we did not expect to find MBAS in this well either.

MBAS tested positive in Well 1 (0.0810 mg/L) and unexpectedly, Well 6 (0.0490 mg/L). The concentration of MBAS in Well 1, which was approximately twice as high as the concentration in Well 6, suggested that the source of MBAS originates closer to Well 1 than Well 6. A positive MBAS test, which would signify the presence of anionic surfactants found in some forms of pesticides (though there were no detections of pesticide related SOCs in Town water samples), would not be expected for water originating from a fully confined aquifer. To check the possibility of sampling or laboratory error (e.g., a bottle labeling mix-up), we recommended repeat sampling. However, the Town did not accept this suggestion.

Nitrate and chloride sampling suggest that Well 1 is open to both aquifers. We hypothesized that water originating from sewage effluent near Wells 1 and 5 may enter Well 1, and travel vertically through the well, where it may travel into the confined Frederica Aquifer. Once present in the confined Frederica Aquifer, such water may be entrained by the active pumping of Well 6.

Comparatively, the absence of a positive MBAS test in Wells 4 and 5 does not mean that these wells cannot be affected by sewage effluent. Water in the unconfined Columbia Aquifer in Sharptown follows the natural gradient to the northwest. If a sewer line leak exists in the proximity of Wells 1 and 5 along State Street, for example, then water within the cone of

[2] MBAS is an imperfect test for surfactants, when performed in agricultural areas where pesticides may have been used. Denver (1989) found that certain MBAS species also can be indicative of pesticide manufacture or use. However, given the potential utility of the findings and the economy of the test, those present at the Steering Committee meeting concurred on this course of action.

depression generated by Well 5 would move against the natural gradient to reach the well. It may take longer for pumping induced water originating from a suspected sewer leak to migrate into Well 5 and manifest as a positive MBAS sampling result.

In 1999, the USGS published a study in which they identified nitrate sources contributing to groundwater in the Indian Hills Area of Douglas County, Nevada. In the study, the researchers collected water samples from effluent ponds and wells in surrounding fields irrigated with this effluent to evaluate the chemical characteristics of sewage effluent from the Indian Hills residential area and possibly effluent-contaminated groundwater. MBAS was measured at 0.11 mg/L in samples taken directly from the effluent ponds (Thomas, 1999), which is only 0.03 mg/L higher than the concentration of MBAS detected in Well 1 in Sharptown.

More raw water data would need to be collected to further accept or reject our sewage effluent hypothesis. MBAS in the confined Frederica Aquifer may originate from alternative unidentified or unappreciated sources, such as unknown and improperly constructed private wells screened within the Frederica Aquifer.

7.4 Other Water Quality Observations

In addition to the water quality trends discussed above, it was noted that TOC was detected for the first time (to our knowledge) in the raw water from Wells 4 (0.923 mg/L) and 5 (1.55 mg/L). TOC concentrations decreased slightly in Wells 1 and 6 since the last sampling event (2011). Given the lack of available data, it is difficult to determine the source of TOC in the unconfined Columbia Aquifer during this sampling period. It may or may not (whether in part or in whole) be related to sewage effluent from a potential leak. Other factors, such as natural soil organic matter should be considered. More data would need to be collected to understand this trend to see if it persists.

7.5 Update to Correlation Graph

As mentioned in Section 4.3, the additional sampling event performed on July 12, 2012 merited an update to our hypothesis of correlating nitrate concentration with depth to water table graph (Figure E6). As hydrograph data was not taken on the date of sampling, it was estimated the actual water level based on water level measurements taken approximately two weeks before and after the sampling event. In comparing the nitrate concentration in Well 5 with perceived water level data in the Linkwood well, a significant decline was noted in the linear R^2 coefficient from 0.99 to 0.26, largely because this trend is based on limited data.

Additionally, it was noticed that water levels declined at a slower rate this year (2012) than in previous years, such as 2009, when the nitrate concentration in Well 5 was significantly higher. Adequate time may not have passed for a recently exposed sewer line leak to manifest as increased nitrate data in surrounding wells. Generally, Figure E3 still shows an increase in nitrate concentrations in Wells 1 and 5 as water levels decline, whereas Well 4 remains relatively constant. Additional frequent sampling during the summer months may depict an increase in nitrate concentrations relative to depth, resulting in a stronger R^2 coefficient. The sewer leak, if present, may not manifest itself similarly each summer due to the rate of decline in water level, which stems from changes in precipitation each year.

7.6 NO CHANGES TO PREVIOUS INTERPRETATIONS

After meeting with the Sharptown Steering Committee, analyzing the 2012 water quality samples, and updating our findings, it is our opinion that a potentially leaking sewer line remains the most likely source of nitrate contamination for Wells 1 and 5. Generally, it remains our opinion that Well 4 primarily reflects non-point nitrate contamination (in unconfined Town wells) originating largely from agricultural land uses. The findings documented in this report are supported by raw data that come from system wells within the Town well-field, which represents a small area compared to the overall SWPA. Concentrations of measured constituents may be different in other portions of the SWPA.

Furthermore, we note that wells contaminated with domestic wastewater in the USGS report from Indian Hills depict similar trends to Well 5 in Sharptown. The USGS identified “elevated specific conductance values, elevated major-ion, minor-ion, trace-element, nutrient, and chlorofluorocarbons (CFC) concentrations as being indicative of sewage effluent.” Higher concentrations of nitrate, total dissolved solids, chloride, and TOC (when detected) in Well 5 compared to Well 4, suggest that Well 5 is differentially impacted by a nitrate source. This is further supported by the lower pH in Well 5. The available data suggest that Wells 1 and 5 could be impacted by sewage effluent and are not as easily explained otherwise.

8.0 RECOMMENDATIONS

After careful consideration of factors including cost and practicality, ALWI recommends the following:

8.1 INVESTIGATIVE RECOMMENDATIONS

Below, in order of decreasing priority, is a list of measures that we recommend for immediate consideration, funding and implementation. The execution of these measures is recommended in order to help verify certain findings that presently are tenuous because of limited data, the budget supporting this effort and/or the non-invasive nature of SWPP development efforts.

1. **Continued MBAS Sampling and Analysis** - The MBAS test remains a low-cost laboratory procedure that verifies the presence of optical brightening dyes found in most commercially-available laundry detergents. For other projects we successfully used MBAS water quality testing to assess whether water has been contaminated by domestic sewage (from sewer lines or septic systems). The method has withstood technical and legal scrutiny. A single round of samples does not refute our hypothesis that Well 5 is affected by sewer line leakage and/or relict septic systems. Resampling should be considered before more costly investigative and remedial measures are considered.

2. **Integrate More Frequent and Sweeping Compliance Testing -** We recommend augmenting periodic water quality compliance sampling with raw water, well-by-well nitrate, nitrite, ammonium, TOC, MBAS, chloride and MBAS analyses until such time that the (1) residual uncertainties identified herein are addressed and (2) effectiveness of corrective actions may be documented. We recommend sampling more frequently during the summer

and fall months (June through November), when the water table generally is lower and cracked sewer lines may permit sewage effluent to enter the unconfined aquifer.

3. **Perform Sewer Line Inspections** - DBF found that the sewer lines are prone to leakage because of a combination of their age, construction materials and methods of installation. Our circumspect finding that the sewer system leak(s) may be imparting nitrates to Well 5 could easily be verified by performing limited sewer line inspections within a few city blocks of Wells 1 and 5. Considering the low topographic gradient, the odds are greatest that a leak, if present, is located within a few blocks of Wells 1 and 5. Consideration should be given to lessening the prioritization of this step if MBAS remains undetected in Well 5, following further sampling performed during future summer and fall months (June through November). MDE officials have suggested that the Town consider contacting the Maryland Rural Water Association (MRWA) to find out if a sewer leak inspection can be completed for free. We agree with MDE and suggest that the Town contact MRWA to see if they can accommodate this service.

4. **Verify Absence of Relict Supply Wells** - Although we did not observe relict wellheads, the absence of continuing or relict supply wells within or near the Zone 1 SWPA should be verified. Hand-installed and/or older wells (and their associated annular spaces) are particularly prone to being potential pathways for land surface contaminants to enter the aquifer system. A house survey by Town officials may be the best and most economic approach. If active or relict wells are identified, we recommend that they be properly and permanently abandoned.

5. **Locate and Review Documentation of Past Waste Removal Activities** - Our initial understanding of a past accumulation of nitrate-laden solid waste never was verified. Because we lack an understanding of the specific nature and position of this waste, we also lack a means to assess the completeness of the removal action, as it occurred sometime prior to our initial service to the Town in 2001. ALWI suggests that the possibility of incomplete removal could have resulted in the continuing presence of some proportion of relict waste on the land or in the shallow subsurface. We suggest researching the supporting facts and undertaking supplemental removal actions based on the findings.

8.2 REMEDIAL RECOMMENDATIONS

Below is a list of remedial recommendations, again presented in decreasing order of our present sense of their relative importance, implementation feasibility (including cost) and benefit. The need and order of these easily could change based on investigative findings, available funding and other Town priorities.

1. **Replace Well 1 With Well 7** - If sustainable capacity evaluations reveal that the capacity of Well 1 is needed to achieve requisite, system-wide sustainable yield criteria, the Town should engage a competent hydrogeologist to design and execute a well siting, drilling, testing and permitting program. Pending the other findings herein, Well 7 should be completed in the Frederica Aquifer. Positioning it too close to the existing well-field risks well-to-well interference. Positioning it too far increases interconnection costs. Once Well 7 is online (or once the Town and MDE verify that it is unneeded), Well 1 should be

abandoned and sealed.

2. **Operate Wells 4 and 6 On an Interim Basis; Use Well 5 for Peaking and Backup -** Because nitrate concentrations are appreciably less in Well 4 than Well 5, we recommend a modest adjustment in Town well operational strategies to depend more on Well 4 and less on Well 5 as an interim measure. Well 6 will remain needed to dilute nitrates, but less so once Well 4 routinely supplies more water than Well 5.

3. **Verify Well-Specific Yields and Capacities** - Well 1 being open to both aquifers potentially lessens the efficacy of any aquifer-specific protective strategy. The circumstance of this well also makes its water quality more difficult to predict. Ostensibly it should be abandoned and sealed, as reconstructing it would cost more than replacing it. ALWI recommends before any such actions are undertaken, the Town satisfy itself and MDE that relevant yield and capacity requirements can be met with a three-well system (Wells 4, 5 and 6). We therefore recommend that the Town consider commissioning a hydrogeologic evaluation that focuses on verifying the present sustainable capacities of each well, including rehabilitative measures that may arise from the initial steps of such an evaluation. If the existing wells cannot provide needed capacity with requisite redundancy, consideration should be given to drilling a “Well 7” before Well 1 is abandoned.

4. **Install Conventional Denitrification** - If the measures herein are unsuccessful and/or if funding can be secured, the Town should engage a competent engineer to design and oversee the installation of a permanent, conventional denitrification system.

8.3 PROTECTIVE RECOMMENDATIONS

Below is a list of protective recommendations, again presented in decreasing order of our present sense of their relative importance, implementation feasibility (including cost) and benefit. The need and order of these easily could change based on investigative findings, available funding and other Town priorities.

We see potential benefit in financial incentives (including but not necessarily restricted to property tax reductions) offered to agricultural property owners, for their proactive and voluntary cooperation in changing land management practices in a way that results in improved Town water quality. The implementation of such a program would require careful planning and ongoing public relations to be successful in the long term. Also, the concurrence and active assistance of the County would be needed for effective implementation.

Notwithstanding the novelty of the foregoing concept, the following measures also warrant consideration:

1. **Encourage CAFO Compliance With Applicable Nutrient Management Standards -** The Town should consider requesting that MDE and Maryland Department of Agriculture carefully review environmental compliance matters at the CAFOs and CAFO-like facilities within and near the SWPAs. To the degree voluntary or other nutrient management compliance is not readily achievable; the Town also should consider asking State and County officials to require strict nutrient management compliance practices at potential nitrate source

properties outside Town but within the SWPAs.

2. **Plant Trees and Rotate Crops -** The Town and County could work together on an awareness and outreach program focused on planting trees, cover vegetation and crop rotation on agricultural fields in the SWPA.

3. **Acquire or Ease Specific Properties** - Absent other beneficial results and assuming the availability of financial resources, the Town could consider acquiring and/or granting easements with respect to specific properties to lessen the likelihood of existing or potentially incompatible land uses.

4. **Other Protective Measures -** The Town and County could work together to develop and implement an ordinance or other means focused on one or more of the following objectives within the SWPA:

   - No new septic systems, CAFOs, or groundwater discharge permittees;
   - Public awareness and community outreach measures (homeowner focused); and
   - Proper abandonment of unwanted and unneeded wells (via enforcement).

5. **Replace Chlorine With an Alternative Disinfectant** - Switching from chlorine to an alternative disinfectant may help reduce the concentration of DBPs formed in the system. Different alternatives exist at various costs and degrees of regulatory acceptance. If this recommendation is pursued, the Town will need to engage an engineer to help determine which alternative disinfectant is within its budget and compliant with MDE requirements.

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