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Chesapeake Bay Groundwater Toxics Loading Workshop Proceedings

Basinwide Toxics Reduction Strategy Reevaluation Report

Chesapeake Bay Program

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Chesapeake Bay Groundwater Toxics Loading Workshop Proceedings

Sponsored by the
Chesapeake Bay Program Toxics Subcommittee

April 15-16, 1992

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PROCEEDINGS OF THE
CHESAPEAKE BAY PROGRAM
TOXICS SUBCOMMITTEE
SPONSORED

CHESAPEAKE BAY GROUNDWATER TOXICS LOADING WORKSHOP

U. S. EPA Chesapeake Bay Program Office
Chesapeake Bay Information and Conference Center
Annapolis, Maryland

April 15 - 16, 1992

1. BACKGROUND/OBJECTIVE

The Basinwide Toxics Reduction Strategy committed the Chesapeake Bay signatories to develop a Toxic Loading Inventory of toxic substance loadings from point and nonpoint sources. Point source loads include inputs from industrial, municipal and federal facilities. Nonpoint-source loads include inputs from atmospheric, shipping, urban, agriculture and groundwater sources. With the exception of groundwater, toxic substance loading and release estimates were developed for these sources using available data.

The Chesapeake Bay Groundwater Toxics Loading Workshop was held April 15 - 16, 1992 at the U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program Office in Annapolis, Maryland. The workshop was held to assess the significance of toxic substances transported by groundwater to the Chesapeake Bay and its tidal tributaries and to develop a strategy for quantifying these loads. The workshop was also one in a series of critical issue forums directed at developing a technical consensus on the nature, extent and magnitude of Chesapeake Bay Toxics problems, as part of the reevaluation of the Basinwide Toxics Reduction Strategy. The workshop, sponsored by the Chesapeake Bay Program's Toxics Subcommittee, was attended by representatives from state and federal agencies, academic institutions, and interested individuals conducting groundwater studies or involved in groundwater protection programs.

The workshop participants reviewed and discussed available information on results from groundwater studies and developed a strategy to provide a first order estimate of the magnitude of groundwater loads of toxic substances to Chesapeake Bay and its tidal tributaries. The participants also recommended that groundwater loads of nutrients should be assessed concurrently with the toxic substance loads.

A major accomplishment of the workshop was a summary of the current state of knowledge regarding the significance of groundwater as a transport mechanism for toxic substances and nutrients to Chesapeake Bay. The primary conclusions of the workshop were:

1. Groundwater itself is not a source of toxic substances, rather, it stores and transports

toxic substances and nutrients that have infiltrated to the groundwater from point and nonpoint sources.

2. Groundwater delivers more than one-half of the freshwater that enters Chesapeake Bay. This large volume of freshwater is transported to the Bay as base flow and as direct discharge or upwelling. Base flow represents groundwater discharge to non-tidal streams and tributaries, while upwelling represents groundwater discharged directly to the Bay mainstem and/or to the Bay's tidal tributaries.

3. The majority of the groundwater flow to the Bay is transported from shallow aquifers that are most sensitive to anthropogenic impacts.

4. Detectable concentrations of toxic substances and nutrients have been observed in shallow aquifers.

5. Surface runoff may be a larger transporter of agricultural herbicides to streams and tributaries than groundwater inflows.

6. The potential for toxic substances to be transported by groundwater and subsequently discharged to the Bay and its tidal tributaries may be greatest at the local scale, close to the source.

7. The potential for nutrient loads to be transported in groundwater and subsequently discharged to the Bay and its tidal tributaries may be significant at both the local and regional scales.

2. STRATEGY TO QUANTIFY GROUNDWATER POLLUTANT LOADS TO THE CHESAPEAKE BAY

As part of the strategy, the workshop participants targeted the Chesapeake Bay Toxics of Concern, the secondary list of Toxics of Concern, and nutrients. It was felt that these constituents have the highest potential to adversely impact Bay water quality. This section summarizes the primary elements of a strategy recommended by the workshop participants for quantifying loadings transported to the Chesapeake Bay by groundwater. The actions the workshop participants believed were necessary to implement this strategy are as follows:

1. Utilize results from the fall line monitoring program to estimate groundwater discharge and toxic substance and nutrient loads to non-tidal streams and tributaries above the fall line. This approach segments the Bay watershed into areas above the fall line and below the fall line. The areas above the fall line are underlain by consolidated rock aquifers, while the areas below the fall line are underlain by unconsolidated sediment aquifers. Nutrient loads could be estimated at all major tributary fall line stations, while loads of toxic substances could be estimated at the Susquehanna, James and Potomac River fall line stations where monitoring for both toxic substances and nutrients is currently in place.

    a. Estimate groundwater base flow above the fall line and integrate with fall line station concentration data to estimate loads for the major tributaries.

    b. Because of the large volume of groundwater, potentially high loads of toxics and nutrients can be estimated from relatively low concentrations. Consequently, ultra-clean field sampling and low-level analytical detection limits must be employed to ensure high quality data. The calculation procedures used to estimate loadings from these data must be consistent and utilize appropriate measures of statistical uncertainty.

2. Classify "hydrogeomorphic regions" for shallow aquifers below the fall line in the unconsolidated sediments of the Coastal Plain physiographic province. These areas have a distinctive combination of hydrogeologic and geochemical characteristics, such as shallow geology, geomorphology, soil type, organic content of shallow sediments, and hydrology. These attributes impart a characteristic groundwater flow and water quality pattern that increases the potential for similar groundwater loadings.

3. Review literature and ongoing studies within each "hydrogeomorphic region" to compile data and better define physical and geochemical characteristics, concentrations of chemical constituents, and information gaps.

    a. Physical Characteristics

        - Define hydrology (surface and groundwater interaction).

        - Evaluate methods to estimate volume of shallow groundwater flow based on available data and perform calculations using best available methods.

        - Identify recharge areas and discharge areas.

        - Develop map of Chesapeake Bay groundwater watersheds (similar to surface watersheds).

        - Identify soils with high potential for leaching using:
            - VIRGIS
            - EMAP land use characterization
            - recharge area maps.

    b. Chemical Constituents

        - Measure or estimate concentrations of toxic substances and nutrients.

        - Define transport chemistry for similar pollutants (soluble and insoluble, etc.).

    - Explore development of toxic substance and nutrient concentration characteristics for each land use in the recharge areas.

c. Information Gaps

    - Identify information gaps and areas requiring additional refinement.
    - Develop proposals that expand existing or planned studies to address identified gaps.
    - Coordinate efforts between Chesapeake Bay Program Subcommittees (Toxics Subcommittee, Nonpoint Source Subcommittee, Modeling Subcommittee, etc.) and agencies with related expert knowledge.

4. Work within existing projects and through the Chesapeake Bay Program Subcommittees to address information gaps.
    - Add sampling stations to existing monitoring programs to get base flow and concentration data.
    - Target sampling station locations based on areas of greatest anthropogenic impacts.
    - Explore correlations between herbicide application, groundwater concentrations, and edge of field export.
    - Extrapolate findings to similar hydrogeomorphic regions.
5. Estimate groundwater chemical constituent loads for below the fall line areas within the hydrogeomorphic classification system where the data exist.
6. Extrapolate the estimates to similar hydrogeomorphic areas below the fall line where information is not available.
7. Target major Superfund and RCRA sites the Bay tidal waters.
    - Access federal and state electronic and paper files (RCRIS and CERCLIS) to estimate potential toxic substance loads to groundwater at the local scale.
    - Attempt to provide cumulative loading estimates from hazardous waste sites.
8. Evaluate other potential sources of loadings of toxic substances to the Bay.
    - Identify and evaluate pesticide mixing and loading facilities as potential sources of pesticides to groundwater and surface water.

        - Investigate effect of groundwater flushing of toxic substances from bottom sediments previously contaminated by other sources.

9. Establish lines of communication to coordinate the development of groundwater loading estimates and management efforts.

    a. Groundwater load estimates

        - Strive for consistent methods between states.

    b. Management efforts

        - Recognize that groundwater movement transcends political boundaries and that a cooperative regional approach is required for its protection.

        - Target leadership at state level.

        - Evaluate the effectiveness of best management practices to protect groundwater and surface water.

    c. Bay Program coordination

        - Establish responsibility to coordinate Chesapeake Bay Program efforts to protect groundwater between Bay Program committees and subcommittees.

2. TECHNICAL STATEMENTS SUPPORTING THE WORKSHOP CONCLUSIONS AND LOAD ESTIMATION STRATEGY

The following background information, summarized from several of the workshop presentations, is provided to facilitate understanding of the proposed strategy to quantify loadings of toxic substances transported by groundwater.

Aquifers

There are two general types of aquifers within the Chesapeake Bay watershed: shallow, near surface aquifers and deep, confined aquifers. Most of the groundwater discharge delivered to the Chesapeake Bay tidal and non-tidal system is from shallow aquifers, not the deeper confined aquifers. The flow of groundwater between the shallow aquifers and the underlying deeper aquifers is constrained by less permeable sediments (confining units). Groundwater flow models have indicated prepumped recharge and discharge rates for the confined aquifers in the Coastal Plain are less than 1 inch per year, while recharge rates to the water table aquifer are commonly 10 inches per year (Hamilton and Larson 1988; Laczniak and Meng 1988; Harsh and Laczniak 1990).

The shallow aquifers are located in either the consolidated crystalline and sedimentary rocks found above the fall line or in the unconsolidated sediments of the Coastal Plain Province found below the fall line (McGreevy and Wheeler 1984). They discharge groundwater as base flow to nontidal tributaries that subsequently flow as surface water to the Bay's mainstem tributaries or mainstem, or upwell groundwater directly to the mainstem estuary or tidal tributaries.

Quantity of Groundwater Entering the Chesapeake Bay

The mean annual streamflow entering the Chesapeake Bay is approximately 18.9 million gallons (at a rate of 80,000 cubic feet per second (cfs)) (Phillips, personal communication). More than one-half of this fresh water is delivered by groundwater discharged through shallow aquifers as base flow to tidal and nontidal tributaries or upwelled as direct discharge to the Bay. Sinnott and Cushing (1978) estimate that approximately 55 percent of the stream flow below the fall line and 40 percent of the stream flow above the fall line is groundwater discharging as base flow (Table 1). Other estimates of base flow as a total percentage of stream flow in the Chesapeake Bay watershed range from 39 to 61 percent. Base flow accounts for an average of 52 percent of stream flow in the Potomac River basin above the fall line (Trainer and Watkins 1975). In the area below the fall line, 57 percent of stream flow on the Delmarva Peninsula was attributed to base flow (Cushing *et al.* 1973). However, Bachman *et al.* (1992) estimated a higher base flow contribution of 63 to 88 percent on the Delmarva Peninsula.

Simmons (1989) estimated groundwater upwelled directly to the Bay to be about equal to the discharge of the James River to tidal waters ($2x10^{6}$ cubic meters per day). Direct groundwater discharge is a mixture of freshwater and seawater. Adjusting Simmon's estimate to account only for freshwater contributions the amount of direct fresh groundwater discharge could be 1-2 orders of magnitude less than that reported for submarine groundwater discharge (Reay and Simmons 1992). Other researchers (Libelo *et al.* 1991; Zimmerman 1991) have reported that direct upwelling from aquifers underlying tidal areas of tributaries may account for up to 25 percent of the fresh water put to these surface-water bodies.

Table 1. Percent Estimates of Groundwater Discharge to the Chesapeake Bay

Base Flow to Tributaries Above the Fall Line	Base Flow to Tributaries Below the Fall Line	Direct Discharge to Tidal Waters
40%[1]	55%[1]	25%[5]
52%[2]	57%[3]	15%[6]
	63-88%[4]	

1. Sinnot and Cushing, 1978.
2. Trainer and Watkins, 1975.
3. Cushing et al., 1973.
4. Bachman et al., 1992.
5. Libelo, et al., 1991.
6. Simmons, 1989.

Quality of Groundwater Entering the Bay

Nutrient Concentrations

Nitrogen is the predominant nutrient of concern because it is water-soluble and more likely to be leached to groundwater than phosphorus. In the Coastal Plain aquifers below the fall line, most of the nitrogen occurs in the shallow unconfined systems (Staver and Brinsfield 1991). The USGS National Water Quality Assessment also reported that water from more than 70 percent of wells in the shallow water table aquifer of the Delmarva Peninsula had detectable concentrations of nitrate and about 15 percent contained concentrations that exceeded 10 milligrams per liter (mg/L), the maximum contaminant level for drinking water established by the U.S. EPA (Hamilton and Shedlock 1992). In contrast, median concentrations of nitrate in uncontaminated groundwater are less than 1 mg/l (Speiran, personal communication). The highest concentrations were observed in shallow groundwater aquifers of the Coastal Plain draining areas of agricultural land use.

Other studies report similar nitrogen concentrations in the groundwater. For example, studies conducted below the fall line in the Coastal Plain on the eastern shore of Maryland and Virginia reported nitrogen concentrations in the shallow aquifer as high as 38 mg/L (Bachman 1984; Brinsfield and Staver 1989; Reay and Simmons 1992; Speiran, personal communication). The Nomini Creek Watershed project in Virginia reported that the mean nitrogen concentration was almost 5 mg/L, based on 119 samples collected at the site (Mostaghimi *et al.* 1989).

Studies in fractured flow systems west of the fall line indicate that monthly base flow nitrate concentrations ranged from 1.7 to 14 mg/L. These studies include the Conestoga River headwaters in Lancaster County, Pennsylvania; the Bush Run Creek site in the lower Susquehanna River basin; and the Owl Run basin in Virginia.

Toxic Substances Concentrations

Excluding local contamination data at hazardous waste sites, there are very limited data on toxic substance concentrations in groundwater within the Bay watershed; the available data are primarily for pesticides. Atrazine and alachlor are the two most common pesticides detected. On the Delmarva Peninsula, concentrations of pesticides were generally low; 94 percent of the water samples with detectable concentrations were less than the U.S. EPA maximum contaminant and health advisory levels for drinking water (Hamilton and Shedlock 1992). Similar results were found at the Nomini Creek Watershed; over 21 pesticides were detected in the ground water, but only atrazine, disulfoton, and paraquat occasionally exceeded the respective drinking water standards (Mostaghimi *et al.* 1989).

In the ground water underlying the Owl Creek site in Virginia, which is above the fall line, no pesticides have been detected (Mostaghimi *et al.* 1989). However, Hippe and co-workers (1992) detected triazine herbicides in 42 of 50 wells sampled in the Cumberland Valley of Pennsylvania, which is above the fall line.

Estimates of Groundwater Loads

Nitrogen

Libelo and co-workers (1991) estimated that groundwater nitrogen contributions to the Chesapeake Bay may represent 30 percent of the total load, based on initial estimates of groundwater nitrogen loads to the James River (14.52 million pounds of nitrogen per year). Bachman and co-workers (1992) estimated that the groundwater nitrogen load may be as high as 40 percent of the total nitrogen load in areas of intense agricultural activity such as the Delmarva Peninsula.

Toxic Substances

No estimates of groundwater transported loadings of toxic substances were available at the time the workshop was held.

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Chesapeake Bay Groundwater Toxics Loading Workshop

April 15-16, 1992

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