STAFFORD Virginia

Community & Economic Development Committee Meeting AGENDA

July 10, 2018 – 12:00 Noon
Conference Room A/B/C, Second Floor

Committee Members: Chairman Wendy Maurer, Cindy Shelton and Gary Snellings

	Agenda Item
1.	Friends of the Rappahannock (FOR), 10-15 presentation on the Rappahannock River Report Card
2.	Chesapeake Bay Act Comp Plan Amendment
3.	TDR Ordinance Amendment
4.	Ordinance Amendment regarding Standards to Revoke a CUP
5.	Cemetery Ordinance Update
6.	Consider a Code Amendment to allow a Merchants Capital Tax Rate Reduction for Large Warehouses/Distributors
7.	Enforcement of County Code Violations
8.	Short Term Dwellings in Residential Dwellings
	Next CEDC meeting is scheduled for September 4, 2018

CEDCAgenda07102018

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STAFFORD Virginia

Project Name: Comprehensive Plan Amendment for Chesapeake Bay Compliance Date Presented to the CEDC: 7/10/18

Current Situation

- Virginia Department of Environmental Quality (DEQ) has conducted its 5-year compliance review of the County's Chesapeake Bay Preservation Act program
- DEQ is requiring additional language be added to the Comprehensive Plan referencing how the County addresses streambank erosion problems
- Staff is developing new language which will include updating information on areas of concern, measures to preclude further erosion, and mitigation of eroded areas
- This component of compliance must be met by October 31, 2018

Proposed End State

- Additional language will be added to the Comprehensive Plan
- The County will be in compliance with the Chesapeake Bay Act Program

Request for the CEDC Committee/Board of Supervisors

- Refer a text amendment to the Comprehensive Plan to the Planning Commission for public hearing and recommendation

Benefits to the County

- Ensures compliance with Chesapeake Bay Act regulations
- Identifies and addresses potential streambank erosion problems

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George Washington's Boyhood Home

Project Name: TDR Ordinance Amendment

Date Presented to the CEDC: July 10, 2018

Current Situation

- The Transfer of Development Rights (TDR) ordinance includes a process for landing severed development rights on property within the Receiving Area at preliminary plan stage
- A property owner is proposing a TDR development plan in the receiving area but has acknowledged concern with the timing of extinguishment of development rights
- A request has been made to require extinguishment of rights at the final plat stage instead of preliminary plan stage
- An incidental revision would clarify that each eligible property in the sending area contains at least one development right. It is not clearly stated in the existing ordinance

Proposed End State

- If the ordinance is amended, it may increase the likelihood of participation and therefore facilitate land conservation in the sending area
- Clarifies that eligible sending properties have at least one development right

Request for the CEDC Committee/Board of Supervisors

- Consider a zoning ordinance amendment to require extinguishment of rights at final plat instead of preliminary subdivision plan, and add language regarding confirmation of one existing development right on eligible sending properties
- Staff would develop the revisions to the ordinance and bring forward to the Board for referral to the Planning Commission

Benefits to the County

- Participation in the TDR benefits the County by focusing new development in areas planned to accommodate higher density

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Transfer of Development Rights (TDR) Timeline

Background

- June 1, 2010 – Resolution R10-178 authorized Planning Commission (PC) to develop TDR program.
- June 10, 2010 – PC requests more guidance on development of TDR program.
- September 7, 2010 – Board requests County Attorney to draft TDR ordinance.
- September 21, 2010 – Resolutions R10-296, 297, 298 and 299 referred a draft TDR program to PC for its review and recommendation.
- September 6, 2011 – Resolutions R11-194 referred Proposed Ordinance O11-25 and Comp Plan sending and receiving areas map to PC.
- December 5, 2011 - PC public hearing, with recommendation that the Board not adopt the TDR Ordinance.
- March 7, 2012 - Board asked the PC to reconsider TDR and make new recommendations for adoption of a TDR ordinance.
- June 20, 2012 – PC conducted a public hearing and recommended approval of the TDR Ordinance and Plan amendments.
- July 3, 2012 - Board established a Committee consisting of Supervisors Paul Milde, Gary Snellings, and Bob Thomas, to review the Commission's recommendations for a new TDR program.
- July 25, 2012, and August 14, 2012 - Board Committee met and recommended adjustments to the Commission's version of the TDR program.
- September 4, 2012 - Resolution R12-284 referred proposed Ordinance O12-02, and proposed amendments to the Comprehensive Plan, including a sending and receiving area map, to the PC.
- October 24, 2012 – PC public hearing, recommending adoption of O12-02 and R12-03.
- December 4, 2012 - Board voted to refer the issue of TDR to Board sub-committee.
- February 6, 2013 - Board committee met.
- February 19, 2013 – Board adopted Ordinance O13-21, which implemented administrative procedures for a TDR program, and sends Comp Plan amendments to PC.
- August 28, 2013 – PC public hearing, recommending adoption of amendments.
- October 15, 2013 – Board does not adopt amendments.
- June 3, 2014 – Board referred new amendment to PC O14-26 and R14-141.
- December 10, 2014 – PC recommended adoption of new amendments.
- February 24, 2015 - Board adopted O15-06 and R15-23 which amended the TDR ordinance, and adopted the Comprehensive Plan maps which enabled an operative TDR program.
- March 21, 2017 – Board referred amendments to the Comp Plan and ordinance to PC to expand receiving area.
- May 10, 2017 – PC recommends approval of amendments.
- June 20, 2017 - Board amended the Comprehensive Plan to expand the TDR receiving area.

TDR Applications

- July, 2017 - First TDR application was submitted.
- As of June 28, 2018, 12 TDR applications have been received, consisting of 294 parcels and 1079.56 acres, with a total of 494 development rights to potentially be severed.
- A determination of development rights has been issued for ten of the applications, with two applications still under review.
- A TDR certificate has been issued for one of the applications, severing fifty development rights.
- May, 2018 – a property owner in receiving area requested amendments to ordinance regarding timing of extinguishment of development rights.

Project Name: Revocation of CUPs

Date Presented to the CEDC: July 10, 2018

Current Situation

- County Code Sec. 28-185(f) describes the terms when the Board can revoke a conditional use permit (CUP)
- That provision stipulates that the permit can be revoked for *"willful noncompliance"* with the zoning ordinance or any conditions imposed by the Board. The *"willful noncompliance"* standard is not defined in County or State codes
- The Virginia Code citation for public hearings is out of date and must be updated

Proposed End State

- Amended County Code that is clear and accurate

Request for the CEDC Committee/Board of Supervisors

- Determine whether *"willful noncompliance"* is the desired standard for the Board to revoke a CUP and if so, create a definition or criteria to ascertain *"willful noncompliance"*
- Authorize update to the County Code provision to reflect the correct State Code citation of 15.2-2204

Benefits to the County

- Clear terms of when a CUP can be revoked helps the Board, staff, and public to understand the ramifications of violations of the terms of a CUP
- "*Willful noncompliance"* is a higher standard than *"noncompliance"* and would give the property owner more opportunities to correct violations but may make it more difficult for the County to revoke a CUP where multiple tenants have occupied a property

Sec. 28-185. - Conditional use permits.

(a) *Purpose and intent.* Issuance of a conditional use permit shall be required for those uses designated as conditional uses in article III. Conditional uses are those uses which are generally compatible with the other land uses permitted in a land use district, but which require individual review of their location, design, and configuration and the imposition of conditions in order to ensure the appropriateness of the use at a particular location. These uses have some unique character or probable special impacts such that their effect on the surrounding area cannot be determined in advance of the use being proposed at a particular location.

(b) *General provisions.* The following provisions shall apply for all conditional use permits:

(1) Conditional use permits may be authorized upon a finding by the board of supervisors that the use will not be detrimental to the character and development of the adjacent land and will be in harmony with the purpose and intent of this chapter.

(2) Any use, building, or activity lawfully existing on the effective date of this chapter, or for which a building permit was issued prior to the effective date of this chapter, shall not require a conditional use permit, so long as such existing use, building, or activity is not expanded or enlarged.

(3) Should a request for a conditional use permit be denied, at least one year shall elapse before another application for the same is considered.

(4) Any application for a conditional use permit may be withdrawn upon written request by the applicant at any time prior to the submission of any public hearing notice for advertisement. If such request for withdrawal is made after publication of notice for public hearing, such withdrawal shall only be with the consent of the body which had advertised for the public hearing. No new application concerning any or all of the land included in the original application shall be filed within six (6) months of the date of the action, unless the respective body approving withdrawal specifies that the time limitation shall not apply.

(5) Minor amendments to approved conditional use permit conditions. Any conditional use permit approved pursuant to this article may be revised by the board of supervisors, after notice and hearing pursuant to Code of Virginia, § 15.2-2204. Any minor amendment shall be allowed subject to the following requirements:

a. No more than two (2) permit conditions can be changed at the time of request;

b. Changes do not materially affect site layout;

c. Changes do not affect intensity, use or functionality of the site; and

d. Applications pursuant to this paragraph may be exempt from subsection (c)(1)b.

(6) Major amendments to approved conditional use permit conditions. Any amendment to a conditional use permit other than that defined in subsection (5).

(c) *Conditional use permits.* No conditional use permit shall be issued except in conformance with the following provisions:

(1) An application for a conditional use permit shall be submitted to the Stafford County Department of Planning and Community Development, and shall contain the following information:

a. A completed application for a conditional use permit in an approved form provided by the department of planning and community development.

b. A generalized development plan in accordance with article XIII.

c. A nonrefundable application fee, as established by the board of supervisors.

d. Impact statements on the effects to traffic volumes and capacities, public water and sewer capacities, noise, dust and smoke emissions.

e. Written verification from the county treasurer that all delinquent real estate taxes on the subject property have been paid in full.

f. Traffic impact analysis as outlined in 24 VAC 30-155 shall be submitted when any conditional use permit would generate one hundred fifty (150) or more vehicle trips per day above the existing use and the site would meet the VDOT requirements for TIAs under 24 VAC 30-155 or Stafford County rezoning TIA requirements. Proffers or conditions which limit the vehicle trips per day may be taken into consideration when calculating the maximum development. An addendum or supplementary TIA shall be submitted when required by VDOT regulations.

(2) An application for a conditional use permit shall be reviewed by the staff.

(3) After receiving the report and recommendation of the staff, the planning commission shall, pursuant to notice and public hearing requirements of Code of Virginia, § 15.2-2204, hold a public hearing and make a recommendation on the application to the board of supervisors to grant, grant with conditions, or deny the conditional use permit.

(4) Upon receiving the report and recommendation of the planning commission, the board of supervisors shall hold a public hearing pursuant to notice and public hearing requirements of Code of Virginia, § 15.2-2204. Subsequent to the public hearing, the board of supervisors shall render a decision on the application to grant, grant with conditions, or deny the conditional use permit.

(5) Per Code of Virginia § 15.2-2289 and section 28-297 of this Code, the application shall include completed affidavit forms as provided by the planning department disclosing the equitable ownership of the real estate to be affected by the application, in the case of corporate ownership, the name of stockholders, officers and directors and in any case the name and addresses of all the real parties of interest.

(6) At least fifteen (15) days prior to a conditional use permit public hearing before the planning commission, board of supervisors, or a joint session of both, the planning commission or its representative shall erect on the property proposed for a conditional use permit a sign or signs furnished by the planning director or his designee indicating the proposed use, and the date, time, and place of the hearing. The sign shall be erected within ten (10) feet of whatever boundary line of such property abuts a public road, and shall be placed so as to be clearly visible from the road. The bottom of the sign shall be not less than fifteen (15) inches above the ground. If more than one public road abuts such property, then a sign shall be erected in the same manner for each such road. If no public road abuts the property proposed for the Conditional use permit, then signs shall be erected in the same manner as provided for, above on at least two (2) boundaries of the property abutting land owned by the applicant.

(7) Written notice shall be given by the planning commission or its representative to all adjoining property owners no less than five (5) days before the public hearing before the planning commission or board of supervisors. Notice sent to the last known address of any such owner, as shown on the current real estate tax assessment books of the county, shall be deemed adequate compliance with this requirement. In the event the adjoining property is within another jurisdiction of the commonwealth, the notice shall be sent to the administrator or executive of that jurisdiction. If the public hearing before the planning commission and/or board of supervisors is cancelled, notice shall be remailed no less than five (5) days before the rescheduled public hearing.

a. The written notice by the planning commission or its representative shall be by certified mail. Costs of all notices, including publication, posting, and mailing, as required under this section, shall be taxed to the applicant.

(d) *Standards for issuance.* A conditional use permit may be granted for any use shown as a conditional use in a land use district only if the board of supervisors finds that the issuance of the permit will meet all other requirements of this chapter and is in accord with the following standards:

(1) The use shall not tend to change the character and established pattern of development in the vicinity of the proposed use;

(2) The use shall be in harmony with the uses permitted by right under a zoning permit in the land use district and shall not adversely affect the use of adjacent properties;

(3) The location and height of buildings, the location, nature and height of walls and fences and the nature and extent of landscaping on the site shall be such that the use will not hinder or discourage the appropriate development and use of adjacent land and buildings or impair the value thereof;

(4) The use shall not adversely affect the health or safety of persons residing or working in the vicinity of the proposed use;

(5) The use shall not be detrimental to the public welfare or injurious to property or improvements in the neighborhood; and

(6) The use shall be in accord with the purposes and intent of this chapter and the comprehensive plan of the county.

(e) *Conditions.* In granting any conditional use permit, the board of supervisors shall designate such conditions in connection therewith as will, in its opinion, assure that the use will conform to the requirements set out in this subsection and that will continue to do so. Such conditions may include, but are not limited to, the following:

(1) Conditions may be imposed to abate or restrict noise, smoke, dust or other elements that may affect surrounding properties;

(2) Establish setback, side or rear yard requirements necessary for orderly expansion and to prevent traffic congestion;

(3) Provide for adequate parking and ingress and egress to public streets and roads; and

(4) Provide adjoining property with a buffer or shield from view of the proposed use, if deemed necessary.

(f) *Revocation.* Any permit issued pursuant to this article may be revoked by the board of supervisors, after notice and hearing pursuant to Code of Virginia § 15.1-431, for willful noncompliance with this ordinance or any conditions imposed under the authority of this article.

(Ord. No. 094-29, § 28-1105, 8-9-94; Ord. No. 095-12, 3-7-95; Ord. No. 096-47, 10-15-96; Ord. No. O05-54, 12-13-05; Ord. No. O06-42, 6-20-06; Ord. No. O06-66, 9-19-06; Ord. No. O08-51, 6-17-08; Ord. No. O08-71, 12-2-08; Ord. No. O10-22, 3-16-10; Ord. No. O10-31, 8-17-10)

State Law reference— Similar provisions, Code of Virginia, § 15.2-2222.1(B).

Project Name: Cemetery Ordinance Amendments Date Presented to the CEDC: July 10, 2018

Current Situation

- In December, 2016, the Board adopted standards and processes for the establishment of cemeteries
- In October, 2017, the Board requested that the Planning Commission consider amendments to County Code Sec. 28-39(o) “Cemeteries,” pursuant to Resolution R17-263
- In May, 2018, after consideration of public comment and additional information received, the Planning Commission presented a report that recommended no changes be made to the existing cemetery ordinance (see attached).
- The Board has requested a briefing of the Planning Commission’s findings

Proposed End State

- Option 1: Confirm the recommendation of the Planning Commission and make no changes to the cemetery ordinance
- Option 2: Determine if additional changes are necessary and refer to the Planning Commission

Request for the CEDC Committee/Board of Supervisors

- The CEDC is requested to review the report and recommendation of the Planning Commission and determine if any further changes to the cemetery ordinance should be reconsidered
- If any changes are recommended by the CEDC, the Board would refer back to the Planning Commission for consideration

Benefits to the County

- Clarifies if existing cemetery ordinance requires changes

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STAFFORD Virginia

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May 9, 2018

MEMORANDUM TO: Stafford County Planning Commission

FROM: Jeffrey A. Harvey, AICP
Director of Planning and Zoning

SUBJECT: ***Zoning Ordinance Standards Regarding Cemeteries***

ATTACHMENTS:

1. Cemetery Sub-Committee Summary Report with Attachments

Attached in the Report from the Cemetery Sub-Committee. At the time of mail out staff has received no comments from Commission members. Staff recommends that the Planning Commission forward its final recommendations to the Board of Supervisors regarding the desire to change the existing ordinance.

JAH:dk

STAFFORD COUNTY PLANNING COMMISSION
CEMETERY ORDINANCE COMMITTEE
SUMMARY REPORT
MAY 9, 2018

BACKGROUND

On October 3, 2017, the Board of Supervisors referred to the Planning Commission a request for amendments to the County Code regarding cemeteries. In December 2016, the Board adopted Ordinance O16-39 (Attachment 1), which moved some cemetery provisions into more appropriate sections of the County Code, and provided additional standards and processes for the establishment of cemeteries, in accordance with Virginia Code Section 57-26 (Attachment 2).

Ordinance O16-39 repealed County Code Chapter 8 and move applicable regulations for cemeteries into Chapters 17 (Offenses—Miscellaneous) and 28 (Zoning), with the bulk of the regulations residing in the Zoning Ordinance. The amendment specified that in order to establish a cemetery (a) there must be the consent of any property owner within 250 yards of the cemetery, unless separated by a public road; (b) the tract of land must be between 25 and 300 acres; (c) no burials may be located within 900 feet of property owned by the County that has a well, used as a public water supply; and (d) no burials may be located within 900 feet of a terminal reservoir or a perennial stream that drains to a terminal reservoir or within 900 feet of any private well used as a drinking water supply. Burials in new private family and churchyard cemeteries are exempt from the requirement to obtain zoning ordinance approval from the Board. All other new cemeteries require ordinance approval. All new cemeteries, regardless of whether zoning ordinance approval is required, are required to obtain site plan approval in order to ensure compliance with the requirements of the County Code. Due to provisions in the Virginia Code, burials in all existing cemeteries are exempt from County Code requirements.

One concern that Ordinance O16-39 addressed was the location of cemeteries relative to drinking water wells. Health Department regulations require setbacks of 50 or 100 feet between any drinking water well and a cemetery. While the Health Department regulations address new wells which are to be located near existing cemeteries, they do not regulate new cemeteries being located near existing wells. State Code prohibits a cemetery from being established within 300 yards (900 feet) of any municipal water well. There was also a desire to protect the surface water quality of County drinking water reservoirs from the potential negative effects of stormwater run-off and groundwater intrusion from cemeteries.

At its meeting on September 19, 2017, the Board discussed amending the Zoning Ordinance with regard to setbacks from existing wells and water resources, based on citizen concerns that the regulations may be too prohibitive for establishing a new cemetery. The Board adopted Resolution R17-263 (Attachment 3) requesting the Planning Commission to consider amendments to County Code Sec. 28-39(o).

On November 15, 2017, the Planning Commission discussed this item at its meeting and established a Cemetery Ordinance Committee of Commissioners Vanuch, English and Coen. Two committee meetings were held, as discussed below. Notification was sent to citizens who previously expressed interest in this issue.

PLANNING COMMISSION CEMETERY ORDINANCE COMMITTEE

The Committee held a meeting on December 6, 2017 to review state code provisions; review the adopted ordinance; and review previous information, including the timeline and public Process of Ordinance O16-39, locality comparison of cemetery provisions, parcel size analysis for potential cemetery property, and related cemetery studies; in order to determine whether a change to O16-39 was needed. Attachment 4 includes copies of each of the above items.

The Committee also received public comment at the meeting.

The Committee recommended holding another meeting in January, 2018 to allow time to review information presented by the public, as well as the studies that have been presented. They also recommended obtaining additional information before its next meeting, including the use of vaults in cemeteries, whether other localities prohibit cemeteries, and whether the County can require certain burial methods including the use of vaults.

The second Committee meeting was held February 15, 2018. Commissioner Coen was no longer part of the Committee as he no longer served on the Planning Commission. The Committee reviewed the draft Groundwater Management Study for Piedmont Areas of the County to gain an understanding of potential impacts to drinking water wells. Public comment was also received. Documents were presented by Ms. Debrarae Karnes (Leming and Healy, PC), and Mr. Glen Patterson (Attachment 5).

RECOMMENDATION:

The Committee recommends leaving the existing ordinance in place, and forwarding this recommendation to the Board. The Committee acknowledged the primary reasons for this recommendation include:

- The distances required in the existing ordinance between drinking-water wells and burial sites are supported by scientific evidence;
- No new information has been presented to refute the studies on the burial distances specified in the existing ordinance;
- While cemetery owners may follow certain practices that would help protect drinking-water resources, such as the use of vaults, the County cannot require these practices; and
- The existing ordinance permits the establishment of new cemeteries while taking into consideration the protection of the County's drinking-water resources.

O16-39

BOARD OF SUPERVISORS
COUNTY OF STAFFORD
STAFFORD, VIRGINIA

ORDINANCE

At a regular meeting of the Stafford County Board of Supervisors (the Board) held in the Board Chambers, George L. Gordon, Jr., Government Center, Stafford, Virginia, on the 13th day of December, 2016:

MEMBERS:	VOTE:
Robert "Bob" Thomas, Jr., Chairman	Yes
Laura A. Sellers, Vice Chairman	Yes
Meg Bohmke	Yes
Jack R. Cavalier	Yes
Wendy E. Maurer	Yes
Paul V. Milde, III	Yes
Gary F. Snellings	Yes

On motion of Mr. Milde, seconded by Ms. Sellers, which carried by a vote of 7 - 0, the following was adopted:

AN ORDINANCE TO REPEAL COUNTY CODE CHAPTER 8, "CEMETERIES," AND TO AMEND AND REORDAIN STAFFORD COUNTY CODE SEC. 17-22, "ENTERING CHURCH OR SCHOOL PROPERTY AT NIGHT," AND SEC. 28-39, "SPECIAL REGULATIONS"

WHEREAS, Stafford County Code Chapter 8 has standards pertaining to the establishment of cemeteries; and

WHEREAS, Stafford County Code Chapter 8 is not consistent with Virginia Code § 57-26; and

WHEREAS, the Board desires to repeal Stafford County Code Chapter 8 in its entirety and applicable provisions be relocated to other appropriate Sections of the Stafford County Code; and

WHEREAS, the Board acknowledges that studies have found cemeteries can be a source of pollution affecting water quality from surface water run-off and groundwater intrusion that negatively affects drinking water supplies: and

WHEREAS, the Board considered the recommendations of the Planning Commission and staff, and the public testimony, if any, received at the public hearing; and

WHEREAS, the Board finds that public necessity, convenience, general welfare, and good zoning practices require adoption of this Ordinance;

NOW, THEREFORE, BE IT ORDAINED by the Stafford County Board of Supervisors on this the 13th day of December, 2016, that Stafford County Code Chapter 8, "Cemeteries," be and it hereby is repealed in its entirety, and Stafford County Code Sec. 17-22, "Entering church or school property at night" and Sec. 28-39, "Special regulations," be and they hereby are amended and reordained as follows, with all other portions remaining unchanged:

~~Chapter 8 – CEMETERIES~~ REPEALED

~~ARTICLE I. - IN GENERAL~~

~~Sec. 8-1. - Entering cemetery at night.~~

~~No person shall, without the consent of the owner, proprietor or custodian, go or enter, in the nighttime, upon the premises, property, driveways or walks of any cemetery, either public or private, for any purpose other than to visit the burial lot or grave of some member of his family. Any person violating this section shall be guilty of a Class 4 misdemeanor.~~

~~ARTICLE II. - PERPETUAL CARE CEMETERIES~~

~~DIVISION 1. – GENERALLY~~

~~Sec. 8-16. - Violations of article~~

~~Unless otherwise specifically provided, a violation of any provision of this article shall constitute a Class 1 misdemeanor.~~

~~Sec. 8-17. - Authorization to establish required; location with respect to residences.~~

~~No perpetual care or endowed cemetery shall be established within the county, unless authorized by ordinance of the board of supervisors, nor shall any such cemetery be established within two hundred fifty (250) yards of any residence without the consent of the owner of the legal and equitable title of the residence; provided that, subject to the foregoing, if the location for the proposed cemetery is separated from any residence by a state highway, it may be established upon such location without the consent of the~~

~~owner of such residence, if it is not less than two hundred fifty (250) feet from the residence at its nearest point thereto.~~

~~Sec. 8-18. - Minimum size.~~

~~The establishment of a perpetual care or endowed cemetery shall not be authorized by ordinance of the board of supervisors, unless the tract of land upon which it is to be situated is at least twenty-five (25) acres in size.~~

~~Sec. 8-19. - Application for authorization to establish.~~

~~Any person desiring to establish a perpetual care or endowment cemetery shall file an application for authorization with the board of supervisors containing the following information:~~

~~(1) A survey of the tract of land proposed to be used as a cemetery showing its dimensions, size and location.~~
~~(2) Full plans showing the layout of the proposed cemetery, including lots, drives, buildings and planned landscaping.~~
~~(3) The names of adjoining land owners and distances to any residences thereon.~~
~~(4) The zoning of the property at the time the application is filed.~~
~~(5) The name and address of the owner of the property and of the applicant, if different.~~
~~(6) A statement of what provisions will be made for perpetual care of the cemetery.~~
~~(7) The name and address of the trustee of the endowment care fund to be appointed by the person owning, operating or developing the cemetery.~~
~~(8) The name and address of the bank in which the trust funds will be deposited, along with a copy of the irrevocable trust fund agreement required by this article.~~
~~(9) The written consent of the owner of any residence which will be closer to the boundary of the cemetery than the distance permitted in section 8-17.~~

~~Each such application shall be accompanied by a fee of twenty dollars ($20.00) to cover the costs of advertising the public hearing provided for in section 8-20.~~

~~Sec. 8-20. - Notice of public hearing on application filed pursuant to section 8-19.~~

~~After receipt of an application pursuant to section 8-19, an ordinance authorizing the establishment of the cemetery shall be introduced to the board. Notice shall than be given to the public, by publication in a newspaper of general circulation in the county, of the intention of the board to consider the application and to propose an ordinance to authorize the same for passage. The notice shall run once a week for two (2) successive~~

~~weeks between the time it is introduced to the board and the time it is considered. The notice shall also advise the public of the time and place of the hearing thereon and shall contain a description of the property which is reasonably calculated to give the public notice of its location.~~

~~Sec. 8-21. - Conditional use permit.~~

~~Upon authorization of the establishment of a perpetual care or endowed cemetery by appropriate ordinance, a conditional use permit may be required by the board of supervisors, containing such limitations and restrictions as it may deem to be in the best interest of the county.~~

~~DIVISION 2. - ENDOWMENT CARE FUND~~

~~Any person authorized by ordinance to establish a perpetual care or endowed cemetery shall comply with the following sections of this division in each and every respect.~~

~~Sec. 8-31. - Compliance with division~~

~~Any person authorized by ordinance to establish a perpetual care or endowed cemetery shall comply with the following sections of this division in each and every respect.~~

~~Sec. 8-32. - Definitions.~~

~~For the purposes of this division, the following words and terms shall have the meanings ascribed to them in this section:~~

~~*Cemetery* means any land or structure used or intended to be used for the interment of human remains. The sprinkling of ashes on church grounds shall not constitute the creation of a cemetery.~~

~~*Endowment care fund* or *care fund* means a fund created to provide a sufficient income to a cemetery which will enable such cemetery to provide care, maintenance, administration and embellishment of such cemetery adequate to the circumstances. It includes the term "perpetual care fund."~~

~~*Interment* means all forms of final disposition of human remains including, but not limited to, earth burial, mausoleum entombment and niche or columbarian inurnment. The sprinkling of ashes on church grounds shall not constitute interment.~~

~~Sec. 8-33. - Initial requirements.~~

~~No person owning, operating or developing any cemetery shall sell or offer to sell, either as principal or otherwise, any lot, parcel of land or burial or entombment right in such cemetery, and in connection therewith represent to the public in any manner,~~

~~express or implied, that the entire cemetery, a single lot therein or burial or entombment right therein will be perpetually cared for, unless adequate provision has been made for the endowment care of the cemetery and all lots and burial or entombment rights therein as to which such representation is made. Each person who shall undertake to develop any such cemetery shall deposit in a bank or savings and loan association in this state, in an irrevocable endowment trust fund, a minimum to twenty-five thousand dollars ($25,000.00) before the first lot, parcel of land or burial or entombment right has been sold.~~

~~Sec. 8-34. - Deposits following sales of lots, burial rights, etc.~~

~~(a) Each person owning, operating or developing any perpetual care or endowed cemetery shall deposit in a bank or savings and loan association in this state a minimum of ten (10) percent of the receipts from the sale of lots, interment rights and above ground crypts and niches, excluding below ground burial vaults, which amount shall be paid in cash and deposited with the trustee of the endowment care fund not later than thirty (30) days after the close of the month in which such receipts are paid to such owner.~~

~~(b) In the event ten (10) percent of the sales price of the items mentioned in subsection (a) above has been deposited in the endowment care fund, no fund deposit shall again be required on subsequent sales of the same lot, crypt or niche.~~

~~Sec. 8-35. - Recovery of amount of original deposit.~~

~~Whenever a person owning, operating or developing a cemetery has deposited in the endowment care fund a sum equal to twice the amount of the original deposit as provided for in section 8-33, exclusive of such original deposit, the trustee shall then allow such person owning, operating or developing such cemetery to recover the original deposit by withholding up to twenty-five thousand dollars ($25,000.00) of the amount thereafter due the care fund or until the amount of the original deposit in the care fund has been recovered.~~

~~Sec. 8-36. - Use of fund income.~~

~~The income from the endowment care fund provided for in this division shall be used solely and exclusively for the general care, maintenance, administration and embellishment of the cemetery and shall be applied in such manner as the person~~

~~owning, operating or developing such cemetery may from time to time determine to be for the best interest thereof.~~

~~Sec. 8-37. - Appointment and bond of trustee; applicability of Code of Virginia, title 26.~~

~~(a) The trustee of the endowment care fund provided for in this division shall be appointed by the person owning, operating or developing the cemetery and shall be removed only as provided in section 57-35 of the Code of Virginia. The trustee, other than a banking institution operating under the laws of this state or a national bank operating within the state, maintaining a trust department, or a state or federally chartered savings and loan association located in the state with federal insurance of accounts and authorized to do business in the state, shall furnish a fidelity bond with a corporate surety thereon, payable to the trust established, which shall be designated "Endowment Care Fund (or Perpetual Care Fund) for (name of cemetery)," in a penal sum equal to not less than fifty (50) percent of the value of the principal of the trust estate at the beginning of each calendar year, which bond shall be deposited with the commissioner of accounts of the county.~~

~~(b) Trustees appointed pursuant to this section shall be governed in their conduct by the provisions contained generally in title 26 of the Code of Virginia, except as provided otherwise in this division.~~

~~Sec. 8-38. - Reports of trustee generally; owner's affidavit.~~

~~A trustee appointed pursuant to section 8-37 shall report, within four (4) months after the close of each fiscal year, to the commissioner of accounts of the county the following information:~~

~~(1) The total amount of the principal of the endowment care fund held by the trustee.~~

~~(2) The securities in which the endowment care fund is invested and the amount of cash on hand at the close of the fiscal period.~~

~~(3) The income received from the endowment care fund during the preceding fiscal year.~~

~~The trustee shall further submit an affidavit by the person owning, operating or developing the cemetery stating that all provisions of this article and article 3.1 of chapter 3 of title 57 (§ 57-35.1 et seq.) of the Code of Virginia have been complied with.~~

~~Sec. 8-39. - Owner's records and reports of receipts and expenditures generally.~~

~~Each person owning, operating or developing any cemetery subject to this article shall record and keep, in a book maintained for that purpose, detailed accounts of all transactions, receipts and accounts receivable subject to section 8-34, and of all expenditures under section 8-36. Each such owner, operator or developer shall report annually to the commissioner of accounts the totals of all receipts subject to section 8-34, and of all expenditures under section 8-36.~~

~~(Code 1979, § 8-17)~~

~~**State Law reference** — Similar provisions, Code of Virginia, § 57-35.8:1.~~

~~**Sec. 8-40. - Audit of trustee's reports and inspection of owner's records.**~~

~~The commissioner of accounts shall audit reports tendered by a trustee pursuant to section 8-38, as well as any sources thereof which he deems necessary, at least annually and shall have full power, including power of subpoena, to inspect the records of the cemetery owners or operators. Failure to comply with a subpoena of the commissioner shall constitute a misdemeanor.~~

Sec. 17-22. - Entering cemetery, church, or school property at night.

(a) No person shall, without the consent of the owner, proprietor or custodian, go or enter, in the nighttime, upon the premises, property, driveways, or walks of any cemetery, either public or private, for any purpose other than to visit the burial lot or grave of some member of their family. Any person violating this section shall be guilty of a Class 4 misdemeanor.

(b) It shall be unlawful for any person, without the consent of some person authorized to give such consent, to go or enter upon, in the nighttime, the premises or property of any church or upon any school property for any purpose other than to attend a meeting or service held or conducted in such church or school property. Any person violating this section shall be guilty of a Class 4 misdemeanor.

Sec. 28-39. - Special regulations.

(o) *Cemeteries*

(1) *Establishment of cemeteries.* The following requirements shall apply to the establishment of any cemetery:

a. *Restrictions as to location of cemeteries.*

(1) No cemetery shall be established within the County unless authorized by an ordinance duly adopted by the Board; provided that authorization by ordinance shall not be required for interment of the dead in any churchyard or for interment of members of a family on private property.

(2) No cemetery shall be established within 250 yards of any residence without the consent of the owner of the legal and equitable title of the residence. However, consent shall not be required if the location for the proposed cemetery is separated from any residence by a state highway, the proposed cemetery is not less than 250 feet from the residence at its nearest point thereto. Such prohibition and restriction shall not apply where the tract of land intended for use as a cemetery is separated from any residence by a state highway and now contains a public or private burial ground.

(3) No cemetery shall be hereafter established, and no burial made in any part of any cemetery, other than a municipal cemetery, located within 900 feet of any property owned by the Board or the County, upon which or a portion of which are now located driven wells from which water is pumped or drawn from the ground in connection with the public water supply.

(4) No cemetery shall be established within 900 feet of any terminal reservoir or any perennial stream that drains into a terminal reservoir. No cemetery shall be located within 900 feet of any private well used as a drinking water supply.

b. *Size of cemeteries.* No cemetery, other than for the interment of the dead in any churchyard or for the interment of members of a family on private property, shall be established on any tract of land less than 25 acres in size or greater than 300 acres in size.

c. *Site plan required.* No cemetery shall be established without receiving approval of a site plan pursuant to Article XIV of this Chapter. In addition to the standards set forth in Article XIV, an application for approval of a site plan shall demonstrate compliance with owner consent, setback and distance requirements as described in paragraph a above.

d. *Application to establish a cemetery.*

(1) Any application petitioning the Board for adoption of an ordinance to establish a cemetery shall be filed on forms provided by the Department of Planning and Zoning for a zoning reclassification. Such applications shall be processed similar to an amendment to the zoning map as described in Article XII of this Chapter.

(2) In addition to the applicable requirements described in Article XII and Article XIII of this Chapter, the application shall demonstrate compliance with owner consent, setback and distance requirements as described in paragraphs a and b above. Notice of any public hearings shall be sent to owners of any property located within 900 feet of the proposed cemetery.

(3) In approving an application for establishment of a cemetery, the Board may set conditions of approval to mitigate impacts of the cemetery and its accessory uses and activities.

(2) *Preservation of existing cemeteries.* The following requirements shall apply to cemeteries within all development plans:

a. ~~(1)~~ Parcels containing cemeteries that are not on its own separately platted lot, not established by an easement within the boundaries of such parcels, or otherwise clearly marked with places of burials delineated, shall be required at the time of site or subdivision plan review to have a professionally prepared archaeological delineation of the limits of burials within the cemetery. The delineation shall be conducted in accordance with the Virginia Department of Historic Resources and their standard archaeological practices, such as, but not limited to, the removal of topsoil around the perimeter of the visible areas of the cemetery to allow a view of any grave shaft soil discolorations beyond the apparent burials, or systematic probing with rods that detect differences in soil compaction. The archaeological delineation shall determine the limits of burials and it shall be used to establish the perimeter of the cemetery on the site plan or subdivision plat and plan. Soil removed during the delineation process shall be replaced within one month of its removal and in a manner that will not disturb the identified burials. Any associated vegetation shall be replaced in a manner that will not disturb the identified burials.

b. ~~(2)~~ The perimeter of a cemetery shall be indicated on a site development plan, subdivision plan and subdivision plat.

c. ~~(3)~~ Pedestrian access to the cemetery shall be provided on a site development plan, subdivision plan and subdivision plat either with a minimum of fifteen (15) feet of frontage on a street or as an easement that shall be a minimum of fifteen (15) feet wide from a street or other point of public ingress.

d. ~~(4)~~ A minimum thirty-five-foot wide buffer area shall be established around the perimeter of the cemetery as delineated per subsections (2)(a) and (b) ~~(c)(1) and (2)~~ directly above and indicated on a site development plan, subdivision plan and subdivision plat.

e. ~~(5)~~ The cemetery and associated buffer area shall be indicated as an easement or as a separate cemetery parcel on the development plan, subdivision plan and subdivision plat.

f. ~~(6)~~ Temporary fencing shall be installed around the perimeter of the cemetery and buffer area as indicated on the plan or plat, prior to receiving construction or grading plan approval. The fence shall be located outside the exterior edge of the buffer area and not within the buffer area.

g. ~~(7)~~ Permanent fencing between three (3) and four (4) feet tall shall be placed around the boundary of the cemetery including the buffer, after any surrounding site work is completed. The fence shall be located outside the exterior edge of the buffer area and not within the buffer area. The type of fence shall be determined on a case-by-case basis, as approved by the county agent, and shall include a gate for public access.

h. ~~(8)~~ Signage identifying the cemetery by its family association, as recorded in the Stafford County Cultural Resource Database, or by another name as deemed appropriate by the county agent, shall be placed on a freestanding sign located adjacent to the cemetery entrance or affixed to the fencing. The sign shall be a brass plaque or a comparable equivalent. The signage and its content shall be approved by the county agent prior to erection.

i. ~~(9)~~ The cemetery grounds, fence and buffer area shall be maintained and the responsibility for maintenance shall be established either on the site plan, subdivision plan, or subdivision plat, or by a separate recordable document submitted to the county agent along with the plan and plat. The cemetery and associated buffer area shall be conveyed to an appropriate entity that would be responsible for perpetual maintenance of the cemetery as well as the associated buffer and fence.

The party responsible for maintenance shall be indicated as one of the following:

(1) ~~1.~~ Owner of the property on which the cemetery is delineated;

(2) ~~2.~~ Homeowners' association, in the case where a homeowners' association is established and the cemetery is created as a separate out-lot, easement, or part of the common open space within a subdivision; or

(3) ~~3.~~ Other applicable association or entity, such as a business association, trust or foundation, with appropriate documentation demonstrating the entity's assent to the maintenance responsibilities and ability to carry out the maintenance responsibilities.

j.~~(10)~~ Preservation of grave markers, including repair or cleaning, shall comply with the Virginia Department of Historic Resources standards.

k.~~(11)~~ No grading shall occur inside the buffer and cemetery area. Grading shall not be sloped at a ratio more than three (3) to one from the existing grade of the cemetery for a distance of fifty (50) feet beyond the perimeter of the buffer area.

l.~~(12)~~ All cemeteries shall be recorded at the county and state level. Along with the development plan, subdivision plan and subdivision plat, a completed Stafford County Cemetery Survey Form, and a completed Virginia Department of Historic Resources Cemetery Form shall be submitted to the county agent.

m.~~(13)~~ Cemetery removals and/or disinterment shall be conducted in accordance with the Virginia Code, Virginia Administrative Code and the Virginia Department of Historic Resources standards and requirements, including but not limited to, obtaining the required permit to conduct such removal and disinterment. Every effort shall be made to contact any living relatives of the proposed body to be disinterred for permission to remove the remains. Reasonable reinterment wishes of the relatives shall be complied with. Removal of cemeteries and/or disinterment shall not occur until a reinterment location has been determined and all reinterment information, including location and contact information for the new burial location, has been provided to the county agent.

n.~~(14)~~ Nothing in this section shall preclude removal and reinterment of burials in accordance with the Code of Virginia, Virginia Administrative Code, County Code and any other applicable legislation.

A copy teste:

C. Douglas Barnes

C. Douglas Barnes
Interim County Administrator

CDB:JAH

§ 15.2-2288.5. Meaning of "cemetery" for purposes of zoning.

A. A "cemetery" for purposes of this chapter shall have the meaning set forth in § 54.1-2310.

B. Nothing in this section shall exempt a licensed funeral home or cemetery from any applicable zoning regulation.

C. The following uses shall be included in the approval of a cemetery without further zoning approval being required: all uses necessarily or customarily associated with interment of human remains, benches, ledges, walls, graves, roads, paths, landscaping, and soil storage consistent with federal, state, and local laws on erosion sediment control.

D. Mausoleums, columbaria, chapels, administrative offices, and maintenance and storage areas that are shown in a legislative approval for the specific cemetery obtained at the request of the owner shall not require additional local legislative approval provided such structures and uses are developed in accordance with the original local legislative approval. This subsection shall not supersede any permission required by an ordinance adopted pursuant to § 15.2-2306 relative to historic districts.

§ 57-26. Restrictions as to location of cemeteries and as to quantity of land.

(1) Restrictions as to location. -- No cemetery shall be hereafter established within a county or the corporate limits of any city or town, unless authorized by appropriate ordinance subject to any zoning ordinance duly adopted by the governing body of such county, city or town; provided that authorization by county ordinance shall not be required for interment of the dead in any churchyard or for interment of members of a family on private property; nor shall any cemetery be established within 250 yards of any residence without the consent of the owner of the legal and equitable title of the residence; provided that subject to the foregoing if the location for the proposed cemetery is separated from any residence by a state highway, it may be established upon such location without the consent of the owner of such residence if it be not less than 250' from the residence at its nearest point thereto; provided such prohibition and restriction shall not apply where the tract of land intended for use as a cemetery is separated from any residence by a state highway and now contains a public or private burial ground and is not within the corporate limits of any city or town; and no cemetery shall be hereafter established, and no burial made in any part of any cemetery, other than a municipal or city cemetery, located within 300 yards of any property owned by any city, town or water company, upon which or a portion of which are now located driven wells from which water is pumped or drawn from the ground in connection with the public water supply.

(2) Quantity of land. -- Nothing contained in §§ 57-22 to 57-25 shall be so construed as to authorize a conveyance of more than 300 acres or the condemnation of more than 2 acres of land for the use of a cemetery.

(3) Action for damages. -- When damage is done to adjacent land by the establishment of such cemetery, whether established by purchase or condemnation, the owners whose lands have been damaged shall have a right to action for such damage against any person, firm, corporation, or municipality, establishing the cemetery; provided such action be instituted within one year from such establishment.

(4) Exceptions. -- The prohibitions and restrictions as to the location or establishment of cemeteries shall not apply to the town of Stuart, in Patrick County, to the town of Gretna, in Pittsylvania County, to the town of Shenandoah in Page County, or to the Woodbine Cemetery in the city of Harrisonburg, Rockingham County. And if the location for the proposed cemetery be in Norfolk County it may be established on such location if consent thereto be given by the owners of every residence within 250' thereof at its nearest point to any such residence, or if the location for the proposed cemetery is separated from any such residence by a state highway it may be established upon such location without the consent of the owner of such residence if it be not less than 150' from the residence at its nearest point thereto.

Code 1919, § 56; 1926, p. 866; 1934, p. 13; 1942, p. 102; 1944, p. 462; 1948, p. 492; 1952, c. 108; 1954, c. 10; 1960, c. 161; 1994, c. 229.

§ 54.1-2310. Definitions.

As used in this chapter, unless the context requires a different meaning:

"Advertisement" means any information disseminated or placed before the public.

"At-need" means at the time of death or while death is imminent.

"Board" means the Cemetery Board.

"Cemetery" means any land or structure used or intended to be used for the interment of human remains. The sprinkling of ashes or their burial in a biodegradable container on church grounds or their placement in a columbarium on church property shall not constitute the creation of a cemetery.

"Cemetery company" means any person engaged in the business of (i) selling or offering for sale any grave or entombment right in a cemetery and representing to the public that the entire cemetery, a single grave, or entombment right therein will be perpetually cared for; (ii) selling property or services, vaults, grave liners, urns, memorials, markers, and monuments used in connection with interring or disposing of the remains or commemorating the memory of a deceased human being, where delivery of the property or performance of the service may be delayed more than 120 days after receipt of the initial payment on account of such sale; or (iii) maintaining a facility used for the interment or disposal of the remains and required to maintain perpetual care or preneed trust funds in accordance with this chapter. Such property or services include but are not limited to burial vaults, mausoleum crypts, garden crypts, lawn crypts, memorials, and marker bases, but shall not include graves or incidental additions such as dates, scrolls, or other supplementary matter representing not more than ten percent of the total contract price.

"Compliance agent" means a natural person who owns or is employed by a cemetery company to assure the compliance of the cemetery company with the provisions of this chapter.

"Cost requirement" means the total cost to the seller of the property or services subject to the deposit requirements of § 54.1-2325 required by that seller's total contracts.

"Department" means the Department of Professional and Occupational Regulation.

"Garden crypt" means a burial receptacle, usually constructed of reinforced concrete, installed in quantity on gravel or tile underlay. Each crypt becomes an integral part of a given garden area and is considered real property.

"General funds" means the sum total of specific funds put together in a single fund.

"Grave" means a below-ground right of interment.

"In-person communication" means face-to-face communication and telephonic communication.

"Interment" means all forms of final disposal of human remains including, but not limited to, earth burial, mausoleum entombment and niche or columbarium inurnment. The sprinkling of ashes on church grounds shall not constitute interment.

"Lawn crypt" means a burial vault with some minor modifications for the improvement of drainage in and around the receptacle and is considered personal property.

"Licensee" means any person holding a valid license issued by the Board.

"Marker base" means the visible part of the marker or monument upon which the marker or monument rests and is considered personal property.

"Mausoleum crypt" means a burial receptacle usually constructed of reinforced concrete and usually constructed or assembled above the ground and is considered real property.

"Memorials, markers or monuments" means the object used to identify the deceased and is considered personal property.

"Perpetual care trust fund" means a fund created to provide income to a cemetery to provide care, maintenance, administration and embellishment of the cemetery.

"Preneed" means at any time other than either at the time of death or while death is imminent.

"Preneed burial contract" means a contract for the sale of property or services used in connection with interring or disposing of the remains or commemorating the memory of a deceased human being, where delivery of the property or performance of the service may be delayed for more than 120 days after the receipt of initial payment on account of such sale. Such property includes but is not limited to burial vaults, mausoleum crypts, garden crypts, lawn crypts, memorials, and marker bases, but shall not include graves or incidental additions such as dates, scrolls, or other supplementary matter representing not more than ten percent of the total contract price.

"Resale" means the sale of an interment right in a cemetery governed by this chapter to a person other than the cemetery company owning the cemetery in which the right exists by a person other than that cemetery company or its authorized agent. The term "resale" shall not be construed to include the transfer of interment rights upon the death of the owner.

"Retail sales price" means the standard, nondiscounted price as listed on the general price list required by § 54.1-2327.

"Seller" means the cemetery company.

"Seller's trust account" means the total specific trust funds deposited from all of a specific seller's contracts, plus income on such funds allotted to that seller.

"Solicitation" means initiating contact with consumers with the intent of influencing their selection of a cemetery.

"Specific trust funds" means funds identified to a certain contract for personal property or services.

1998, cc. 708, 721; 2000, c. 36; 2011, c. 792.

R17-263

BOARD OF SUPERVISORS
COUNTY OF STAFFORD
STAFFORD, VIRGINIA

RESOLUTION

At a regular meeting of the Stafford County Board of Supervisors (the Board) held in the Board Chambers, George L. Gordon, Jr., Government Center, Stafford, Virginia, on the 3rd day of October, 2017:

MEMBERS:	VOTE:
Paul V. Milde, III, Chairman	Yes
Meg Bohmke, Vice Chairman	Yes
Jack R. Cavalier	Yes
Wendy E. Maurer	Yes
Laura A. Sellers	Yes
Gary F. Snellings	Yes
Robert "Bob" Thomas, Jr.	Yes

On motion of Mr. Thomas, seconded by Ms. Bohmke, which carried by a vote of 7 to 0, the following was adopted:

A RESOLUTION REQUESTING THE PLANNING COMMISSION TO CONSIDER AND RECOMMEND CHANGES TO COUNTY CODE SEC. 28-39(O) REGARDING REGULATIONS FOR ESTABLISHING CEMETERIES

WHEREAS, County Code Sec. 28-39(o) specifies restrictions as to locations of new cemeteries; and

WHEREAS, citizens have raised concerns that some of the restrictions, such as setbacks to private wells and water resources, may be too restrictive; and

WHEREAS, the Board desires to receive recommendations from the Planning Commission on this matter;

NOW, THEREFORE, BE IT RESOLVED by the Stafford County Board of Supervisors on this the 3rd day of October 2017, that the Planning Commission be and it hereby is requested to discuss and recommend changes County Code Sec. 28-39(o), "Cemeteries" and report its recommendations to the Board in advance of conducting public hearings.

A Copy, teste:

Thomas C. Foley

Thomas C. Foley
County Administrator

Cemetery Ordinance Timeline/Public Process

- September 7, 2016 - Board of Supervisors Community and Economic Development Committee (CEDC) discussed the local ordinance being out of compliance with state code. Staff presented a draft ordinance. The CEDC voted to send the matter to the Board of Supervisors.
- September 16, 2016 - Board of Supervisors adopted Resolution R16-295 referring proposed Ordinance O16-30 to the Planning Commission for a public hearing, review and recommendation.
- September 28, 2016 – Planning Director advises the Planning Commission of Resolution R16-295. The Planning Commission forms a Committee comprised of Commissioners Coen, English, and Vanuch.
- October 5, 2016 – Planning Commission Cemetery Committee met and discussed the proposed ordinance.
- October 12, 2016 – Planning Commission Cemetery Committee reported its recommendations to the Planning Commission. The Planning Commission authorized a public hearing on the proposed amendments.
- November 9, 2016 – Planning Commission conducted a public hearing and recommended adoption of proposed Ordinance O16-39.
- December 13, 2016 – Board of Supervisors conducted a public hearing and adopted Ordinance O16-39.

COMPARISON OF CEMETERY ORDINANCES 2016

Locality	Where Permitted	How Regulated
Caroline	• Residential Zones – Church cemeteries only in RR-2, RR-5 • Agricultural Zones – family and church cemeteries in RP, AP	• Normal zoning standards • Church cemeteries are accessory uses
Chesterfield	• Residential Zones - R-7, R-9, R-12, R-15, R-25, R-40, R-88, R-C • Manufactured Homes – MH-2 • Agriculture - A	Requires conditional approval by the Planning Director
Fairfax	• Not a listed use	• Church and family cemeteries could be considered accessory uses • Normal zoning standards
Fauquier	Residential Zones – RC, RA, RR-2, V, R-1, R-2, R-3, R-4 Commercial Zones – C-1 Industrial Zones – I-1, I-2	• Special Permit to the BZA • Normal zoning standards • No internments within 50 feet of a street or 25 feet from any side or rear yard
King George	• Agricultural Zones – private cemeteries A-1, A-2, A-3 • Commercial Zones – commercial cemeteries C-1	• Commercial cemeteries by special exception from BOS • Normal Zoning Standards
Prince William	Agricultural Zones - A-1	• Standards for preserving existing cemeteries • Allowed by special use permit by the BOS similar to a zoning map amendment
Spotsylvania	• Residential Zones – R-1 • Agricultural Zones – A-2, A-3	• Allowed by special use permit by the BOS

Stafford County Cemetery Areas

Produced by the Stafford County GIS Office

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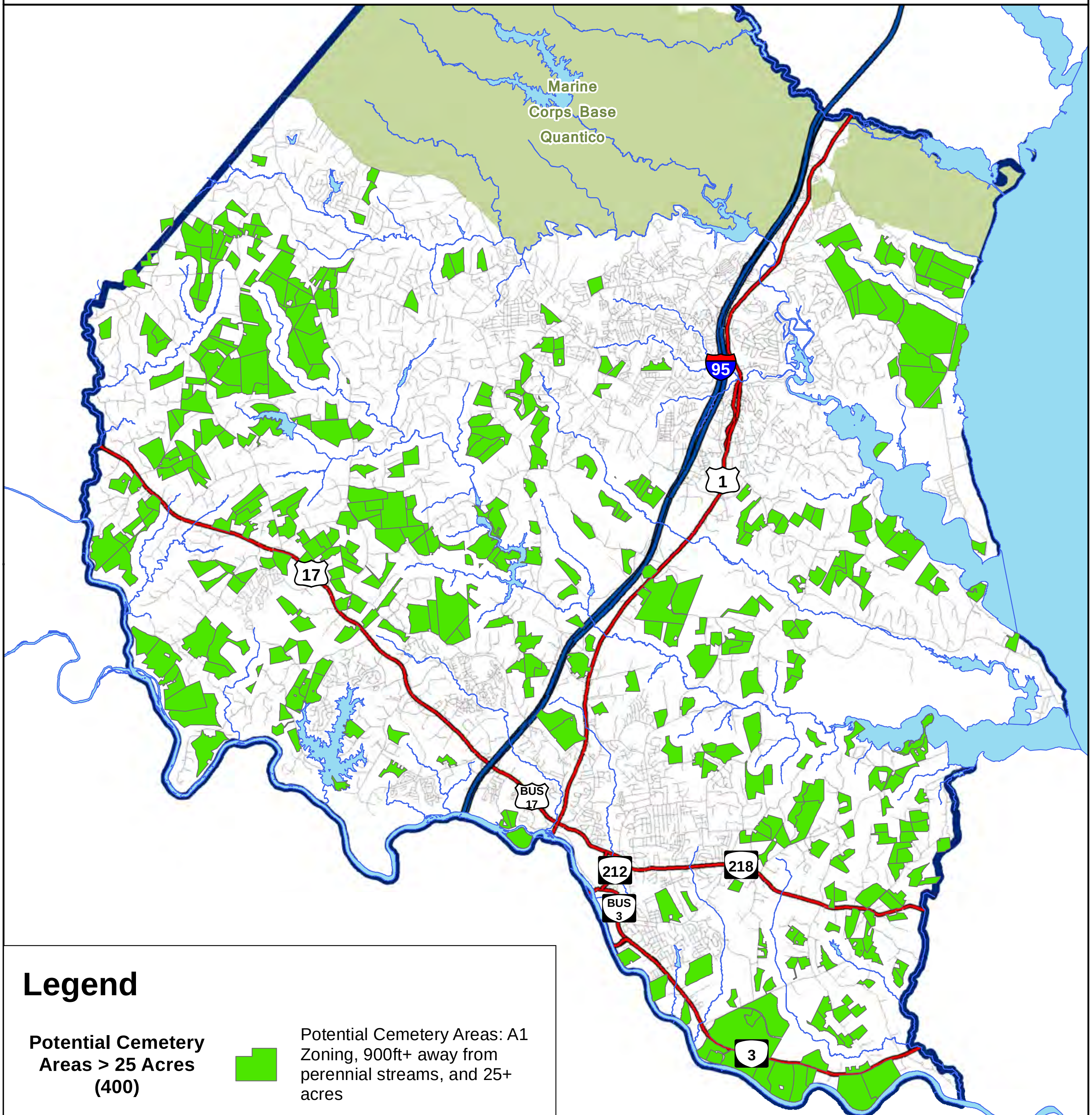

Legend

Potential Cemetery Areas > 25 Acres (400)

Potential Cemetery Areas: A1 Zoning, 900ft+ away from perennial streams, and 25+ acres

Coordinate System: NAD 1983 HARN StatePlane Virginia North FIPS 4501 Feet
Produced: 9/30/2016
MXD Path: W:\users\gis\Brad\Planning\Cemetery Areas\CemeteryAreas.mxd

0 1 2 4 Miles

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Data layers are compiled from various sources and are not to be construed or used as a "legal description." Data layers are believed to be accurate, but accuracy is not guaranteed.

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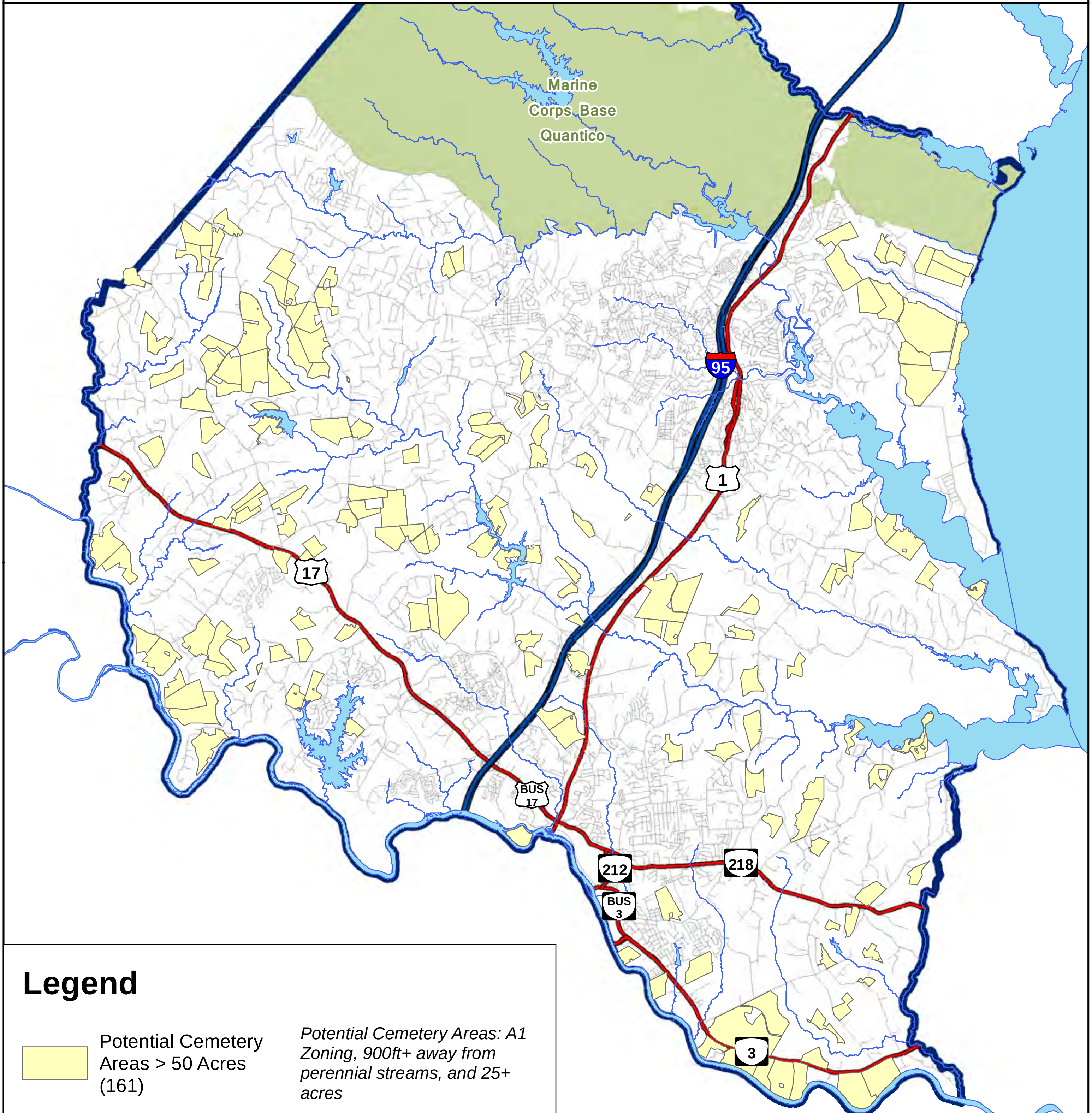

Legend

Potential Cemetery Areas > 50 Acres (161)

Potential Cemetery Areas: A1 Zoning, 900ft+ away from perennial streams, and 25+ acres

Coordinate System: NAD 1983 HARN StatePlane Virginia North FIPS 4501 Feet
Produced: 9/30/2016
MXD Path: W:\users\gis\Brad\Planning\Cemetery Areas\CemeteryAreas.mxd

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0 1 2 4 Miles

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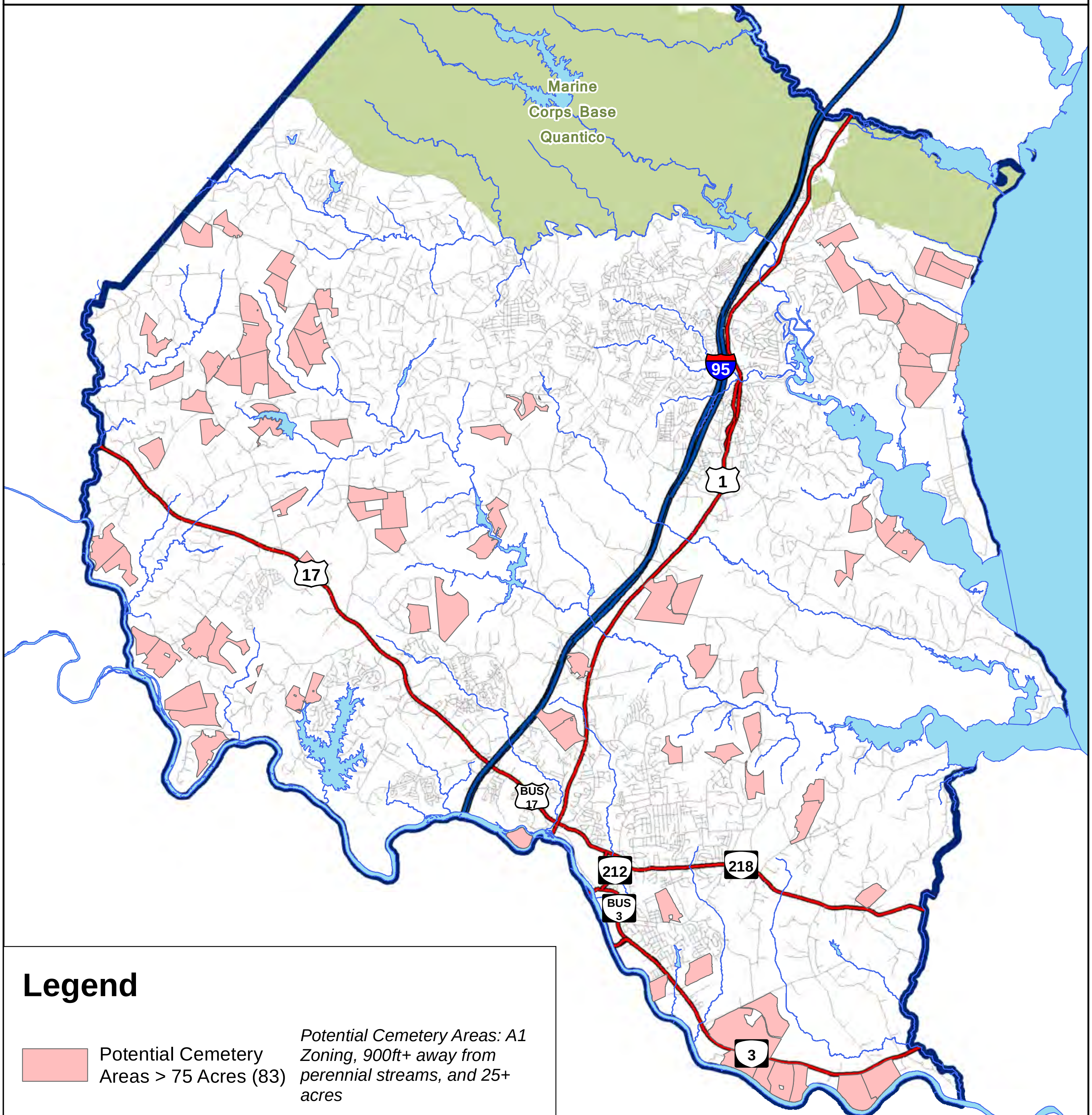

Legend

Potential Cemetery Areas > 75 Acres (83)

Potential Cemetery Areas: A1 Zoning, 900ft+ away from perennial streams, and 25+ acres

Coordinate System: NAD 1983 HARN StatePlane Virginia North FIPS 4501 Feet
Produced: 9/30/2016
MXD Path: W:\users\gis\Brad\Planning\Cemetery Areas\CemeteryAreas.mxd

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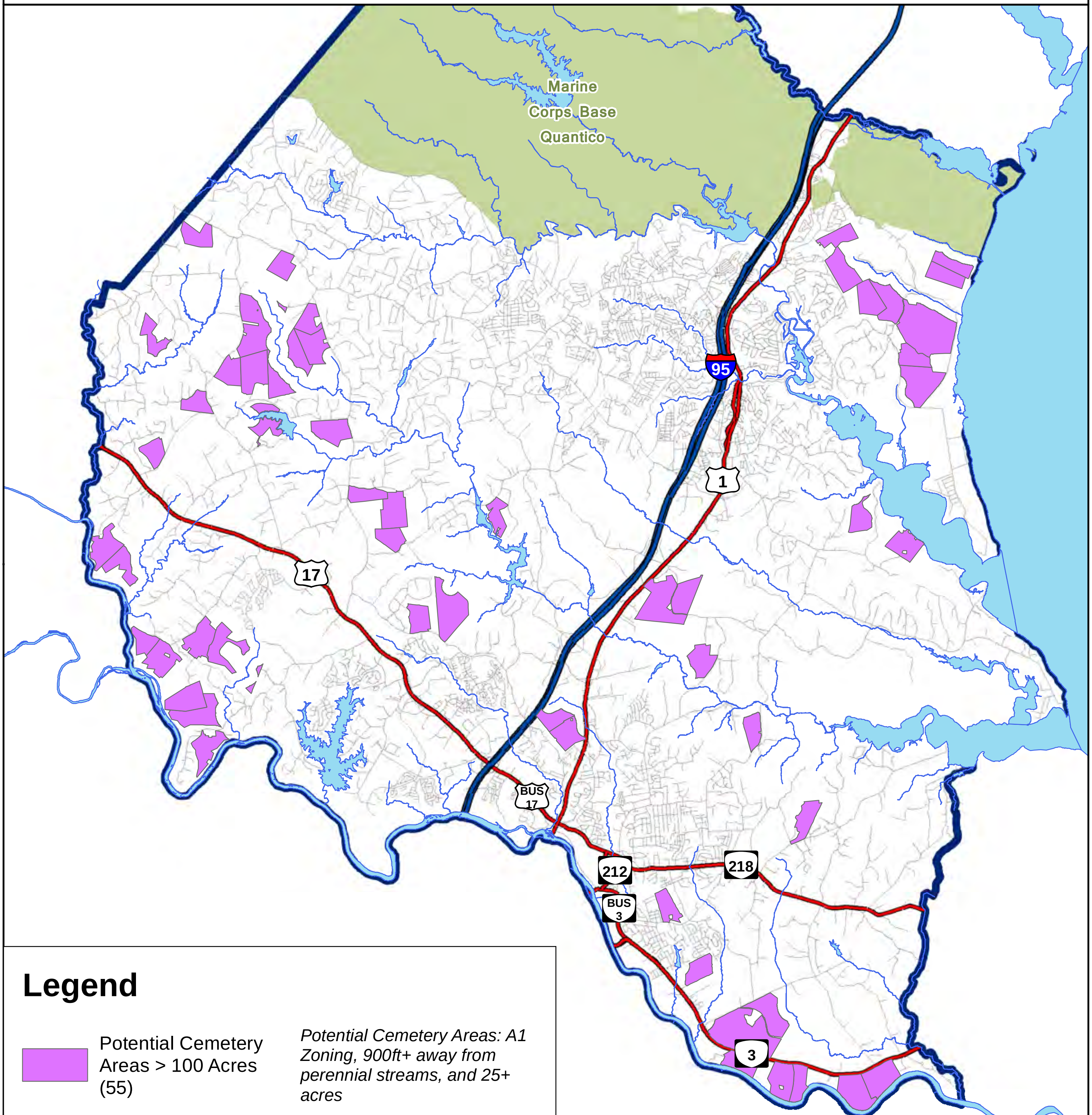

Legend

Potential Cemetery Areas > 100 Acres (55)

Potential Cemetery Areas: A1 Zoning, 900ft+ away from perennial streams, and 25+ acres

Coordinate System: NAD 1983 HARN StatePlane Virginia North FIPS 4501 Feet
Produced: 9/30/2016
MXD Path: W:\users\gis\Brad\Planning\Cemetery Areas\CemeteryAreas.mxd

Data layers are compiled from various sources and are not to be construed or used as a "legal description." Data layers are believed to be accurate, but accuracy is not guaranteed.

0 1 2 4 Miles

N

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Published online 2012 Feb 7. doi: 10.3390/ijerph9020511

Mineral Contamination from Cemetery Soils: Case Study of Zandfontein Cemetery, South Africa

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Received 2012 Jan 3; Revised 2012 Jan 16; Accepted 2012 Jan 17.

Abstract

Go to:

The burial of coffins may pose an environmental and health hazard since the metals that are used in coffin-making may corrode or degrade into harmful toxins. These may leach into the surrounding soils and groundwater. Very little research has been conducted world-wide on the mineral contamination potential of cemeteries, and virtually none in South Africa. The aim of the study is to determine whether burial practices affect the mineral content of soils in cemeteries. This was done by comparing the mineral concentrations of soils within the Zandfontein Cemetery in Tshwane (Gauteng, South Africa) to those off-site as well as those in zones with high burial loads with those zones with fewer burials. Twenty three soil samples were collected from various sites on- and off-site and analyzed for 31 minerals using ICP-AES. It was found that mineral concentrations of soils within the Zandfontein Cemetery were considerably higher than those off-site. Soil samples in multiple burials blocks also have elevated metal concentrations. These excess metals are probably of anthropogenic origin associated with burial practices and could pose an environmental and human health hazard. Strict monitoring of water quality in boreholes in the vicinity of the cemetery is recommended.

Keywords: minerals, heavy metals, cemetery, coffins, burial load, pollution, soil

1. Introduction

Go to:

Agriculture, industry and landfills are commonly believed to be major anthropogenic sources of environmental contamination. Little attention has been given to cemeteries as possible pollution sources. Research conducted on the latter has been limited to examining pollutants emanating from the bodies. However, cemeteries are not only the final resting place to bodies but also to coffins and caskets used for the interment of remains. Indeed, recent studies conducted found the highest contamination arising from cemeteries originated from minerals that are released by burial loads [1]. The minerals that are used in coffin-making may corrode or degrade releasing harmful toxic substances [2]. These may be transported from the graves through seepage and diffuse into surrounding soils. From there they may leach into groundwater and become a potential health risk to the residents in areas surrounding the cemetery [3,4,5,6,7,8]. Most existing cemeteries were sited without thinking about potential risks to the local environment or community [9].

Toxic chemicals that may be released into groundwater include substances that were used in embalming and burial practices in the past as well as varnishes, sealers and preservatives and metal handles and ornaments used on wooden coffins.

Wood preservatives and paints used in coffin construction contain minerals such as copper naphthalene and ammoniac or chromated copper arsenate (CCA) [2,10]. Besides CCA, ammonium copper quaternary (ACQ) and copper boron azole (CBA) are available on the market [11]. Prior to the 1940s, lead compounds were commonly used as colouring agents in paints [12]. Toxic metals such as manganese, nickel, copper and vanadium were also identified in old paint samples [13]. Currently, many paints still contain lead, mercury, cadmium, and chromium [14,15,16,17]. Arsenic is used as a pigment, a wood preservative and as an anti-fouling ingredient while barium is used as a pigment and a corrosion inhibitor [18,19].

Metals are also used for the handles and other ornaments that are attached to the outside of a coffin. The fasteners and coffin ornaments also contain minerals such as zinc and zinc- or copper-alloys, silver or bronze. Often these items are spray painted, vacmetalized, electroplated or a combination of these processes to enhance their aesthetic value [20].

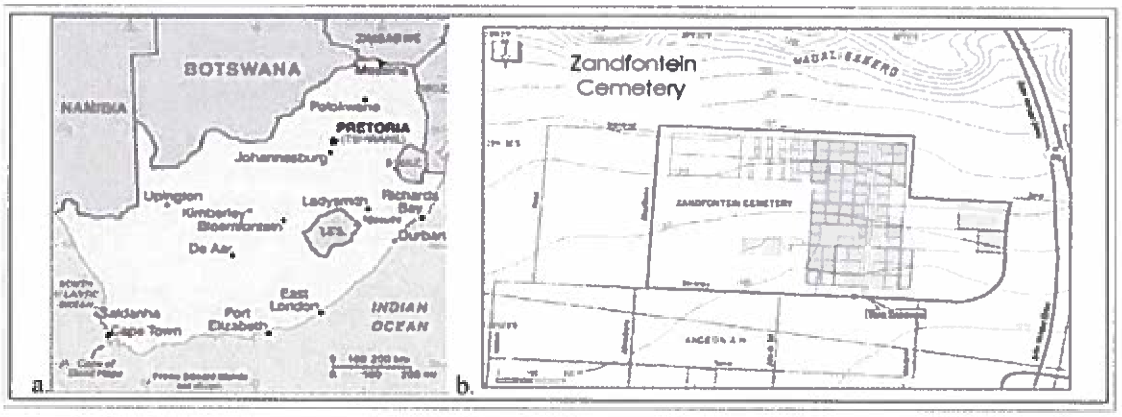
Although wood has traditionally been used in South Africa for the construction of coffins, the price of wood is becoming prohibitive and cheaper materials such as cardboard, plywood, MDF boards, supa-wood, chipboard or pressboard are being used as substitutes [21]. These plywood products contain preservatives that are regulated by Hazard Communication Standards (United States Occupational Safety and Health Administration (OSHA) and may contain chromium and copper. Another recent new development overseas is the use the of light-weight titanium for the construction of coffins [22].

The current state of knowledge regarding the contamination loads from cemeteries is limited, with only sparse published information available [9]. One of the few studies conducted on spatial variations of metals content of cemetery soils was that by Spongberg and Becks (2000). This study revealed that metal concentrations of copper, lead, zinc and iron in soils in a cemetery in Ohio in the USA not only differed in from one zone to another within the cemetery, but also differ on- and off-site. To date, no such studies have been conducted in South Africa.

This article aims to investigate whether the mineral contents of soils in a cemetery are affected by burial practices, and thus by anthropogenic activities. In order to achieve this, the mineral contents of soils within a cemetery were compared with those off-site; and the soil mineral contents of densely "populated" areas of a cemetery with those in areas with fewer burials. Since the burial load may impact directly on the mass of anthropogenically introduced minerals into cemetery soils, the spatial distribution of burials and the burial loads were also determined.

The study was conducted in the city of Tshwane in the province of Gauteng, South Africa. The City of Tshwane Metropolitan area, Pretoria, has a total of 40 cemeteries and one crematorium within the municipal boundary. The Zandfontein Cemetery, the study area, is one of the oldest cemeteries in the City of Tshwane (Pretoria) that is still in operation. Zandfontein Cemetery is located ten kilometres north-west of the city centre on a portion of the farm Zandfontein 318 JR and centres on the following coordinates: S25°41'38.70"; E28°06'50.86" (Figure 1). It is located on the southern slopes of the Magaliesberg. Due to urban encroachment, the cemetery is surrounded by the suburbs of Booysens, Hercules, Kirkney and Andeon L.H. and Lady Selborne.

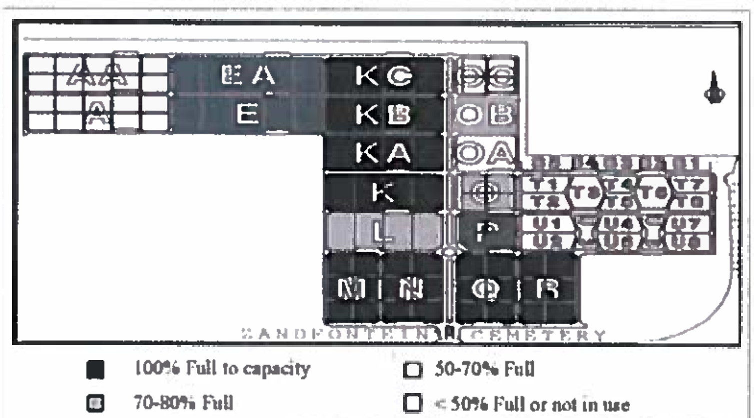
Figure 1



Location and map of study area.

The cemetery covers an area of about 123.25 ha. It is divided into quadrangular blocks with each block allocated a pre-determined number of burials. The locations of the blocks are shown in Figure 2. At present blocks AA, A, and some plots in S and T have not been used whilst M, N, Q, R, K, KA, KB and KC have reached capacity [22]. Due to the structure of the soils, most blocks were used for single burials (Sandy-loam soils), whereas blocks T and U are used for multiple burials (clayey soils). A total of 60,437 grave plots were used for burials between 1958 and 2010.

Figure 2



Burial zones in Zandfontein Cemetery.

2. Methodology

Go to:

2.1. Calculation of Burial Loads

All the data on the burials at Zandfontein Cemetery were obtained from the administrative centre on site. The records on all burials have been noted by hand since 1958 by administrative personnel of the CCTM. Each block or section area in the cemetery has its own record book where the date of burial, particulars of the deceased such as gender and age of the deceased, and grave plot numbers are noted. The number of burials in each of the cemetery zones was obtained from these worksheets.

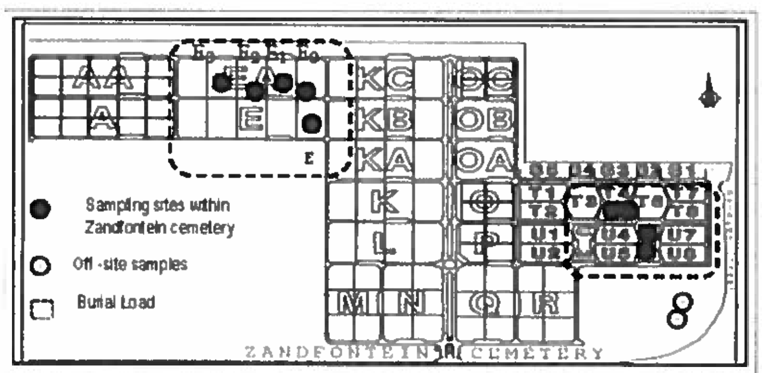
A few problems were encountered while attempting to calculate the burial load. Firstly, record-keeping was not always adequate regarding the number of people buried (and hence the number of coffins) in each grave. It is thus difficult to make an accurate estimate of the mass of minerals in any given cemetery, especially in an older, fuller cemetery such as Zandfontein, where grave plots are re-used or where a single grave is used for multiple burials. Moreover, burials take place in different parts of a cemetery at different times and thus exhibit a very large range of spatial and temporal decomposition processes [3].

A further shortcoming is that the exact mineral content of each coffin is not known, hence the mass of the mineral content of the burial load could not be determined with any degree of accuracy. However, literature reveals that one coffin handle weighs 300 g [19]. The estimated total metal/mineral mass of the burial load at Zandfontein Cemetery could thus be obtained by multiplying this mass with 6 (handles) and the number of burials.

2.2. Collection and Analysis of Soil Samples

Soil samples were collected on- and off-site for chemical analysis. The City Council of Tshwane Municipality (CCTM) by-laws on cemeteries stipulate that no person may, unless permitted to do so by the Strategic Executive Officer, disturb the soil in a cemetery [23]. Soil samples were thus only collected from blocks E, EA, T and U, where and whilst contractors for CCTM excavated soil for new grave plots (Figure 3). A total of 23 soil samples were collected from depths ranging between 1 to 2.8 m within the Zandfontein Cemetery. All protocols and safety precautions for collecting possible contaminated soil samples in historical cemeteries were followed, which include wearing a facemask, coverall, booties, and latex gloves.

Figure 3



Location of sampling sites.

To establish the naturally occurring background soil levels for the Zandfontein area, two samples were collected from a nearby off-site area (Figure 3). Samples were collected at one meter depth at each sample point and mixed together into one sample to establish an off-site control sample for the soils inside Zandfontein Cemetery.

One kilogram samples were collected from all sample points and placed in plastic bags. Samples were labelled with date, time, sample I.D, block name and sample depth. Samples were taken to the Agriculture Research Council's—Institute for Soil Climate and Water (ARC-ISCW) accredited laboratories at Belvedere Street, Pretoria, for analysis. Microwave digestion and Inductively Coupled Plasma-atomic Emission Spectroscopy (ICP-AES) (USEPA Method 6010) were used to analyse 31 micro element concentrations in the soils. Unfortunately, the laboratory did not test for the concentrations of lead and aluminium.

Means were calculated for each of the minerals in on-site samples. Student's *t*-test was used to determine whether there is a statistically significant difference between the total mineral content of the soils in different parts of the cemetery.

3. Results and Discussion

Go to:

The estimated mineral burial mass due to coffins alone is approximately 108,000 kg (6 handles/coffin × 300 g/handle × 60,000 coffins). This mineral mass only accounts for metals that are used in coffin handles and may thus be an underestimation of the total mineral load.

The possibility that cemetery soils are contaminated with toxic minerals was assessed by calculating the ratio of on- to off-site soil mineral content. Table 1 show the mean mineral concentrations and standard deviations of the samples collected within the cemetery and those from off-site samples. The on:off site ratios are also presented.

Table 1

Mean mineral concentrations on- and off- site.

Metal	Mean mineral concentrations on-site (mg/kg) and standard deviations	Mean mineral concentrations off-site (mg/kg) and standard deviations	Approximate ratio of means for on: off-site samples
Li	6.58	2.04	3:1
Be	0.65	0.16	4:1
B	5.99	0.76	8:1
Ti	200.49	26.20	8:1
V	61.59	29.41	2:1
Cr	321.07	76.34	4:1
Mn	430.66	53.44	8:1
Co	20.71	2.56	8:1
Ni	44.63	5.29	8:1
Cu	17.39	3.73	5:1
Zn	7.76	5.93	1:1
As	0.39	0.09	4:1
Se	0.11	0.08	4:1
Rb	10.63	4.48	2:1
Sr	3.06	1.30	2:1
Mo	0.12	0.05	2:1
Cd	0.04	0.02	2:1
Sn	0.15	0.05	3:1
Sb	0.03	0.01	3:1
Te	0.01	0.00	-
Cs	8.78	0.74	11:1
Ba	29.36	6.26	5:1
La	13.21	6.41	2:1
W	0.02	0.00	-

Metal	Mean mineral concentrations on-site (mg/kg) and standard deviations	Mean mineral concentrations off-site (mg/kg) and standard deviations	Approximate ratio of means for on: off-site samples
Pt	0.01	0.00	-
Hg	0.02	0.01	2:1
Tl	0.18	0.05	4:1
Pb	26.92	11.84	2:1
Bi	0.10	0.04	3:1
U	0.94	0.38	3:1
Total	1211.6	237.67	5:1

Table 1 indicates that the mean metal concentrations off-site is far less than the on-site metal concentrations. The largest differences in mineral concentrations are those of caesium, boron, manganese, titanium, cobalt and nickel, with ratios exceeding 8:1. The source of the high levels of caesium in the cemetery is not clear since this mineral is not used in coffin construction. The relatively high concentrations of boron, manganese and nickel are more easily explained since these are used either in the metal ornaments or in paints and varnishes on coffins. However, the sources of the relatively high uranium and cobalt loads are not known. Interestingly, Spongberg and Becks (2000) could not explain the presence of high cobalt levels in the Ohio cemetery either. The results at Zandfontein Cemetery for lead correspond to the ratio found in the U.S. [2] but there is relatively more zinc, copper, arsenic, nickel and chrome at Zandfontein. It should also be kept in mind that the Ohio cemetery only had 14,600 graves in comparison to the 60,000+ at Zandfontein. Nevertheless, the results in this study seem to indicate that burial practices do indeed influence the concentration of minerals in cemetery soils.

Further proof of the anthropogenic origin of soil contamination requires that the areas within the cemetery with high burial loads should have higher mineral concentrations, than those with lower burial loads.

The approximate number of coffins was obtained by summing the number of graves in the immediate vicinity of the two sets of sample sites *i.e.*, those in blocks E and EA as well as in the adjacent sub-blocks of KA, KB and KC, and those around T_5 and T_6 (*i.e.*, T_{4-6} and U_{3-8}). The estimated number of burials in the various blocks is shown in Table 2.

Since the graves in blocks T and U are used for multiple burials, the total number of coffins is higher in these blocks than in the relatively more densely "used" blocks E and EA.

Table 2

Estimated number of burials in various blocks of Zandfontein Cemetery (2010).

Blocks	Used grave plots	Blocks	Used grave plots
EA	4442	T_4	890
E	4375	T_5	871
KC	4096/4 = 1024	T_6	1116
KB	4126/4 = 1031	U_3	671
KA	4126/4= 1031	U_4	1613
		U_5	-

Blocks	Used grave plots	Blocks	Used grave plots
		U_6	367
		U_7	692
		U_8	648
Total no graves used	11,903	Total no. graves used	6869
Estimated no burials	11,903 (single plot burials)	Total no. burials	6869 × 3 (multiple burials) = 20,607

If the mineral content in the soils is influenced by the burial loads, the mineral content of soil samples collected in the T and U should exceed those in blocks E and EA. This assumption was tested using data obtained for each of the blocks, as shown in Table 3.

Table 3

Mean soils mineral concentrations in various blocks of Zandfontein Cemetery (mg/kg).

mg/kg	Sample points in blocks in Zandfontein									Total
Metal	T_5	T_5	U_6	U_6	EA_O	EA_1	EA_2	EA_3	E	
Li	6.58	6.27	4.73	4.84	4.49	7.45	4.05	8.57	12.27	**59.25**
Be	0.84	0.85	0.70	0.76	0.36	0.64	0.52	0.75	0.42	**5.84**
B	1.44	1.19	1.97	3.07	0.56	1.04	0.47	34.74	9.47	**53.95**
Ti	228.91	467.80	319.10	354.65	70.86	91.06	135.40	88.30	48.33	**1804.41**
V	95.29	92.61	53.66	56.08	39.99	50.58	61.56	61.31	43.20	**554.28**
Cr	325.00	363.67	193.93	254.57	234.00	608.45	395.00	363.95	151.03	**2889.6**
Mn	1623.6	566.30	499.13	512.33	95.26	109.30	156.64	256.30	57.10	**3875.96**
Co	62.06	29.91	22.10	20.77	7.34	9.32	12.19	17.87	4.86	**186.42**
Ni	69.98	72.47	47.29	56.87	21.03	39.88	24.81	54.08	15.27	**401.68**
Cu	31.14	24.84	18.29	20.18	7.03	13.14	17.92	15.05	8.97	**156.56**
Zn	12.47	9.88	8.74	10.15	4.68	5.17	4.47	9.98	4.34	**69.88**
As	0.92	0.53	0.37	0.35	0.31	0.11	0.21	0.51	0.20	**3.51**
Se	0.14	0.08	0.16	0.14	0.08	0.07	0.14	0.15	0.08	**1.04**
Rb	9.25	8.46	10.09	9.05	10.16	14.09	7.84	17.13	9.58	**95.65**
Sr	2.83	2.86	2.53	3.08	2.23	2.50	1.31	7.22	2.98	**27.54**
Mo	0.22	0.16	0.12	0.10	0.08	0.07	0.15	0.13	0.07	**1.1**
Cd	0.05	0.07	0.03	0.06	0.04	0.03	0.02	0.03	0.02	**0.35**
Sn	0.20	0.24	0.24	0.22	0.08	0.08	0.11	0.14	0.05	**1.36**
Sb	0.04	0.04	0.04	0.03	0.02	0.02	0.03	0.04	0.02	**0.28**
Te	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	**0.1**
Cs	1.49	1.53	1.70	1.51	66.24	1.87	1.23	2.16	1.28	**79.01**
Ba	95.79	21.52	26.76	29.35	15.93	20.92	13.00	26.40	14.58	**264.25**
La	10.52	10.40	14.66	18.88	9.19	13.16	11.80	16.76	13.50	**118.87**
W	0.03	0.02	0.03	0.02	0.01	0.01	0.01	0.02	0.01	**0.16**
Pt	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.03	0.01	**0.12**

mg/kg	Sample points in blocks in Zandfontein									Total
Hg	0.05	0.03	0.04	0.02	0.01	<0.01	0.02	0.03	<0.01	0.2
Tl	0.48	0.20	0.19	0.19	0.11	0.08	0.11	0.19	0.09	1.64
Pb	37.47	17.59	17.26	13.09	11.58	17.62	93.94	20.11	13.65	242.31
Bi	0.16	0.16	0.10	0.10	0.06	0.09	0.11	0.11	0.06	0.95
U	1.12	1.29	0.81	0.77	0.68	1.02	0.99	1.05	0.72	8.45
Total	2618.11	1701.01	1244.79	1371.25	602.43	1007.78	944.07	1003.12	412.16	

As expected, Student's *t*-test shows that there is a significantly higher concentration of minerals in blocks T and U (Mean $_{T, U}$ = 1733.8 mg/kg *vs*. mean $_{E, EA}$ = 627.9; $t = 3.64$, df = 7; $\alpha = 0.01$), signifying that the cause of contamination could be due to burial practices. The concentration of especially titanium, vanadium, chrome, manganese, cobalt, nickel and zinc are considerably higher in blocks T and U than in E and EA. Contrary to the general trends, the lead content is higher in soils from E and EA than from T and U. Exceptionally high levels of boron, rubidium and strontium were found in soils in EA_3, lead in EA_2, chrome in EA_1 and caesium in EA_0. The latter cannot be explained.

4. Conclusion

Go to:

Approximately 60,000 coffins have been buried at the Zandfontein Cemetery in Tswane (Pretoria, South Africa). These are estimated to produce a burial load of approximately 108,000 kg minerals. This study was aimed at determining whether this burial load affected the mineral composition of the cemetery soils, thereby causing a potential health risk.

It was found that the mineral composition of soils within Zandfontein Cemetery was significantly higher than those off-site and that the soils in the zones with the highest burial loads were more contaminated than in the less used parts of the cemetery. This indicates that burial loads have a direct impact on soil-mineral content and thus cemeteries can be regarded as anthropogenic sources of contamination.

It should be kept in mind that the research did not include the pathogenic or organic releases from gravesites due to burials. It relies on estimations of the amount of metals that are already introduced into the Zandfontein cemetery. Because burials are not carried out in a fixed pattern the results reflect metal contamination from metal deposits that have accumulated over time and not necessarily from metals that have recently been introduced into cemetery soils. Moreover, these results do not necessarily reflect the situation at other cemeteries in Tshwane. The fact that this cemetery is located on the slopes of a mountain may cause leaching of minerals into groundwater and aggravate potential health risks.

It is recommended that the mineral concentration of groundwater be measured and monitored at boreholes in the surrounding suburbs. Similar studies should be conducted at other cemeteries—not only in Tshwane but countrywide. Such studies will also establish whether cemeteries should be considered to be potential anthropogenic contamination sources—similar to—or even more hazardous than landfill sites.

Acknowledgments

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We would like to thank the City of Tshwane for allowing us to carryout surveys on the Zandfontein cemetery as well as UNISA for their support.

Conflict of Interest

Go to:

The authors declare no conflict of interest

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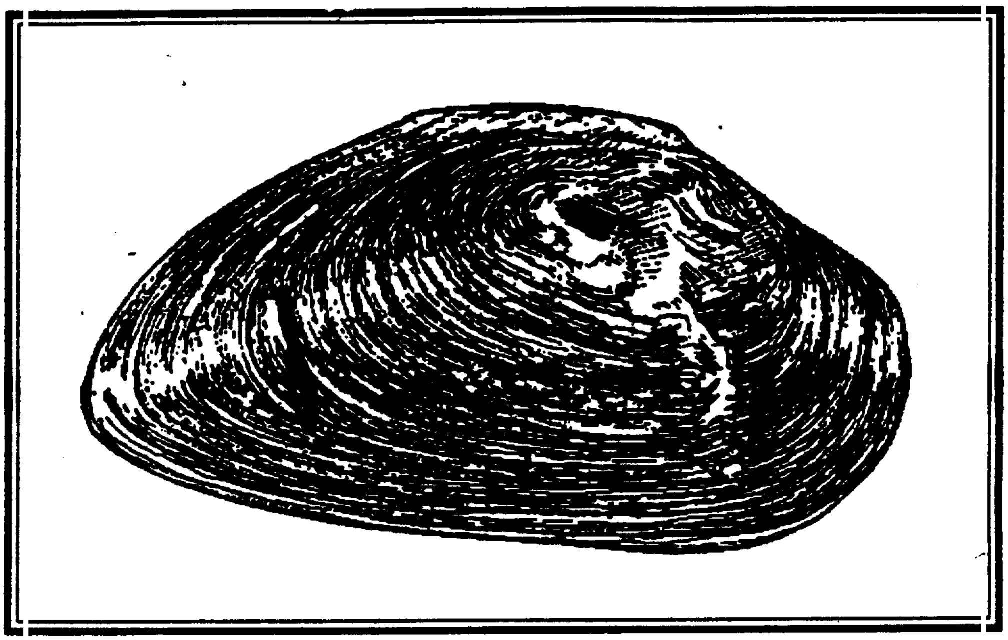
DWARF WEDGE MUSSEL

(Alasmidonta heterodon)

RECOVERY PLAN



U.S. Fish and Wildlife Service, Northeast Region

DWARF WEDGE MUSSEL *(Alasmidonta heterodon)*

RECOVERY PLAN

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EXECUTIVE SUMMARY OF THE DWARF WEDGE MUSSEL RECOVERY PLAN

CURRENT STATUS: This freshwater mussel has declined precipitously over the last hundred years. Once known from at least 70 locations in 15 major Atlantic slope drainages from New Brunswick to North Carolina, it is now known from only 20 localities in eight drainages. These localities are in New Hampshire, Vermont, Connecticut, New York, Maryland, Virginia, and North Carolina. The dwarf wedge mussel (*Alasmidonta heterodon*) was listed as an endangered species in March of 1990.

HABITAT REQUIREMENTS AND LIMITING FACTORS: The dwarf wedge mussel lives on muddy sand, sand, and gravel bottoms in creeks and rivers of various sizes. It requires areas of slow to moderate current, good water quality, and little silt deposition. The species' recent dramatic decline, as well as the small size and extent of most of its remaining populations, indicate that individual populations remain highly vulnerable to extirpation.

RECOVERY OBJECTIVES: (1) Downlist to threatened status, and (2) delist.

RECOVERY CRITERIA: To downlist, populations of *A. heterodon* in the mainstem Connecticut River, Ashuelot River, Neversink River, upper Tar River, three sites in the Neuse River system, as well as in at least six other rivers, must be viable based on monitoring results over a 10-15 year period. To delist, populations must be dispersed widely enough within at least 10 of these rivers such that a single event is unlikely to eliminate a population from a given river reach. These populations must be distributed throughout the species' range, and must be permanently protected from foreseeable threats.

ACTIONS NEEDED:

1. Collect basic data needed for protection of *A. heterodon* populations.
2. Preserve *A. heterodon* populations and occupied habitats.
3. Develop an education program.
4. Conduct life history studies and identify ecological requirements of the species.
5. If feasible, re-establish populations within the species' historical range.
6. Implement a program to monitor population levels and habitat conditions.
7. Periodically evaluate the recovery program.

ESTIMATED COSTS ($1000s):

Year	Need 1	Need 2*	Need 3	Need 4	Need 5	Need 6	Total**
FY1	82	31		35			148
FY2	107	65	6			30	208
FY3	107	75	11				193
FY4	55	45	1				101
FY5		45	1		15	30	91
FY6		45	1		15		61
FY7		15	1		15		31
FY8		15	1		15	30	61
FY9		15	1		15		31
FY10		15	1			30	45
Total	351	366	24	35	75	120	971

* Total costs to provide long-term protection of essential habitats (Need 2) are not yet known.
** No costs are associated with Need 7.

DATE OF RECOVERY: Because a period of at least 10 years is required to document the stability of dwarf wedge mussel populations, downlisting will be considered sometime after the year 2002, when the recovery criterion has been met.

* * *

Recovery plans delineate reasonable actions needed to recover and/or protect listed species. Attainment of recovery objectives and availability of funds are subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities.

Recovery plans do not necessarily represent the views or official position of any individuals or agencies involved in plan formulation, other than the U.S. Fish and Wildlife Service. Approved recovery plans may be modified as dicatated by new findings, changes in species status, and the completion of recovery tasks.

Literature citations for this plan should read as follows:

U.S. Fish and Wildlife Service. 1993. Dwarf Wedge Mussel (Alasmidonta heterodon) Recovery Plan. Hadley, Massachusetts. 52 pp.

Copies of this plan can be purchased from:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814
301-4[illegible]-6403
or
1-800-582-3421

Fees vary according to number of pages.

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FIGURES AND TABLES

PART I: INTRODUCTION

The dwarf wedge mussel (Alasmidonta heterodon) was listed as an endangered species on March 14, 1990 (55 FR 9447). This freshwater mussel has declined precipitously in the past hundred years (Master 1986). Always a rare species confined to Atlantic slope drainages from North Carolina to New Brunswick, the dwarf wedge mussel has been recorded in approximately 70 localities in 15 major drainages since the species' discovery in the early 1800s. It is now thought to have been extirpated from all but 20 localities. The 20 known remaining populations, with one exception, are thought to be relatively small and to be declining as a result of continued environmental assaults in the form of agricultural, industrial, commercial, and domestic pollution/runoff. Channelization, removal of shoreline vegetation, development, and road and dam construction also threaten some populations.

DESCRIPTION

The dwarf wedge mussel was first described by Lea (1829) as Unio heterodon. It was subsequently placed in the genus Alasmidonta by Simpson (1914). Due to its unique soft-tissue anatomy and conchology, Ortmann (1914) placed it in a monotypic subgenus Prolasmidonta. Fuller (1977) believed the antiquity and unique shell characters of Prolasmidonta were sufficient for elevation to full generic rank and named the species Prolasmidonta heterodon. Clarke

(1981a) retained the genus name Alasmidonta and considered Prolasmidonta to be a subjective synonym of the subgenus Pressodonta Simpson 1900.

The species name, heterodon, refers to the chief distinguishing characteristic of this species, which is the only North American freshwater mussel that consistently has two lateral teeth on the right valve, but only one on the left (Fuller 1977). It is a small mussel whose shell rarely exceeds 1.5 inches (38 mm) in length. The largest specimen ever recorded was 56.5 mm long, taken from the Ashuelot river in New Hampshire (Clarke 1981a).

Clarke (1981a) describes the species as follows:

> "Shell up to about 45 mm long, 25 mm high, 16 mm wide, and with shell wall about 1 mm thick in mid-anterior region; more or less ovate or trapezoidal, roundly pointed posterio-basally, thin but not unduly fragile, with rounded posterior ridge, and of medium inflation. Females more inflated posteriorly than males. Sculpturing absent except for lines of growth and beak sculpture. Periostracum [outer layer of shell] brown or yellowish brown, and with greenish rays in young or pale-coloured specimens. Nacre bluish or silvery white, and iridescent posteriorly. Beak sculpture composed of about 4 curved ridges, which are angular on the posterior slope. Hinge teeth small but distinct; pseudo-cardinal teeth compressed, 1 or 2 in the right valve and 2 in the left; lateral teeth gently curved and reversed, that is, in most specimens, 2 in the right valve and 1 in the left."

Because atypical lateral dentition can occur in this species and others, the lateral tooth configuration should not be used alone to distinguish the species. The dwarf wedge mussel is likely to be confused only with young members of the genus Elliptio, from which it can be distinguished by its mottled but colorful mantle margin (Fuller 1977).

LIFE HISTORY AND ECOLOGY

The dwarf wedge mussel lives on muddy sand, sand, and gravel bottoms in creeks and rivers of varying sizes, in areas of slow to moderate current and little silt deposition. In the southern portion of its range, it is often concentrated in areas along logs or in root mats. In the upper Connecticut River system in New Hampshire, it occurs in shallow water (generally less than one-meter depth during low water) with a firm substrate of sandy mud and gravel, scattered patches of wild celery (Valisneria americana), and little silt deposition (Master 1986). The most commonly associated freshwater mussels are Elliptio complanata and Alasmidonta undulata. Other mussels co-occurring throughout the species' range include Alasmidonta varicosa, Strophitus undulatus, Anodonta cataracta, Anodonta imbecilis, Anodonta implicata, Elliptio lanceolata, Elliptio fisheriana, Elliptio icterina, Villosa constricta, Villosa delumbus, Lampsilis radiata, Lampsilis cariosa, Lasmigona subviridis, and Leptodea ochracea.

Little is known about the reproductive biology of the dwarf wedge mussel; however, the reproductive biology of freshwater mussels appears to be similar among nearly all species (Figure 1). During the spawning period, males discharge sperm into the water column, and the sperm are taken in by females during siphoning (Figure 2). Eggs are fertilized in the suprabranchial cavity or gills, which also serve as marsupia for larval development to mature glochidia. A. heterodon glochidia (Figure 3) are roughly triangular, with hooks, and measure about 0.30 mm in length and 0.25 mm in height (Clarke 1981a). Clarke (1981b) indicates that the dwarf wedge mussel is a long-term brooder. In long-term brooders, fertilization typically occurs in mid-summer and fall, and glochidia are released the following spring and summer. Glochidial release for some long-term brooders also has been observed during fall and winter (Zale 1980). D. Michaelson (Virginia Polytechnic Institute and State University,

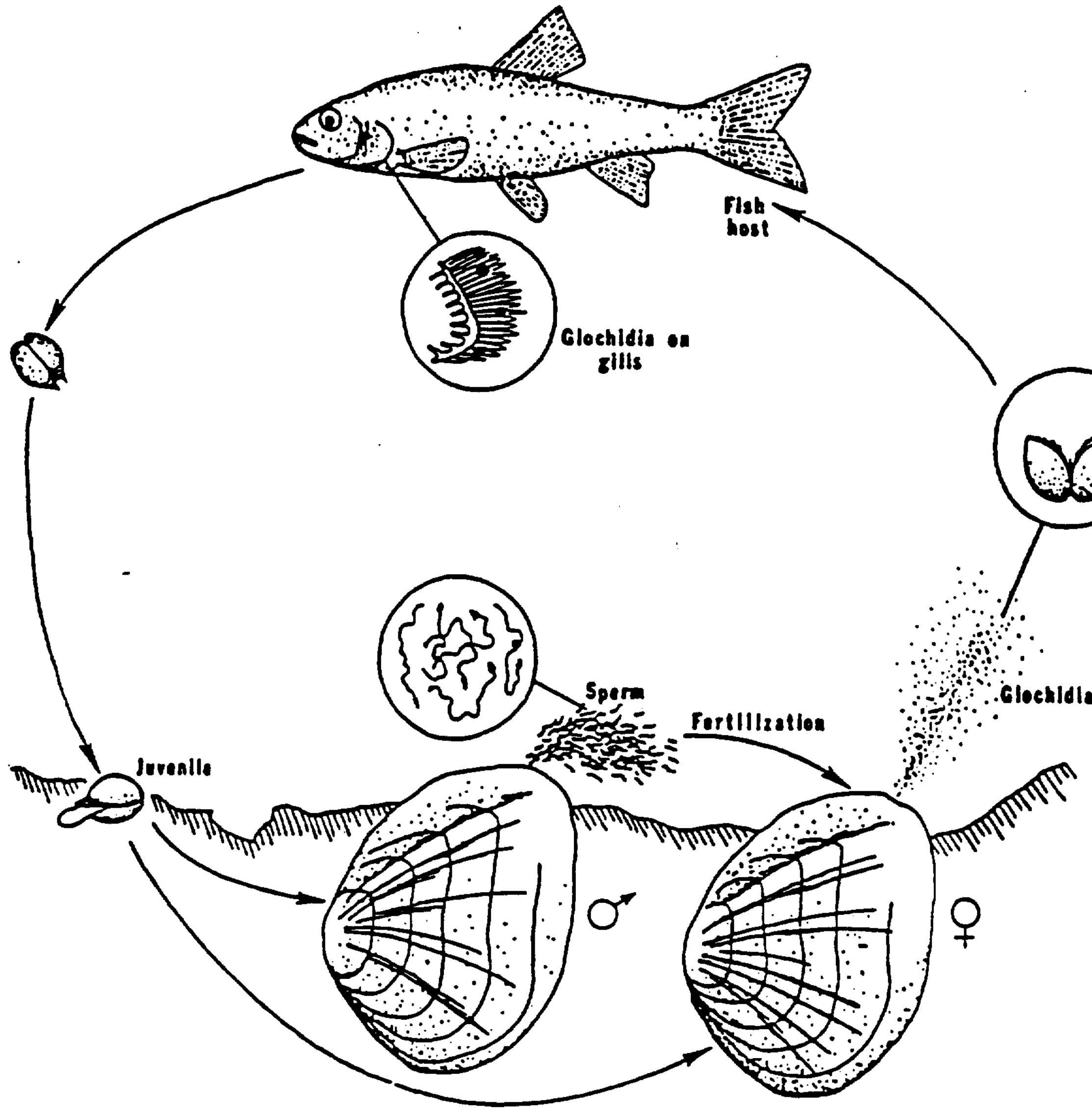


Figure 1. Typical life cycle of a freshwater mussel

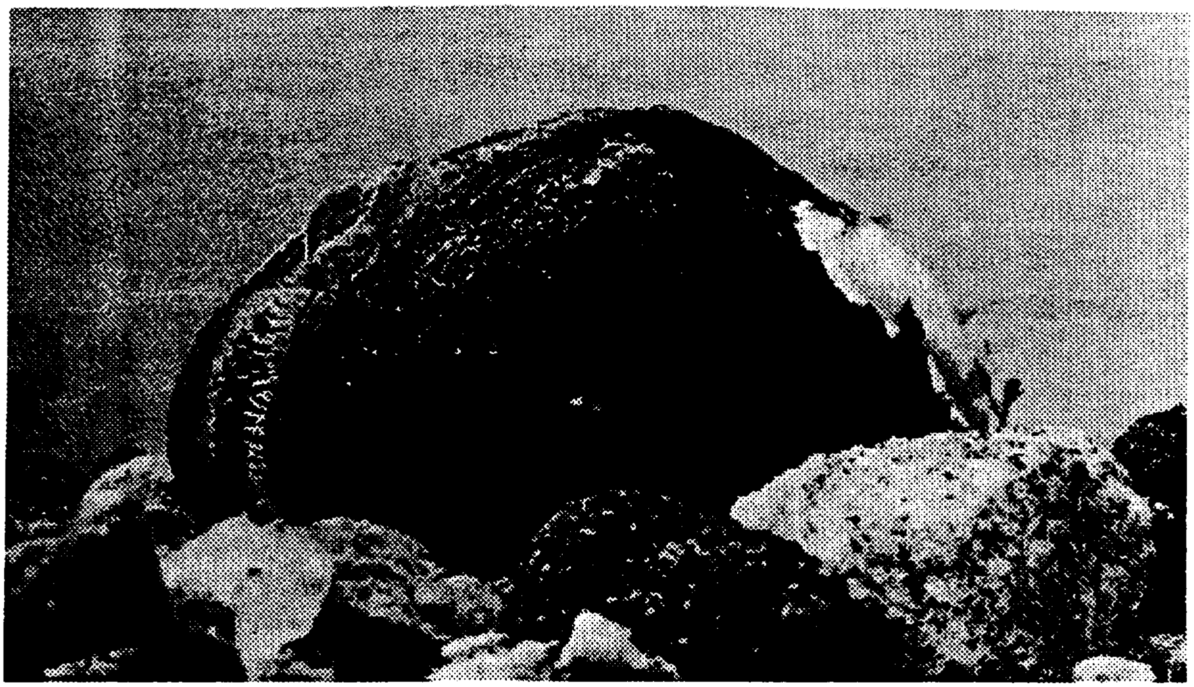


Figure 2. Partially exposed <u>Alasmidonta heterodon</u>, siphoning

Photo courtesy of Doug Smith, University of Massachusetts, Amherst

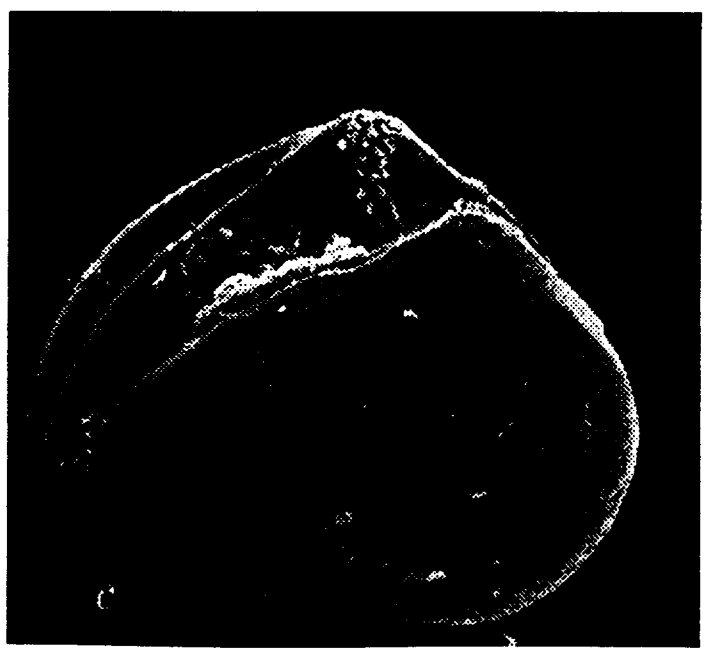


Figure 3. Glochidia of <u>Alasmidonta heterodon</u>

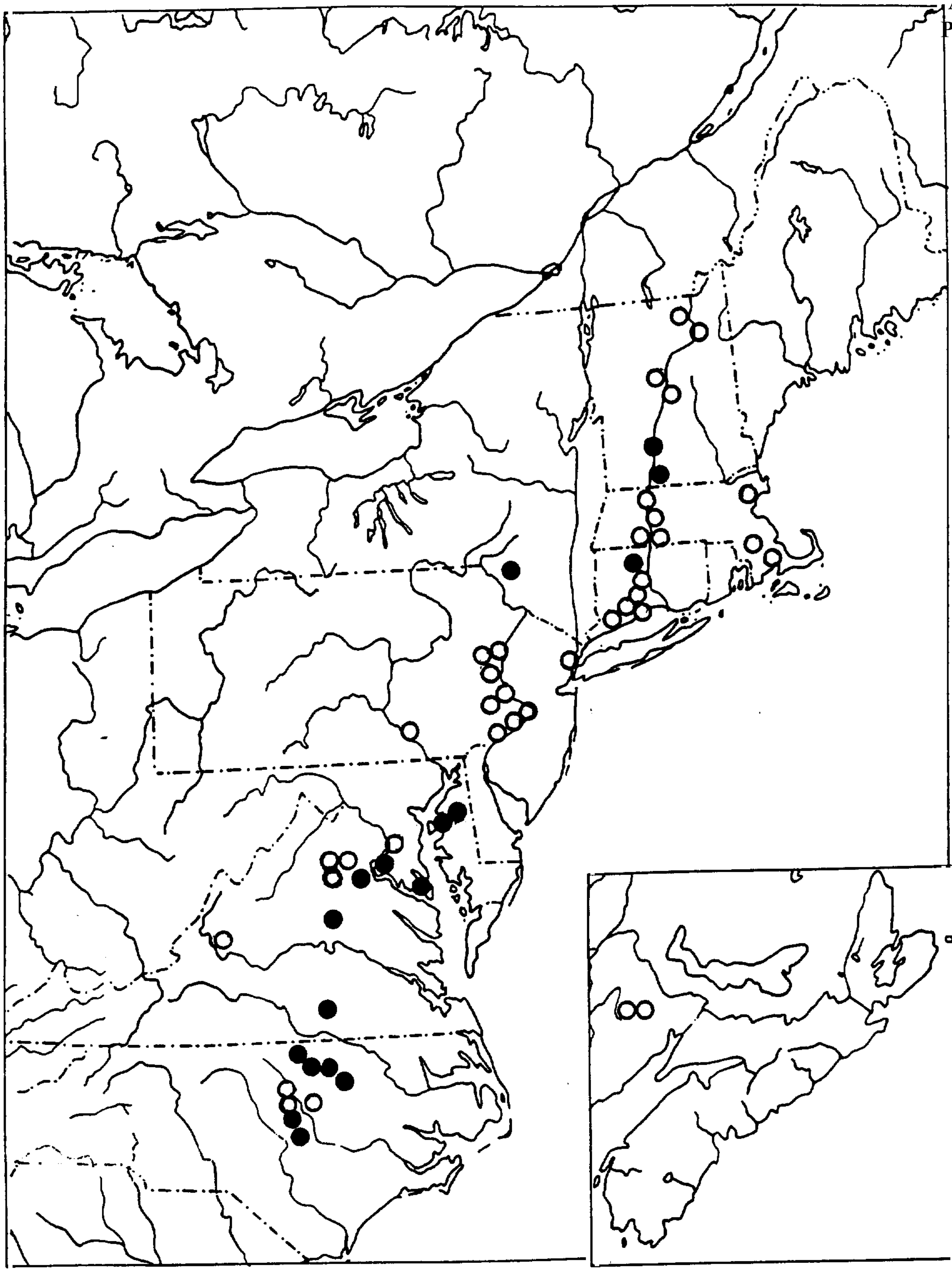
Photo courtesy Smithsonian Institution Press, from Clarke (1988a) pers. comm.) has indicated that the periods of gravidity and glochidial release are highly variable; much of this variation appears to be based on latitude. Upon release into the water column, mature glochidia of the genus Alasmidonta attach to the fins and soft tissue of the buccal cavity of appropriate host fishes to encyst and eventually metamorphose to the juvenile stage. When metamorphosis is complete, they drop to the streambed as juvenile mussels.

The host fish(es) for A. heterodon have not been determined. Studies are currently underway at the Cooperative Fishery and Wildlife Unit of the Virginia Polytechnic Institute and State University (VPI&SU) to determine this and other life history requirements.

DISTRIBUTION

Historically, the dwarf wedge mussel was widely but discontinuously distributed in Atlantic drainages from the Petitcodiac River in New Brunswick, Canada, south to the Neuse River in North Carolina. The species was known from at least 70 locations in 11 states and one Canadian province.

Master (1986) reported that an extensive status survey of historical and potential sites turned up only eight extant populations. Since then, 12 additional extant populations have been found in Maryland, North Carolina, Virginia, and New York. Although a few additional populations may still be discovered, a clear pattern has emerged -- relatively small, scattered relict populations remain from a once extensive distribution. The Neversink River population in New York, estimated at 80,000 mussels, appears to be the sole exception to this pattern; it far outnumbers any other population, although it occupies a relatively short reach of the river. Figure 4 and Table 1 describe current and historical localities for the dwarf wedge mussel. The locations of the 20 extant populations are as follows:



● = Present occurrence
○ = Historical occurrence, presumed extirpated

Figure 4. Distribution of _Alasmidonta heterodon_

(insert shows locations in New Brunswick)

Connecticut River Drainage

1. Connecticut River from the confluence with the Ottauquechee River to Weathersfield Bow in Sullivan County, New Hampshire and Windsor County, Vermont
2. Ashuelot River in Cheshire County, New Hampshire
3. Muddy Brook in Hartford County, Connecticut

Delaware River Drainage

4. Neversink River in Orange County, New York

Tuckahoe Creek (Choptank River) Drainage

5. Norwich Creek in Queen Anne's and Talbot Counties, Maryland
6. Long Marsh Ditch in Queen Anne's and Caroline Counties, Maryland

Potomac River Drainage

7. McIntosh Run in St. Mary's County, Maryland
8. Nanjemoy Creek in Charles County, Maryland
9. Aquia Creek in Stafford County, Virginia

York River Drainage

10. South Anna River in Louisa County, Virginia

Nottoway River Drainage

11. Nottoway River in Nottoway and Lunenberg Counties, Virginia

Tar River Drainage

12. Tar River in Granville County, North Carolina
13. Cedar Creek in Franklin County, North Carolina
14. Crooked Creek in Franklin County, North Carolina
15. Stony Creek in Nash County, North Carolina

Neuse River Drainage

16. Little River in Johnston and Wake Counties, North Carolina
17. Swift Creek in Johnston County, North Carolina
18. Middle Creek in Johnston County, North Carolina
19. Turkey Creek in Wilson and Nash Counties, North Carolina
20. Moccasin Creek in Nash, Wilson, and Johnston Counties, North Carolina

Of these populations, those located in the Connecticut River, the Neversink River, and the Upper Tar River appear to be the largest.

Table 1. Historical (H) and present (P) occurrences of the dwarf wedge mussel

	Petitcodiac River System, New Brunswick, Canada	
(H) 1953	North River NW of Salisbury	Westmoreland County, NB
(H) 1960	Petitcodiac River at River Glade	Westmoreland County, NB
	Merrimack River System	
(H)	Merrimack River at Andover	Essex County, MA
	Taunton River System	
(H) 1969	Canoe river near Norton	Bristol County, MA
	Agawam River System	
(H)	Agawam River	Plymouth County, MA
	Connecticut River System	
(H)	Connecticut River at Bloomfield	Essex County, VT
(H)	Connecticut River at Northumberland	Coos County, NH
(H)	Connecticut River at Ryegate	Caledonia County, VT
(H)	Connecticut River N of Monroe	Grafton County, NH
(P)	Connecticut River from confluence with the Ottauquechee River to Weathersfield Bow	Sullivan County, NH and Windsor County, VT
(P)	Ashuelot River near Keene	Cheshire County, NH
(H) 1948	Connecticut River at Northfield	Franklin County, MA
(H) 1979	Connecticut River at Sunderland	Franklin County, MA
(H)	Connecticut River at Chicopee	Hampden County, MA
(H) 1940	Canal at Westfield	Hampden County, MA
(H)	Connecticut River at Springfield	Hampden County, MA
(H) 1951	Scantic River near Hampden	Hampden County, MA
(H) 1984	Fort River in Amherst	Hampshire County, MA
(H) 1973	Mill River at Northampton	Hampshire County, MA
(H)	Connecticut River at Hadley	Hampshire County, MA
(H)	Connecticut River at Granby	Hartford County, CT
(H) 1959	Philo Brook at Suffield	Hartford County, CT
(P)	Muddy Brook	Hartford County, CT
	Quinnipiac River System	
(H)	Ten Mile River at Mixville	New Haven County, CT
(H)	Quinnipiac River at Meriden	New Haven County, CT
(H)	Wilmot Brook at New Haven	New Haven County, CT
	Hackensack River System	
(H)	Brook flowing W from Closter to Hackensack	Bergen County, NJ
	Delaware River System	
(P)	Neversink River	Orange County, NY
(H) 1919	Delaware River at Shawnee	Monroe County, PA
(H) 1919	Princess Creek at Kunkleton	Monroe County, PA
(H)	Pohopoco Creek near Leighton	Carbon County, PA
(H)	Delaware River	Bucks County, PA

Table 1 (continued). Historical (H) and present (P) occurrences of the dwarf wedge mussel

	Delaware River System (continued)	
(H)	Big Neshaminy Creek near Edderson	Bucks County, PA
(H)	Schuykill River at junction with Darby Creek	Delaware County, PA
(H) 1919	Canal along Schuykill at Manayunk	Philadelphia County, PA
(H) 1919	Schuykill River below Fairmount Dam	Philadelphia County, PA
	Susquehanna River System	
(H)	Susquehanna River at Columbia	Lancaster County, PA
	Choptank River System	
(P)	Norwich Creek	Queen Anne's and Talbot Cos., MD
(P)	Long Marsh Ditch	Queen Anne's and Caroline Cos., MD
	Potomac River System	
(H)	Potomac River near Washington, D.C.	Washington, D.C.
(P)	McIntosh Run	St. Mary's County, MD
(P)	Nanjemoy Creek	Charles County, MD
(P)	Aquia Creek	Stafford County, VA
	Rappahannock River System	
(H)	Mountain Run	Culpeper County, VA
(H)	Marsh Run near Remington	Fauquier County, VA
(H)	Blue River	Orange County, VA
	York River System	
(P)	South Anna River	Louisa County, VA
(H)	South Anna River	Hanover County, VA
	James River System	
(H)	Maury River (North River) at Lexington	Rockbridge County, VA
	Nottoway River System	
(P)	Nottoway River	Nottoway and Lunenberg Cos., VA
	Tar River System	
(P)	Tar River	Granville County, NC
(P)	Cedar Creek	Franklin County, NC
(P)	Crooked Creek	Franklin County, NC
(P)	Stony Creek	Nash County, NC
	Neuse River System	
(H)	Neuse River at Poolec Bridge	Wake County, NC
(H)	Neuse River E of Raleigh	Wake County, NC
(H)	Neuse River NE of Wendell	Wake County, NC
(P)	Little River	Johnston and Wake Cos., NC
(P)	Swift Creek	Johnston County, NC
(P)	Middle Creek	Johnston County, NC
(P)	Turkey Creek	Wilson and Nash Cos., NC
(P)	Moccasin Creek	Nash, Wilson, and Johnston Cos., NC

REASONS FOR DECLINE AND THREATS TO CONTINUED EXISTENCE

Although the dwarf wedge mussel still survives at a number of sites, its dramatic decline as well as the small size and extent of most of its remaining populations indicate that it is highly vulnerable to extirpation. Evidence is growing that the decline of Alasmidonta heterodon may be the forerunner of a general decline in the Unionid fauna of the Atlantic slope drainages. For example, recent status surveys indicate that other formerly widespread mussel species, including Alasmidonta varicosa and Lampsilis subviridis, are also declining. This section provides a general discussion of factors that may have contributed to the decline of the dwarf wedge mussel in the various Atlantic slope drainages within its range.

Impoundment

The damming and channelization of rivers throughout the species' range has resulted in the elimination of much formerly occupied habitat. For example, dams have converted much of the Connecticut River mainstream into a series of impoundments (Master 1986). Immediately upstream from each dam, conditions (including heavy silt deposition and low oxygen levels) are inimical to mussel species such as the dwarf wedge mussel. Immediately downstream from these dams, daily water level and water temperature fluctuations resulting from intermittent power generation and hypolimnetic discharges are also stressful to mussels (Master 1986). Some extreme variations in flow have been observed below dams on the Ashuelot River in New Hampshire. Master (1992, in litt.) indicates that mollusks, including the dwarf wedge mussel, have been stranded by extreme low water on two recent occasions -- once when water discharge was lowered from over 100 CFS to 10 CFS in one day, and once in the summer of 1991 when a dam in Keene was under repair.

Hypolimnial discharges from reservoirs produce cold tailwater conditions that alter the typical fish and benthic assemblages (Fuller 1974). Fuller stressed that these changes associated with inundation adversely affect both juvenile and adult mussels and also alter the native fish fauna, eliminating possible fish hosts for glochidia.

Effects of dams on mussel habitat have not been entirely adverse. Some water supply reservoirs have protected watersheds and, therefore, high quality waters downstream. Populations of dwarf wedge mussels and other mussel species are often especially dense below mill dams and beaver dams (W. Adams, Army Corps of Engineers, pers. comm.)

Siltation

Siltation, generated by road construction, agriculture, forestry activities, and removal of streambank vegetation is considered to be an important factor in the decline of many freshwater mussel species, including the dwarf wedge mussel.

Sediment loads in rivers and streams during periods of high discharge may be abrasive to mollusk shells. Erosion of the periostracum allows carbonic and other acids to reach and corrode underlying shell layers (Harman 1974). Feeding mollusks respond to heavy siltation by instinctive closure of their valves, since irritation and clogging of the gills and other feeding structures occurs when suspended sediments are siphoned from the water column (Loar et al. 1980). Although mussels possess the ability to secrete mucus to remove silt from body tissues, Ellis (1936) observed dying mussels with excessive quantities of silt in their gills and mantle cavities.

Freshwater mussels are long-lived and sedentary, with limited ability to move to more favorable habitats when silt is deposited over mussel beds. Ellis (1936) found that mussels could not survive in substrate on which silt (0.6-2.5 cm) was allowed to accumulate; death was attributed to interference with feeding and to suffocation. In this same study, Ellis determined that siltation from soil erosion reduced light penetration, altered heat exchange in the water, and allowed organic and toxic substances to be carried to the bottom where they were retained for long periods of time. This resulted in further oxygen depletion and possible absorption of these toxicants by mussels (Harman 1974).

Erosion and siltation resulting from land clearing and grading, and construction of bridges, roads, and other structures may be especially damaging to the dwarf wedge mussel's habitat. For instance, in Massachusetts, a dwarf wedge mussel population was decimated in one small stream when "... the construction of a small bridge resulted in accelerated sedimentation and erosion which buried and killed many of the bivalves" (Smith 1981).

Paradoxically, some bank erosion control measures such as riprapping may also adversely affect the species. A significant portion of one of the extant Connecticut River populations was eliminated in 1987 by burial under rock riprap placed along the shore of a Vermont State park.

Pollution

The continuing decline and ultimate loss of the dwarf wedge mussel from most of its historical sites can best be explained by agricultural, domestic, and industrial pollution of its aquatic habitat. Mussels are known to be sensitive to potassium (a common pollutant associated with paper mills and irrigation return water), zinc, copper, cadmium, and other elements (Havlik and Marking 1987). Pesticides, chlorine, excessive nutrients, and silt carried by agricultural runoff also present a threat to this species.

No mussels survive in several large, undammed sections of the Connecticut and Delaware River drainages where water pollution has exacted a heavy toll on the benthic fauna. Even where water quality has improved, as in the lower Connecticut River, chemicals trapped in the sediments inhabited by mussels may impede the recovery of sensitive species (Master 1986).

One of the largest known remaining populations of the dwarf wedge mussel occurs where the Ashuelot River meanders through a golf course. This population has undergone a dramatic decline over the past 10-30 years. The continuing decline of the dwarf wedge mussel at this site, particularly downstream of the golf course, may well be attributed to fungicides, herbicides, insecticides, and fertilizers applied to the golf course and to agricultural runoff from abutting corn fields and pastures (Master 1986). It has been suggested that elevated cadmium levels, which have been found in the Ashuelot for short periods of time, may also be a contributing factor in this decline (S. von Oettingen, U.S. Fish and Wildlife Service, pers. comm.). In this case, the elevated cadmium levels appear to result from cleaning the gates on the Surry Mountain Dam, just upstream of the mussel population.

Pollutants may also affect the mussels indirectly; nitrogen and phosphorus input cause organic enrichment and, if extreme, oxygen depletion. Acid rain may mobilize toxic metals and lead to decreased alkalinity which is inimical to most mussels. Increased acidity may have contributed to the recent decline of the dwarf wedge mussel in the Fort River in Massachusetts (D. Smith, University of Massachusetts Museum of Zoology, pers. comm.).

Several studies have investigated the effects of specific chemicals and heavy metals on mussels. Fuller (1974) reviewed the effects of arsenic, cadmium, chlorine, copper, iron, mercury, nitrogen, phosphorus, potassium, and zinc on naiads. Of the heavy metals, zinc was noted as the most toxic, whereas copper, mercury, and silver were less harmful. Goudreau (1988) studied the effects on aquatic mollusks of chlorinated effluent from sewage treatment plants. She found that recovery of mollusk populations may not occur for up to two miles below the discharge point. Imlay (1973) studied the effects of different levels of potassium, an industrial pollutant associated with paper mills, irrigation return water, and petroleum brine. The maximum level of potassium which most mussel species could tolerate was 4 to 10 mg/l.

Salanki and Varanka (1978) found that insecticides have significant effects on mussels. Low concentrations of lindane (.006 g/l), phorate (.008 g/l), and trichlorfon (.02 g/l) caused a 50 percent reduction in siphoning activity, and 1 g/l phorate or 1 ml/l trichlorfon were lethal concentrations.

Recent studies on contaminants have focused primarily on heavy metal effects on mussels. Mathis and Cummings (1973) investigated concentrations of certain heavy metals (copper, nickel, lead, chromium, zinc, cobalt, cadmium) in the sediments, water, mussels, fishes, and tubificids in the Illinois River. Mussels analyzed (Fusconaia flava, Amblema plicata, Quadrula quadrula) contained higher concentrations of all metals than the water and lower concentrations than sediments. Mussels concentrated zinc to a greater degree than fishes or tubificids; all other metals were accumulated to intermediate concentrations. Salanki and Varanka (1976) found that the rhythmic activity (siphoning) of Anodonta cygnea was reduced by 10 percent when exposed to 10^{-5} mg/l of copper sulfate, the chemical was lethal at 10 mg/l. Havlik and Marking (1987) indicated that long-term exposure of mussels to concentrations of copper as low as 25 parts per billion (ppb) was lethal. Salanki (1979) investigated the behavior of Anodonta cygnea subjected to certain heavy metals (mercury and cadmium), herbicides, and pesticides (paraquat, lindane, phosphamidon, and phorate). The siphoning period of this species was reduced at some concentrations and the metabolic rate decreased. Manly and George (1977) collected Anodonta anatina from the River Thames and determined the distribution of zinc, nickel, lead, cadmium, copper, and mercury in body tissues. Zinc and copper were most highly concentrated in the mantle, ctenidia (gills), and kidneys; nickel levels were highest in the kidneys; lead in the digestive gland and kidneys; cadmium in the ctenidia, digestive gland, and gonads; and mercury in the kidneys.

Recent studies by Keller and Zam (1991), using juvenile Anodonta imbecilis, have shown that freshwater mussels are quite sensitive to metal pollution. Acute toxicity tests, using juvenile mussels reared in the laboratory, were performed for the following six metals: cadmium, chromium, copper, mercury, nickel, and zinc. Keller and Zam concluded that, overall, mussels were as sensitive to metals as Daphnia, but more sensitive than commonly tested fish and aquatic insects (Table 2).

Other Factors

Land use changes throughout watersheds supporting the dwarf wedge mussel, especially along riparian corridors, may affect the species in a multitude of ways. The removal of streambank vegetation affects both the physical and biological processes of the waterways. Tree removal alters the amount of organic material and light reaching the stream, impacting both temperature and dissolved oxygen, which are critical factors for both fish and mussels. The floodplain biomass can also help buffer the stream from pollutants. Many of the "threats" identified above could be mitigated most efficiently by protecting the floodplain.

The invasion of the Asian clam (Corbicula fluminea) may be a significant threat to the dwarf wedge mussel. The Asian clam is one of 204 introduced mollusk species in North America (Dundee 1969). It was first discovered in the United States in the Columbia River, Oregon, in 1939. It appeared in California in the 1940's and 1950's, in the Ohio/Mississippi and Gulf of Mexico drainages in the 1960's and 1970's, and in the Atlantic drainage in the 1970's and 1980's (Clarke 1988). Once established in a river, Corbicula fluminea populations achieve high densities and expand rapidly. Densities of 1,000/m^2 in the James River, Virginia (Diaz 1974), the New River, Virginia (Rodgers et al. 1977), and the Tar River, North Carolina (Clarke 1983), and densities of 10,000/m^2 in the Altamaha River in Georgia (Gardner et al. 1976) have been reported. Clarke (1988) indicates that Corbicula was first introduced into the James River in 1971 near Hopewell, Virginia, about 15 miles below Richmond, and by 1984 had spread 195 miles upstream (an average of 15 miles per year). Malacologists are now concerned about the possibility of a competitive interaction between Asian clams and native bivalves. Quantitative studies by Cohen et al. (1984) support the hypothesis that an extensive C. fluminea bed in a reach of the Potomac River removed 40-60% of the phytoplankton in this reach. It is not unreasonable to conclude that C. fluminea has the potential to deplete the food supply of unionids. A similar threat may be posed by the recent invasion of the zebra mussel (Dreissena polymorpha). Although not yet known to be present in any of the rivers supporting the dwarf wedge mussel, the zebra mussel is expanding its range rapidly and can be expected to arrive in some of these rivers in the near future.

Mussel die-offs, the cause of which remains unknown, may be a threat to the dwarf wedge mussel. Since 1982 biologists and commercial musselmen have reported extensive mussel die-offs in rivers and lakes throughout the United States. Kills have been documented from the Clinch River (Virginia), Powell River (Virginia, Tennessee), Tennessee River (Tennessee), Grand River (Oklahoma), the Upper Mississippi River (Wisconsin to Iowa), and rivers in Illinois, Kentucky, and Arkansas (USFWS 1987). Lake St. Clair (Michigan), Chatauqua Lake (New York), and Court Oreilles Lac (Wisconsin) have also been affected. The cause is unknown, but numerous species of mussels are involved, including several commercially important and Federally listed species (USFWS 1987). A large mussel die-off has occurred in at least one river supporting the dwarf wedge mussel -- the Tar River in North Carolina. Personnel involved in a survey for the endangered Tar River spinymussel in April 1986 dicovered hundreds of freshly dead and recently dead juvenile and adult mussels of various species at two locations in the Tar River below Rocky Mount, North Carolina (USFWS 1987).

Most of the dwarf wedge mussel populations are small, and all are geographically isolated from each other. This isolation restricts the natural interchange of genetic material between populations. The small population size also reduces the reservoir of genetic variability within populations. It is likely that several of these populations are now below the level required to maintain long-term genetic viability. Furthermore, the small size of many of the dwarf wedge mussel's populations makes the species especially vulnerable to overcollecting.

Table 3 summarizes the status and extent of each extant dwarf wedge mussel population, and indicates the known threats -- current or potential -- to each population. These threats are keyed to the following list.

KEY TO MAJOR THREATS:

1. Point sources of pollution
2. Non-point chemical pollution
3. Sedimentation from forestry operations
4. Sedimentation from agriculture
5. Competition from exotic species
6. Food resource modification via forest overstory removal
7. Discharge rate modifications
8. Population density too low to allow successful reproduction
9. Population fragmentation
10. Significant point source non-compliance
11. Residential, highway, or industrial development
12. Reservoir construction
13. Possible landfill construction near waterbody
14. Toxic spill associated with highway or railroad
15. Headwater channelization and "stream improvement" projects

Table 3. Status of Dwarf Wedge Mussel Populations

POPULATION	STATUS[1]	REPRODUCING[2]	MAJOR THREATS[3]	APPROXIMATE EXTENT
Connecticut River Drainage				
Connecticut River (5 sites but one population) -- Sullivan County, NH and Windsor County, VT	fair to good	small numbers (since 1988 very few juveniles found)	1, 2, 4, 7, 9, 11, 15	16-18 miles
Ashuelot River -- Cheshire County, NH	fair to poor, declining	unknown (no evidence of reproduction in 1991 and 1992)	1, 2, 6, 7, 11, 16	1.5 miles
Muddy Brook -- Hartford County, CT	poor	no	1, 2, 3, 6, 8, 9, 11	1 mile
Delaware River Drainage				
Neversink River -- Orange County, NY	stable, very good (largest population)	yes	1, 2, 4, 7, 13	5 miles
Tuckahoe Creek (Choptank River) Drainage				
Norwich Creek -- Queen Anne's and Talbot Counties, MD	poor	no	2, 4, 8, 11, 17	0.5 mile
Long Marsh Ditch -- Queen Anne's and Caroline Counties, MD	poor	no	2, 3, 4, 8, 15	3 miles (scattered individuals)
Potomac River Drainage				
McIntosh Run -- St. Mary's County, MD	fair (small population)	yes	11	3 miles
Nanjemoy Creek -- Charles County, MD	fair (small population)	yes		1 mile
Aquia Creek -- Stafford County, VA	fair to good	unknown	2, 3, 4, 11	Approx. 0.5 mile

1 Based on information provided by those individuals from each state or region most familiar with their respective populations.
2 Evidence of reproduction found, i.e., individuals less than 5 years of age or gravid.
3 See key on preceding page.

Table 3. Status of Dwarf Wedge Mussel Populations (continued)

POPULATION	STATUS	REPRODUCING	MAJOR THREATS	APPROXIMATE EXTENT
York River Drainage				
South Anna River -- Louisa County, VA	poor	unknown	3, 4, 8, 11	Approx. 0.5 mile
Nottoway River Drainage				
Nottoway River -- Nottoway and Lunenberg Counties, VA	poor	unknown	3, 4, 8, 11, 14	Approx. 0.5 mile
Tar River Drainage				
Tar River -- Granville County, NC	very good (largest in NC)	yes	2, 9, 11, 14	10-15 miles
Cedar Creek -- Franklin County, NC	poor	no	1, 2, 3, 4, 5, 8, 9, 11, 14	< 1 mile
Crooked Creek -- Franklin County, NC	good	yes	3, 4, 6, 9	1-2 miles
Stony Creek -- Nash County, NC	poor	no	1, 2, 4, 8, 9, 11	< 1 mile
Neuse River Drainage				
Little River -- Johnston and Wake Counties, NC	fair to good	yes	2, 3, 4, 5, 6, 9, 11, 12, 14	10-20 miles
Swift Creek -- Johnston County, NC	good	yes	1, 2, 3, 4, 5, 6, 7, 9, 11, 14	> 15 miles
Turkey Creek -- Nash and Wilson Counties, NC	good	yes	1, 2, 3, 4, 5, 6, 9, 11, 12, 14	5-6 miles
Moccasin Creek -- Nash, Wilson, and Johnston Counties, NC	good	yes	1, 2, 3, 4, 5, 6, 9, 11, 12, 14	6-7 miles
Middle Creek -- Johnston County, NC	poor/fair	no	1, 2, 3, 4, 5, 8, 9, 11, 14	1-2 miles

PART II: RECOVERY

RECOVERY GOAL

The goal of this recovery plan is to maintain and restore viable populations of Alasmidonta heterodon to a significant portion of its historical range in order to remove the species from the Federal list of endangered and threatened species. This can be accomplished by (1) protecting and enhancing habitat containing A. heterodon populations, and (2) establishing or expanding populations within rivers and river corridors that historically contained this species.

RECOVERY OBJECTIVES

Objective 1. Reclassify Alasmidonta heterodon from endangered to threatened status when the likelihood of extinction in the foreseeable future has been eliminated according to the following criterion:

A. Populations of A. heterodon in the mainstem Connecticut River, Ashuelot River, Neversink River, upper Tar River, Little River, Swift Creek (Neuse system), and Turkey Creek, as well as populations in at least six other rivers (or creeks) representative of the species' range, must be shown to be viable[1]. This will require monitoring the occupied river reach over a 10-15 year period during which adequate population numbers, population stability, and evidence of recent recruitment (specimens age five or younger) are demonstrated.

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1 Viable population -- a population containing a sufficient number of reproducing adults to maintain genetic variability and in which annual recruitment is adequate to maintain a stable population.

Objective 2. Remove Alasmidonta heterodon from the Federal list of endangered and threatened species when the following additional criteria have been met:

B. At least ten of the rivers or creeks referred to in criterion A must support a viable population widely enough dispersed within its habitat such that a single adverse event in a given river would be unlikely to result in the total loss of that river's population. Meeting this criterion will require significant expansion of populations in most of the rivers. These rivers/populations should be distributed throughout the current range of the species, with at least two in New England, one in New York, and four to the south of Pennsylvania.

C. All populations referred to in criteria A and B must be protected from present and foreseeable anthropogenic and natural threats that could interfere with their survival.

RECOVERY TASKS

1. Collect basic data needed for protection of Alasmidonta heterodon populations.

   1.1 Conduct additional population and habitat surveys.

      1.11 Conduct studies of species distribution and status. A considerable effort has been made over the past several years to locate extant dwarf wedge mussel populations. However, because of the wide distribution of this species on the Atlantic slope, some sites remain to be surveyed. These include the Connecticut River in the Thetford and Bloomfield/

Weathersfield areas in Vermont, and sections of the Connecticut River in Massachusetts. Other Connecticut River basin sites in need of surveys include Sugar River, Cold River, and Muscoma River in New Hampshire. In New York and New Jersey, the Upper Wallkill basin, Rondout Creek, the Ten Mile River, and the east and west branches of the Delaware River should be searched. To the south, a number of rivers and streams remain to be surveyed in Virginia, including sections of the Rappahannock, Pamunkey, Mattaponi, Shenandoah, Appomatox, Rivanna, and Pedlar Rivers, and several areas in the James and Chowan River basins. The total extent of each population must also be determined.

1.12 Identify an initial list of potential reintroduction sites. Observations of habitat conditions and species diversity while implementing task 1.11 should provide an initial indication of potential sites for future reintroduction efforts. Fish surveys may be needed later to determine whether host fish are present in sufficient numbers (following completion of Task 4.1).

1.2 Identify essential habitat and key areas in need of protection. Essential habitat can be delineated in the best known rivers/streams, including the Connecticut and Ashuelot, and other well-known sites, with little additional surveying. Delineation of essential habitat in most other rivers and creeks must await more definitive survey data developed during implementation of Task 1.11.

1.3 <u>Identify and determine the significance of specific threats faced by the species such as pesticide contamination, siltation, acidification, and municipal and industrial effluents.</u>

1.31 <u>Review literature and compile existing information on point and non-point pollution sources; map pollution sources.</u> Point sources of pollution and, where feasible, non-point sources should be mapped in each of the watersheds supporting populations of <u>A. heterodon</u>. Where large watersheds are involved, it may be necessary to focus pollution-source mapping in the stream section within 10 to 20 miles of known dwarf wedge mussel population sites.

1.32 <u>Conduct water quality and contaminants sampling at extant population sites and potential reintroduction sites.</u> This sampling program will determine the presence of contaminants at specific sites. Contaminants found at extant population sites could be the subject of further study, as called for in Task 1.33. Presence of significant levels of toxic contaminants at potential transplant sites would eliminate these sites from further consideration.

1.33 <u>Conduct toxicity tests and bioassays of pesticides and other contaminants using surrogate mussel species.</u> Because of the known intensive use of pesticides at the golf course adjacent to the Ashuelot River site, priority should be given to tests of turf/golf course chemicals. EPA has funded some work to develop pesticide toxicity test protocols for freshwater mussels (Johnson <u>et al</u>. 1988), and would be a logical agency to carry out further testing.

2. Preserve *A. heterodon* populations and occupied habitats.

2.1 Continue to utilize existing legislation and regulations (Federal and State Endangered Species Acts, water quality regulations, stream alteration regulations, etc.) to protect the species and its habitats. Known populations cannot be protected without full enforcement of existing laws and regulations. Land management and regulatory agencies that may have important roles to play in assisting the U.S. Fish and Wildlife Service with the recovery of this species include the U.S. Environmental Protection Agency, Soil Conservation Service, Army Corps of Engineers, Federal Energy Regulatory Commission, State natural resource agencies, and local planning and zoning departments. FERC may have an important role in reviewing low flow releases from hydro-electric facilities on the Connecticut River during relicensing. The assistance of EPA and State water quality control agencies may be particularly important since strict conditioning and enforcement of NPDES permits and non-point discharge permits will be essential for the recovery of this species. In addition, it will be the responsibility of EPA's pesticide labeling program to implement alternatives to avoid pesticide impacts on the dwarf wedge mussel, as required by Section 7 of the Endangered Species Act. Data developed by Task 1.33 should be helpful in this process.

2.2 Determine and implement protection strategies for essential habitat areas identified in Task 1.2.

2.21 Encourage additional legal protection through wild and scenic river designation, establishment of regulations to protect water quality, etc. The U.S. Fish and Wildlife Service will work with the National Park Service and State agencies to consider special status for river and stream reaches providing prime habitat for this mussel. For instance, in Virginia the Water Control Board is now considering designation of specific river/stream reaches for the protection of this endangered species. Additional legislation requiring or providing incentives for riparian buffer strips may be needed.

2.22 Work with landowners, local government officials, and regulatory agency representatives to solicit support for protection of the species and mitigation of impacts to the species and its essential habitats. Owners of riparian lands and local governments and regulatory agency officials will be informed of the species' presence and the importance of protecting its habitats. Zoning agencies will be encouraged to develop regulations or guidelines to protect aquatic habitats. Landowners will also be encouraged to work with the SCS and State agriculture agencies to develop measures to reduce sediment erosion, and runoff of pesticides toxic to mussels.

2.23 Provide long-term protection of essential habitats through acquisition, registry, management agreements, and the establishment of stream buffer zones. Where feasible, acquisition would provide the most effective protection for the species and its habitat, although a lesser degree of protection could be provided by registry and management agreements (including establishment of buffer zones) with private landowners. Management agreements or other mechanisms are needed to control erosion caused by agriculture, timber cutting, and other land-use activities adjacent to stream banks. Where riparian lands remain in private ownership, landowners should be encouraged to install fencing to limit access by farm animals, and to leave agricultural and silvicultural buffer strips along streambanks. A major role in this process could be played by SCS and related State programs through installation of agricultural best management practices and development of buffer zones under the conservation reserve program of the 1990 Food Security Act.

2.24 Develop an interim approach to deal with pesticide usage not currently covered by EPA/FWS endangered species consultations. Special attention must be given to pesticides used in agriculture, silviculture and turf management adjacent to dwarf wedge mussel habitats. Interim measures should be developed to protect freshwater mussels until EPA/FWS consultations and EPA labeling requirements have been completed. This is especially crucial for sites such as the Ashuelot River, where pesticides are thought to be a key factor in the species' decline.

3. Encourage protection of the species through development of an educational awareness program.

3.1 Develop and distribute informational and educational materials such as slide/tape shows and brochures to school children, civic groups, and the general public. Many schools are incorporating endangered species as subjects in their curricula, and they welcome new material. The development and distribution of material focusing on the protection of the dwarf wedge mussel's aquatic environment will enable a broad audience to become familiar with this species and its habitat.

3.2 <u>Develop and distribute informational and educational materials aimed specifically at farmers and other pesticide users</u>. This educational program should be developed under the leadership of EPA with input from State agriculture agencies. This program should include information on alternative methods of pest control or less hazardous pesticides to avoid negative impacts on the dwarf wedge mussel and other endangered species.

3.3 <u>Continue to facilitate the initiation of River Watch Programs in dwarf wedge mussel rivers</u>. River Watch Programs are volunteer programs established to provide information about existing and potential water quality problems. These programs promote a greater awareness of the importance of the aquatic systems being monitored and, in turn, involve citizens and students in the protection of these systems.

4. <u>Conduct life history studies and identify ecological requirements of the species.</u>

4.1 <u>Conduct life history research on the species to include reproduction, food habits, age and growth, mortality factors, etc</u>. Life history research, including population demographics, development of an age/length key, and the determination of host fishes, is currently underway at the VPI&SU. Supplementary studies may be needed to determine host species for dwarf wedge mussel populations in New England and New York.

4.2 <u>Characterize the species' habitat requirements (relevant physical, biological, and chemical components) for all life history stages</u>. Elements that should be considered include: current speed, water depth, substrate grain size, firmness and embeddedness of substrate, substrate stability, water temperature, and water quality factors such as nitrate and potassium levels, dissolved calcium, dissolved oxygen, and pH. The studies underway at VPI&SU will provide this information for southern populations. Additional studies may be needed to characterize features throughout the species' range.

5. <u>Determine the feasibility of re-establishing populations within the species' historical range and, if feasible, introduce the species into such areas</u>. The present range of the dwarf wedge mussel is much smaller than it was historically. There may be areas within the species' former range that could support re-established populations.

5.1 <u>Determine the need, appropriateness, and feasibility of augmenting and expanding existing populations</u>. Several populations are likely below the number needed to maintain long-term viability. These populations may be able to expand naturally if environmental conditions are improved; however, some populations may need to be supplemented to reach a viable size. Populations for this task will be selected based on present population size, habitat quality, and the likelihood of long-term benefits from the effort. At any site selected for augmentation or re-establishment, the host fishes must be present in adequate numbers. Task 1.12 should provide the necessary information; the list of potential reintroduction sites generated in that task will be refined and feasibility will be determined on a site-specific basis.

5.2 <u>Develop a successful technique for re-establishing and augmenting populations</u>. This task is included in several other mussel recovery plans. Techniques developed for those species may work for the dwarf wedge mussel as well.

5.3 Coordinate with appropriate Federal and State agency personnel, local governments, and interested parties to select streams that may be suitable for augmentation and reintroduction and can be effectively protected from further threats. Results of Task 1.32 should provide preliminary information on potential sites. Special attention should be focused on sections of the Connecticut River to be included in the Silvio Conte National Wildlife Refuge.

5.4 Where appropriate, reintroduce the species within its historical range and evaluate success.

5.5 Implement the same protective measures for any introduced populations as outlined for established populations in Task 2.

6. Develop and implement a program to monitor population levels and habitat conditions at present and introduced population sites. In light of the dwarf wedge mussel's dramatic decline in the Ashuelot River, this task is critical.

6.1 Develop a monitoring protocol. A monitoring protocol will need to be established for all major *A. heterodon* sites. At a minimum, this will involve a semi-quantitative approach using mussels observed per unit effort. Quadrat sampling should be used, where appropriate, to provide a more quantitative indication of population trends and age-class distribution.

6.2 Implement monitoring. This task will begin with a baseline quantitative survey (including age-class distribution) and continue with systematic monitoring of all significant populations every two to three years.

7. <u>Periodically assess overall success of the recovery program and recommend appropriate actions (changes in recovery objectives, downlisting, implementing new measures, other studies, etc.)</u>. An informal recovery implementation group composed of representatives of the U.S. Fish and Wildlife Service, State agencies, conservation groups, etc., will be established to assist in implementing this task as well as other aspects of the recovery plan. The recovery plan will be evaluated to determine if it is on track and to recommend future actions. As more is learned about the species, the recovery objectives may need to be modified.

Table 4. STEPDOWN RECOVERY OUTLINE

1. Collect basic data needed for protection of *Alasmidonta heterodon* populations.

   1.1 Conduct additional population and habitat surveys for *A. heterodon*.

      1.11 Conduct studies of species' distribution and status.

      1.12 Identify an initial list of potential reintroduction sites.

   1.2 Identify essential habitat and key areas in need of protection.

   1.3 Identify and determine significance of specific threats faced by the species such as pesticide contamination, siltation, acidification, and municipal and industrial effluents.

      1.31 Review literature and compile existing information on point and non-point pollution sources; map pollution sources.

      1.32 Conduct water quality and contaminants sampling at extant population sites and potential reintroduction sites.

      1.33 Conduct toxicity tests and bioassays of pesticide and other contaminants using surrogate mussel species.

2. Preserve *A. heterodon* populations and occupied habitats.

   2.1 Continue to utilize existing legislation and regulations to protect the species and its habitats.

   2.2 Determine and implement protection strategies for areas identified in Task 1.2.

      2.21 Encourage additional legal protection through wild and scenic river designation, and establishment of regulations to protect water quality.

      2.22 Work with landowners, local government officials, and regulatory agency representatives to solicit support for protection of the species and mitigation of impacts to the species and its essential habitats.

      2.23 Provide long-term protection of essential habitats through acquisition, registry, management agreements, and the establishment of stream buffer zones.

      2.24 Develop an interim approach to deal with pesticide usage not currently covered by EPA/FWS endangered species consultations.

3. Encourage protection of the species through development of an educational awareness program.

   3.1 Develop and distribute informational and educational materials, such as slide/tape shows and brochures to school children, civic groups, and the general public.

Table 4 (continued). STEPDOWN RECOVERY OUTLINE

3.2 Develop and distribute informational and educational materials aimed specifically at farmers and other pesticide users.

3.3 Continue to facilitate the initiation of River Watch Programs in dwarf wedge mussel rivers.

4. Conduct life history studies and identify ecological requirements of the species.

4.1 Conduct life history research on the species to include reproduction, food habits, age and growth, mortality factors, etc.

4.2 Characterize the species' habitat requirements (relevant physical, biological, and chemical components) for all life history stages.

5. Determine the feasibility of re-establishing populations within the species' historical range and, if feasible, introduce the species into such areas.

5.1 - Determine the need, appropriateness, and feasibility of augmenting and expanding existing populations.

5.2 Develop a successful technique for re-establishing and augmenting populations.

5.3 Coordinate with appropriate Federal and State agency personnel, local governments, and interested parties to determine which of the streams identified in Task 1.12 are suitable for augmentation and reintroductions and most easily protected from further threats.

5.4 Where appropriate, reintroduce the species within its historical range and evaluate success.

5.5 Implement the same protective measures for any introduced populations as outlined for established populations.

6. Develop and implement a program to monitor population levels and habitat conditions of presently established and introduced populations.

6.1 Develop a monitoring protocol.

6.2 Implement monitoring.

7. Periodically assess overall success of the recovery program and recommend appropriate actions (changes in recovery objectives, downlisting, implementing new measures, other studies, etc.).

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PART III: IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines actions and estimated costs of the recovery program. It is a guide for meeting the objectives discussed in Part II of this plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, responsible agencies, and estimated costs. These actions, when accomplished, should bring about the recovery of the species and protect its habitat.

Key to Implementation Schedule Priorities (column 1)

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to provide for full recovery of the species.

Key to Agency Abbreviations (column 6)

COE = Army Corps of Engineers
EPA = Environmental Protection Agency
FERC = Federal Energy Regulatory Commission
NPS = National Park Service
SAGD = State Agriculture Department
RIG = Recovery Implementation Group
SCS = Soil Conservation Service
SNGP = State Nongame and Endangered Species Programs
SNHP = State Natural Heritage Programs
SWCB = State Water Control Boards
TNC = The Nature Conservancy
VPI&SU = Virginia Polytechnic Institute and State University

IMPLEMENTATION SCHEDULE
DWARF WEDGE MUSSEL

February 1993

Priority	Task Description	Task Number	Duration	Responsible Agency		Cost Estimates, $000			Comments
				USFWS	Other	FY1	FY2	FY3	
1	Conduct additional population and habitat surveys.	1.1	3 years	Region 5 Region 4	SNHP, SNGP	30	30	30	
1	Identify essential habitat and key areas in need of protection.	1.2	3 years	Region 5 Region 4	SNHP, SNGP	2	2	2	
2	Review literature and compile information on point and non-point pollution; map pollution sources.	1.31	3 years	Region 5 Region 4	SWCB, SNHP, SNGP, EPA	20	20	20	FWS Contaminants Program will have lead.
2	Conduct water quality and contaminants sampling.	1.32	3 years	Region 5 Region 4		---	25	25	+ $25K in FY4.
1	Conduct toxicity tests of pesticides and other contaminants.	1.33	4 years	Region 5 Region 4	EPA	30	30	30	+ $30K in FY4.
1	Continue to utilize existing legislation and regulations to protect the species.	2.1	Continuous	Region 5 Region 4	SWCB, SNHP, SNGP, COE, EPA, FERC	10	10	10	+ $10K/yr for 7 more years.
2	Encourage designation of wild and scenic rivers, and regulations to protect water quality.	2.21	?	Region 5 Region 4	SWCB, SNHP, SNGP, NPS	---	20	30	+ $30K/yr for 3 more years.
1	Work with landowners and others to solicit support for protection of the species.	2.22	Continuous	Region 5 Region 4	TNC, SNHP, SNGP, SAGD, SCS	5	5	5	+ $5K/yr for 7 more years.
1	Provide long-term protection of essential habitats.	2.23	10 years	Region 5 Region 4	TNC, SNHP, SNGP, SCS	15	30	30	Amount and cost of land acquisition not yet known.

Dwarf Wedge Mussel Implementation Schedule (continued), February 1993

Priority	Task Description	Task Number	Duration	Responsible Agency		Cost Estimates, $000			Comments
				USFWS	Other	FY1	FY2	FY3	
1	Develop an interim approach to deal with pesticide usage.	2.24	1 year	Region 5	EPA	2	---	---	
3	Develop an educational program for school children etc.	3.1	1 year	Region 5	Contract or TNC, SNGP, SNHP	---	5	---	
3	Develop an educational program aimed at pesticide users.	3.2	1 year	Region 5 Region 4	SAGD, EPA	---	---	10	
3	Facilitate river watch programs.	3.3	Continuous	Region 5 Region 4	SNHP, SNGP	---	1	1	+ $1,000/yr for 7 more years.
1	Conduct life history studies and identify requirements of the species.	4.	2 years	Region 5	Contract (VPI&SU)	---	---	---	Already funded ($35K) and underway.
3	Determine feasibility of re-establishing populations within historic range.	5.	5 years	Region 5 Region 4	SNHP, SNGP	---	---	---	Implementation to be initiated after FY3 at approx. $15K/yr for 5 years.
1	Monitor populations levels and habitat conditions.	6.	Continuous	Region 5 Region 4	SNHP, SNGP	---	30	---	+ $30K/yr in FY5, FY8, and FY10.
3	Assess overall success of the program and recommend appropriate actions.	7.	Continuous	Region 5 Region 4	RIG	---	---	---	

APPENDIX: LIST OF REVIEWERS

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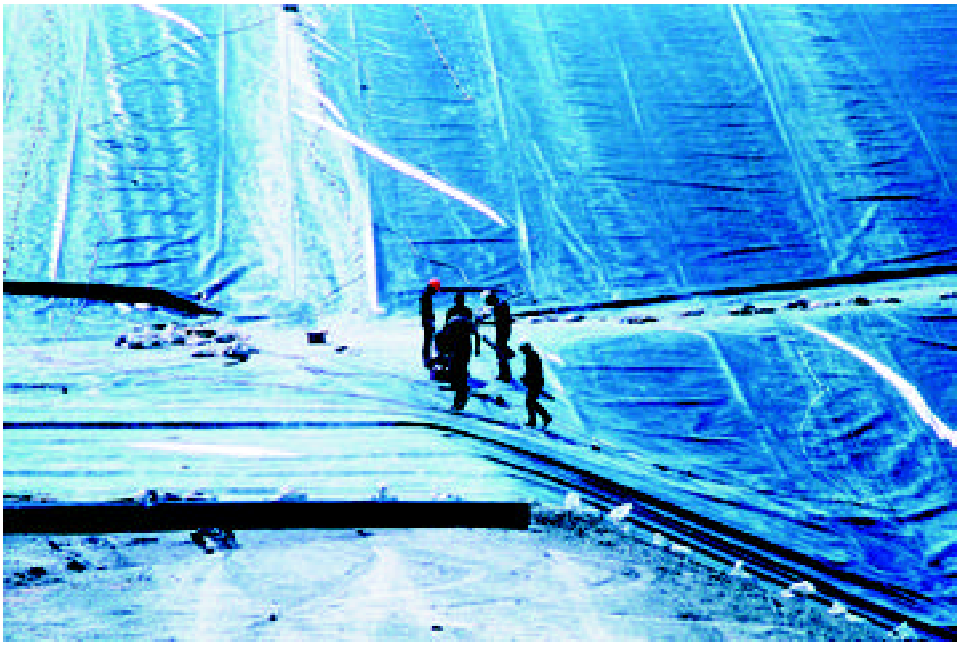
GROUND WATER CONTAMINATION

Alabama enjoys an abundant supply of ground water that, if managed wisely, will help fulfill our need for clean water indefinitely. As citizens, we should be aware of potential threats to our ground water supplies and help to protect those supplies from contamination. Contaminated ground water may be unfit for certain uses and may become harmful to humans, animals, vegetation, and property. Treatment of contaminated ground water is usually expensive, and sometimes a contaminated water supply must be abandoned and a new supply located. Preventing contamination before it occurs is the best solution. Because ground water contamination can have such serious consequences, many citizens, as well as local, state, and federal agencies, are taking action to protect ground water resources.



Installation of liner in hazardous waste storage pit.

POTENTIAL CONTAMINANT SOURCES

Common sources of anthropogenic contaminants include septic tanks and privies; underground storage tanks; areas where fertilizer, pesticides, or herbicides are used or stored; landfills; and unauthorized dump sites. A more complete list of potential sources of ground water contamination is shown in Table 1.

The most common sources of ground water contamination nationwide are underground storage tanks (**UST**'s), septic systems, pesticides, and nitrates. The Alabama Department of Environmental Management (**ADEM**) considers UST's and failing septic systems to be the most serious threats to ground water in Alabama, because they are so numerous. Other sources of potential ground water contamination include unauthorized hazardous waste disposal sites, old landfills, unauthorized dumps, and abandoned wells.

Common products which can contaminate ground water

Applied correctly, pesticides and fertilizer have minimal impact on ground water quality.

Ground water contamination occurs when ground water comes in contact with naturally occurring contaminants or with contaminants introduced into the environment by anthropogenic activities. Naturally occurring substances found locally in soil and rocks that can affect ground water include lead, iron, manganese, aluminum, selenium, and arsenic, as well as petroleum, **microorganisms**, and **brine** (salty water). Contaminants associated with human activity most commonly include bacteria, petroleum products, natural and synthetic organic compounds, fertilizer, pesticides, herbicides, and metals.

One gallon of gasoline can render more than one million gallons of water unfit to drink!

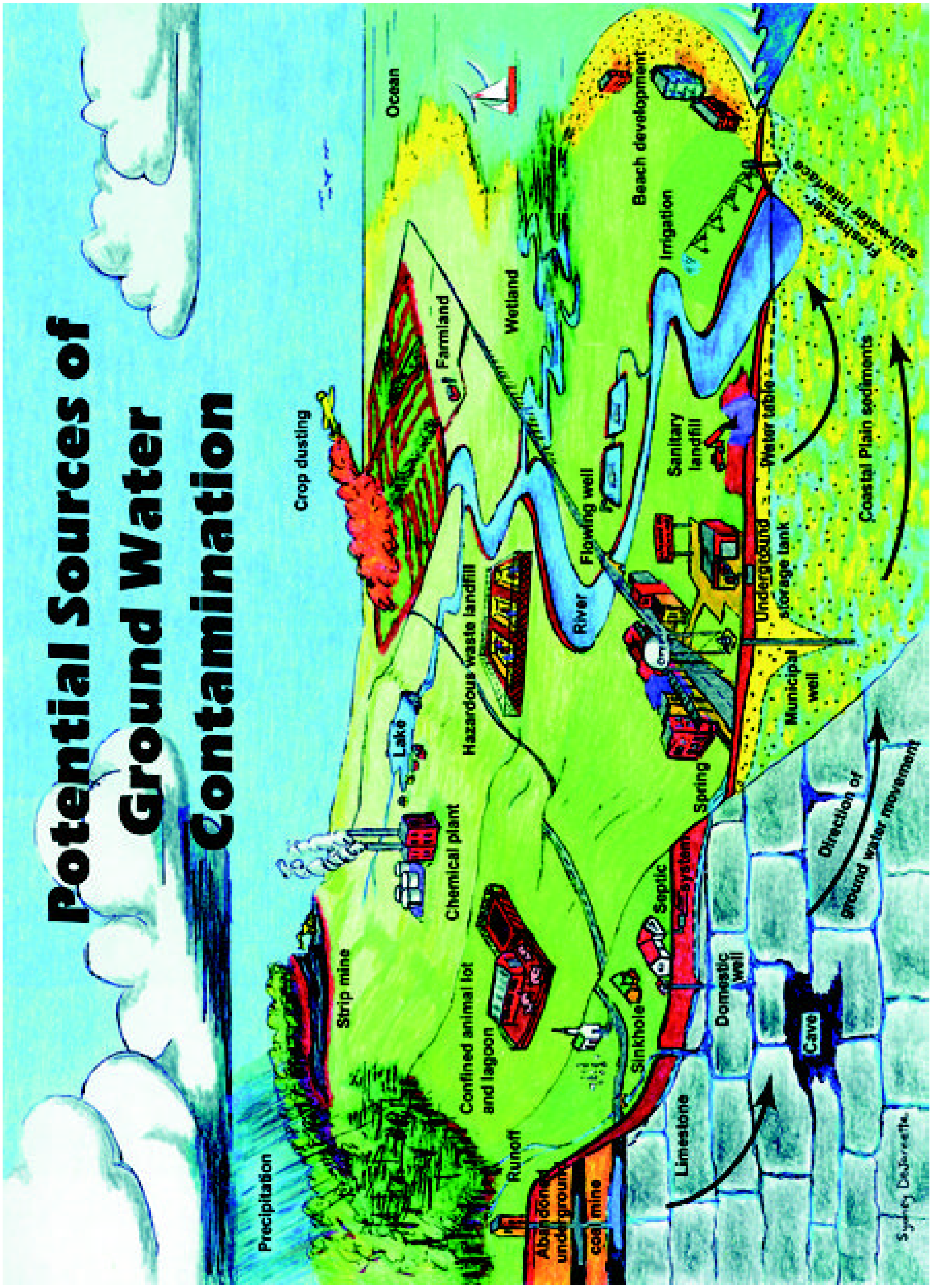

Potential Sources of Ground Water Contamination
Precipitation
Strip mine
Chemical plant
Lake
Hazardous waste landfill
Crop dusting
Farmland
Wetland
Ocean
Beach development
Irrigation
Freshwater-salt-water interface
Coastal Plain sediments
Water table
Sanitary landfill
Flowing well
River
Underground storage tank
Municipal well
Spring
Septic system
Direction of ground water movement
Domestic well
Cave
Sinkhole
Limestone
Confined animal lot and lagoon
Runoff
Abandon undergroun coal mine

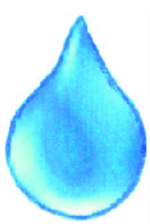
Table 1. *Potential Sources of Ground Water Contamination (Based upon lists compiled by EPA and ADEM)*

1. Improperly functioning septic tanks
2. Gas stations/service stations
3. Dry cleaners
4. Agricultural chemicals, fertilizer, and pesticides spreading/spraying
5. Truck terminals
6. Fuel oil distributors/storage
7. Oil pipelines
8. Auto repair shops
9. Body shops
10. Rustproofers
11. Auto chemical suppliers/ wholesalers/retailers
12. Pesticide/herbicide/insecticide wholesalers/retailers
13. Small engine repair shops
14. Furniture strippers
15. Painters/finishers
16. Photographic processors
17. Printers
18. Car Washes
19. Laundromats
20. Beauty salons
21. Medical/dental/veterinarian offices
22. Research laboratories
23. Food processors
24. Meat packers/slaughterhouses
25. Concrete/asphalt/tar/coal companies
26. Treatment plant lagoons
27. Railroad yards
28. Stormwater impoundments
29. Cemeteries
30. Airport maintenance shops
31. Airport fueling areas
32. Airport firefighter training areas
33. Industrial manufacturers
34. Machine shops
35. Metal platers
36. Heat treaters/smelters/descalers
37. Wood preservers
38. Chemical reclamation sites
39. Boat builders/refinishers
40. Industrial waste disposal sites
41. Wastewater impoundment areas
42. Municipal wastewater treatment plants and land application areas
43. Landfills/dumps/transfer stations
44. Junk/salvage yards
45. Subdivisions
46. Individual residences
47. Heating oil storage(consumptive use) sites
48. Golf courses/parks/nurseries
49. Sand and gravel mining/other mining
50. Abandoned wells
51. Manure piles/other animal waste
52. Feedlots
53. Agricultural chemical storage sites
54. Construction sites
55. Transportation corridors
56. Fertilized fields/agricultural areas
57. Petroleum tank farms
58. Existing wells
59. Nonagricultural applicator sites
60. Sinkholes
61. Recharge areas of shallow and highly permeable aquifers
62. Injection wells
63. Drainage wells
64. Waste piles
65. Materials stockpiles
66. Animal burial sites
67. Open burning sites
68. Radioactive disposal sites
69. Salt-water intrusion
70. Mines and mine tailings

UNDERGROUND STORAGE TANKS

UST's are commonly used at service stations, refineries, and other industrial sites where gasoline, fuel oil, and other chemicals are used. If these tanks develop leaks, ground water supplies can be seriously contaminated. Between 5 million and 6 million UST's exist nationwide. About 17,000 inventoried UST's are currently in use in Alabama at about 6,000 locations. To date, soil or ground water has been contaminated by leaking UST's at about 9,000 sites in Alabama. Cleanups have been completed at about 75 percent of these sites. Cleanup is continuing at approximately 1500 more locations. Sometimes owners cannot be found or do not have the money to clean up these sites. **EPA** and **ADEM** are requiring new UST systems to meet standards that should sharply reduce the incidence of new leaks and aid in detecting leaks quickly when they do occur.

Testing an underground storage tank for leaks.



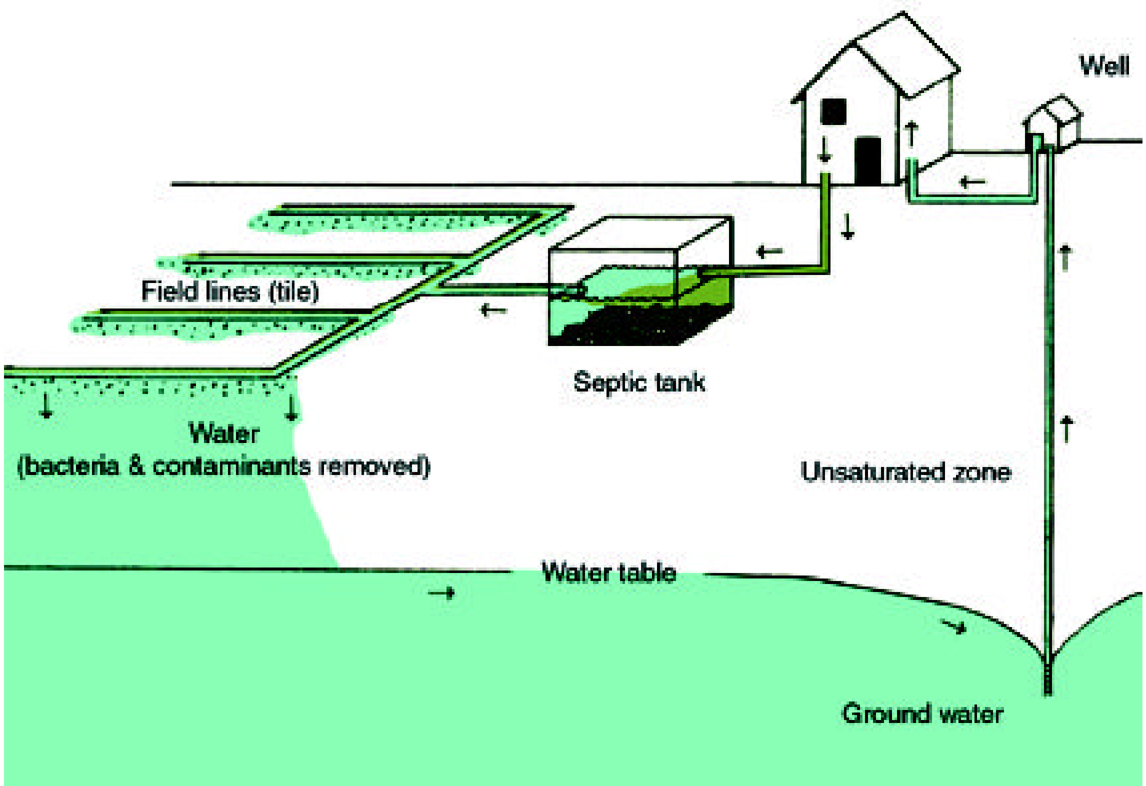
Leaking underground storage tanks have caused more than 90 percent of soil and water contamination in Alabama, but 75 percent of known releases have been cleaned up.

Leaking underground storage tanks are the leading cause of ground water contamination in Alabama. Underground storage tanks must meet standards to prevent and detect leaks and spills.

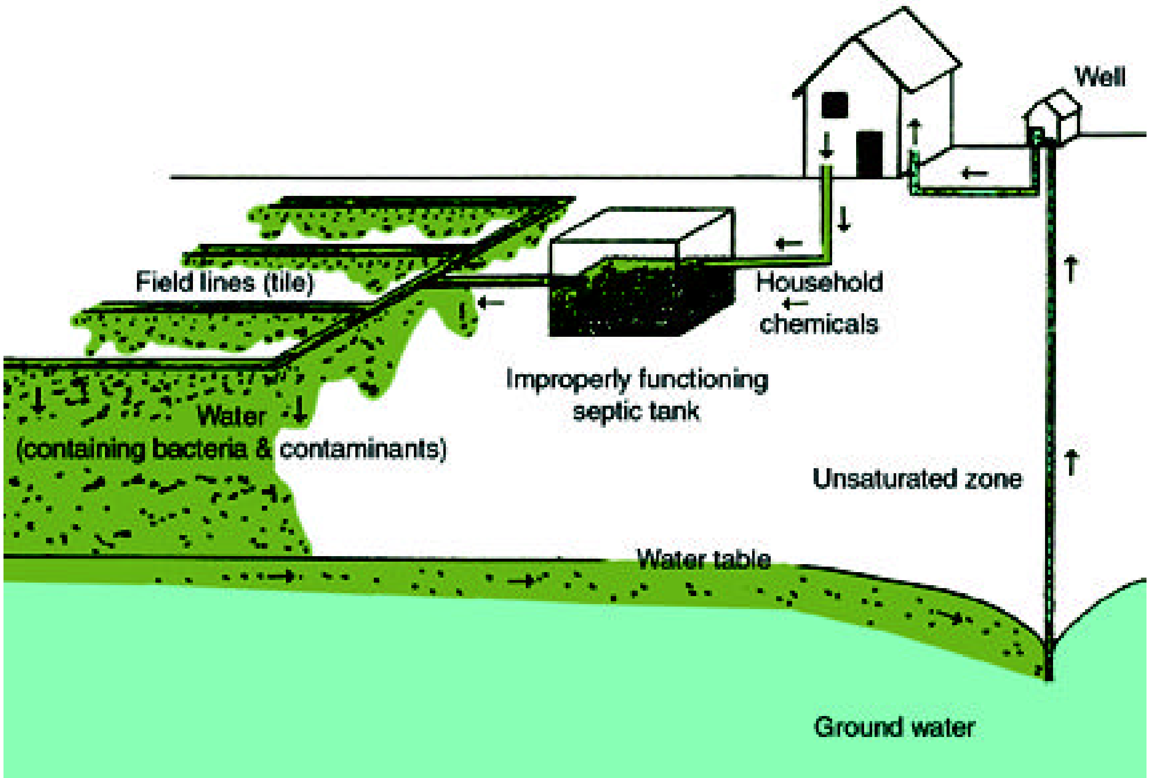
SEPTIC SYSTEMS

Septic systems are the most common on-site domestic waste disposal systems in use. It is estimated that more than 670,000 active septic systems exist in Alabama, along with an unknown number of older, abandoned systems. More than 20,000 new systems are permitted annually. If properly installed, used, and maintained, septic systems pose no threat to water quality; however, the Alabama Department of Public Health estimates that as many as 25 percent of all septic systems in Alabama could be failing. Every septic system that malfunctions is a potential source of ground water contamination and can have consequences that extend beyond the boundaries of the owner's property.

Properly functioning septic systems are a simple and effective way to manage household waste. The waste first enters a tank where solid materials settle out and are digested by bacteria. The solids must be periodically cleaned from the tank to prevent blockage of field lines and subsequent overflow. Liquid waste passes from the septic tank into the field lines, where it percolates down through the soil. Breakdown of these wastes is accomplished before the wastes reach the water table by bacterial action in the septic system and the soil and by the filtering effect of the soil. Introducing hazardous household wastes, including oil, powerful cleaners, and other substances into the septic system may kill the bacteria in the septic system and impair the system's efficiency. Septic systems do not work well in some parts of the state, such as the coastal areas because soil conditions there are unfavorable. To provide adequate filtering of liquid wastes, septic systems require a fairly thick and moderately permeable unsaturated zone. In some locations, soils may be thin and the underlying rock, for the most part, impermeable. Near the coast, the sandy soils may be too permeable to properly filter out contaminants or the water table may be too near the land surface to allow for proper operation. If a septic system ceases to function correctly, contaminated wastewater may enter the shallow aquifer, which could threaten the homeowner's own well. If contaminated wastewater from a malfunctioning septic system saturates soils this could also result in a surface discharge that could be a health hazard and would not be allowable under state law.



If a septic tank is well designed and functioning properly, contaminants are removed before reaching the water table.



Contamination from a malfunctioning septic system. This household is in danger from a contaminated water supply.

PESTICIDES

Pesticides are common ground water contaminants. About 3.8 million pounds of solid pesticides and 450,000 gallons of liquid pesticides are applied in Alabama each year to kill insects, rodents, mold, and weeds. Some pesticides are now prohibited by EPA because they were contaminating surface and ground water. Others are being studied to determine how their use should be restricted.

Agricultural Spraying Utilizing Aerial Application

Most modern pesticides when used properly degrade naturally with time and generally do not pose long term contamination problems. Therefore, contamination of aquifers by pesticides travelling long distances is unlikely. Instead, pesticide contamination of shallow aquifers through direct runoff and **infiltration**, and contamination through abandoned or improperly sealed wells and sinkholes are more likely.

The presence of trace quantities of pesticides in drinking water is not uncommon, but instances where concentrations exceed permitted levels are rare. Nationwide, about 10 percent of public water supply wells contain detectable amounts of pesticides, but less than 1 percent contain quantities sufficient to constitute a public health risk. Where this occurs the water must be treated to remove contaminats before being provided to the public. One quarter of the private wells and springs tested by ADEM have contained detectable quantities of pesticides. Three percent of the private wells and 6 percent of the springs had concentrations that exceeded drinking water standards or health advisory limits.

NITRATES

Nitrates, chemical compounds commonly used as fertilizer, can be a significant threat to ground water quality. On-site residential septic tanks can also be a source of nitrates. Nitrates, unlike most agricultural and lawn chemicals, do not chemically degrade with time. If more nitrate compounds are applied than can be absorbed by plant root systems, they are likely to contaminate shallow ground water. Nitrate in drinking water can cause health problems in small children, notably a type of anemia called methemoglobinemia, or blue baby disease. About 1 percent of public drinking water wells in the United States exceed established levels of nitrates for public drinking water supplies. Nitrate contamination has caused the abandonment of more ground water supplies nationwide than toxic wastes. More than 42 billion pounds of fertilizer is used annually in the United States.

Nitrate contamination has caused the abandonment of more ground water supplies nationwide than toxic wastes.

Unsafe levels of nitrates have been found in some private wells in Alabama, although the extent of the problem is difficult to determine. Agricultural areas characterized by large amounts of rainfall and sandy, permeable soils, such as the southern part of Alabama's Coastal Plain, tend to be more vulnerable to nitrate contamination.

Concentrations of nitrate will also vary with the season and rainfall. The detection of nitrate above 3.0 milligrams per liter (mg/L) usually indicates that nitrate from anthropogenic sources is entering the ground water. In a study conducted on 158 residential wells in Houston County, about 5 percent of the wells contained nitrate concentrations between 5 mg/L and 10 mg/L. Less than 1 percent of the samples showed nitrate levels exceeding the drinking water standard of 10 mg/L. In a Geneva County study no samples had nitrate concentrations exceeding 5 mg/L. A similar study conducted in the Tennessee Valley region of the state showed approximately 20 percent of the samples to contain between 5 and 10 mg/L of nitrate; only 1 percent showed nitrate levels at or above 10 mg/L. The Alabama Department of Public Health recently tested 479 wells throughout the state for nitrate. Three of these wells exhibited unsafe levels of nitrate, but one of these was located between two chicken houses which could be a source of nitrates. The other two were old and shallow wells, the kind most susceptible to contamination. The other 476 wells (more than 99 percent of the total) contained levels of nitrate lower than 10 mg/L.

Some midwestern states with heavy agricultural production have more serious problems with nitrates in ground water than Alabama. This difference might be explained by differing soil types and agricultural practices.

LAND DISPOSAL

People have used the land to dispose of unwanted materials and garbage since the beginning of civilization. We have learned much about early cultures by studying artifacts found in their garbage heaps. As knowledge grew of how diseases are spread, the practice of burying waste began, especially organic, degradable waste, which contains or supports the growth of **pathogens** (microorganisms that cause disease). These materials are sometimes referred to as putrescible waste.

While the burial of these materials eliminated a pathway for the spread of disease, it meant that they were placed close to or sometimes within the water table, creating sources of ground water contamination. Rainfall infiltrates the layers of waste, creating contaminated **leachate** that can pose a threat to surface waters as well as ground water. Today, our country is having to deal with soil and ground water contamination caused by land disposal of industrial waste as well as wastes typically sent to

An authorized non-hazardous waste landfill sanitary landfills. Sanitary landfills continue to be the receptacles for residues of acidic or caustic household cleaners, batteries, leftover paint, and common engine cleaning products containing solvents.

The federal Resource Conservation and Recovery Act, **RCRA**, now requires protective liners in landfills, leachate collection systems, and monitoring of area ground water. This is true for landfills used for disposal of hazardous waste and non-hazardous waste from residential sources. Industrial and commercial waste sent to landfills may contain much more concentrated sources of toxic materials. Toxic materials that may be concentrated in industrial and commercial waste include metals, and solvents used for dry cleaning and degreasing such as tetrachloroethylene and trichloroethylene.

Because suitable landfill locations are becoming increasingly difficult to find, and no one wants a landfill located next to his or her property, landfill space is at a premium. Many communities have begun aggressive recycling efforts to conserve landfill space so it will last longer.

TRASHING THE LANDSCAPE

Our country is having to deal with soil and ground water contamination caused by land disposal of industrial waste as well as wastes typically sent to sanitary landfills.

In many rural areas, dead end dirt roads and sinkholes commonly become disposal sites for garbage and other waste materials. These places are eyesores, posing a threat to ground and surface water quality and promoting the spread of disease through the growth of insect or rodent populations that can transmit disease. Organisms such as these which carry disease-causing pathogens are called **vectors**.

Hazardous materials, dead animals, and even household garbage placed in uncontrolled dumps where surface water has easy access to the underlying aquifer can quickly contaminate that aquifer. Limestone aquifers with sinkholes are particularly susceptible to contamination in this way, but all shallow aquifers can be seriously damaged by unregulated dumping.

Sinkholes like this one are thoughtlessly used for dumping trash, with unsafe and expensive consequences for ground water supplies.

UNDERGROUND INJECTION

There are state laws and regulations which prohibit illegal dumping. If you find an illegal disposal site, you should contact the Solid Waste Branch of the Alabama Department of Environmental Management.

The subsurface environment has been used for centuries to dispose of liquid wastes such as household wash waters and sewage. This was commonly done through construction of underground catchment basins called cesspools. These structures allowed liquid wastes to gradually discharge to the surrounding soils and ground water. Today, in areas where there are no sanitary sewers or central treatment systems for homes to connect to, septic tanks and drainage fields are used.

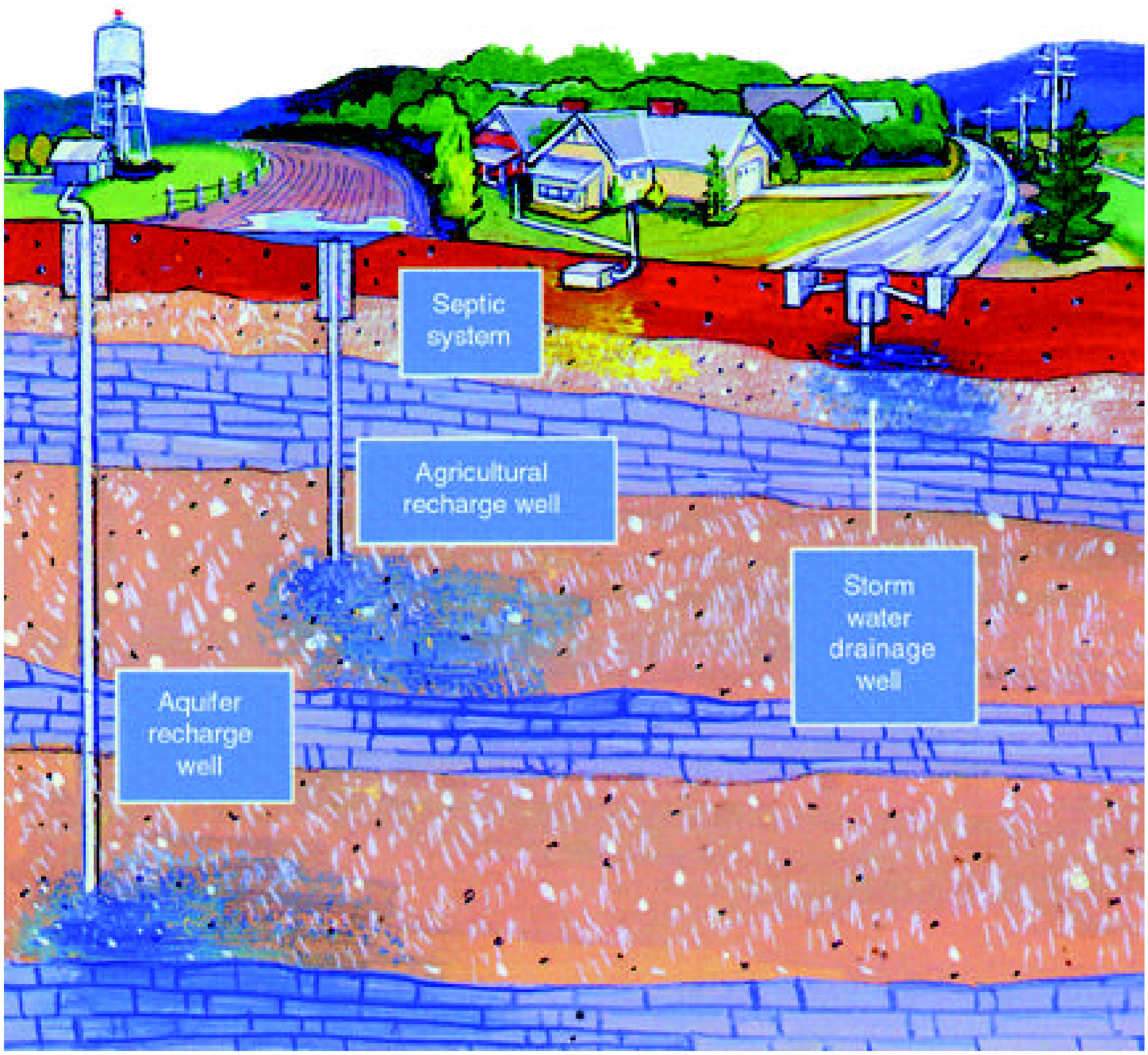
As our civilization has developed, new types of liquid wastes, such as those from manufacturing operations, had to be disposed of. Most of the time, liquid wastes were discharged to surface streams. If a stream or river was not available, the subsurface was again used. Wastes were sometimes pumped under pressure into surrounding soils, rock, and ground water. Typically, these wastes were given little or no treatment.

Improper subsurface waste disposal can contaminate ground water and threaten both public and private drinking water wells. The **Underground Injection Control** (**UIC**) Program was developed under the federal **Safe Drinking Water Act (SDWA**, 1974) to prevent contamination of underground sources

Improper subsurface waste disposal can contaminate ground water and threaten both public and private drinking water.

of drinking water by improper disposal of wastes through underground injection, or injection wells.

In Alabama, subsurface disposal of household wastewater and sewage through septic tanks and field lines is permitted through the county offices of the Alabama Department of Public Health. The Alabama Department of Environmental Management regulates any other type of subsurface liquid disposal through the UIC Program. This national regulatory program separates the different types of underground injection activities into five classes of disposal wells.



Shallow injection wells

Class I – Wells used to dispose of wastes below the deepest aquifer that could be used as a source of drinking water. This type of well is no longer permitted in Alabama, and all existing wells have been closed.

Class II – Wells used to inject fluids associated with the production of oil and natural gas. Injection occurs below the deepest aquifer that could be used as a source of drinking water. This type of well is regulated by the State Oil and Gas Board.

Class III – Wells used to inject fluids for the solution mining of minerals. An example of this would be injection of fresh water into naturally occurring underground deposits of salt. Salt can then be recovered from the solution as a product.

Class IV – Wells that dispose of hazardous or radioactive wastes into or above an underground source of drinking water. These wells are banned nationwide. If an operating well of this type is found, it must be closed.

Class V – Wells not included in the other classes, that inject non-hazardous wastes into or above an aquifer that could be used as a source of drinking water. Under Alabama's UIC program, permits are required for these types of wells. Regulations prohibit these wells from contaminating ground water above Maximum Contaminant Levels, or drinking water standards.

Disposal of wastes through Class V wells is a type of pollution source that historically has been poorly regulated in our country, and which has led to many instances of soil and ground water contamination.

The decision to require permits for Class V wells in the state was made in 1983 when Alabama received approval from EPA to implement the UIC program. The permit requirement allows the review of proposed activities prior to beginning operation so that discharges can be required to have treatment, if needed, or a permit could be denied if ground water contamination could result.

There are about 300 permitted Class V wells in Alabama. The majority of these wells are for facilities such as car washes or laundromats located in rural areas where there are no sanitary sewers that could receive the wastewater. In most cases, a drainage field, such as would be used for household wastewater disposal, is used to discharge wastewater, after treatment, beneath the surface to soils. Another common activity requiring a Class V UIC permit is the discharge of treated ground water from ground water corrective action systems. For example, contaminated ground water may be pumped to the surface, treated to remove contaminants, and then put back into the ground, thus improving the quality of ground water at that location. Substances such as oxygen releasing compounds and nutrients are sometimes injected to stimulate ground water cleanup.

In many parts of the country Class V wells are used to recharge aquifers where water tables may be declining. They may also be used to drain storm water to prevent flooding. These types of uses are uncommon in Alabama. Class V wells are also used to discharge water from some types of heat pumps.

A Class V storm water drainage well in Colbert County. Only a few of these types of wells are known to be in use in Alabama.

ABANDONED WELLS AND BOREHOLES

There may be more than 100,000 active private water wells in Alabama. As public water supply systems continue to expand into areas that previously depended on private water wells as their water supply, more and more of these wells have been abandoned. In 1980, public water systems in Alabama supplied 6 times as much water as did private domestic wells; by 1990, the number had increased to 27 times as much. The total number of abandoned water wells in Alabama is probably in the tens of thousands.

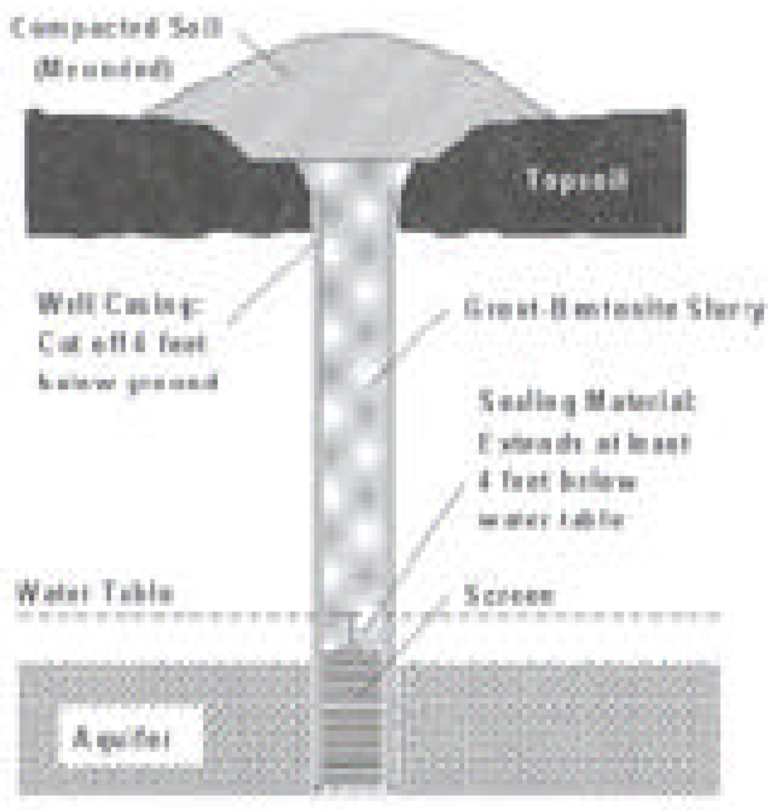
Like sinkholes, abandoned wells are directly linked to aquifers and can channel harmful materials such as sewage, pesticides, fertilizer, toxic chemicals, and bacteria from the land surface into aquifers. Abandoned wells are not difficult to seal properly, but many remain open. Because of their large number and wide distribution, abandoned wells pose a significant threat to local ground water supplies.

Because Alabama is a mineral-rich state, widespread mining operations exist, all of which use boreholes. Boreholes penetrating shallow aquifers which have not been properly sealed could also become conduits for surface pollutants to enter the subsurface.

The Department of Environmental Management has developed guidelines for abandonment of water wells and boreholes in Alabama. When a well is no longer useful, it should not simply be left as an open hole. Any open well is a threat to the environment. A few years ago a small child became trapped in an open abandoned well, attracting national attention. If the well is a flowing well, millions of gallons of water can be wasted if the well is simply allowed to flow unchecked. If more than one aquifer is penetrated by a well bore, waters from several aquifers may mix. If one aquifer is contaminated then contaminated water could flow from it into the well bore, and from there into other aquifers. For all these reasons, it is important to properly seal wells and boreholes when they are no longer needed.

Abandonment methods vary depending on the kind of well involved. For instance, a very deep well, or a monitoring well near a hazardous waste disposal facility, requires more care in abandonment than does a 10-foot deep hand-dug private well. Wells in farming country must be cut off and sealed at least 4 feet below the surface to prevent damage to farm equipment.

In general, proper well abandonment involves three tasks. First, one must clean out any debris or equipment that may partially block the well bore and prevent a proper seal. Second, remove the casing (if possible), also for the purpose of ensuring a tight seal. Third, fill the well bore from bottom to top with material, such as cement bentonite (clay) grout, that will prevent mixing of water from different aquifers and also prevent surface water from entering the aquifers. Anyone planning to abandon a well should contact the Ground Water Branch of the Alabama Department of Environmental Management for more detailed instructions.



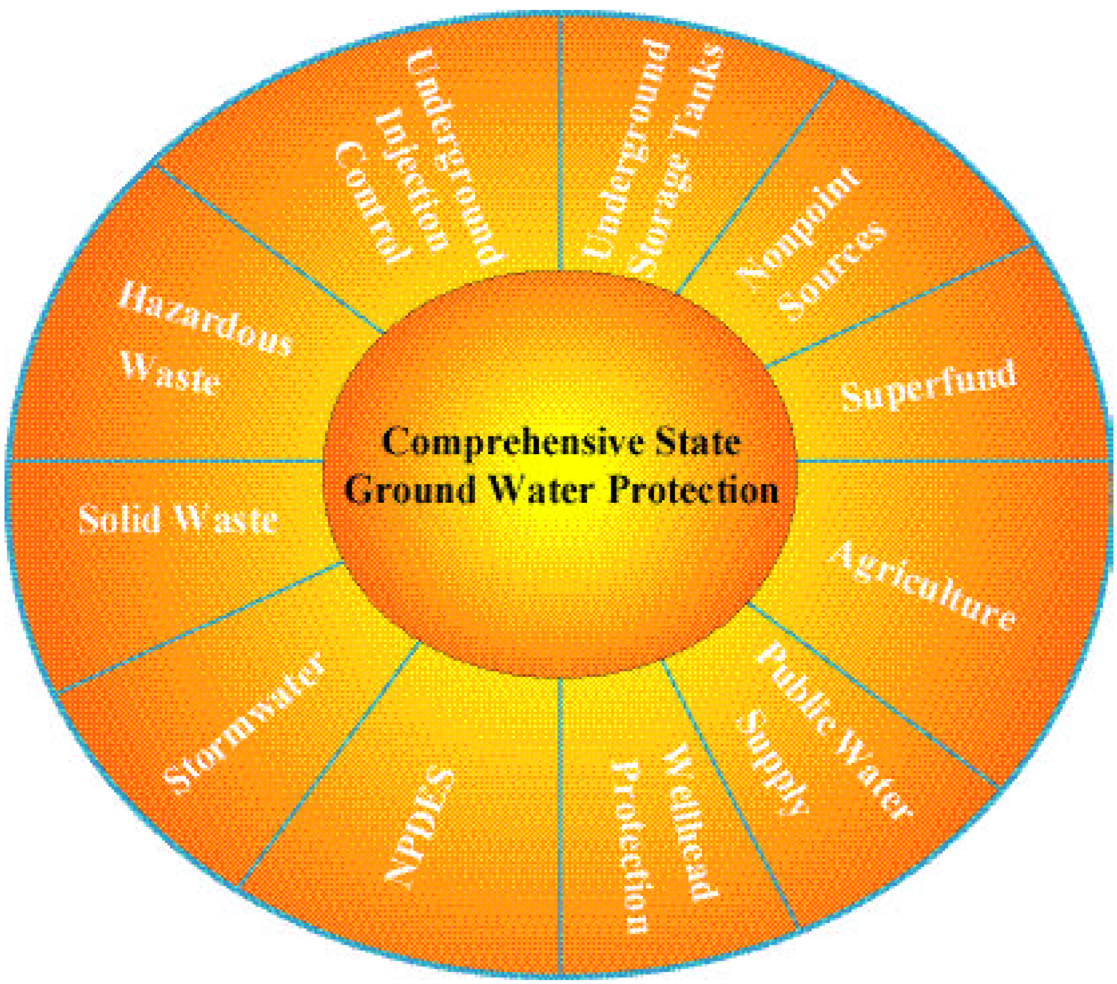
Water Well Abandonment Procedure

GROUND WATER PROTECTION IN ALABAMA

Ground water is protected by laws at both the federal and state levels. The U.S. Environmental Protection Agency (EPA) has been designated by Congress to be one of the primary federal agencies responsible for ground water protection. Congress authorized EPA to carry out requirements of federal laws having provisions that protect ground water quality. One such law is the **Safe Drinking Water Act**, which requires that standards be set for maximum contaminant levels in drinking water. This act also established the **Underground Injection Control**, **Wellhead Protection**, and **Source Water Protection Programs**, which in Alabama are administered by ADEM. Other important federal environmental laws include the **Resource Conservation and Recovery Act (RCRA)**, which regulates disposal of solid and hazardous wastes and established a national program for the regulation of underground storage tanks. The **Comprehensive Environmental Resource, Compensation, and Liability Act** (**CERCLA**) set up a Superfund and authorized the federal government to clean up chemical spills or hazardous substance sites that threaten the environment. The **Federal Insecticide, Fungicide, and Rodenticide Act** (**FIFRA**) allows EPA to control the availability of potentially harmful pesticides. The **Toxic Substances Control Act**

(TSCA) authorizes EPA to control toxic chemicals that could pose a threat to the public and contaminate ground water. The **Surface Mining Control and Reclamation Act (SMCRA)** regulates mining activities, some of which can negatively impact ground water.

In 1993 Alabama joined a pilot program with EPA to document the environmental programs in Alabama that together make up a **Comprehensive State Ground Water Protection Program**. Alabama's Ground Water Protection Program was one of the first in the nation to receive EPA endorsement and is the core of an evolving plan for statewide ground water protection. The program focuses on prevention and concentrates efforts in areas of the state determined to be most vulnerable to ground water contamination. Specific laws passed by the Alabama Legislature that



address protection of ground water include the **Alabama Water Pollution Control Act**, the **Hazardous Waste Management and Minimization Act**, the **Alabama Underground Storage Tank and Wellhead Protection Act**, and an act which established the **Hazardous Substances Cleanup Fund**. The goal of Alabama's Ground Water Protection Program, is *the protection of ground water for drinking water and other beneficial uses*. This goal is found in the Alabama Water Pollution Control Act.

With the authority provided by these state laws, EPA allows the State of Alabama to administer the national environmental programs previously discussed. ADEM administers all of these programs except for those under **FIFRA,** which are carried out by the Alabama Department of Agriculture and Industries. State and federal laws dealing with ground water protection are summarized in Tables 2 and 3.

A basic step in protecting Alabama's ground water resources is to identify and assess areas affected by contaminants. Several different agencies are involved in ground water assessment in Alabama.

ADEM is presently conducting studies designed to evaluate nitrates and pesticides in wells throughout the

Geologist analyzing a water sample

Table 2. *State Laws Affecting Ground Water Protection*

Laws	Date	Summary
AL Solid Wastes Disposal Act	1969	Regulates solid Waste collection and disposal and landfill construction, authorizes local goverments to provide necessary services
AL Water Pollution Control Act	1975	Authorizes programs to protect waters of the state, including standards, permits, and compliance assurance
AL Water Well Standards Act	1975	Regulates construction and driller qualifications for potable water wells
AL Hazardous Waste Management & Minimization Act	1975	Regulates the transport, storage, treatment, disposal, and other management of hazardous wastes
AL Coastal Area Management Act	1975	Requires Coastal Consistency Determinations of any permitting activity affecting coastal resources
AL Safe Drinking Water Act	1977	Authorizes programs for potable ground and surface water supplies, systems, and distribution for public and certain private sources, including standards, permits, and compliance assurance
AL Environmental Management Act	1982	Consolidated various environmental agencies and programs into the Department of Environmental Management; provided for permits/license fees and administrative penalties
AL Underground Storage Tank & & Wellhead Protection Act	1988	Regulates the construction and operation of USTs and sets requirements for leak detection standards, corrective actions, and financial responsibility
AL Underground Storage Tank Trust Fund Act	1988	Provides a fee-supported fund for participating UST owners for corrective actions and for third-party claims arising from leaking USTs

Table 3. *Federal Laws Affecting Ground Water Protection*

Laws	Date	Summary
Federal Insecticide, Fungicide, & Rodenticide Act	1969 1988*	Authorized EPA to control pesticides
Safe Drinking Water Act and Amendments (SDWA)	1974 1986* 1996*	Authorized EPA to set standards for maximum contaminant levels in drinking water, regulates underground waste disposal, designates areas that rely on a single aquifer, established the Wellhead Protection Program and the Source Water Protection Program
Resource Conservation & & Recovery Act (RCRA)	1976 1984*	Regulates storage, transport, treatment, and disposal of solid and hazardous waste to prevent gound water contamination
Toxic Substances Control Act (TSCA)	1976 1988*	Authorized EPA to control toxic chemicals
Clean Water Act (CWA)	1977	Authorized EPA to make grants to the states for the development of ground water protection (affects ground water shown to have a connection to surface)
Surface Mining Control & Reclamation Act (SMCRA)	1977	Regulates mining activity
Comprehensive Environmental Response Compensation, & Liability Act (CERCLA)	1980	Authorized federal government to clean up contamination caused by chemical spills or hazardous waste sites that could or do pose threats to the environment
Superfund Amendments & Reauthorization Act (SARA)	1988	Authorized citizens to sue violators of Superfund and established community right-to-know programs (Title III)

state, and is also involved in several other detailed ground water assessment projects in other areas of the state.

The Geological Survey of Alabama (GSA) has conducted an annual ground water sampling program from wells and springs in Alabama for many years, testing for the presence of inorganic contaminants.

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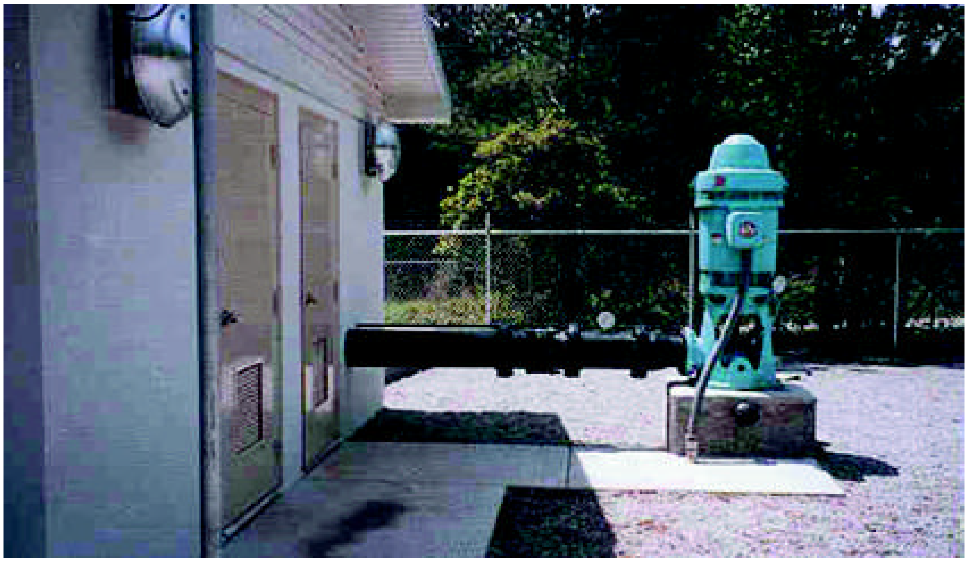
The GSA is also participating in a number of other projects that involve detailed ground water assessments, including several wellhead protection program projects. The Wellhead Protection and Source Water Assessment Programs are designed to protect ground water used for public water supplies. Wellhead Protection and Source Water Protection projects emphasize the need for managers of public water supply systems to understand how ground water reaches public water supply wells. Public involvement is also emphasized to prevent contamination of these wells. Wellhead and Source Water Assessment projects begin with geological and hydrological evaluation of the aquifers used for public water supplies. The goal of these evaluations is to determine what land areas should be included in protection programs for public water supplies. Potential sources of contaminants within the critical areas are then inventoried. A map of a Wellhead Protection Area for a public water supply well in Prattville, AL is shown on the adjacent page. Finally, for a wellhead protection program, management plans are developed to help ensure that public water supplies are kept safe.

Wellhead protection study. Pouring nontoxic dye for an aquifer time-of-travel test (dye tracing).

Map showing wellhead protection ares for a public water supply well



Water Supply Well in Butler County

The U.S. Geological Survey (**USGS**) has conducted regional aquifer studies that included Alabama, and is currently conducting a national water quality survey, which will include detailed sampling of several Alabama **watersheds**.

The Alabama Department of Public Health (**ADPH**) also plays an important role in protecting the state's ground water by analyzing water samples for bacterial contamination to locate and eliminate potential contaminant sources. These are only a few of the agencies and programs involved in assessing and protecting Alabama's ground water resources. A more complete list is provided in Table 4.

The most effective way to protect a ground water supply is by isolating it from potential contaminants. Once an aquifer has become contaminated, cleanup is usually a lengthy and expensive process. An industrial site in Butler County contaminated with PCB's is one of the 12 identified **superfund** sites in Alabama. Work at this site has been on going since the early 1980's with the total cost estimated at $25 million for full clean up. The total estimated cost for cleaning up all 12 superfund sites in Alabama is $300 million.

The responsibility for protecting the state's ground water does not stop at the federal and state levels but extends to the local level and to every citizen. Individuals can help

Table 4. *Agencies with Ground Water Programs*

Alabama Department of Environmental Management (ADEM) (334) 271-7700

ADEM Water Division	(334) 271-7823	Surface and Ground Water Protection Programs
ADEM Ground Water Branch	(334) 270-5655	
Hydrogeology Unit		Hydrogeologic Support
UST Corrective Action Unit		UST Trust Fund, Assessment, and Corrective Action Programs
UST Compliance Section		UST Regulatory Compliance Program
Underground Injection Control		Class I, III, and V UIC Wells
Wellhead Protection Program		Protection of Public Water Supply Wells
ADEM Municipal Branch	(334) 270-7810	NPDES Permitting, Municipal Land Application Projects, Engineering & Compliance
ADEM Industrial Section	(334) 271-7943	NPDES Permitting, Industrial Land Application Projects, Engineering & Compliance
ADEM Water Supply Branch	(334) 271-7773	Source Water Protection, Municipal Water Supply Program
ADEM Land Division	(334) 271-7730	Solid and Hazardous Waste Management, Permitting, Engineering & Compliance
ADEM Hazardous Waste Branch	(334) 271-7874	Hazardous Waste Management
Industrial Facilities Section		Hazardous Waste Management Permitting, Engineering
Northern Section		Hazardous Waste Management Compliance
Southern Section		Hazardous Waste Management Compliance
Government Facilities Section	(334) 271-7738	Hazardous Waste Management Permitting, Engineering
Site Assessment Unit		State Superfund Program, Spills, Soil Cleanup, Hazardous Substances Control
ADEM Solid Waste Branch	(334) 271-7771	State Solid Waste Management Program Permitting Engineering
Compliance Section	(334) 271-7761	State Solid Waste Management Program Compliance
ADEM Field Operations Division	(334) 394-4382	ADEM Field Offices, Emergency Response
Mobile Branch	(334) 450-3400	Emergency Response, UST Compliance
Montgomery Branch	(334) 260-2711	Sampling, Emergency Response
Birmingham Branch	(205) 942-6168	Emergency Response, UST Compliance
Decatur Branch	(205) 353-1713	Emergency Response, UST Compliance
State Oil and Gas Board	(205) 349-2852	Regulates the Oil and Gas Industry
Underground Injection Control		Class II Underground Injection Control (UIC) Program

Alabama Department of Public Health

Environmental Health Services	(334) 206-5673	On-Site Sewage Treatment
County Health Departments	Local Listings	On-Site Sewage Treatment

NPDES = National Pollutant Discharge Elimination System (Surface Water Discharge Permitting)

UST = Underground Storage Tank

Table 4. Agencies with Ground Water Programs

State Nonregulatory Agencies Wtih Ground Water Responsibilities

Geological Survey of Alabama

Hydrogeology Division	(205) 349-2852	Wellhead Protection, Public Education/Outreach, Hydrogeological Research
Ground Water Section	(205) 349-2852	Ground Water Resources, Ground Water Level Database
Water Information Section	(205) 349-2852	Water Well Database
Environmental Geology Division	(205) 349-2852	Environmental Health, Water Quality Database

Alabama Department of Agriculture and Industries

	(334) 242-2650	Pesticides

Alabama Department of Economic and Community Affairs

Recycling Program	(334) 271-5651	Recycling
Water Resources Office	(334) 242-5499	Water Use Database

Natural Resources and Conservation Department

Fisheries Program	(334) 242-3465	Environmental Health
Wildlife Program	(334) 242-3469	Environmental Health

Federal Agencies with Ground Water Programs

United States Environmental Protection Agency (USEPA)

USEPA Region 4, Ground Water	(404) 562-9329	Public Water Supplies, UST and UIC Regulation, and Wellhead Protection and Drinking Water Branch
USEPA RCRA/CERCLA Hotline	(800) 424-9346	Solid Waste and Hazardous Waste Information
	(202) 382-3000	Solid Waste and Hazardous Waste Information
USEPA Safe Drinking Water Hotline	(800) 426-4791	Environmental Health Information
USEPA Region 4, WHP Coordinator	(404) 562-9453	Wellhead Protection Regulation and Information

United States Department of Agricuture (USDA)

USDA Rural Development Administration	(202) 720-9589	Agricultural Contamination, Solid and Hazardous Waste,
USDA Natural Resources Conservation Service	(334) 887-4506	Agricultural Contamination, Evnironmental Health

United States Department of Commerce (USDC)

USDC National Oceanographic and Atmospheric Administration	(704) 271-4800	Environmental Health, National Climatic Data Center

United States Department of the Interior (USDI)

USDI Geological Survey	(334) 832-7510	Water Resources, Water Research

safeguard ground water supplies by responsible use of potentially harmful materials such as fertilizers, pesticides, and household products. Manufacturer's information and county agents can aid in selecting and applying lawn and garden chemicals that produce minimal impact on ground water supplies. Individuals, farms, industry, and other operations may apply pollution prevention methods through education, best management practices, and safeguards to prevent ground water pollution.

Many common household products contain hazardous or toxic substances that could contaminate ground water. Some of these products are listed in Table 5. Care should be taken in disposing of these materials. because some of them contain substances that are not easily removed from sewage and that may damage or ruin septic systems.

Perdido Ground Water Contamination

The 15-acre Perdido Site, located in Baldwin County, was contaminated as a result of a train derailment in 1965. Approximately 7,600 gallons of the toxic chemical benzene were spilled into drainage ditches and seeped into the underlying aquifer. The contaminated area extends about 1,000 yards from the derailment site. Contamination of nine private wells has been confirmed. Baldwin County Health officials recommended that residents within a 1-mile radius of the derailment use alternate water supplies, which have been provided. In 1988, EPA selected a plan to clean up the ground water that included extraction and treatment of the ground water by a technology called air stripping. Water is pumped out of the aquifer using wells drilled for that purpose. After the benzene is removed, the treated water is returned to the aquifer by specially designed injection wells. Construction of the treatment facilities was completed in 1992, and treatment will continue until the ground water contaminant levels meet the cleanup goals established by EPA. The treatment program shows continuing progress in reducing ground water contamination at the Perdido Site. The estimated cost for the cleanup at the Perdido Site is $2,900,000 for capital investment plus $270,000 per year throughout the cleanup process.

Table 5. ***Common Household Products and Some of their Hazardous Components***

Product	Hazardous Components
Antifreeze	methanol, ethylene glycol
Battery acid	sulfuric acid
Degreasers	petroleum solvents, alcohols, glycolether, chlorinated hydrocarbons, toluene, phenols
Engine and radiator flushes	dichloroperchloroethylene
Hydraulic (brake) fluid	hydrocarbons, fluorocarbons
Motor oil, grease, lubes	hydrocarbons
Gasoline, diesel fuel, heating oil	hydrocarbons
Kerosene	hydrocarbons
Rustproofers	phenols, heavy metals
Transmission fluid (automatic)	petroleum distillates, xylene
Car wash detergent	alkylbenzene sulfonates
Car wax or polish	petroleum distillates, hydrocarbons
Asphalt, roofing tar	hydrocarbons
Paint, varnish, stain, dye	heavy metals, toluene
Paint thinner	acetone, benzene, toluene, butyl acetate, methyl ketones
Paint and varnish removers	methylene chloride, toluene, acetone, xylene, ethanol, benzene, methanol
Paint brush cleaners	hydrocarbons, toluene, acetone, methanol, glycol ethers, methyl ethyl ketones
Floor and furniture strippers	xylene
Metal polishes	petroleum distillates, isopropanol, petroleum naptha
Laundry soil and stain removers	petroleum distillates, tetrachloroethylene
Spot removers and dry cleaning fluid	hydrocarbons, benzene, trichloroethylene, tetrachloroethylene, 1,1,1 trichloroethane
Other solvents	acetone, benzene
Rock salt (Halite)	sodium and chloride
Refrigerants	1,1,2 trichloro – 1,2,2 triffluoroethane
Bug and tar removers	xylene, petroleum distillates
Household and oven cleaners	xylenols, glycol ethers, isopropanol
Drain cleaners	1,1,1 trichloroethane
Toilet cleaners	xylene, sulfonates, chlorinated phenols
Disinfectants	cresol,
Pesticides	napthalene, phosphorus, xylene, heavy metals, chlorinated hydrocarbons
Photochemicals	phenols, sodium sulfite, cyanide, silver halide, potassium bromide, selenium
Printing Ink	heavy metals, phenol-formaldehyde
Wood preservatives(creosote)	pentachlorophenols
Wood pressure treatment	heavy metals, cyanide
Swimming pool chlorine	sodium hypochlorite
Lye or caustic soda	sodium hypochlorite
Jewelry cleaners	sodium cyanide
Fertilizers	nitrate

(Modified from "Natural Resources Facts: Household Hazardous Wastes" Fact Sheet No. 88-3, Department of Natural Science, University of Rhode Island, August 1988)

Lessons learned from past mistakes have led to better siting and design of facilities such as industrial wastewater treatment facilities and landfills, which in the past have been sources of ground water contamination. Shown below are above ground treatment units which have replaced earthen treatment ponds. Other facilities such as landfills are now designed to effectively prevent ground water contamination, using devices such as double liners and leachate-collection systems. Monitoring of ground water is required of facilities having the potential to adversely affect ground water quality.

Several options are available to communities and city governments desiring to protect ground water resources. These include source-water assessment and wellhead protection programs. A number of communities have initiated wellhead protection studies. These efforts help to safeguard public ground water supplies by evaluating the local aquifer system, identifying potential sources of contamination, and developing a wellhead protection management plan to protect ground water supplies, as well as a contingency plan in case contamination occurs. Public participation in developing the wellhead protection plans is encouraged.

A landmark example of a group of individuals organizing to protect

Above ground treatment units at Ciba Specialty Chemicals, McIntosh, Alabama.

and control the development of their water resources occurred in a group of watersheds in southeast Alabama. The group first formed into a local organization, which later became a legislatively funded local agency called the Choctawhatchee, Pea and Yellow Rivers Watershed Management Authority (CPYRWMA). The CPYRWMA is administered locally and focuses on the water resources of the entire Alabama portion of the Choctawhatchee River and Pea River watersheds in Alabama, an area including parts of 10 counties.

Another good way for citizens to get involved in source water protection is the Groundwater Guardian program, founded by the Groundwater Foundation. This voluntary program encourages local groups of citizens to organize creative projects to protect their ground water. Madison County was the first community in Alabama to establish a Groundwater Guardian program and also the first to host a Ground Water Festival for elementary aged school children.

Other ways that local governments can protect ground water quality are through regulating land uses that could degrade water quality in the recharge areas of municipal wells; by supplying water, sewer, and waste disposal services; by monitoring water supplies for possible contaminants; and by establishing a collection and disposal schedule for hazardous household wastes. Because many households have no safe place to dispose of hazardous wastes, this last suggestion is potentially of great importance. A collection day for hazardous wastes, called an amnesty day, was held in the Flint Creek area and was very successful, resulting in the collection of

Tuscumbia is a Ground Water Guardian Community thousands of pounds of unwanted and out-of-date chemicals.

It is important to emphasize that ground water should not be considered an isolated resource, but rather as an integral part of the total freshwater resource. If surface water in the recharge area of an aquifer becomes polluted, the aquifer itself may become polluted through recharge. Many communities, such as Auburn, Birmingham, Gadsden, Mobile, Montgomery, Muscle Shoals, Talladega, and Tuscaloosa depend on surface water for part or all of their water supplies. The surface water on which these communities depend is, in the dry season, largely supplied by ground water discharge to streams. For these reasons, the most effective resource protection program should be comprehensive in scope and not restricted to ground water or surface water alone.

Swift Creek Park, Autauga County

The very best and most cost effective way to ensure adequate long term ground water protection is through education. Providing planners, students, and the general public with a knowledge of our ground water is the best guarantee that all Alabamians will enjoy clean, safe drinking water for generations to come.

GLOSSARY

(Glossary terms used in the definitions of other glossary terms are italicized where used.)

ADAI Alabama Department of Agriculture and Industries

ADEM Alabama Department of Environmental Management**.**

ADPH Alabama Department of Public Health**.**

Artesian well An artesian well is drilled into an aquifer that is under pressure (a confined aquifer). If the pressure is high enough, water flows to the surface

.

Aquifer Rock, soil, or sediment that contains ground water and is capable of yielding significant amounts of water to a well or spring.

Brine Salty water.

Calcite A mineral, the primary constituent of limestone. The most common form of calcium carbonate ($CaCO_3$).

CERCLA *Comprehensive Environmental Response, Compensation, and Liability Act*. Also called Superfund.

Concentration In chemistry, the concentration of a substance is the decimal fraction or percentage of that substance in a mixture of two or more substances, per unit volume. Thus, if one part of salt is mixed with nine parts of water, then the salt concentration is 10 percent, or 0.1.

Confined aquifer An aquifer bounded above and below by confining units. A confined aquifer is entirely filled with liquid and may be under pressure.

Confining unit A confining unit is a rock, soil, or sediment unit that stores water, but does not transmit significant quantities of water.

Contaminant A substance which either by its presence or concentration makes water unsuitable for a desired use. Some contaminants occur naturally.

CSGWPP Comprehensive State Ground Water Protection Program.

Discharge In the context of ground water, the movement of water from the ground water system to the surface water system.

Dolomite A mineral ($Ca,Mg(CO_3)_2$) related to calcite and common in some limestones.

PESTICIDES

Pesticides are common ground water contaminants. About 3.8 million pounds of solid pesticides and 450,000 gallons of liquid pesticides are applied in Alabama each year to kill insects, rodents, mold, and weeds. Some pesticides are now prohibited by EPA because they were contaminating surface and

EPA United States Environmental Protection Agency.

Evaporation The conversion of a liquid to a gas.

Evapotranspiration *Evaporation* plus transpiration.

Fall line The boundary between older, hard, igneous and metamorphic rocks and the younger, soft sedimentary rocks of the coastal plain. Marked by a break in slope and waterfalls in rivers.

FIFRA Federal Insecticide, Fungicide, and Rodenticide Act.

Formation A rock unit that has recognizable characteristics and that is thick and extensive enough to be mappable. An aquifer is commonly a formation, part of a formation, or two or more formations.

Ground water Water in the saturated zone below the surface of the ground.

GSA Geological Survey of Alabama.

Hardness See *hard water*.

Hard water Hard water does not readily produce a lather with soap. Because it contains substantial amounts of dissolved carbonate, hard water tends to form a chalky white scale on hot water heaters and in tea kettles. The origin of the name is unknown, but it may have referred to the "hard rocks" (limestone and dolomite mountains) from which hard water comes in southern Europe where the name was coined.

Hydrogeologic province A region, typically much larger than a county, defined by a certain kind or kinds of aquifers. Hydrogeologic provinces approximately correspond to physiographic provinces, which are defined by characteristic kinds of rocks. For example, the Coastal Plain physiographic province, with its gently dipping sands, shales, and limestones, coincides with the Coastal Plain hydrogeologic province, with its evenly layered sand and limestone aquifers.

Hydrogeology The scientific study of ground water and rock, sediment, and soil units (aquifers) containing ground water.

Hydrologic cycle The circulation of water from the oceans, through the atmosphere and back to the Earth's surface, over the land surface and underground, and eventually back to the oceans.

Infiltration In soil science and hydrology, the downward movement of water into soil during and after a precipitation event.

Ingeous rock Rocks that solidified from a hot, liquid state.

Leachate See *leaching*. Liquid product of leaching.

Leaching Generally, any process in which a fluid selectively removes material from a solid through which it passes. Leaching commonly refers to the downward passage of surface water or rain water through soil, sediment, or landfill material,

Leachate See *leaching*. Liquid product of leaching.

Leaching Generally, any process in which a fluid selectively removes material from a solid through which it passes. Leaching commonly refers to the downward passage of surface water or rain water through soil, sediment, or landfill material, and the resulting transport of dissolved contaminants into the ground water system.

Limestone A sedimentary rock composed chiefly of calcium carbonate ($CaCO_3$) particles made by marine animals and plants.

MCL Maximum contaminant level, the maximum permissible level in drinking water of a particular chemical, established by the EPA.

MGD Million gallons per day.

Metamorphic rock made by heating and squeezing preexisting rocks so that new minerals replace the preexisting ones.

Microorganisms Organisms such as bacteria and viruses which are too small to see with the human eye.

Nonpoint source pollution Pollution whose sources are diffuse, multiple, or widespread.

NRCS Natural Resources Conservation Service. Formerly the Soil Conservation Service. Part of the U.S. Department of Agriculture.

Overpumping Withdrawing more water from an aquifer than is replenished by recharge.

Pathogens Microorganisms which cause disease.

Permeability A measure of the interconnectedness of a pore or fracture system, which determines the ability of a rock unit to transmit fluids.

Physiography The genesis and nature of land forms.

Point source pollution Pollution from a known and well defined source. For example, a factory, waste treatment plant, or leaking underground storage tank.

Porosity The amount, usually represented as percent, of open pore space in an aquifer.

PPM Parts per million. One ppm=1 unit of a substance in 1,000,000 units of another substance.

Public water system A system to provide piped water to the public for human consumption, if such system has at least 15 service connections or regularly serves an average of at least 25 individuals at least 60 days of the year.

RCRA *Resource Conservation and Recovery Act*.

Recharge Water that enters an aquifer from the surface or the process of aquifer replenishment.

Recharge area That region in which an aquifer is exposed at the surface (perhaps covered by *soil*), so that water falling within the recharge area can penetrate into the aquifer.

Runoff That portion of precipitation that flows on or just beneath the land surface until it reaches a surface water body, enters the ground, or evaporates.

Sand A sediment consisting of small rock particles (62 micrometers to 2 millimeters in size). The most common mineral in sand is quartz (SiO_2), which is the primary ingredient in glass.

Sandstone A rock consisting chiefly of sand-sized particles cemented together by some natural cement (typically quartz, calcium carbonate, or iron oxide).

Salt water intrusion The introduction into a freshwater aquifer of sea water or subsurface brine. Usually caused by excessive pumping of wells, which permits salt water to flow into the aquifer laterally or from below.

Saprolite A soft, earthy, decomposed rock formed in place by chemical weathering of igneous and metamorphic rocks. Saprolite is commonly red or brown, and forms in warm, humid climates.

SARA *Superfund Amendments and Reauthorization Act*.

Saturated zone That region below the water table in which all voids are filled with liquid.

Sedimentary rock A rock that consists chiefly either of small pieces of rock cemented together (e.g., sandstone) or of crystals that grew from water (rock salt). There are some odd earth materials that are commonly considered sedimentary rocks, such as coal. The other two kinds of rock are igneous and metamorphic.

Shale A sedimentary rock consisting of very small fragments (less than 62 micrometers) that tend to be thin and flat. Shales are not good aquifers because the holes between particles are too small and because the chemical properties of many shale minerals permit them to hold onto a large amount of water. Shales generally form confining units.

Sinkhole A hole caused by collapse of the land surface, commonly because underlying limestone rock has dissolved away, forming a cavity.

Soil Particulate matter, commonly containing sand, silt, clay, and organic material and having a definite layered structure, forming a layer a few inches or many of feet thick that covers most of the earth.

Source Water Protection A program initiated by the EPA in 1996 to protect public water supplies. Source water assessment is required of each water system and involves delineating source water protection areas, inventorying significant contaminants in these areas, and determining the vulnerability of each public water supply to contamination. Source water protection is voluntary and involves actions taken to protect drinking water supplies.

Spring A point or zone of natural discharge of water from underground to the land surface or to the bottom of a surface water body.

Strata Layers, specifically layers of rock, laid down during a certain period of time, and commonly possessing certain physical and paleontological characteristics.

Superfund See CERCLA.

TSCA *Toxic Substances Control Act*.

Transpiration The passage of water vapor out of plant leaves through pores and into the air.

UIC (Underground Injection Control) A national environmental program authorized by the federal *Safe Drinking Water Act* to protect underground sources of drinking water.

Unconfined aquifer An aquifer consisting of an overlying unsaturated zone and underlying saturated zone, separated by a water table.

Unsaturated zone That region of soil, sediment, or rock above the water table containing both air and water in void spaces.

USGS United States Geological Survey.

UST Underground Storage Tank.

Vectors Organisms carrying pathogens.

Water budget An estimate of the amount of water moving through each part of the *hydrologic cycle* for a given region.

Water table That surface within soil or rock below which all pore spaces are filled with water and above which at least some of them contain air.

Waters of the State The *Alabama Water Pollution Control Act* defines this as all surface or ground water in the state except water entirely confined and retained completely upon the property of a single individual, partnership or corporation unless the water is used in interstate commerce.

Watershed A natural unit of land from which the surface water runoff subsurface, and ground water drain to a common outlet.

Well A bored, drilled, or driven shaft or dug hole. Wells range from a few feet to more than 6 miles in depth, but most water wells are between 100 and 2,000 feet in depth.

Wellhead protection area The surface and subsurface area surrounding a public water supply well or well field that a community has taken steps to protect, and through which contaminants are likely to move toward and reach such well or well field.

Wetland Land characterized by any of the following: water loving plants, hydric soils, and flooding part or all of the year. Hydric soils have distinctive characteristics resulting from the common presence of abundant moisture.

WHPP Wellhead Protection Program.

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BY THE NUMBERS

696 Public Water Systems in Alabama serve a population of approximately 5.0 million.

499 systems (72%) utilize Ground Water as a Source.

16 Systems in Alabama utilize Ground Water along with Surface Water.

Approximately 1.98 million (40%) of Alabama's population are served by Ground Water.

Figures based on 2001 data

Ground Water Guardian

The Department was designated a Groundwater Guardian Affiliate by the Groundwater Foundation in November 1997 and again in November 1998. The Groundwater Guardian program is designed to empower local citizens and communities to voluntarily protect their groundwater resources and generate local solutions that effectively address local groundwater protection priorities.

In being named an affiliate, ADEM was honored for promoting the program in Alabama, assisting with the first two Groundwater Festivals in the state, and financially supporting the Alabama Cooperative Extension Service workshops on groundwater protection.

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WHO

REGIONAL OFFICE FOR EUROPE

THE IMPACT OF CEMETERIES ON THE ENVIRONMENT AND PUBLIC HEALTH

AN INTRODUCTORY BRIEFING

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TARGET 23

WASTE MANAGEMENT AND SOIL POLLUTION

By the year 2000, public health risks caused by solid and hazardous wastes and soil pollution should be effectively controlled in all Member States.

ABSTRACT

Most existing cemeteries were sited without thought being given to potential risks to the local environment or local community. The impact of degradation products from seepage waters from cemeteries has only been studied by a few researchers. This review considers the current state of knowledge on the fate of decomposition products from human corpses as they pass through the soil and into groundwater.

This report is intended to provide an introductory briefing on the state of knowledge regarding water pollution from cemeteries and the mechanisms operating to ameliorate the pollution potential. Some suggestions are provided on the siting and design of future burial sites. The findings of research by other workers in Australia, Brazil and Europe are also summarized.

Keywords

MORTUARY PRACTICE
SOIL POLLUTANTS
WATER POLLUTION
ENVIRONMENTAL HEALTH

CONTENTS

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Introduction

The WHO Nancy Project Office has undertaken a short review of the current state of knowledge regarding the presence, or absence, of soil and groundwater contamination from cemeteries. This was due to an interest to identify more information on their environmental and health impact. There is little published information on whether cemeteries should be regarded as potential sources of pollutants. Few examples of groundwater or surface-water pollution from cemeteries have been found in the scientific literature references in the past. Consequently, this literature review was undertaken by the WHO Nancy Project Office to gather together more information on the subject.

Most existing cemeteries were sited without thinking about potential risks to the local environment or local community. Commonly, they are constructed close to settlements because of religious and culture circumstances. However, religious and sociological reasons for cemetery siting are outside of the scope of this project. This report concentrates on the geological and hydrological properties of burial sites. Often, these have not been investigated.

This review considered first, the mechanisms of decay of the human corpse, and second, the fate of the products of decomposition, both chemically and microorganically in the surrounding strata and groundwaters.

During putrification of the human corpse, there is a seepage of decay products into percolating water. This seepage contains bacteria, viruses and organic and inorganic chemical decomposition products. If the cemetery is located in a porous soil type, such as sand or gravel, movement of seepage can be rapid and mix easily with the groundwater beneath the site. This could conceivably be a cause of local epidemics from waterborne diseases where the groundwater is used as a water source. Typical microorganisms known to be responsible for waterborne diseases and present in seepage include micrococcaceae, streptococci, bacillus and entrobacteria.

Another important factor that should be considered before using aquifers beneath cemeteries as water sources, especially shallow aquifers, is the distance from cemeteries to water abstraction points. The quantity of decay products from buried people and wood, fabrics and plastics used in coffins is directly influenced by the age and number of the human corpses decaying in the cemetery at any one time. Ideally, coffins should be made of materials that decompose rapidly and do not release persistent chemical by-products into the environment.

Today, sufficient land area for cemeteries is difficult to find in populated areas, and in the near future areas sufficient space for cemeteries may not be found at all in cities in most parts of the world. For instance, in Australia about 1.34 million adults (>15 years) will die in the next 10 years. If just 40% of these are interred and 75% of them occupy new graves of an average size 1.1 m by 2.4 m; then 106 ha of land will be consumed. These new cemeteries ought to be constructed to bury the expected number of corpses, but land availability is uncertain.

In England, out of 10 000 planning applications between 1989 and 1997, a total of 104 (equal to only 1% of planning applications) were for burial grounds and cemeteries. Given the need for an increase in the number of burial sites in many countries, there is a need to identify more precisely if, or in what way, cemeteries have any harmful impacts on the environment and public health. One approach would be to establish a set of basic design criteria for the siting and construction of new cemeteries. In addition, more careful consideration has to be given to finding the most suitable soil types in which to bury human remains so as to minimize the effect of seepage on the environment and public health.

No reports have been found in the literature of epidemics or widespread disease outbreaks which were unequivocally the result of seepage from cemeteries. However, doubt and concern persist due to the paucity of sufficient and clear scientific data.

Microbiology of the human corpse

The microorganisms isolated from general tissues in human corpses are similar to those isolated from unfit meat carcasses or from the lymph nodes of humans and animals. Ninety percent of the organisms found in human tissues are strict anaerobes (bacteria spp. and gram positive non-sporulating anaerobes – bifidobacteria, etc.) with lower numbers of *Lactobacillus*, *Streptococcus spp*. (mostly *Enterococcia*) and *Enterobacteriaceae* (about 10% in all). In addition to these, small numbers of *Clostridia spp*., *Bacillus spp*., yeasts, *Staphylococcus spp*. and pseudomonas aeruginosa can be found *(1)*. Table 1 presents a list of the important bacteria in a healthy human intestine.

Tissues are known to remain relatively free of microorganisms during the first 24 hours after death unless the invading pathogen was of a type not previously encountered by the host. There is evidence that bacteria may penetrate the intestinal walls during the process of death and become distributed throughout the tissues in the blood stream. However, organisms distributed through the blood stream may be prevented from multiplying and may be destroyed by the antimicrobial defences of the body. These defences are not completely inactivated until up to 48 hours after death *(2)*.

The redox potential (Eh) of tissues falls rapidly after death so that by the time antimicrobial activity has been lost the Eh is low enough to prevent obligate aerobic organisms, such as *micrococci*, *pseuaidomonads* and *acinetobacters*, from thriving except very close to the surface *(2)*. Anaerobic microorganisms begin to replace the aerobic organisms within a few hours of death and, provided the prevailing temperature exceeds 5 °C, they will start to multiply. Although the intestine harbours a large variety of microorganisms, only relatively few groups have been implicated as major colonisers of human corpses during putrification (i.e. during the first few days after death); these are *Clostridium spp*., *Streptococci* and *Enterobacteria*.

Anatomy of the human body

Seepage waters from the cemeteries occur as a result of the putrification of human corpses. The seepage may mix with groundwater and may become a potential risk for the environment if the pollutants are not ameliorated before coming into contact with a host community. Before considering whether or not seepage is a potential pollution source, it is useful to first review the substances that are found in the human body.

The human body of a 70 kg adult male contains approximately: 16 000 g carbon, 1800 g nitrogen, 1100 g calcium, 500 g phosphorous, 140 g sulfur, 140 g potassium, 100 g sodium, 95 g chlorine, 19 g magnesium, 4.2 g iron, and water 70–74% by weight. The elemental composition of females is between two thirds and three quarters of that for males *(3)*.

Table 1. Important bacteria in a healthy human intestine

Families and genera represented	Prominent species	Other species isolated from the intestine
Pseudomonadaceae		*Pseudomonas aeruginosa (pyocyanea)*
Pseudomonas		*Ps. (Alkaligenes) faecalis*
Enterobacteriacene	*Escherichia coli*	
Klebsiella		*Klebsiella (Aerobacter) pneumoniae*
Enterobacter		*Enterobacter (Aerobacter) aerogenes*
Proteus		*Proteus mirabilis*
Bacteroidaceae		*Bacteroides capillosus. B. oralis*
Bacteroides	*Bacteroides fragilis*	*B. clostridiformis. B. putredinis*
		B. coagulans. B. ruminicola
Fusabacterium		*Fusobacterium mortiferum*
		F. necrogenes. F. fusiforme
		F. girans
Neisseriaceae		*Neisseria catarrhalis*
Neisseria		*Veillonella parvula*
Veillonella		*V. alcalescens*
Micrococcacene		*Staphylococcus albus*
Staphylococcus		*Peptococcus asaccharolyticus*
Acidaminococcus		*Sarcina centriculi*
Sarcina		*Acidaminococcus fermentans*
Peptococcus		*Streptococcus salivarius*
Streptococcaceae		
Streptococcus	*Streptococcus faecalis*	*Strep. sangius*
		Strep. viridans (mitior)
		Strep. faecium
Lactobacillacene		*Lactobacillus brevis*
Lactobacillus	*Lactobacillus acidophilus*	*L. casei*
		L. catenaforme. L. fermentum
		L. leichmanii. L. plantarum
Leptotrichia		*Leptotrichia buccalis*
Bifidobacterium	*Bifidobacterium adolecentis*	*Bifidobacterium (Actinomyces*
	Bifidobacterium longum	*lactobacillu) bifium (bifidus)*
		Bif. breve. Bif. cornutum
		Bif. eriksonii. Bif. infantis
Ruminoccus	*Ruminococcus bromii*	*Peptostreptoccus intermedius*
Peptostreptococcus		*P. productus*
Propionobacteriacene		
Propionobacterium		*Propionobacterium*
		(Corynebacterium) acnes
		Prop. granulosum
Eubacterium	*Eubacterium (Bacteroides)*	*Eubacterium contortum*
	Aerofaciens (biforme)	*Eu. cylinderoides. Eu. lentum*
		Eu. limpsum. Eu. rectale
		Eu. tortuosum. Eu. ventriosum
Corynebacteriaceae		*Corynebacterium (pseudo-*
Corynebacterium		*diphtheriticum (hojmanni)*
		C. xerosis. C. ulcerans
Bacillacene		*Bacillus cereus. B. subtilis*
Bacillus		*Clostridium cadaveris*
		Cl. innocuum
Clostridium	*Clostridium perfringens*	*Cl. maienominatum. Cl. ramosum*
	(weichii)	*Cl. sordellii*
	Clostridium paraputrificum	*Cl. certium. Cl. bifermentans*
		Cl. sporogenes. Cl. indolis
		Cl. sphenoides. Cl. feisineum
		Cl. difficile. Cl. oroticum

Source: Corry, 1978 *(2)*.

Survival and retention of bacteria and viruses

In order to identify the environmental impacts of cemeteries, information is needed on the survival of bacteria and viruses and the fate of the decay products from human corpses in soils and groundwater.

Both survival and retention are dependent on the type of the soil in which a cemetery is sited, the type of microorganisms present, the prevailing ground temperature and rainfall. Microorganism die-off rates increase approximately two times faster with every 10 °C rise in temperature between 5 °C to 30 °C *(4)*. Consequently, the survival of the microorganisms is prolonged considerably at lower temperatures. Several organisms in the soil are known to survive better in a pH range of 6–7, and die off more quickly under more acidic soil conditions.

Where soil pH is above 7, the fraction of bacteria and viruses retained by the soil decreases markedly. Furthermore, an increase in cation concentration of the seepage water from cemeteries increases the retention capacity of the soil for bacteria and viruses *(4)*.

Adsorption is the major factor controlling virus retention. Most polioviruses are held in the soil layer. Viruses may move through some soils to the groundwater with the help of rainfall and downward seepage flow. Polioviruses may move considerable distances through sandy forest soils and gravels, although it has been shown that trees intercept a portion of the rainfall *(5)*. Survival of the poliovirus was monitored in the soil at 4 °C and 20 °C for 84 days during which time its capacity to migrate was unchanged. Many soils which have a small pore size, such as clay, have a high adsorption capacity for viruses *(6)*.

The ionic strength of seepage water influences bacterial attachment through its effect on charge density and electrostatic repulsion. The presence of organic and iron oxide coatings also increases retention of bacteria on the surfaces of sand grains *(7)*. These organic and iron oxide coatings could break down during the putrification of the human corpses.

Other soil properties such as particle size, clay content, cation exchange capacity and moisture influence retention, but the relative extent to which they do this requires further research. Climatic factors such as rainfall also influence retention. They increase the mobilization of bacteria and viruses from tissues retained on soil particles, and facilitate their transportation to groundwater. Important factors affecting the survival of viruses in soil are given in Table 2.

Table 2. Factors affecting the survival of viruses in soil

Factor	Comments
Temperature	One of the most detrimental factors
Desiccation	Increased virus reduction in drying soils
Soil pH	May indirectly affect the survival of viruses by controlling their adsorption on to soils
Cations	Certain cations have a thermal stabilizing effect on viruses; may also indirectly influence virus survival by controlling their adsorption to soils
Soil texture	Clay minerals and humid substances increase water retention by soils and thus have an impact on viruses subjected to desiccation
Biological factors	No clear trend with regard to effect of soil microflora on viruses

Sources: Environment Agency, 1998 *(1)*.

Movement of bacteria and viruses through soils

Soils play a major role in the movement of bacteria and viruses. From laboratory work, it has been found that most of the microorganisms, such as polioviruses, are filtered out on or near the soil surface. Most polioviruses are held within the first 5 cm depth below the surface of loamy sandy soil *(6)*.

Whilst soil adsorbs most of the pathogens, adsorption decreases with increasing water velocity. Polioviruses applied to effluents may move considerable distances through sandy soils after rainfall. The adsorption pattern indicates that most viruses are adsorbed near the surface but the remainder may move much greater distances *(6)*, and studies have found that virus adsorption is also affected by the strength of the negative charge on the virus particle. Lance et al *(6)* have added that viruses with a net negative charge below a certain level were immediately adsorbed, while viruses with a stronger negative charge moved farther away.

Infective viruses have been isolated directly from vegetable crops *(8)*. Therefore, plants could possibly be used to remove some viruses and bacteria from the soil. Also, the movement of bacteria and viruses is restricted physically by the root system of plants. Planting of trees and border plants should be encouraged around cemeteries to help decrease the movement off-site of bacteria and viruses in seepage water and rain water.

Groundwater composition in the vicinity of the cemeteries

During the progress of decomposition within human corpses, the products of decomposition are released. The principal mechanism for the transport of decomposition products is percolating water entering the groundwater. Many of the decomposition products are identical to those present naturally in the environment. In addition, ammonia gas and carbon dioxide are also formed as decay products from human corpses. Another important point is the presence of wood, fabrics and plastics, which come from coffins. Little is known about the composition of their products of degradation.

Studies by Schraps reported high concentrations of bacteria, ammonium and nitrate ions in a contamination plume which rapidly diminished with distance from graves in Germany. On the other hand, van Haaren measured a very saline (2300 µS/cm) plume of chloride, sulfate and bicarbonate ions beneath graves in Holland. No information was given on the soil types in these studies. Also, recent studies by Dent *(9)* at the Botany Cemetery in Australia provided an opportunity to assess groundwater conditions near recent interments. The results showed a definite increase in electrical conductivity (or salinity) close to recent graves. Elevated chloride, nitrate, nitrite, ammonium, orthophosphate, iron, sodium, potassium and magnesium ions were found beneath the cemetery. In his study, he also found that the groundwater samples down-gradient of the cemetery and at control sites had very similar compositions. The groundwater was found to be suitable for irrigation purposes as specified in Australian water quality criteria. Three cemeteries at Woronora, The Necropolis and Guildford in Australia were also examined for their pollution potential *(3)*. In addition, recent work was conducted on groundwater samples beneath the Cheltenham Cemetery (Australia). The results from these investigations showed no significant presence of pathogens, with the exception of *Pseudomonas aeruginosa*, a pathogenic bacterium, which is responsible for waterborne diseases. The key analyses investigated are given in a combined table (Table 3).

Table 3. Typical parameters of groundwaters beneath cemeteries

Analyte	Botany cemetery			Cheltenham cemetery		Worona cemetery		Necropolis cemetery		Guildford cemetery	
mg/l or FU/100ml	BG	CBG	NRIR	NBB	IB	BG	ISW	CSW	ISW	BG	BDB
Hg	0	<0.005	0.008	–	–	–	–	–	–	–	–
Ni	0	<0.005	0	–	–	–	–	–	–	–	–
Pb	0	<0.005	0	–	–	–	–	–	–	–	–
Zn	0.692	0.17	0.103	–	–	–	–	–	–	–	–
HCO3	7.2	11	0	–	–	–	–	–	–	–	–
CO3	0	0	0	–	–	–	–	–	–	–	–
Cl	49	27	58.5	52–1120	107–576	85–170	24–41	40–45	42–390	133–160	20–33
NO3-N	14	6.05	6.16	0–0.6	0–11.4	0.2–0.3	0–1.16	0–2.2	0–14.3	0.4–6.3	4.1–33.2
NO2-N	0.01	0	0.07	0–0.34	0–0.01	0–0.001	0–0.003	0–0.002	0–0.056	0.002–0.315	0–0.015
PO4	0.1	0.9	3.4	0–7	0–6.2	0	0–0.85	1.6–2.55	0.5–1.6	0–1.9	0.06–4.7
SO4	24.2	15	57	22–255	52.5–179	57–77	17–56	3.2–3.7	48–290	66–95	0–21
NH3-N	0	0.13	1.24	0.01–0.59	0–0.53	–	–	–	–	–	–
F	–	<0.5	–	–	–	–	–	–	–	–	–
TKN	–	–	–	0.16–0.81	<0.05–0.61	–	–	–	–	–	–
TOC	–	–	–	1.6–28	1.3–21.2	2.0–19	1.6–12	2.0–4.0	0–30	58–73	4.0–23
BOD	–	–	–	<2–15	<2–16	5.0–21	3.0–16	4.0–6	0–9	<5–22	<5
CO2	–	–	–	210–325	135–220	–	–	–	–	–	–
Total coliforms	–	–	–	0–2000	0–17	0–2	0–>500	0	3–>2400	0–8	0–8
Faecal coliforms	–	–	–	0–1	0	0	0–2	0	0–10	0	0
Faecal streptococci	–	–	–	0–1	0	0	0	0	0–22	0	0
Pseudomonas aeruginosa	–	–	–	0–1	0–40	0	0–4	0	0	0	0–11

BG: background groundwater away from cemetery
CBG: background groundwater within cemetery
NRIR: groundwater within cemetery, Recently Interred Remains Study Area
NBB: near boundary bores, near the boundary but within cemetery grounds
IB: internal bores within the cemetery
ISW: internal seepage wells
CSW: comparative seepage well
BDB: bores down-gradient at boundary

Sources: Table 1 *(3)*, Table 1 *(9)*, Table 1 *(11).*

Three cemeteries in Brazil, at Vila Formosa, Vila Nova Cachoeirinha and Areia Branca, were studied by another research team *(12)*. Each cemetery exhibited geological and geophysical differences. The Vila Formasa basin is composed of tertiary sediments where the alternation of soil layers of varying thickness and grain size is frequent. In Vila Nova Cachoeirina, the basin is derived from granite alteration where clay-rich layers are predominant. Areia Branca is composed of quaternary sandy, marine sediments with high porosity and permeability. At each place, the groundwaters beneath the cemeteries were examined for their bacterial contamination. No coliphages (viruses that are parasitic to bacteria of the coliform group) were detected in the groundwaters. This is probably due to the fact that viruses are more readily fixed to soil particles than the bacteria and, consequently, fewer are carried into the groundwater flowing beneath the cemeteries. However, *Streptococci*, sulfide-reducing bacteria and *Clostridia* were found in the majority of samples collected by the researchers. No faecal coliforms were found in the samples and the work showed that the presence of *streptococci* and sulfide-reducing bacteria were more indicative when evaluating the quality of groundwater.

Geological properties of the cemeteries

The cemeteries reported on in the published literature and considered in this report have different types of geology. A review of their characteristics may provide an indication of the more suitable soil types to retain and ameliorate the degradation products in seepage from cemeteries. Table 4 lists the geological properties of the soils beneath several cemeteries.

Table 4. Geological properties of the selected cemeteries

Cemetery	Geology
Botany (Sydney/Australia)	Botany Sands
Worona (Sydney/Australia)	Hawkesbury Sandstone(sand clays and minor clayey sands, often lateritised, overlain by a quartz sandstone)
The Necropolis (Melbourne/Australia)	Fyansford Formation Brighton Group (densely unconsolidated silty sands)
Guildford (Perth/Australia)	Bassendean Sand (unconsolidated shallow marine deposits of clayey and silty sands and fine sands)
Areia Branca (Santos/Brazil)	Quaternary sandy, marine sediments with high porosity and permeability
Vila Formosa (Sao Paulo/Brazil)	Tertiary sediments (assumed: porous)
Vila Nova Cachoeirinha (Sao Paulo/Brazil)	Granite alteration where clay-rich layers are predominant

An unsaturated soil layer has been found in past studies to be the most important line of defence against the transport of degradation products into aquifers. It acts as both a filter and an adsorbent. It can also reduce the concentrations of some microorganisms and decomposition compounds that occur during the putrification of human corpses. It is postulated that the most useful soil type to maximize retention of degradation products is a clay-sand mix of low porosity, and a small to fine grain texture.

The size of the bacteria, the pore size distribution of the soil and the interaction between the bacteria and the solid phase should be taken into account to select the soil. The pore size distribution of the soil is an important factor for increasing the surface area for adsorption and also for the removal of bacteria. Therefore, a soil should have strong adsorbance characteristics to remove degradation products from seepage water and so minimize the impact of cemeteries on their local groundwater. Also, the size of the pores of the soil affects the efficiency of filtration. Soil-water content is another factor for removing microorganisms. The capacity of a soil to remove organisms increases with a decrease in soil-water content *(4)*. Therefore, measurements need to be made to find the most beneficial soil-water contents when sites for new cemeteries are being considered. Research is needed to determine the optimum values.

An unsaturated zone beneath a cemetery increases the opportunity for attenuation of the seepage during putrification of human corpses. The unsaturated zone is where faecal pollutants are degraded to innocuous compounds. Therefore, a maximization of the residence time in the unsaturated zone is a key factor affecting the effective removal of bacteria and viruses *(12)*.

Cemeteries can be regarded as special kinds of landfills, in that a limited range of organic matter is covered by soil fill *(3*). Therefore, it is useful to examine the fate of leachate from waste landfills as a potential analogue to leachate from cemeteries. Two landfills were considered in studies by Lewin and co-workers in the United Kingdom *(13)*. One of the landfills has a thick (>50m) unsaturated zone (Burntstump) and the other has a thin (<20m) unsaturated zone (Gorsethorpe). Leachate was passed through the shallow unsaturated zone, which produced only limited attenuation at Gorsethorpe before entering the groundwater. However, the deep unsaturated zone at Burntstump allowed the establishment of conditions conducive to methanogenesis and achieved a progressive and significant reduction in the organic strength of the leachate front. No firm evidence of groundwater pollution by leachate was recorded at Burntstump, either immediately beneath the landfill area or in the direction of groundwater flow. This study demonstrated that the unsaturated zone is one of the most important factors to protect the environment. This study supported earlier predictions, as described, for example, in Mather *(14)*. Most of the biodegradation of organic components occurs within the unsaturated zone, and a thicker zone increases the opportunities for attenuation of leachates.

The back-fill soil around a coffin is another factor that plays a role on the impact of degradation products in seepage water. The part of the soil between coffin and the ground surface is usually less compact. It allows some air to enter. Human corpses aerobically decompose quickly when aeration is provided. However, rainfall can also more easily enter the soil by this route and provide a means for microorganisms within the corpse to escape.

Hydrogeological properties of the cemeteries

The base of all burial pits at cemeteries should be above the highest natural water table to minimize seepage directly into the aquifer during putrification of human corpses. Cemeteries could also be planted with deep-rooting trees that consume large volumes of groundwater and seepage water passing through the unsaturated zone. Also, the water level beneath cemeteries will be decreased by trees and so further help to contain seepage within the environs of a cemetery.

Most viruses are adsorbed through the depth of the soil and some, such as polioviruses, are held near the soil surface *(6)*. After rainfall, these retained viruses may escape from the soil and move into groundwater if the permeability of the soil is high enough.

Another important point is the difference in elevation between a cemetery and the surrounding area. A cemetery should not be located in the lowest part of an area where the rainwater runoff collects and the infiltrated water comes into contact with interred remains. This, ultimately, would permit more decomposition products to be carried into the groundwater.

Conclusions

In cemeteries, human corpses may cause groundwater pollution not because of any specific toxicity they possess, but by increasing the concentrations of naturally occurring organic and inorganic substances to a level sufficient to render groundwaters unusable or unpotable. Viruses are fixed to soil particles more easily than bacteria and they are not carried into groundwaters in large numbers *(2)*. Nevertheless, pathogenic organisms are largely retained at or near the soil surface *(4)*. Because of these features, the risk of pollution would seem to be greatest for users of wells, which access a shallow water-bearing stratum.

Through the action of infiltrating rainfall, adsorbed pathogenic organisms can escape from the soil particles, mix with the groundwaters beneath the cemeteries and migrate considerable distances. This process is easier in some particular soil textures, such as sand and gravel, because their pore sizes are not small enough to filter and adsorb the microorganisms efficiently. The planting around cemeteries of trees and plants with extensive root systems can also reduce microbial populations. These trees absorb water and seepage to isolate some infective microorganisms from the soil. This also helps to reduce the quantity of the seepage water that mixes with the groundwater.

The thickness of the unsaturated zone in the soil is an important factor in determining the impact of cemeteries on the environment. Most of the biodegradation occurs in this zone and it is the most important line of defence against cemetery-derived pollution polluting underlying aquifers. Therefore, the maximization of the residence time and the thickness of this layer is a desirable factor for the removal and elimination of bacteria and viruses *(12)*.

The age, size and state of decomposition at burial of human corpses, and also the materials used in coffins, are important factors that affect the characteristics of seepage water during putrification *(3)*. The impact on groundwaters from the degradation of coffins and burial clothes is not known. Standards should be set for the types of material from which coffins are made to minimize their effects on the environment. Ideally, coffins and human corpses should decay rapidly and the products of decomposition become adsorbed or oxidised quickly. Access of air and moisture can facilitate this situation.

Studies by Schraps reported high concentrations of bacteria, ammonium and nitrate ions in a contamination plume which rapidly diminished with distance from graves in Germany. On the other hand, van Haaren measured a very saline (2300µS/cm) plume of chloride, sulfate and bicarbonate ions beneath graves in Holland. The studies by Dent *(9)* for Botany Cemetery in Australia, where an opportunity was available to assess groundwater conditions near recent interments, showed a definite increase in electrical conductivity (or salinity) close to recent graves, and elevated concentrations of chloride, nitrate, nitrite, ammonium, orthophosphate, iron, sodium, potassium, and magnesium ions beneath the cemetery. The studies found that salinity and chloride concentrations rapidly diminished with distance from graves.

Conceptually, cemeteries can be regarded as special kinds of landfills. Therefore, it is useful to examine the fate of leachate from waste landfills as a potential analogue to seepage from cemeteries. Research carried out by Gray and his group has shown that “the concentration of the highly soluble chloride ions which is extremely high in leachates from domestic refuse directly below a landfill, drops drastically in water samples taken a short distance away and at 100 m to 200 m falls to almost background levels” *(15)*.

In conclusion, aquifer pollution can vary greatly according to the geological strata and cemetery layout and management. Surface drains will intercept most surface runoff water entering a site from outside before any serious contamination takes place. The pollution potential from cemeteries is present, but in a well managed cemetery with suitable soil conditions and drainage arrangements, the risk is probably slight. The draft conditions given below could be used to site and design a future well managed cemetery *(1)*:

1. Human or animal remains must not be buried within 250* metres of any well, borehole or spring from which a potable water supply is drawn.

2. The place of interment should be at least 30 metres away from any other spring or watercourse and at least 10 metres from any field drain.
3. All burial pits on the site must maintain a minimum of one metre of subsoil below the bottom of the burial pit (i.e. the base of the burial must be at least one metre above solid rock).
4. The base of all burial pits on the site must maintain a minimum of one metre clearance above the highest natural water table. (Any variability in the water table should be taken into account.)
5. Burial excavations should be backfilled as soon as the remains are interred, providing a minimum of one metre soil cover at the surface.

***** This distance may be greater if the site has a steep hydrogeological gradient or the velocity of groundwater flow within an aquifer is rapid.

Suggested topics for future research

1. What are the safe distances between aquifers and cemeteries in various geological and hydrogeological situations?
2. What is the fate of materials used in coffins and burial clothes? Propose suitable materials which minimize their potential effects on groundwaters.
3. Why and how do most of the microorganisms, produced during the putrification process, <u>not</u> appear in the groundwaters beneath cemeteries?
4. Have there been any recorded disease outbreaks or epidemics caused by microorganisms seeping from cemeteries? What is the epidemiological evidence for population groups living near cemeteries?
5. What should be the desirable minimum thickness of the unsaturated zone beneath cemeteries?
6. Collect together existing regulations on cemetery siting and design from different countries and prepare, with the latest scientific findings, a set of common practices.

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New Vision
UGANDA'S LEADING DAILY

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How graves contaminate ground water

By Vision Reporter

From which source is your drinking water? Well, if you live off urban zones, chances are high you drink from under-earth.

true
By Boaz Opio

From which source is your drinking water? Well, if you live off urban zones, chances are high you drink from under-earth, through a borehole.

It's a bit of a forbidden subject, but just what happens when you're six feet under? At depth, a solid wooden coffin will take longer to degrade than the wicker or cardboard 'green' alternatives, now becoming popular in the US.

But typically, 10 years on your body will have been reduced to a skeleton. And in the process you'll have leached chemicals including ammonia, formaldehyde (from embalming) chloride and metals. Approximately half the chemicals will leach out in the first year and if groundwater is near to the surface that can cause serious contamination.

As easily as water seeping through rocks, the embalmed body's toxic secretion escapes its host and eventually leaches into the environment, tainting surrounding soil and groundwaters.

Cemeteries bear the chemical legacy of their embalmed dead, and well after their graves have been closed. In older cemeteries, arsenic may be the longest-enduring contaminant. As highly toxic and powerful preservative, arsenic was a mainstay of early embalming solutions especially among the ancient Egyptians.

Nearly a quarter of the water samples that a one John Konefes of the Northern Iowa University drew from hand-pump wells on the grounds of some dozen of villages scattered around the States tested positive for arsenic. Two samples contained arsenic at levels above the then-proposed drinking water standards.

He says his limited, 1990 research only suggests the potential for arsenic contamination of older cemeteries, but believes it's strong enough to warrant further study. The toxic element "will not bioremediate, it will not break down," he says. "Exposed to water seeping through the grave, some of the arsenic in an embalmed body will leach out and it has to go somewhere."

His work exposes that nearby groundwater, which may supply individual families or communities with their drinking water, is a logical place for arsenic to run. With grave's co-existing with boreholes in every Ugandan rural community, and hamlet, safety measures should be taken as soon as possible.

Groundwater protection guidance: what is Uganda's NEMA waiting for?

The UK's Environment Agency has recognised the risk and its Groundwater Protection guidance, addresses the grizzly task of making sure that when our loved ones go under, that they're not causing more problems than the probate. The guidance states:

▪ Graveyards – both new and (ideally) existing must not have groundwater closer than 2.8m below ground level.

▪ Graves can't be built within areas most sensitive for groundwater. These, for the technical minded, are within a Source Protection Zone or 250m from a water supply well used for drinking water, whichever is the greatest distance. One study reveals the presence of microbiological indicators (Total coliform and fecal coli-form) in the sampled groundwaters obtained from boreholes near merely a single grave.

Recommendations

1. Understand which graveyards have shallow groundwater and/or are in source protection zones. Monitoring groundwater levels over seasons is highly recommended.

2. If groundwater is shallow, then model the risk. The EA's guidance 'Assessing the Groundwater Pollution Potential of Cemetery Developments' is a useful reference.

3. Engineering solutions to prevent contamination are a third option. This option is really a last resort, however, and likely to be expensive when compared to the taxes and incomes from burials.

Striking Possibility: An innovative greener alternative

Cremation could be a greener alternative, but this emits large amounts of mercury. So time for some innovation... resomation or Alkali hydrolysis - using a mixture of water, potassium hydroxide and steam heat to dissolve the body.

The writer is a climate tracker for #Call4climate and a student of Development Economics at Makerere University

How graves contaminate ground water

Private Water Wells

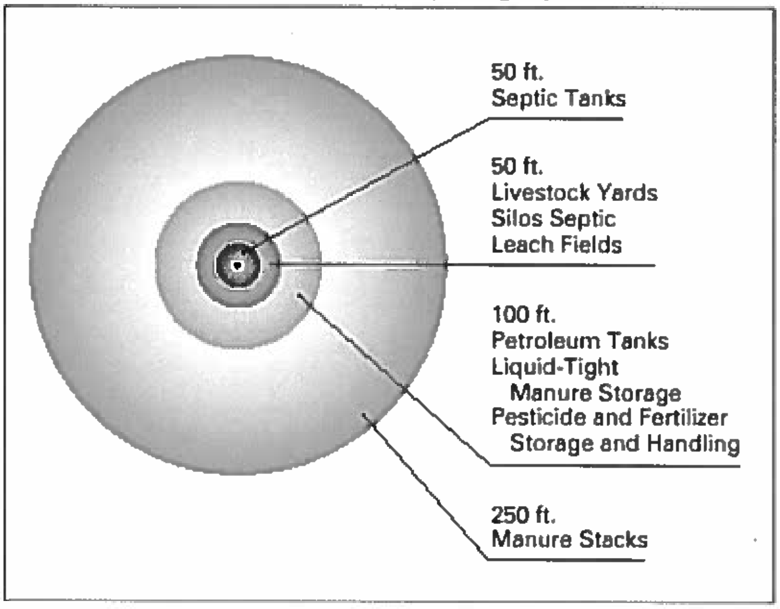
If your family gets drinking water from a private well, do you know if your water is safe to drink? What health risks could you and your family face? Where can you go for help or advice? The EPA regulates public water systems; it does not have the authority to regulate private drinking water wells. Approximately 15% of Americans rely on their own private drinking water supplies, and these supplies are not subject to EPA standards, although some state and local governments do set rules to protect users of these wells. Unlike public drinking water systems serving many people, they do not have experts regularly checking the water's source and its quality before it is sent to the tap. These households must take special precautions to ensure the protection and maintenance of their drinking water supplies.

Basic Information

There are three types of private drinking water wells: dug, driven, and drilled. Proper well construction and continued maintenance are keys to the safety of your water supply. Your state water-well contractor licensing agency, local health department, or local water system professional can provide information on well construction. The well should be located so rainwater flows away from it. Rainwater can pick up harmful bacteria and chemicals on the land's surface. If this water pools near your well, it can seep into it, potentially causing health problems. Water-well drillers and pump-well installers are listed in your local phone directory. The contractor should be bonded and insured.

Make certain your ground water contractor is registered or licensed in your state, if required. If your state does not have a licensing/registration program, contact the National Ground Water Association.

To keep your well safe, you must be sure that possible sources of contamination are not close by. Experts suggest the following distances as a minimum for protection — farther is better (see graphic on the right):



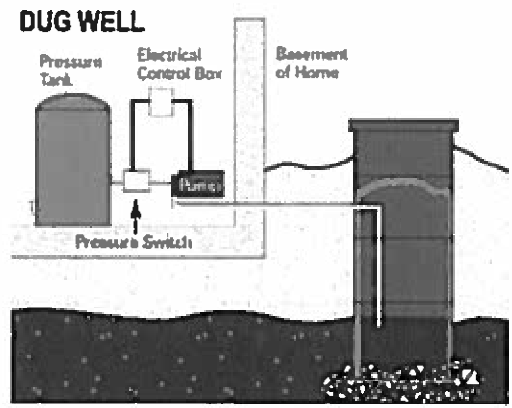
- septic tanks: 50 feet;
- livestock yards, silos, septic leach fields: 50 feet;
- petroleum tanks, liquid-tight manure storage and fertilizer storage and handling: 100 feet; and
- manure stacks: 250 feet.

Many homeowners tend to forget the value of good maintenance until problems reach crisis-levels. That can be expensive. It's better to maintain your well, find problems early, and correct them to protect your well's performance. Keep up-to-date records of well installation and repairs, plus pumping and water tests. Such records can help spot changes and possible problems with your water system. If you have problems, ask a local expert to check your well construction and maintenance records. He or she can see if your system is okay or needs work.

Protect your own well area. Be careful about storage and disposal of household and lawn-care chemicals and wastes. Good farmers and gardeners minimize the use of fertilizers and pesticides. Take steps to reduce erosion and prevent surface water runoff. Regularly check underground storage tanks that hold home heating oil, diesel, or gasoline. Make sure your well is protected from the wastes of livestock, pets and wildlife.

Dug Wells

Dug wells are holes in the ground dug by shovel or backhoe. Historically, a dug well was excavated below the ground water table until incoming water exceeded the digger's bailing rate. The well was then lined (cased) with stones, brick, tile, or other material to prevent collapse. It was covered with a cap of wood, stone or concrete. Since it is so difficult to dig beneath the ground water table, dug wells are not very deep. Typically, they are only 10 to 30 feet deep. Being so shallow, dug wells have the highest risk of becoming contaminated.To minimize the likelihood of contamination, your dug well should have certain features. These features help to prevent contaminants from traveling along the outside of the casing, or through the casing and into the well.



Dug Well Construction Features

- The well should be cased with a watertight material (for example, tongue-and-groove pre-cast concrete), and a cement grout or bentonite clay sealant poured along the outside of the casing to the top of the well.
- The well should be covered by a concrete curb and cap that stands about a foot above the ground.
- The land surface around the well should be mounded so that surface water runs away from the well and is not allowed to pond around the outside of the wellhead.
- Ideally, the pump for your well should be inside your home or in a separate pump house, rather than in a pit next to the well.

Land activities around a dug well can also contaminate it. While dug wells have been used as a household water supply source for many years, most are relics of older homes, dug before drilling equipment was readily available, or when drilling was considered too expensive. If you have a dug well on your property and are using it for drinking water, check to make sure it is properly covered and sealed. Another problem relating to the shallowness of a dug well is that it may go dry during a drought when the ground water table drops.

Driven Wells

Like dug wells, driven wells pull water from the water-saturated zone above the bedrock. Driven wells can be deeper than dug wells. They are typically 30 to 50 feet deep and are usually located in areas with thick sand and gravel deposits where the ground water table is within 15 feet of the ground's surface. In the proper geologic setting, driven wells can be easy and relatively inexpensive to install. Although deeper than dug wells, driven wells are still relatively shallow and have a moderate-to-high risk of contamination from nearby land activities.

Driven Well Construction Features

- Assembled lengths of 2- to 3-inch diameter metal pipes are driven into the ground. A screened "well point" located at the end of the pipe helps drive the pipe through the sand and gravel. The screen allows water to enter the well and filters out sediment.
- The pump for the well is in one of two places: on top of the well, or in the house. An access pit is usually dug around the well down to the frost line, and a water discharge pipe to the house is joined to the well pipe with a fitting.
- The well and pit are capped with the same kind of large-diameter concrete tile used for a dug well. The access pit may be cased with pre-cast concrete.

To minimize this risk, the well cover should be a tight-fitting concrete curb and cap with no cracks, and should sit about a foot above the ground. Slope the ground away from the well so that surface water will not pond around the well. If there's a pit above the well, either to hold the pump or to access the fitting, you may also be able to pour a grout sealant along the outside of the well pipe. Protecting the water quality requires that you maintain proper well construction and monitor your activities around the well. It is also important to follow the same land-use precautions around the driven well as described under dug wells.

Drilled Wells

Graphic of a Drilled Well

Drilled wells penetrate about 100 to 400 feet into the bedrock. Where you find bedrock at the surface, it is commonly called ledge. To serve as a water supply, a drilled well must intersect bedrock fractures containing ground water.

Drilled Well Construction Features

- The casing is usually metal or plastic pipe, 6 inches in diameter, that extends into the bedrock to prevent shallow ground water from entering the well. By law, the casing has to extend at least 18 feet into the ground, with at least 5 feet extending into the bedrock. The casing should also extend a foot or two above the ground's surface. A sealant, such as cement grout or bentonite clay, should be poured along the outside of the casing to the top of the well. The well should be capped to prevent surface water from entering the well.
- Submersible pumps, located near the bottom of the well, are most commonly used in drilled wells. Wells with a shallow water table may feature a jet pump located inside the home. Pumps require special wiring and electrical service. Well pumps should be installed and serviced by a qualified professional registered with your state.
- Most modern drilled wells incorporate a pitless adapter designed to provide a sanitary seal at the point where the discharge water line leaves the well to enter your home. The device attaches directly to the casing below the frost line, and provides a watertight sub-surface connection, protecting the well from frost and contamination.
- Older drilled wells may lack some of these sanitary features. The well pipe used was often 8, 10 or 12 inches in diameter, and covered with a concrete well cap either at or below the ground's surface. This outmoded type of construction does not provide the same degree of protection from surface contamination. Also, older wells may not have a pitless adapter to provide a seal at the point of discharge from the well.

Hydrofracting a Drilled Well

Hydrofracting is a process that applies water or air under pressure into your well to open up existing fractures near your well, and can even create new ones. Often, this can increase the yield of your well. This process can be applied to new wells with insufficient yield and to improve the quantity of older wells.

How can I test the quality of my private drinking water supply?

Consider testing your well for pesticides, organic chemicals, and heavy metals before you use it for the first time. Test private water supplies annually for nitrate and coliform bacteria to detect contamination problems early. Test them more frequently if you suspect a problem. Be aware of activities in your watershed that may affect the water quality of your well, especially if you live in an unsewered area.

Human Health

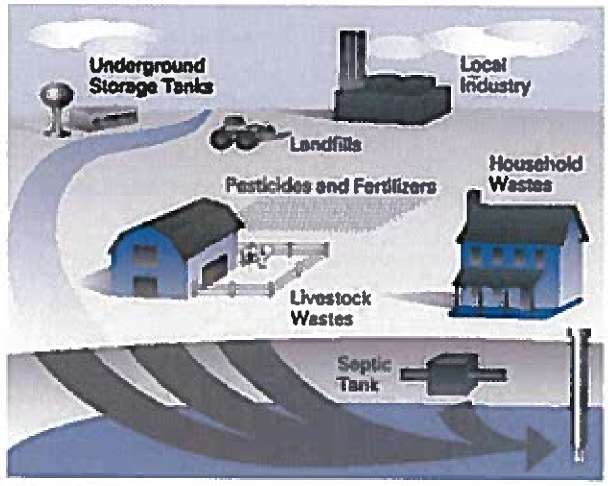
The first step to protect your health and the health of your family is learning about what may pollute your source of drinking water. Potential contamination may occur naturally, or as a result of human activity.

What are some naturally occurring sources of pollution?

- **micro-organisms**: Bacteria, viruses, parasites and other microorganisms are sometimes found in water. Shallow wells — those with water close to ground level — are at most risk. Runoff, or water flowing over the land surface, may pick up these pollutants from wildlife and soils. This is often the case after flooding. Some of these organisms can cause a variety of illnesses. Symptoms include nausea and diarrhea. These can occur shortly after drinking contaminated water. The effects could be short-term yet severe (similar to food poisoning), or might recur frequently or develop slowly over a long time.
- **radionuclides**: Radionuclides are radioactive elements, such as uranium and radium. They may be present in underlying rock and ground water.
- **radon**: Radon is a gas that is a natural product of the breakdown of uranium in the soil and can also pose a threat. Radon is most dangerous when inhaled, and contributes to lung cancer. Although soil is the primary source, using household water containing radon contributes to elevated indoor radon levels. Radon is less dangerous when consumed in water, but remains a risk to health.
- **nitrates and nitrites**: Although high nitrate levels are usually due to human activities (see below), they may be found naturally in ground water. They come from the breakdown of nitrogen compounds in the soil. Flowing ground water picks them up from the soil. Drinking large amounts of nitrates and nitrites is particularly threatening to infants (for example, when mixed in formula).
- **heavy metals**: Underground rocks and soils may contain arsenic, cadmium, chromium, lead, and selenium. However, these contaminants are not often found in household wells at dangerous levels from natural sources.
- **fluoride**: Fluoride is helpful in dental health, so many water systems add small amounts to drinking water. However, excessive consumption of naturally occurring fluoride can

damage bone tissue. High levels of fluoride occur naturally in some areas. It may discolor teeth, but this is not a health risk.

What human activities can pollute ground water?



Septic tanks are designed to have a leach field around them, which is an area where wastewater flows out of the tank. This wastewater can also move into the ground water.

- **bacteria and nitrates**: These pollutants are found in human and animal wastes. Septic tanks can cause bacterial and nitrate pollution. So can large numbers of farm animals. Both septic systems and animal manure must be carefully managed to prevent pollution. Sanitary landfills and garbage dumps are also sources. Children and some adults are at higher risk when exposed to waterborne bacteria. These include the elderly and people whose immune systems are weak due to AIDS or treatments for cancer. Fertilizers can add to nitrate problems. Nitrates cause a health threat in very young infants called "blue baby syndrome." This condition disrupts oxygen flow in the blood.

- **concentrated animal feeding operations (CAFOs)**: The number of CAFOs, often called "factory farms," is growing. On these farms, thousands of animals are raised in a small space. The large amounts of animal waste/manure from these farms can threaten water supplies. Strict and careful manure management is needed to prevent pathogen and nutrient problems. Salts from high levels of manure can also pollute ground water.

- **heavy metals**: Activities such as mining and construction can release large amounts of heavy metals into nearby ground water sources. Some older fruit orchards may contain high levels of arsenic, once used as a pesticide. At high levels, these metals pose a health risk.

- **fertilizers and pesticides**: Farmers use fertilizers and pesticides to promote growth and reduce insect damage. These products are also used on golf courses and suburban lawns and gardens. The chemicals in these products may end up in ground water. Such pollution depends on the types and amounts of chemicals used and how they are applied. Local environmental conditions (soil types, seasonal snow and rainfall) also affect this pollution. Many fertilizers contain forms of nitrogen that can break down into harmful nitrates. This could add to other sources of nitrates mentioned above. Some underground agricultural drainage systems collect fertilizers and pesticides. This polluted water can pose problems to ground water and local streams and rivers. In addition, chemicals used to treat buildings and homes for termites and other pests may also pose a threat. Again, the possibility of problems depends on the amount and kind of chemicals. The types of soil and the amount of water moving through the soil also play a role.

- **industrial products and waste**: Many harmful chemicals are used widely in local business and industry. These can pollute drinking water if not well-managed. The most common sources of such problems are:
    - **local businesses**: These include nearby factories, industrial plants, and even small businesses such as gas stations and dry cleaners. All handle a variety of hazardous chemicals that need careful management. Spills and improper disposal of these chemicals and other industrial wastes can threaten ground water supplies.
    - **leaking underground tanks and piping**: Petroleum products, chemicals and waste stored in underground storage tanks and pipes may end up in the ground water. Tanks and piping leak if they are constructed or installed improperly. Steel tanks and piping corrode with age. Tanks are often found on farms. The possibility of leaking tanks is great on old, abandoned farm sites. Farm tanks are

exempt from the EPA rules for petroleum and chemical tanks.

- **landfills and waste dumps**: Modern landfills are designed to contain any leaking liquids. But floods can carry them over the barriers. Older dumpsites may have a wide variety of pollutants that can seep into ground water.

- **household waste**: Improper disposal of many common products can pollute ground water. These include cleaning solvents, used motor oil, paints, and paint thinners. Even soaps and detergents can harm drinking water. These are often a problem from faulty septic tanks and septic leaching fields.

- **lead and copper**: Household plumbing materials are the most common source of lead and copper found in home drinking water. Corrosive water may cause metals in pipes or soldered joints to leach into your tap water. Your water's acidity or alkalinity (often measured as pH) greatly affects corrosion. Temperature and mineral content also affect how corrosive it is. They are often used in pipes, solder and plumbing fixtures. Lead can cause serious damage to the brain, kidneys, nervous system, and red blood cells. The age of plumbing materials — in particular, copper pipes soldered with lead — is also important. Even in relatively low amounts, these metals can be harmful. The EPA rules under the Safe Drinking Water Act limit lead in drinking water to 15 parts per billion. Since 1988, the Act allows only lead-free pipe, solder and flux in drinking water systems. The law covers both new installations and repairs of plumbing.

What You Can Do...

Private, individual wells are the responsibility of the homeowner. To help protect your well, here are some steps you can take:

Have your water tested periodically. It is recommended that water be tested every year for total coliform bacteria, nitrates, total dissolved solids, and pH levels. If you suspect other contaminants, test for those. Always use a state-certified laboratory that conducts drinking water tests. Since these can be expensive, spend some time identifying potential problems. Consult your InterNACHI inspector for information about how to go about water testing.

Testing more than once a year may be warranted in special situations if:

- someone in your household is pregnant or nursing;
- there are unexplained illnesses in the family;
- your neighbors find a dangerous contaminant in their water;
- you note a change in your water's taste, odor, color or clarity;
- there is a spill of chemicals or fuels into or near your well; or
- you replace or repair any part of your well system.

Identify potential problems as the first step to safe-guarding your drinking water. The best way to start is to consult a local expert -- someone who knows your area, such as the local health department, agricultural extension agent, a nearby public water system, or a geologist at a local university.

Be aware of your surroundings. As you drive around your community, take note of new construction. Check the local newspaper for articles about new construction in your area.

Check the paper or call your local planning and zoning commission for announcements about hearings or zoning appeals on development or industrial projects that could possibly affect your water.

Attend these hearings, ask questions about how your water source is being protected, and don't be satisfied with general answers. Ask questions, such as: "If you build this landfill, what will you do to ensure that my water will be protected?" See how quickly they answer and provide specifics about what plans have been made to specifically address that issue.

Identify Potential Problem Sources

To start your search for potential problems, begin close to home. Do a survey around your well to discover:

- Is there livestock nearby?
- Are pesticides being used on nearby agricultural crops or nurseries?
- Do you use lawn fertilizers near the well?
- Is your well downstream from your own or a neighbor's septic system?
- Is your well located near a road that is frequently salted or sprayed with de-icers during winter months?
- Do you or your neighbors dispose of household waste or used motor oil in the backyard, even in small amounts?

If any of these items apply, it may be best to have your water tested and talk to your local public health department or agricultural extension agent to find ways to change some of the practices which can affect your private well.

In addition to the immediate area around your well, you should be aware of other possible sources of contamination that may already be part of your community or may be moving into your area. Attend any local planning or appeals hearings to find out more about the construction of facilities that may pollute your drinking water. Ask to see the environmental impact statement on the project. See if the issue of underground drinking water sources has been addressed. If not, ask why.

Common Sources of Ground Water Contamination

Category	Contaminant Source

Agricultural	• animal burial areas • drainage fields/wells • animal feedlots • irrigation sites • fertilizer storage/use • manure spreading areas/pits, lagoons • pesticide storage/use
Commercial	• airports • jewelry/metal plating • auto repair shops • laundromats • boat yards • medical institutions • car washes • paint shops • construction areas • photography establishments • cemeteries • process waste-water drainage • dry cleaners fields/wells • gas stations • railroad tracks and yards • golf courses • research laboratories • scrap and junkyards • storage tanks

Industrial	• asphalt plants • petroleum production/storage • chemical manufacture/storage • pipelines • electronic manufacture • process waste-water drainage • electroplaters fields/wells • foundries/metal fabricators • septage lagoons and sludge • machine/metalworking shops • storage tanks • mining and mine drainage • toxic and hazardous spills • wood-preserving facilities
Residential	• fuel oil • septic systems, cesspools • furniture stripping/refinishing • sewer lines • household hazardous products • swimming pools (chemicals) • household lawns
Other	• hazardous waste landfills • recycling/reduction facilities • municipal incinerators • road de-icing operations • municipal landfills • road maintenance depots • municipal sewer lines • Storm water drains/basins/wells • open burning sites • transfer stations

(http://inspectorseek.com/)

Outhouse Inspection (https://www.nachi.org/outhouse-inspection.htm)
Hand-Dug Well Inspection (https://www.nachi.org/hand-dug-well-inspection.htm)
International Association of Certified Indoor Air Consultants (http://www.iac2.org/)
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Impact of cemeteries on groundwater contamination by bacteria and viruses – a review

Józef Żychowski and Tomasz Bryndal

ABSTRACT

In the process of decomposition of a human body, 0.4–0.6 litres of leachate is produced per 1 kg of body weight. The leachate contains pathogenic bacteria and viruses that may contaminate the groundwater and cause disease when it is used for drinking. So far, this topic has been investigated in several regions of the world (mainly Brazil, Australia, the Republic of South Africa, Portugal, the United Kingdom and Poland). However, recently more and more attention has been focused on this issue. This study reviews the results of investigations related to the impact of cemeteries on groundwater bacteriology and virology. This topic was mainly discussed in the context of the quantities and qualities of changes in types of microorganisms causing groundwater contamination. In some cases, these changes were related to the environmental setting of a place, where a cemetery was located. The review is completed by a list of recommendations. Their implementation aims to protect the local environment, employees of funeral homes and the residents living in the vicinity of cemeteries. In this form, this review aims to familiarize the reader with the results of this topic, and provide practical guidance for decision-makers in the context of expansion and management of cemeteries, as well as the location of new ones.

Key words | aquifer contamination, cemeteries, groundwater, interments, quality indicator microorganisms

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INTRODUCTION

Cemeteries are among the chief anthropogenic sources of pollution and contamination of water in urban areas and beyond them (Silva *et al.* 2011). Many researchers are convinced that all cemeteries represent potential threats to the environment (Rodrigues & Pacheco 2003; Dent 2004). In the process of decomposition of a human body, 0.4–0.6 litres of leachate with a density of 1.23 g·cm^{-3} is produced per 1 kg of body weight (Silva 1995). The leachate contains 60% water and 30% salts in the form of ions containing nitrogen, phosphorus, Cl, HCO_3^-, Ca^{2+}, Na^+, compounds of various metals (e.g., Ti, Cr, Cd, Pb, Fe, Mn, Ni), and 10% of organic substances (Beak Consultants Ltd 1992; Silva 1998; Matos 2001; Żychowski 2008). This liquid is characterized by high conductivity, pH and biochemical oxygen demand (BOD) values, and by its specific fishy odour (Matos 2001). The contaminants come from the body and can include chemical substances applied in chemotherapy and embalming processes (e.g., arsenic, formaldehyde and methanol), makeup (e.g., cosmetics, pigments and chemical compounds), as well as various additional items, such as fillings, cardiac pacemakers, paints, varnishes, metal hardware elements, iron nails, etc. (Silva & Filho 2011; Fiedler *et al.* 2012). These leachates also contain microorganisms that may pollute substrates, surface water and groundwater. The microorganisms chiefly include bacteria, viruses, intestinal fungi and protozoa. They can also originate from other sources, e.g., animals, soil, water and the atmosphere (Trick *et al.* 2001).

The corpses of healthy humans and animals release bacteria, for example, those which form the group classified as total coliform bacteria: *Escherichia coli*, *Enterobacter*, *Klebsiella*, *Citrobacter*, *Streptococcus faecalis*, *Clostridium perfringens*, *Clostridium welchii* and *Salmonella typhi*, and

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human-hosted viruses, e.g., enterovirus (Matos 2001; Dent *et al.* 2004; Castro 2008). In most cases, the contamination of the environment comes from pathogenic intestinal bacteria such as *E. coli* (Singleton 1999; Gleeson & Gray 2002), *Pseudomonas aeruginosa* (Knight & Dent 1998; Dent 1998, 2004), *C. perfringens* (Martins *et al.* 1991), and – in Brazil – even *Salmonella* spp. (Pacheco *et al.* 1991; Braz *et al.* 2000).

Most of these microorganisms accelerate the decomposition of organic matter and they are not pathogenic (De Ville de Goyet 1980). Many pathogens gradually die after the death of the host body as they are not capable of surviving for a long time outside of the host body, especially when environmental conditions are inappropriate (Gerba & Bitton 1984). These include, for example, *Yersinia pestis*, *Vibrio cholerae*, *S. typhi*, *Mycobacterium tuberculosis*, *Bacillus anthracis*, variola virus, hepatitis virus and HIV (human immunodeficiency virus) (Yates & Gerba 1983; Yates *et al.* 1985; Gerba *et al.* 1991; Healing *et al.* 1995; Üçisik & Rushbrook 1988; Cook 1999; Trick *et al.* 1999; De Ville de Goyet 2000; Matos 2001; Morgan 2004; Dent 2004). Therefore, some researchers (Bitton *et al.* 1983; Trick *et al.* 1999) have suggested that the groundwater contamination by bacteria and viruses in cemeteries results from contemporary pollutions. However, some microorganisms are long-living and, in appropriate environmental conditions, can survive in soil profile or in groundwater for some time, e.g., *B. anthracis*, variola virus and *Clostridium* spp. (Yates *et al.* 1985; Haagsma 1991; West *et al.* 1998). The survival period varies (Rudolfs *et al.* 1950; Romero 1970; Creely 2004). Lower temperature, higher soil moisture content associated with lower microbial activity, more alkaline environment, and higher organic matter content are the factors that extend the survival period of these microorganisms (Pacheco 2000), especially in the form of endospores. Creely (2004) states that the survival period of pathogens and saprophytes in the ground is limited to a maximum two to three years. In the case of *V. cholerae* this period is shorter and lasts approximately 4 weeks. However, some microorganisms can survive even up to 5 years and, in this time, they can migrate and reach the groundwater, e.g., *E. coli* (Rudolfs *et al.* 1950; Romero 1970). Usually, the migration time takes from 1 to 4 weeks (Pacheco 1986). Dent (2004) reported that in Australia this process may take up to 100 days. Some investigations suggest that this period may be extended to 6 to 8 months (Silva 1994).

Decomposition of interred bodies causes an increase in microbial activity in the surrounding substrate, associated with the release of persistent organic compounds (Matos 2001). Some of these organic compounds are highly toxic, e.g., putrescine (1,4-butanediamine) and cadaverine (1,5-pentanediamine) (Żychowski 2007; Castro 2008). These compounds can cause highly dangerous infectious disease such as liver inflammation (hepatitis C virus) and typhoid fever (*S. typhi*) (Dent 2000a, 2004; Bocchese *et al.* 2007; Leite 2009). Microorganisms associated with decomposition of interred bodies can also cause other diseases such as tetanus (*Clostridium tetani*), gaseous gangrene (*C. perfringens*), toxic contamination of food (*E. coli*), tuberculosis (*Mycobacterium tuberculosis*), paratyphoid fever (*Salmonella paratyphi*), bacterial dysentery (*Shigella dysenteriae*) and cholera (*V. cholerae*) (Silva, J. A. F. 2000; Silva, L. M. 2000; Josias & Harris 2004). It is worth emphasizing that bacteria transported by water, like those of the genus *Shigella*, as well as rotaviruses and protozoans of the genera *Entamoeba* and *Giardia*, often cause asymptomatic or serious infections with high mortality rates, particularly among children (Matos 2001).

A brief introduction indicated that cemeteries may have large adverse impacts on groundwater and can be a source of dangerous infectious diseases. So far, this topic has been investigated in several regions of the world (mainly Brazil, Australia, the Republic of South Africa (RSA), Portugal, the United Kingdom and Poland). Most of the studies are presented in Portuguese and for this reason have not yet reached worldwide attention. However, recently the international hydrological community has focused more and more attention on this issue. This study reviews the results of investigations related to the impact of cemeteries on groundwater contamination by bacteria and viruses. This issue was mainly discussed in the context of the quantities and qualities of changes in types of microorganisms causing the groundwater contamination. In some cases, these changes were related to the environmental setting of a place, where a cemetery was located. The review is completed by a list of recommendations. Their implementation aims to protect the local environment, employees of funeral homes and the residents living in the vicinity of cemeteries.

In this form, this review aims to familiarize the reader with the results of this topic, and provide practical guidance for decision-makers in the context of the location of new cemeteries, and the expansion and management of existing cemeteries.

CEMETERIES AND GROUNDWATER CONTAMINATION BY BACTERIA AND VIRUSES – REGIONAL OVERVIEW

Studies in Europe

The adverse impact of cemeteries on groundwater caught the attention of scientists at the end of the nineteenth century. In 1879, the French Society for Hospital Hygiene noticed the relationship between typhoid fever and groundwater contaminated by leachates from a cemetery in Paris (Migliorini 2002). This kind of adverse impact was also confirmed by Mulder in the summer of 1954 (Bouwer 1978). He found somewhat sweet-tasting water and an unpleasant smell exuding from wells situated close to cemeteries in Paris. A more serious consequence was the increased number of typhoid fever cases observed between 1963 and 1967 among people living around a cemetery in Berlin and using the groundwater from its vicinity (Bouwer 1978). In other studies carried out in West Germany in 1972, the groundwater of the alluvial substrate situated 0.5 m from burial sites showed quantities of bacteria 60 times higher than those found in natural water (Bouwer 1978). The quantities of these bacteria decreased rapidly to 8×10^3 CFU·100 ml^{-1} (CFU, colony forming unit) at a distance of 3 metres from the interments, and to 1.8×10^2 CFU·100 ml^{-1} at a distance of 5.5 m from the burial plots.

Contemporary research conducted in England within a nineteenth century cemetery in Nottingham, confirmed the occurrence of bacteria around burial plots (Trick *et al.* 1999). However, the general indicator of the total bacteria numbers at 1.38×10^5 CFU·100 ml^{-1} in the groundwater did not indicate a hazard associated with the cemetery. Similar conclusions were voiced by Trick *et al.* (2001) with respect to the current Danescourt Cemetery in Wolverhampton (Table 1). In the groundwater of this cemetery they did find evidence of intestinal bacteria such as faecal streptococci (*S. faecalis*), *Bacillus cereus, C. perfringens*, *Staphylococcus aureus* and the thermotolerant coliforms. Neither the *Salmonella* spp., nor the enteroviruses and rotaviruses were found. Relatively high levels of *S. aureus* and faecal streptococci (*S. faecalis*) were recorded during long-lasting precipitation periods (Trick *et al.* 2001). *S. faecalis* and thermotolerant coliforms probably originated from the ground surface. *Bacillus cereus* showed a great seasonal variation although it did not appear in all piezometers. In turn, *C. perfringens* was found along the groundwater run-off line from the cemetery (Trick *et al.* 2001). This bacterium is very resistant to adverse environmental conditions and, at favourable temperatures (15 to 45 °C), can proliferate under relatively high redox potential (Corry 1978).

In Portugal, extensive studies were conducted in three cemeteries: Querenc, Luz de Tavira and Seixas. In these places, Rodrigues & Pacheco (2003) found high numbers of, for example, *S. faecalis*, *C. perfringens,* faecal coliforms, heterotrophic and proteolytic bacteria. The samples were obtained from six boreholes and a well situated within a 800-m radius around the Querenc cemetery. The boreholes and the well were situated in karst structures. All samples contained bacteriological pollution (Table 2). However, the authors cited have not excluded a possible impact of septic tanks which were in use in the vicinity of this cemetery. This factor was also highlighted in Brazil (Carvalho & Silva 1997; Braz *et al.* 2000; Matos 2001).

High bacterial counts were also found in porous aquifers at the Luz de Tavira cemetery. The largest differences

Table 1 | Numbers of selected bacteria in groundwater, within cemeteries in a temperate climate zone

Cemeteries	Thermotolerant coliforms[a]	Faecal streptococci[a]	*S. aureus*[a]	*B. cereus*[a]	*C. perfringens*[a]
Danescourt Cemetery in Wolverhampton[b]	1.3×10^3	44	70	9	30
Nine cemeteries and mass graves in Poland[c]	2	3	3	2	2

[a]Max. in CFU·100 ml^{-1}, CFU, colony forming unit.
[b]Trick *et al.* (2001).
[c]Żychowski (2009).

Table 2 | The microbiological contamination of groundwater in three selected cemeteries in Portugal (shortened table, Rodrigues & Pacheco 2003)

		The bacteriological parameters (minimum and maximum)[a] for the borehole samples P (4, 7, 8, 6, 9, 11)				
Boreholes in		**GHM T22**[a]	**TC**[b]	**FC**[c]	**FE**[d]	**CSR**[e]
Querenc	P4	$20–29.6 \times 10^3$	$130–6.9 \times 10^3$	$0–4.4 \times 10^3$	0–6	7–460
	P7	3–133	0–23	0–20	0–4	4–93
	P8	$2–5.0 \times 10^3$	$46–1.9 \times 10^3$	0–395	1–128	$23–4.6 \times 10^3$
Luz de Tavira	P6	27–365	$3–1.9 \times 10^3$	1–121	0–11	$23–1.1 \times 10^3$
	P9	1–293	0–595	0–60	0–7	0–48
Seixas	P11	5–3	4–9	4	0	4

[a]GHM T22, heterotrophic and mesophile bacteria (CFU·100 ml^{-1}) developing at temperatures above 22 °C.
[b]TC, total coliforms (CFU·100 ml^{-1}).
[c]FC, faecal coliforms (CFU·100 ml^{-1}).
[d]FE, faecal streptococci (*S. faecalis*) (CFU·100 ml^{-1}).
[e]CRS, *Clostridium* (MPN·100 ml^{-1}), MPN, most probable number.

between the samples taken from the cemetery and those from the reference site – a distance of c. 300 m – were related to heterotrophic and mesophilic bacteria, total coliforms and the bacteria of the genus *Clostridium* (Table 2).

The highest numbers of all the bacteria studied were found in the Seixas cemetery in Minho. The cemetery is located in a place where sea tides increase the thickness of the filtration layer. The samples from a borehole located in the central part of the cemetery contained decidedly higher quantities of bacteria than those from a borehole situated 290 m away from it.

Rodrigues & Pacheco (2003), on the basis of these studies, suggested that the climate of Portugal, where high precipitation and high air moisture occur in winter, is also a factor boosting bacteriological contamination of groundwater.

Studies in Poland concerned the impact of nine cemeteries and mass graves on the presence of *B. cereus, S. aureus, Staphylococcus* spp., *C. perfringens,* faecal streptococci (*S. faecalis*) and the thermotolerant coliforms in the groundwater (Żychowski 2009). The studies confirmed the differences between the numbers of bacteria in wells situated within the cemeteries or below their sites and their bacteriological background. However, these differences were not large (Table 1). The largest differences occurred in *S. aureus* and faecal streptococci (*S. faecalis*), which were detected in three out of nine burials. Higher numbers of *S. aureus* and thermotolerant coliforms are fostered by sandy substrates, shallow groundwater table levels, contemporary interments and landslides destroying the slopes.

Studies conducted by the World Health Organization (Üçisik & Rushbrook 1988) concerning groundwater under cemeteries revealed the presence of *B. cereus,* faecal streptococci (*S. faecalis*), Micrococcaceae and Entrobacteriaceae. Researchers from Europe (and some from the USA) drew particular attention to the occurrence at such sites of, for example, faecal streptococci (*S. faecalis*), *P. aeruginosa* and *Clostridium* spp. (Rodriguez & Bass 1985; Iserson 1995; Environment Agency UK 2002). It is worth mentioning that the researchers from the USA have not found faecal coliforms at cemeteries within their own country.

Studies in South America

Studies focusing on groundwater quality in cemeteries were mainly developed in Brazil. Bergamo (1954) was the first to draw attention to the impact of cemeteries on the groundwater and surface water contamination in cemeteries and beyond them. During the Fourth Inter-American Congress of Sanitary Engineering in São Paulo, he emphasized the need for geological research and delineation of zones at risk of contamination around cemeteries. Since the early 1980s, these studies have been developed by Professor A. Pacheco at the Centre of Underground Water Research at the University of São Paulo, supported by the Institute of Biomedical Sciences at the same university (Costa *et al.* 2002). His first study covered 22 cemeteries in São Paulo (Pacheco 1986). In this study, he focused on the impact of public cemeteries on the environment and suggested that geological, geotechnical and hydrogeological studies should precede decisions concerning localization of new cemeteries. He also emphasized the need to protect surface and underground water near cemeteries, so that the water could still be used for drinking (Miotto 1990).

Most of the Brazilian studies confirmed the adverse impact of cemeteries on bacteriological contamination of the groundwater. The main results of these studies are briefly presented below.

The Vila Nova Cachoeirinha, Vila Formosa and Areia Branca cemeteries

The studies conducted by Pacheco's team in three Brazilian cemeteries, Vila Formosa and Vila Nova Cachoeirinha in São Paulo and Areia Branca in Santos, confirmed the presence of bacteria in all samples (Pacheco *et al.* 1991). However, the quantities of the bacteria found were not high in any of them.

Samples collected in Vila Nova Cachoeirinha contained mainly proteolytic, heterotrophic, lipolytic bacteria and faecal coliforms (Table 3). When the numbers of these bacteria were high, the samples exuded an insipid smell. It should be mentioned that many of these pathogenic bacteria, e.g., *Pseudomonas* and *Bacillus*, are good indicators of contaminants originating from graves, because they decompose proteins and lipids (Higgins & Burns 1975; Martins *et al.* 1991; Matos 2001).

These authors also found other indicators of contamination, e.g., total coliforms, thermotolerant coliforms, *S. faecalis* and sulphite reducer clostridia. In one case, they even confirmed the presence of *Salmonella*. The thermotolerant coliforms and total coliforms also showed higher numbers in all samples collected from four out of five wells within the Santa Inês Cemetery in Espírito Santo state (Neira *et al.* 2008).

The subsequent studies (Matos & Pacheco 2000, 2002) at the same cemetery (Vila Nova Cachoeirinha) also revealed that samples of groundwater mainly contained heterotrophic and proteolytic bacteria, *C. perfringens*, as well as enteroviruses and adenoviruses (Table 4). These studies demonstrated, however, the low levels of total and faecal coliforms in the groundwater (Matos & Pacheco 2000).

In his voluminous PhD dissertation, Matos (2001) confirmed the high maximum numbers of many bacteria (Table 3). It is worth mentioning that heterotrophic bacteria (being aerobic bacteria) are good indicators for detecting contaminants originating from graves. They are not pathogenic but may pose a hazard to health when high quantities occur.

The groundwater of these three cemeteries (Vila Formosa, Vila Nova Cachoeirinha, Areia Branca) was also investigated by Martins *et al.* (1991). Pacheco's investigations

Table 3 | The numbers of selected bacteria in the groundwater within cemeteries in Brazil, RSA and Portugal

Cemeteries	Heterotrophic bacteria[a]	Proteolytic bacteria[b]	*Clostridium perfringens*[b]	Total coliforms[b]	Faecal coliforms[b]
Vila Nova Cachoeirinha, Brazil[c]	53×10^3	9×10^3	27	1.6×10^3	7
Vila Nova Cachoeirinha, Brazil[d]	40×10^3	16×10^3	2.2×10^3	1.6×10^3	1.6×10^3
Várzea, Recife, Brazil[e]	$\approx 172 \times 10^3$	$\geq 2.4 \times 10^3$	>23	–	–
Santo Amaro, Campo Grande, Brazil[f]	up to 4.4×10^4	up to 1.1×10^5	up to 200	3.6×10^1	–
Ditengteng, Tshwane, South Africa[g]	5×10^3	–	–	9×10^3	up to 6.1×10^3
Western Cape, South Africa[h]	5.9×10^6	–	–	–	77.4×10^3
Seixas w Minho, Portugal[i]	4.8×10^3 ([j])	–	4.6×10^3	3.9×10^3	4.4×10^3

[a]CFU·100 ml^{-1}, CFU, colony forming unit.
[b]MPN·100 ml^{-1}, MPN, most probable number.
[c]Pacheco *et al.* (1991).
[d]Matos (2001).
[e]Espindula (2004).
[f]Abrão (2007).
[g]Tumagole (2006).
[h]Engelbrecht (1993).
[i]Rodrigues & Pacheco (2003), borehole P10.
[j]heterotrophic and mesophilic bacteria.

Table 4 | The quantities of selected bacteria in underground water in several of the 20 piezometers installed in the de Vila Nova Cachoeirinha cemetery in São Paulo, Brazil (shortened table, Matos & Pacheco 2002)

Number of boreholes	Heterotrophic bacteria[a] (from..to..)	Total coliforms[b] (from..to..)	Faecal coliforms[b] (from..to..)	Proteolytic bacteria[b] (from..to..)	Clostridium sulfito redutores[b] (from..to..)
P1	120 to 110×10^4	< 2 to 10	<2 to 10	< 2 to 300	< 2 to 1.6×10^3
P5	90×10^2 to 77×10^3	23 to170	2 to 30	22 to 16×10^3	130 to $\geq 1.6 \times 10^3$
P7	54×10^3 to 40×10^5	< 2 to $\geq 1.6 \times 10^3$	<2 to $\geq 1.6 \times 10^3$	10 to $\geq 16 \times 10^3$	< 2 to $\geq 1.6 \times 10^3$
P9	180×10^2 to 170×10^3	< 2 to $\geq 1.6 \times 10^3$	<2 to 300	< 2 to $\geq 1.6 \times 10^3$	13 to 1.3×10^3
P13	32×10^3 to 86×10^3	< 2 to 4	<2 to 2	10 to 500	23 to 1.3×10^3
P15	85×10^3 to 29×10^3	< 2	<2	20 to 500	500 to 2.2×10^3
P20	95×10^2 to 52×10^3	2 to 23	<2	8 to 170	8 to 170

[a]CFU·100 ml^{-1}, CFU, colony forming unit.
[b]MPN·100 ml^{-1}, MPN, most probable number.

(Pacheco *et al.* 1991) were performed at almost the same time as those of Martins *et al.* (1991). Martins' team analysed 67 groundwater samples. Most of the samples contained higher quantities of *S. faecalis* and sulphite reducer clostridia compared with the faecal coliforms (Table 5). The presence of coliphages was not confirmed (Martins *et al.* 1991). The authors suggested that *S. faecalis* and sulphite reducer clostridia content are more appropriate indicators for evaluation of the sanitary conditions of the cemetery groundwater. In this study the *Salmonella* spp. were detected in one of the 44 analysed samples. However, the occurrence of these dangerous bacteria, with a maximum of 3,000 CFU·100 ml^{-1} (determined by the membrane filter method), was confirmed by Final (2007) in two cemeteries: São Goncalo and Parque Bom Jesus in the Cuiabá region of Mato Grosso state.

Table 5 | The maximum values of bacteriological indicators found in samples collected in three Brazilian cemeteries (Martins *et al.* 1991), simplified table

	Cemeteries		
Bacteria	Areia Branca, Santos	Vila Formosa, São Paulo	Vila Nova Cachoeirinha, São Paulo
Total coliforms[a]	1.6×10^3	1.6×10^3	1.6×10^3
Faecal coliforms[a]	1.6×10^3	3.0×10^2	7
S. faecalis[a]	1.6×10^3	1.6×10^3	1.6×10^3
Sulphite reducer clostridia[a]	1.6×10^3	2.4×10^2	27
Proteolytic[a]	1.6×10^3	1.6×10^3	9.0×10^3
Heterotrophic[b]	8.1×10^6	7.1×10^5	5.3×10^4
Lipolytic[b]	1.2×10^6	1.5×10^3	3.6×10^4

[a]MPN·100 ml^{-1}, MPN, most probable number.
[b]CFU·100 ml^{-1}, CFU, colony forming unit.

Among the cemeteries (Vila Nova Cachoeirinha, Vila Formosa, Areia Branca) the worst quality of groundwater was recorded at the Areia Branca cemetery in Santos (Table 5).

According to Pacheco *et al.* (1991), diversity in the numbers of bacteria in cemeteries' groundwater is associated mainly with varying lithological conditions as well as the depth of the groundwater table. Similar conclusions were formulated by Martins *et al.* (1991) and Matos (2001). The poor quality of the groundwater at the Areia Branca cemetery in Santos is associated with the permeable sandy formations (Quaternary age marine sediments) and shallow groundwater table – c. 2.2 m below the terrain surface (Martins *et al.* 1991). The environmental settings of the remaining two cemeteries in São Paulo are slightly different. The groundwater table is significantly deeper and reaches, on average, 12.0 m below the terrain surface (Bastianon *et al.* 2000). The substrate of the Vila Formosa cemetery is mainly composed of alternating layers of clays and sandy clays of Tertiary age sediments (Migliorini 1994). In turn, in the Vila Nova Cachoeirinha cemetery, the substrate is mainly composed of sandy sediments containing clayey layers. These clayey layers are acidic and contain few organic substances. As a result, they are not very active in terms of ion exchange (Matos *et al.* 2002). The authors even emphasized hydraulic conductivity of the substrate. Clayey substrates are less permeable to a cemetery's effluents. In this way they limit a cemetery's impact on the bacteriological contamination of the groundwater. The large influence of this factor was also confirmed in the studies at the Vila Rezende cemetery in Piracicaba, where hydraulic conductivity amounted to 6.5×10^{-7} cm·s^{-1} (Silva *et al.* 2011).

It should be noted that those investigations contributed to the development of a method enabling evaluation of susceptibility of the groundwater to bacteriological contamination. The GOD method (an abbreviation of Groundwater hydraulic confinement; Overlaying strata; Depth to groundwater table) suggested by Foster *et al.* (2006) was used to estimate the susceptibility to contamination of groundwater at four cemeteries in Santa Maria in the state of Rio Grande do Sul (Kemerich *et al.* 2010). The results revealed that the method may be very useful for the evaluation of the bacteriological contamination hazard in cemeteries and their vicinity.

Finally, it is worth presenting an investigation concerning the migration of bacteria, performed by Matos (2001) in the Vila Nova Cachoeirinha cemetery. The studies revealed that bacteria may migrate over a distance of several metres beyond the cemetery. The number of bacteria decreased as the distance from the interments increased. Viruses turned out to be more mobile than bacteria, moving tens of metres. The viruses were also transported at least 3.2 m through the unsaturated layer and reached the groundwater layer. These investigations also revealed that the highest contamination occurred at those places where the graves were close to the water table, the graves were not older than one year and the graves were situated in the low-lying parts of the cemetery.

The effect of shallow groundwater table on the high bacteria content, mentioned by Pacheco *et al.* (1991), Martins *et al.* (1991) and Matos (2001), was also confirmed in research conducted in two cemeteries: da Paz and da Saudade in Belo Horizonte in the state of Minas Gerais by Costa *et al.* (2002) and in two necropolises (São Gonçalo and Parque Bom Jesus) in the Cuiabá region of the Mato Grosso state (Final 2007). In all of these four cemeteries the groundwater quality was unsatisfactory. No presence of *E. coli* was found in these cemeteries. In general, however, in all these four cemeteries, the quality of groundwater was unsatisfactory. Of particular concern is the maximum number of thermotolerant coliforms – 2.4×10^6 CFU·100 ml^{-1} in a sample collected from a low-lying place. It is worth emphasizing that thermotolerant coliforms are rarely recorded near places of burial (Martins *et al.* 1991). This fact results from their shorter survival time in the soil and groundwater compared with other bacteria of the coli group.

The Itaquera cemetery

Studies at the Itaquera cemetery (Silva *et al.* 2008) revealed the presence of total coliforms and bacteria classified as *Shigella* and *Klebsiella* spp., capable of causing diarrhoea. The high level of groundwater contamination was explained by: (1) location on a steep slope (40%); (2) sandy-clayey bedrocks with suspended aquifer, covered by an impermeable layer of red lateritic loam; (3) lack of a sewage system at the cemetery; (4) lack of management plans at the cemetery; (5) leaking tombs and graves; (6) faults in grave construction; (7) faults in the interment procedures; and (8) lack of appropriate collection and utilization of the solid waste from the cemetery. Such conditions were conducive to ground erosion and landsliding that even predisposed groundwater contamination. In addition, a distance of less than 50 m to the nearest building estate also had an adverse impact on the quality of water. All these factors contributed to the conclusion that the location of the Itaquera cemetery in São Paulo was unfavourable.

The São José cemetery

The elevated numbers of bacteria: heterotrophic – up to 300×10^2 CFU·100 ml^{-1}, total and faecal coliforms – up to 8×10^3 MPN·100 ml^{-1} (MPN, most probable number), and faecal streptococci (*S. faecalis*) – up to 235 CFU·100 ml^{-1}, were also confirmed at the São José cemetery in Belém in Pará state (Braz *et al.* 2000). The faecal coliforms and faecal streptococci were not found in a control artesian well. However, significant contamination of the groundwater by faecal and total coliforms (up to 13×10^3 MPN·100 ml^{-1}) occurred in the well below the cemetery, as well as in a stream flowing c. 100 m from the cemetery boundary. This small stream acts as a water-collector for the surface water from the cemetery. Some contamination may even come from neighbouring households (Braz *et al.* 2000). High groundwater contamination was also boosted by permeable, vulnerable-to-pollutants Tertiary age outcrops made of fine- and medium-grained sands.

The Várzea cemetery

In the Várzea cemetery in Recife, Espindula & Santos (2004) collected samples from three piezometers and five wells. They were located within and beyond the cemetery, at distances ranging from 6 to 110 m from the cemetery boundary. He found *P. aeruginosa* in all samples, with numbers $\geq$1,600 MPN·100 ml^{-1}. Remarkable quantities of *P. aeruginosa* were confirmed by other researchers in individual wells (Martins *et al.* 1991; Vasconcelos *et al.* 2006). It should be emphasized, that this bacterium inhibits the growth of total coliforms (CETESB 1996; Guilherme & Silva 1998; Almeida *et al.* 2006). Therefore, these bacteria were not found (Table 3).

In this cemetery, water from the piezometers also contained heterotrophic and proteolytic bacteria, as well as sulphite reducer clostridia (Table 3). High numbers of these bacteria, particularly the proteolytic types, provided the evidence that higher quantities of microorganisms appear, especially in the piezometers situated near the graves less than one year old (Almeida *et al.* 2006).

In the Várzea necropolis, the clastic substrates, where the graves were located, are up to 8 m in thickness. Unfortunately, these sediments have high permeability due to their lithology, composed to a depth of 3 m of sands, silts and loams; from 3 m to 6 m of poorly graded gravels; and below 6 m of sands. Moreover, the groundwater table fluctuates in the range of 2.9–9.5 m below terrain surface (Espindula & Santos 2004; Almeida *et al.* 2006). The contamination is facilitated by mostly shallow graves with coffins placed directly into the ground at depths ranging from 0.6 to 0.8 m (Santos & Espindula 2005). At the time when this necropolis was studied, there were 3,519 graves on an area of 2.2 ha.

The Santo Amaro cemetery

Studies at the Santo Amaro cemetery in Campo Grande in Mato Grosso do Sul state (Abrão 2007) revealed higher numbers of heterotrophic and proteolytic bacteria. At this site, *C. perfringens* and total coliforms occurred only in two wells (Table 3). In one well higher numbers of *S. faecalis* and *E. coli* were also found (Table 6). These wells were situated in the middle and lower parts of the slope. According to a cautious opinion expressed by Abrão (2007), such a contamination of the groundwater could be linked to the decomposition of corpses during the period of the studies. At that time, there were 24,000 graves on an area of 27.3 ha. The contamination could also be increased by shallow graves with depths ranging from 1.70 to 2.50 m. The corpses were also buried sporadically on three levels. According to Abrão (2007), the groundwater level is shallow there, ranging between 5.65 and 12.50 m. This diversity results from the cemetery being situated on an upland slope of a basaltic cuesta, descending gently from an elevation of 597.50 to 585.77 m

Table 6 | The numbers of selected bacteria found in groundwater within cemeteries in Australia and Brazil

Cemeteries	Total coliforms[a]	*S. faecalis*[b]	*P. aeruginosa*[b]	*E. coli*[b]
Botany in Sydney[c]	to 5	to 2	to 2	–
Guildford in Perth[d]	to 8	–	to 11	–
Necropolis in Melbourne[d]	2.4×10^3–3×10^3	to 22	–	10
Cheltenham in Adelaide[e]	2×10^3	–	to 40	–
Woronora in Sydney[d]	to 500	0	to 4	to 2
Santo Amaro in Campo Grande[f]	–	9.1×10^1	–	3.6×10^1

[a]MPN·100 ml^{-1}, MPN, most probable number.
[b]CFU·100 ml^{-1}, CFU, colony forming unit.
[c]Dent 2005.
[d]Dent & Knight 1998.
[e]Knight & Dent 1998.
[f]Abrão 2007; [c,d,e]in Australia; [f]in Brazil.

above sea level. The infiltration of relatively high rainfall, c. 1,500 mm per year in a tropical climate, is facilitated by the considerable proportion of sand in the substrate (44% sand, 31% loam and 25% silt). This is indicated by a high permeability coefficient which ranges from 5 to 10 cm·s^{-1}.

The studies presented so far emphasized the adverse impact of cemeteries on the groundwater quality in their surroundings. According to Silva, L. M. (2000) 75% of 600 cemeteries in Brazil pollute the environment. However, some Brazilian research has revealed that the influence of cemeteries on groundwater contamination is less noticeable. This fact was confirmed in the studies conducted on a newly founded but closed municipal cemetery in Parque Bom Jardim on Estrada Jatobá street in Fortaleza in Ceará state (Sousa *et al.* 2008). In contrast to the previously discussed cemeteries, this cemetery was established on clays and silts. In such environmental settings, average velocity of the groundwater flow (calculated on the basis of monitoring the contamination in nine piezometers), reached 0.27 m per day. The study revealed that the zone of groundwater contamination around the border of the cemetery did not exceeded 13.5 m and time of migration took up to 50 days (Sousa *et al.* 2008). It is worth remembering that in fine-grained sediments the biological contaminants may migrate up to 30 m (Romero 1970).

The influence of limited infiltration in clayey sediments on the biological contamination of the groundwater was also confirmed by Oliveira *et al.* (2002). They noted an increasing biodegradation of organic matter and elimination of bacteria in substrate downward of the vertical profile. This phenomenon occurred in the moist tropical climate in the Domini Max II cemetery, in the Belém region in Pará state.

No negative impact on the groundwater was demonstrated in the study carried out by Mello *et al.* (1995) on a contemporary cemetery at da Paz in São Paulo. The study did not confirm the presence of faecal coliforms, faecal streptococci (*S. faecalis*), sulphite reducer clostridia, coliphages and *Salmonella* in the groundwater collected from two wells near the graves. There were only small numbers of heterotrophic bacteria and total coliforms.

The preliminary studies conducted at the Santana cemetery, on the Ilha de Maré island in Salvador in the state of Bahia (Leite 2009), confirmed that groundwater was polluted by total coliforms and thermotolerant coliforms (c. 200 CFU·100 ml^{-1}). However, the author concluded that the contamination did not exceed the norms (Leite 2009).

Worthy of mention is that some Brazilian researchers have doubts concerning the negative impact of cemeteries on groundwater quality in the vicinity of these areas. According to Espindula (2004), the increased quantities of total coliforms and the presence of faecal coliforms or thermotolerant coliforms in two household wells near the Várzea cemetery in Recife, can be also connected to other factors, e.g., leaky sewage systems. Similar doubts have also been raised by other researchers (Mello *et al.* 1995; Carvalho & Silva 1997; Braz *et al.* 2000; Matos 2001; Almeida *et al.* 2006; Sousa *et al.* 2008; Leite 2009). Almeida *et al.* (2006) found relatively low levels of contamination in a household well near the cemetery compared with a more distant well. In their opinion, this finding resulted from other factors, including additional sources of pollution, such as the lack of sewage systems or their leakages, the conservation and cleanliness of the well, the type of aquifer in use, and the rainfall amounts.

These arguments may suggest that investigation focusing on groundwater contamination by bacteria and viruses must take into account additional factors not directly related to the cemeteries, e.g., spatial distribution of the sewerage system and its condition, etc.

Studies in Africa

Studies carried out in South Africa revealed that the localization of many cemeteries was incorrect. Significant microbiological contamination of groundwater was found by Engelbrecht (1993) in a municipal cemetery in the Western Cape Province (Table 3). He evaluated the water quality on the basis of 20 wells situated within the cemetery, one well located at 50-m distance, and a reference (control site) municipal well 500 m away from the cemetery (Engelbrecht 1993). The wells, set in sands, showed high quantities of *E. coli* (57.4×10^3 CFU·100 ml^{-1}), *S. faecalis* (205.0×10^3 CFU·100 ml^{-1}), *S. aureus* (5.4×10^3 CFU·100 ml^{-1}), heterotrophic bacteria and faecal coliforms (Table 3).

High groundwater contamination was also diagnosed at Ditengteng cemetery in Tshwane (Tumagole 2006). In samples collected from several wells situated in their vicinity, high levels of several microbiological parameters (e.g., total coliforms and faecal coliforms and a number of heterotrophic bacteria) were found (Table 3). Moreover, Tumagole (2006) found *E. coli* in two samples. These bacteria occurred in shallow groundwater in an unconfined sandy aquifer and in the coastal zone. The level of the groundwater increases during the rainy season in Tshwane. As a consequence, the contamination of the environment by microorganisms originating from the cemetery takes place (Tumagole 2006).

Total and faecal coliforms were also found in groundwater in the urban Granaville cemetery in Harare, Zimbabwe (Tumagole 2006). These results were obtained in seven piezometers situated at the cemetery itself, and downslope, and compared to a control site.

African researchers are of the opinion that the biological contamination of groundwater at the African cemeteries are associated with: (1) the number of burials; (2) the physical, chemical and biological properties of the natural environment; (3) fluctuations of the groundwater table; (4) circulation of the groundwater in the substrate; and (5) the ability to create binding between decomposition products and the substrate, and organic matter (Wright 1999).

Studies in Australia

A smaller impact of cemeteries on the groundwater contamination was found in Australia. Two series of studies by Dent (1995, 2005) carried out at the Botany cemetery in Sydney revealed low levels of bacteriological contamination. The groundwater was polluted by total coliforms, *S. faecalis*, faecal coliforms and *P. aeruginosa* (Table 6). These microorganisms were found in piezometers situated along the line of water runoff, particularly below new graves, in four out of 11 boreholes (Dent 2005).

Dent (2000a) also reported increased quantities of microorganisms: faecal coliforms (*E. coli*), faecal streptococci (*S. faecalis*) and *P. aeruginosa* in the vicinity of graves at the Botany cemetery in Sydney, and at the Guildford cemetery in Perth (Table 6). The number of bacteria decreased rapidly with a growing distance from the graves. According to Knight & Dent (1998) and Dent (2000a) the migration of microorganisms in these cemeteries is hampered by the lithology of substrate. In Sydney, the substrate is composed of sandy clays and a clayey mantle of sandstone (Knight & Dent 1998). The cemetery in Perth is located on shallow marine sediments of Holocene age, composed of clayey and silty sands, and fine sands (Dent 2000a). A considerable reduction of the decomposition products may also result from the activities of naturally occurring microorganisms not associated with interments, e.g., with iron bacteria, and also sulphur bacteria of the genus *Thiobacillus* (Knight & Dent 1998).

The importance of hydrogeological conditions was also confirmed by studies carried out in the Cheltenham cemetery in Adelaide. This cemetery is above an aquifer of the Adelaide Plain (River Torrens Fan of the Lower Outwash Plain), Pooraka Formation, with a phreatic surface between 4 and 4.7 m below the terrain surface. The substrate is composed of silty and sandy clays, silty clayey sands and minor silty sandy lenses, the latter probably representing channel fills. In this case, the depth of the groundwater table (4.0–4.7 m) was considered a factor that restricted groundwater contamination (Knight & Dent 1998). In spite of these good hydrogeological conditions, a pathogenic bacterium *P. aeruginosa* was found in the groundwater. Moreover, higher quantities of total coliforms were found (Table 6).

The unconsolidated but firm clays up to 10–12 m thick that overlie sandy silts and silty sands of the Brighton Group formations at the Necropolis cemetery in Melbourne also did not appeared to constitute an efficient barrier (Dent & Knight 1998). Even though the aquifer was sampled at a depth ranging from 14 to 28 m, the researchers found the presence of several groups of bacteria: total coliforms, *S. faecalis* and faecal coliforms (Table 6). Their numbers varied considerably over time. Additionally, in three wells situated at the cemetery, the bacteria classified as total coliforms were found in quantities ranging from 2.4×10^3 to 3×10^3 CFU·100 ml^{-1}. The numbers of *E. coli* and *S. faecalis* were significantly higher (Table 6). Their numbers decreased rapidly with distance from the cemetery. Dent & Knight (1998) regarded that the presence of all decomposition products in the groundwater resulted from water seeping into the wells at a depth of 2.5–5.5 m below the terrain surface. Some contamination might come from the decomposition of coffins and embalming substances.

The studies carried out by Dent in Australia (2000b, 2004) revealed low levels of bacteriological groundwater pollution in a moderate climate condition. Irrespective of the bedrock settings, most of the microorganisms did not migrate deeper than 3 m (Bitton & Harvey 1992; Dent 2004). Only during long-lasting rainfall periods did they migrate a distance further than 100 m (Kieft & Brockman 2001).

The increased numbers of bacteria are usually related to: (1) inappropriate localization of cemetery (e.g., adverse hydrogeological conditions); (2) inappropriate management practices; and (3) occurrence of natural disasters (e.g., storms, floods or landslides). According to Dent (2004), (1) dry sands, (2) anaerobic conditions, (3) high temperatures (>40 °C), (4) direct insolation, (5) low pH and (6) presence of other bacteria species create preferable conditions for a decrease in the numbers of bacteria and viruses.

CONCLUSIONS

Summary of contamination characteristics

In a moderate climate condition, a relatively low impact of cemeteries on groundwater pollution by bacteria and viruses was observed. Higher numbers of bacteria are primarily associated with long-lasting rainfall periods. This regularity was confirmed by an increase in the numbers of thermotolerant coliforms, faecal streptococci and *S. aureus* at a contemporary cemetery in Wolverhampton, and in nine cemeteries and mass graves in Poland (Table 1).

Low groundwater contamination was also observed in the Guilford cemetery in Perth, located in Mediterranean climate conditions (870 mm annual rainfall) and in the Woronora and Botany cemeteries in Sydney (Table 6), located in a subtropical climate (1,100 mm annual rainfall). Slightly higher numbers of *S. faecalis* and *E. coli*, found in the Cheltenham cemetery in Adelaide (Mediterranean climate – 560 mm annual rainfall), could be a result of fluctuation of saline groundwater (Knight & Dent 1998).

Significantly higher biological groundwater contamination was recorded in warmer and moister climates (Tables 3, 4 and 6). The Santo Amaro cemetery in Campo Grande (Table 6), located in a tropical climate (annual rainfall of 1,500 mm) with a rainy summer and dry winter is one example.

High numbers of bacteria occurred in groundwater in cemeteries in Brazil, the Republic of South Africa and Portugal (Tables 3–6). In the vicinity of necropolises located in the southern part of Africa, the increases were recorded with respect to all microbiological indicators (Table 3), namely, total coliforms, faecal coliforms, heterotrophic bacteria, faecal streptococci, *E. coli* and *S. aureus* (Fisher & Croukamp 1993; Engelbrecht 1998; Tumagole 2006). One of the highest contamination levels was diagnosed in the Western Cape cemetery in the Republic of South Africa, situated in loose sands (Engelbrecht 1993). Such a substrate is particularly conducive to contamination (Martins *et al.* 1991; Braz *et al.* 2000; Rodrigues & Pacheco 2003; Almeida *et al.* 2006; Żychowski 2009; Silva *et al.* 2011).

Many authors noted the occurrence of *P. aeruginosa* at the cemeteries in Brazil (Pacheco *et al.* 1991; Espindula 2004) and in Australia (Knight & Dent 1998; Dent 1998; 2005; Dent & Knight 1998).

Thermotolerant coliforms were often absent from the vicinity of interments (Martins *et al.* 1991). This results from their shorter survival time in the soil and groundwater, compared with other bacteria from the coli group. These bacteria were most often reported in samples taken from low-lying places at contemporary cemeteries in Brazil (Final 2007; Neira *et al.* 2008). They were also reported during rainfall periods at cemeteries in England (Trick *et al.* 2001).

The largest quantities of *E. coli* (Abrão 2007) were noted in Brazil. Small amounts were found in Australia, in the Necropolis cemetery in Melbourne, in the Woronora and Botany cemeteries in Sydney and in the Guildford cemetery in Perth (Table 6).

Salmonella spp. bacteria were found in cemeteries in Brazil (Pacheco *et al.* 1991; Martins *et al.* 1991; Final 2007); however, they were not detected in groundwater in cemeteries in Poland, England, South Africa and Australia.

The research approaches used to evaluate the bacteriological contamination of the groundwater by cemeteries differ slightly in the regions studied. This fact hampers comparison of the results obtained. For example, in the World Health Organization report (Üçisik & Rushbrook 1988), attention has been drawn to the presence of *B. cereus,* faecal streptococci (*S. faecalis*), Micrococcaceae and Enterobacteriaceae in groundwater under cemeteries. In turn, the indicators of water contamination universally used in Brazil include the bacteria from the group of total coliforms (*Citrobacter*, *Klebsiella* and *Enterobacter*), faecal coliforms, thermotolerant coliforms (*E. coli*), *Streptococcus* (*S. faecalis*) and *Clostridium* (*C. perfringens)* (CETESB 1996). Braz *et al.* (2000) have also noted *Salmonella*, lipolytic and proteolytic bacteria, whereas Matos & Pacheco (2000) identified heterotrophic bacteria. Few researchers have paid attention to viruses, e.g., coliphage 30, coliphage T134 and coliphage T4 (Final 2007). In Australia, the indicators of microbiological contamination include faecal coliforms, *P. aeruginosa,* as well as *E. coli* and faecal *Streptococcus* (Dent 2000b).

The role of environmental factors – summary

The review revealed the large influence of climatic conditions on the bacteriological contamination of the groundwater, at the regional scale. Most researchers express the opinion that warmer and moister climate is the principal factor in significant contamination of the environment – including the groundwater (Silva, J. A. F. 2000; Silva, L. M. 2000). They observed that during long-lasting periods of rainfall, microorganisms can be transported even over a distance exceeding 100 m. The Brazilian researchers are of the opinion that this negative impact could be contained through proper burial site management and the correct placement of cemeteries (Silva, J. A. F. 2000; Silva, L. M. 2000). Therefore, in many reviewed studies the role of other environmental factors was emphasized. These factors influence the groundwater pollution, especially at the local scale. Many researchers emphasized the role of geological settings and lithology of substrate, the relief conditions as well as the depth of the groundwater table and its fluctuation (Gray *et al.* 1974; Pacheco *et al.* 1991; Martins *et al.* 1991; Engelbrecht 1993; Rodrigues & Pacheco 2003; Almeida *et al.* 2006; Żychowski 2008). These factors were often responsible for spatial diversity of the groundwater contamination within a cemetery and its vicinity (Pacheco 1986; Antunes *et al.* 1998; Dent 1998; Morgan 2004). It is particularly significant for the cemeteries situated on slopes.

Geological settings and lithology of substrate affect infiltration rate, sorption capacity and groundwater circulation. In this way, these factors influence migration of the microorganisms – both in time and distance (Pacheco 1986; Silva 1994; Dent 2004). In this context, few studies revealed some kind of regularity. As the distance from the places of interment increases, the quantity of microorganisms rapidly decreases (Mello *et al.* 1995; Knight & Dent 1998; Dent & Knight 1998; Oliveira *et al.* 2002). This regularity was observed mainly in sandy clays and clayey grounds, and was explained by limited infiltration. The role of the substrate sorption capacity was emphasized by Matos (2001), Dent *et al.* (2004) and Josias & Harris (2004). The higher the sorption capacity (e.g., in clays) the more viruses were retained. The fine-grained substrate may also retain larger organisms such as bacteria during the filtration process. In this context, silty substrates more effectively retain bacteria contrary to corase sand (Matos 2001).

Pathogens quickly migrate to the groundwater when the water table is shallow, e.g., in periods of intensive precipitation (Pedley & Guy 1996; Josias & Harris 2004). The pathogens die faster in the aeration zone than in the saturation zone and their transport in the saturation zone is slower than the groundwater flow (Gray *et al.* 1974). Many reviewed studies revealed some kind of regularity, namely, the more shallow the groundwater table the more bacteria occur in the water.

Many studies confirmed higher numbers of microorganisms in the vicinity of graves less than a year old (Pacheco 1986; Martins *et al.* 1991; Matos 2001; Migliorini 2002; Morgan 2004; Almeida *et al.* 2006) as well as near those which were placed close to the groundwater table (Dent & Knight 1998; Matos 2001; Costa *et al.* 2002; Almeida *et al.* 2006; Abrão 2007; Final 2007; Żychowski 2008).

According to Australian researchers, the groundwater contamination could also be predisposed by: (1) the lack of sewage systems at cemeteries; (2) errors made in grave construction; (3) faults in preparation and interment of corpses; (4) leaky tombs, cracks in graves; and, finally, (5) the lack of appropriate collection and utilization of solid waste in cemeteries (Silva *et al.* 2008). The researchers in South Africa see a dependence of the impact of cemeteries on groundwater contamination with one or more of the following factors: (1) the number of interments; (2) the physical, chemical and biological properties of natural habitats; (3) fluctuation in groundwater tables; (4) circulation of water in the substrate; and (5) the processes of binding between the decomposition products and the substrate, soil and organic matter (Wright 1999).

A number of cemeteries are parts of urban areas (Hirata & Suhogusoff 2004). In the context of studies presented in this review, evaluation of the cemetery impact on the groundwater contamination must be well balanced. It should take into account the influence of other factors natural and anthropogenic – e.g., the lack of sewage systems or their leaking, conservation and cleanliness of wells (Mello *et al*. 1995; Braz *et al*. 2000; Espindula 2004; Almeida *et al*. 2006; Sousa *et al*. 2008; Leite 2009).

Recommendations

The reviewed studies allow development of some recommendations intended to protect the health of employees of funeral homes and the residents living in the vicinity of cemeteries, as well as preserve the natural environment for future generations. Therefore, this review is summarized by the following list of recommendations:

(1) Location of new cemeteries, and expansion and management of existing cemeteries should be preceded by obtaining appropriate environmental licence (e.g., Gambin *et al.* 2008). In this context the legal regulations are required. Older cemeteries should be successively changed and adapted to the new requirements.
(2) Cemeteries should be located on gentle slopes. Higher slope gradients create favourable conditions for surface flow, flooding of graves, leaching and migration of decomposition products.
(3) Cemeteries should be located on bedrocks where:
  (a) the clay mineral content ranges between 20 and 40%;
  (b) the bottom of the grave is at least 1.5 m above the maximum groundwater level. When the substrate has a permeability ranging from 10^{-5} to 10^{-7} $cm{\cdot}s^{-1}$ (or higher), this distance should be higher.
(4) Cemeteries should not be located in areas where:
  (a) the groundwater level is shallow;
  (b) seasonal or ephemeral floods occur;
  (c) the substrate is very permeable (e.g., sands and gravels, fractured rocks, karst structures);
  (d) the substrate has low permeability (e.g., clays and loams) and anaerobic conditions create favourable conditions for adipocere.
(5) Cemeteries and the neighbouring areas should have stormwater drainage systems.
(6) Cemeteries should be surrounded by buffer zones composed of trees with deep root systems.
(7) The groundwater in cemeteries should be monitored both in terms of biological contamination and the depth of its table level.
(8) People responsible for management processes in a cemetery should:
  (a) develop a model for storing special waste, i.e., human corpses;
  (b) establish recommendations concerning appropriate treatment of remains and leachates;
  (c) establish recommendations in order to prevent migration of decomposition products into the substrate;
  (d) establish recommendations for preparation of interments; those should focus on: construction of coffins, the manner of preparing corpses (including embalming), conservation of coffins, clothing items placed in coffins;
  (e) establish recommendations concerning maintenance of gravestones and their surrounding areas (including their conservation practices); these solutions should be authorised by the relevant environmental agencies.
(9) People directly involved in the interment of victims of catastrophic events, namely soldiers, paramedics and other people exposed to infectious bacteria should be equipped properly.
(10) Employees of funeral homes should use appropriate boots, gloves and face masks during work related to burials or exhumations. They should wash their hands and take a shower before leaving the cemetery.

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GROUNDWATER CONTAMINATION FROM CEMETERIES CASES OF STUDY

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KEY WORDS
Groundwater contamination; Cemeteries; Burial; Human body decomposition

ABSTRACT

This paper presents a study of special interest because up to now there are no publications in Portugal, which investigate the impacts of physical, chemical and microbiological groundwater contamination caused by cemeteries.
The question of the potential risk for adverse impact of cemeteries on ground and superficial water has never received enough attention in our country. However, this risk may exist when cemeteries are placed in groundwater areas that are vulnerable to contamination.
In order to reduce the risk, planning for new cemeteries should evaluate geological and hydrogeological aspects, which constitutes a gap in the Portuguese legislation. This and other considerations about Portuguese legislation concerning cemeteries have been discussed.
This work reports a study that was carried out between September 2000 and September 2001, in three different areas to understand the risk of groundwater contamination from cemeteries placed in different lithology, hydrogeology and geographic areas: Querença and Luz de Tavira located in Algarve and Seixas located in Minho.
Several tests were conducted every two months: physical, chemical and bacteriological variables were analysed in several bored wells placed in the area of cemeteries. The physical-chemistry variables analysed were: temperature, pH, electrical conductivity, nitrites, nitrates, ammonium ion, chloride, oxidizability, total phosphorous, calcium, magnesium, hardness, sulphates, sodium, potassium, total zinc, total lead and TOC. The microbiological indicators analysed were: total and fecal coliform, fecal streptococcos, heterotrophic bacteria (22ºC and 36 ºC), clostridia and proteolytic bacteria. Additionally the geophysics in the area around Querença cemetery was studied.
The results from Querença were not conclusive with respect to determining the influence of cemetery contamination on groundwater, despite the fact that high levels of chemical and bacteriological contamination were detected in all the bored wells sampled. Since it is a karst aquifer and due to the existence of many septic tanks in the area, this can mask the impact from the cemetery. Although, there are indications that the closest sampling point from the cemetery must be under the influence of the cemetery, specially with shallow groundwater after periods of precipitation.
The analysis from the cemetery water of Luz de Tavira and Seixas had higher levels of bacteriological (both cemeteries) and physical-chemical values (Luz de Tavira) than the water from other sampling points further away from the cemetery, which indicated the impact from these cemeteries on groundwater quality.

INTRODUCTION

The question of the potential risk for adverse impact of cemeteries on ground and superficial water has never received enough attention in our country. Consequently, cemeteries have never been perceived as having a significant potential contaminant effect in the environment. In Portugal, cemeteries are, often located close to populations, in the radius of influence of water sources.

Literature related with this aspect of contamination of groundwater has been found to be limited (BASTIANON *et al*., 2000; BECKS, 1997; ENGELBRECHT, 1998; FISHER and Croukamp, 1993; MATOS, 2001; MATOS and PACHECO, 2000; PACHECO *et al*., 1991; VAN HAAREN, 1951).

The biological process of contamination

Cemeteries are laboratories of decomposition. The human body is a complex structure therefore the final products of decomposition are several: volatile fatty like acid butyric and propionic, primarily breakdown products of both muscle and fat (VASS *et al*., 1992), amino acids, fatty acids, ptomaine (skatole, indol, cadaverine and putrescine) and end products like: ammonia, ammonium compounds, hydrogen sulphide, mercaptan, methane, carbon dioxide and phosphoric acid.

When ever a cadaver is buried there are several alterations. Soft tissue starts to decompose a few hours after death due autolyse mechanisms (VASS *et al*., 1992), followed by a process of fermentation due to the action of endogen bacteria, mostly located in human intestine. The process includes a first stage anaerobic, followed by others, provided from aerobic and anaerobic facultative bacterial groups. Besides bacteria, other microorganisms, like saprophyte fungi and diverse entomofauna act during putrefaction of cadavers.

There are four principal phases of human body decomposition – chromatic, gaseous, humorous and skeletonization – however, in the ambit of the present study, the gaseous and the humorous are the most important.

The gaseous period occurs normally during the first three weeks of decomposition (at air exposition of the body) and is typified by the formation of gases in different organs and tissue (CUESTA, 1986). These gases may cause the rupture of cavities and consequently release humorous liquids. Humorous phase is characterized by the dissolution of cellular elements and the consequent liquefaction of tissue resulting in the production of lixiviates. This phase may occur during several months (CUESTA, 1986), or even years, depending of the structure of the cadavers and the burial conditions (FÁVERO, 1980). The rupture of the abdominal cavities may be accompanied for lixiviation of humorous liquids. The leakage from the disposal sites of the buried human bodies is very slow and the most part of the water evaporates simultaneously when it is released and only observed around the burial site. However, the unsaturated zone will be impregnated with fatty substances, and intermediate non volatile products, resulting from the process of decomposition. Subsequently these products can be percolated through the soil to the water taken after precipitation, and contaminate the groundwater.

Factors that interfere with putrefaction

In average human bodies are consisting of 64% of water, 10 % of lipids**, 6,4% proteins,** 5% of mineral salts and 1% of carbohydrates (VAN HAAREN, 1951) and takes around ten years to decompose in Portugal. Duration of decomposition steps is influenced by several intrinsic and extrinsic factors. The intrinsic factors are related to the cadavers, like age, sex, height, race, cause of dead or if it is was made an autopsy. Extrinsic factors are related with the environment around the body, like environmental temperature, precipitation, depth of burial and soil oxygenation (depending on type of soil), which can accelerate, retard or even stop the decomposition process (RODRIGUEZ and Bass, 1985). MANN *et al.* (1990) classified the variables intervenient in the decomposition of bodies and found that the most important are the temperature, the access to insects and depth of burial.

Estimation of contaminant flux

The amount of liquids lixiviate produced from a cemetery is related with the dimension of it.

Table 1: Example of estimates of effluent concentrations at a small (I) and large municipal cemetery (II) in UK

Year	Cumulative area of burials (m^2)		Annual effluent production (liters)	
	I	II	I	II
1	125	4 375	25 000	918 750
2	250	8 750	50 000	1 837 500
3	375	13 125	75 000	2 756 250
4	500	17 500	100 000	3 675 000
5	625	21 875	125 000	4 593 750
6	750	26 250	150 000	5 512 500
7	875	30 625	175 000	6 431 250
8	1000	35 000	200 000	7 350 000
9	1125	39 375	225 000	8 268 750
10	1250	43 750	250 000	9 187 500

Adapted from YOUNG *et al.,* 1999

Risk of contamination

Shallow groundwater protected by a thin unsaturated zone, composed of coarse grained or fissured materials must be avoided in order to site cemeteries because is potentially vulnerable to contamination, since it has high permeability and low capacity of retention of contaminants. Also fine soils where prevail anaerobic conditions, even if the filtration zone is above the water table, must be avoided in order to site cemeteries (ENGELBRECHT, 1998). An unsaturated zone underneath a cemetery increases the opportunity for attenuation of the seepage during decomposition of corpses (WHO, 1998). Carsick aquifers, with a very small vadose zone have weak capacity of filtration and are not adequate to cemeteries. The most useful soil type to maximize retention of degradation products is finergrained non-fissured material, as clay-sand mix of low porosity, and a small to fine grain texture (WHO, 1998).

This project has been carried out to provide information about the potential risks to groundwater resources associated with siteing of cemeteries.

Cases of study

The principal criteria used to select the cemeteries were geological and hydrogeological characteristics of the area of implantation of cemeteries and the proximity with groundwater sources (domestic or public), with the objective of evaluating the response of areas with different characteristics to the contamination process.

MATERIALS AND METHODOLOGY

Selection of the study areas

The three study areas selected are located in the north (Seixas, District Viana do Castelo) and south (Querença and Luz de Tavira, District Faro) of Portugal. Both cemeteries were constructed between the end of the the nineteenth and the beginning of twenteth. Climacteric conditions from north to the south of Portugal are very different. In the north the prevailing climatic conditions are moderate summers and strongly determined by rain and humidity in winter. The climatic conditions have a Mediteranean character in the south. The three cemeteries are located in areas with different geologies. Concerning the hydrogeology, Querença is located in a karst aquifer and Luz de Tavira in a porous aquifer. At Seixas the groundwater table was under the influence of the tides of Rio Minho.

Water samples were collected for bacteriological, physical and chemical testing between September 2000 and September 2001, each two months. At Querença no sample points where inside of the cemetery. Instead seven sample points of groundwater located in a radius of 800 meters around the cemetery were monitored: P1, P2, P3, P4, P7 and P8 artesian wells and a well, P5. At Luz de Tavira two wells were studied: P6 and P9: The first was inside of the cemetery and P9 at 300 meters of distance. Seixas cemetery had also a well inside of the cemetery (P10). Groundwater was extracted for different purposes (drinking, irrigation and ornamentation). On-site sewage disposal had been were also localized in the area around the cemeteries.

Testing water quality

The hydro-chemical study of groundwater involved the analyses of the following determinants: temperature (T) pH, electrical conductivity (EC), nitrites (NO_2), nitrates (NO_3), ammonium ion (NH_4), chloride (Cl), oxidizability, total phosphorous (P), calcium (Ca), magnesium (Mg), hardness ($CaCO_3$), sulphates (SO_4), sodium (Na), potassium (K), total zinc (Zn), total lead (Pb) and total organic carbon (TOC).

Water samples were analyzed for fecal-indicator organisms. Indicator organisms are bacteria whose presence in drinking water indicates that pathogens may be present. Indicator organisms are easier to detect and test for than the pathogens themselves. It were studied total coliform, fecal coliform and fecal streptococci and sulfite reducer clostridia, indicator of remote contamination. Heterotrophic bacteria (growing at 22 and 37 ºC), and proteolytic bacteria with capacity to produce extra cellular enzymes were also determined by the method usually used in food microbiology (VERA e Dumoff, 1974), adapted by MARTINS *et al.* (1991). Water samples were processed by use of membrane filtration techniques (0.45 µm pore-size membrane filters), incorporation media and most probable number (MPN).

Additionally, it was promoted a geophysics study in the area around Querença cemetery.

RESULTS

The bacteriological results are presented in table 2 and graphics.

Table 2: Microbiological groundwater contamination

Sample points		Bacteriological parameter (1) (Minimum and maximum interval)						
		GT22	GT36	T C	F C	T E	CSR	PROT
Querença	P1	2-132	2-670	0-300	0-475	0 - 3	23->1100	0- 130
	P2	29-1696	24-1575	35-750	1-530	0-28	43-240	0- 180
	P3	9-1420	440-1380	10-480	0-1800	0-282	93-2400	0- 94
	P4	20-29560	61-28560	130-6900	0-4400	0 - 6	7-460	0- 180
	P5	81-580	36-680	10-2600	3-330	1-110	0-43	0
	P7	3-133	13-400	0-23	0-20	0 - 4	4-93	0- 280
	P8	21-5020	25-4700	46-1900	0-395	1-128	23-4600	0- 94
Luz de Tavira	P6	27-365	1-1100	3-1850	1-121	0-11	23-1100	0-90
	P9	1-293	2-293	0-595	0-60	0 - 7	0-48	2-90
Seixas	P10	5-4800	6-2610	193-3900	0-4400	0-580	4-4600	nd (2)
	P11	5 3	2 4	4 9	4	0	4	nd (2)

(1) GT22, GT36=CFU/1ml total germs, heterotrophic, mesophile growing at 22 ºC and 37 ºC, respectivly; TC, FC and FE=CFU/100 ml of total coliform, fecal coliform and fecal streptococci ; CRS=NMP/100ml of sulfite reducer clostridia
(2) nd= no data

DISCUSSION OF RESULTS

The high levels of bacteriological contamination found in the most of the sampled points showed that the three cemeteries might constitute potential sources of contamination of groundwater.
Analysis from the cemetery water of Luz de Tavira (P6) showed higher levels of bacteriological and physical-chemical parameters when comparing with a well placed about 300 meters (P9).
At Querença physical and chemical quality of water reflect the different hydrogeology characteristics of the carsick aquifer where the cemetery is placed. In general, the samples from P3 and P4 showed much higher levels of bacteriological contamination. The geophysics study in the area showed high carsification in this direction. The samples showed low levels of the heavy metals Pb and Zn.
In Seixas the samples of water collected from a well sited inside of the cemetery (P10) showed increased levels of the bacteriological indicators analyzed, when compared with a spring 290 meters away from the cemetery (P11).
Sources of fecal-indicator bacteria include septic system failure or improper septic system construction or design. At Seixas there was municipal sludge treatment of wastewater and no other sources of organic contamination could be found close to the cemetery, this lead to the assumption that the obtained results are directly related to the presence of the cemetery. However that wasn't the case at the other two areas studied. The results from Querença were not conclusive with respect to determining the influence of cemetery contamination on groundwater, despite the fact that high levels of chemical and bacteriological contamination we re detected in all the boreholes sampled. Since it is a karst aquifer and due to the existence of many septic tanks in the area, this can mask the impact from the cemetery. Although, there are indications that the closest sampling point from the cemetery must be under the influence of the cemetery, specially during high level of groundwater after periods of precipitation.

CONCLUSION

The results obtain conduce us to the conclusion that cemeteries may contribute to groundwater contamination.
Portuguese legislation gives protection perimeters to public captations of groundwater from cemeteries within Zone 1 and Zone 2 under the Regulation 382/99, 22 of September. We believe that is important to review the Portuguese legislation concerning with siteing of cemeteries. Site-specific risk assessments should be conducted for cemetery site selection, taking into account the geological and hidrogeological conditions, proximity of receptors, such as water supply boreholes and springs, as well as other environmental factors, in order to protect the groundwater and provide a normal process of body decomposition. World Health Organization (WHO) proposes that human or animal remains must not be buried within 250 meters of any well, borehole or spring from which a potable water supply is drawn and that place of interment should be at least 30 meters away from any other spring or watercourse and at least 10 meters from any field drain. This distance may be greater if the site has a steep hydrogeological gradient or the velocity of groundwater flow within an aquifer is rapid (WHO, 1998).
The scope of groundwater contamination from cemeteries must not be generalized.

ACKNOWLEDGMENTS

The authors wish to express their thanks to all the homeowners who kindly permitted the sampling of their private water wells, to *Direcção Regional do Ambiente e Ordenamento do Território - Algarve* that carried out physical-chemical water analyzes, to *Universidade do Algarve* that lent the laboratory installations to proceed to bacteriological analyses and to *Águas do Algarve S.A.* which gave financial support to the geophysics study. Without them this study wouldn't be possible.

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1. Introduction

1.1 This document provides guidance on the protection of the water environment from cemetery developments. It is for developers and local authorities intending to expand or construct human cemeteries. This guidance applies to both traditional and green burial grounds.

1.2 The burial of humans and subsequent degradation can pose a risk of pollution to groundwater. This risk can be mitigated if either a) the natural ground conditions allow attenuation of pollutants, and/or b) the design of the cemetery is amended to minimise pollutant loading. This guidance describes how the planning applicant can demonstrate these types of mitigation are sufficient.

1.3 SEPA recommends pre-application discussions on any cemetery developments and can provide a scoping opinion to assist with the identification of issues which should be addressed as part of the application.

2. Assessing the potential risk to Groundwater

2.1 Stage 1 Screening Assessment

2.1.1 This is a simple assessment to check if the location of the site is feasible. It is a test to see if the site is too close to sensitive receptors.

2.1.2 The criteria are described in Box 1.

- If the development is for <100 burials/year and it meets the criteria in Box 1 then proceed to undertake a stage 2 assessment.
- If the development is for ≥100 burials/year and it meets the criteria in Box 1 then proceed to undertake a stage 3 assessment.
- If the development does not meet the criteria in Box 1 then it is unlikely to be suitable unless the design of the cemetery is altered to reduce or eliminate the pollutant loading (see Annex 2) AND a stage 3 assessment is undertaken.

BOX 1
Stage 1 site screening criteria

a) >250 metres from any groundwater abstraction (spring, well or borehole) used as a source of drinking water[1];

b) >50 metres from any spring, well or borehole for non-potable use ;

c) >50 metres from any watercourse[2];

d) >10 metres from a field drain[3];

e) Not above known or probable shallow mine workings if it can be reasonably judged that the workings form a preferential pathway to surface waters[4];

f) Not on designated Contaminated Land under Part IIA of the Environmental Protection Act (1990);

g) Has a slope with a gentle gradient (slope <10^{o}, which is equivalent to a slope of 17%;

h) Is not on land prone to flooding[5].

Notes:
1 – The local authority is the lead regulator for private water supplies. SEPA holds records of other abstractions >10m^3/day.
2 – Note that the term "watercourse" here includes lochs but does not include the sea, unless there is potential for contaminants to emerge at the shoreline via exposed cliffs or springs.
3 – Field drains here includes both buried pipe drains and ditches; note this restriction does not apply if the base of the field drain is <0.5m depth or if the field drainage will be diverted as part of the cemetery development.
4 – The Coal Authority holds records of known and probable shallow coal mine workings. The British Geological Survey holds information regarding other types of mining. Note that in relation to historic mining, SEPA will focus on the risks to the water environment. It is expected that, where shallow mining is known or likely to be present, the developer will also undertake a mining risk assessment that will consider ground stability and gas risks for the consideration of the relevant statutory consultees.
5 – SEPA flood maps will help with this. http://map.sepa.org.uk/floodmap/map.htm.

2.2 Stage 2: Initial Site Investigation

2.2.1 This stage relates to developments of <100 burials/year that meet the criteria in Box 1. It involves obtaining site specific information on groundwater levels, soil depth and soil permeability at the base of the burial lairs. This should be done by digging trial pits and then examining the soil type and groundwater levels exposed within the pits.

2.2.2 For sites where there are <30 burials /year then at least 3 pits are required in the development area. For larger scale burials (>30 burials/yr), a minimum of 6 trial pits or site investigation boreholes per hectare is required; SEPA may accept a lesser frequency at large sites (>5 hectares) provided this is agreed in advance through pre-application consultation.

2.2.3 The key assessment criteria are as follows:

- Investigations should occur to a depth of at least 1m below the planned base of the burial lairs.
- The soil strata exposed by the investigations should be described in accordance with British Standards[1]. The key is to describe the “principal soil type”, backed up with particle size analysis from the coarsest material within each hole.
- The presence of groundwater inflows or a water table should be noted. Exploratory holes should be surveyed to Ordnance Datum to enable groundwater levels across the site to be compared. Investigations should be sufficient to demonstrate that the annual maximum water table should be at least 1m below the planned bottom of the burial lairs. Thus, it is recommended that the initial site investigation is undertaken in winter or early spring (November to March). Where it is not possible to conduct investigations during this period, then information from the pits should be supplemented by estimates regarding the likely maximum water table based on information gathered by desk study, which could include measurements or records from adjacent developments.

A summary is provided in Box 2.

2.2.4 If the development is for <100 burials per year, and it meets the criteria in Box 2, then the site is suitable and can proceed.

2.2.5 If the site does not meet the criteria in Box 2 the site is unlikely to be suitable unless:

- the design of the cemetery is altered to minimise the pollutant loading;
- and, if necessary, a detailed Stage 3 assessment, taking account of the revised design, meets the criteria outlined in Section 2.3.

[1] *BS 5930:2015 Code of practice for ground investigations*

BOX 2
Stage 2 site suitability criteria
A suitable site is one that meets the criteria in Box 1 AND:

a) If the burial rate is less than 10 burials per year:

   i. There is >1m between the planned base of the lairs and the annual maximum water table.

b) If the burial rate is 11 to 100 burials per year:

   a) There is no rock outcropping at surface and no rock exposed in investigations to at least 1m below the planned base of the lairs;
   b) AND there is no “coarse SAND” or “GRAVEL” exposed by the investigations;
   c) AND there is >1m between the planned base of the lairs and the annual maximum water table.

Note that in making these calculations the thickness of soil cover above the coffin or shroud should not be less than 1m.

Burials below the water table are not acceptable at any site.

2.3 Stage 3: Detailed Quantitative Risk Assessment

2.3.1 Developments >100 burials per year or those failing the criteria in Boxes 1 or 2 may still be acceptable. This is if it can be demonstrated via Stage 3 that the pollutants from the cemetery will not cause significant adverse impacts on the water environment by considering a) the catchment of a receptor such as an abstraction b) information on the particular ground conditions at the site, and c) additional measures to reduce pollutant loading. Position Statement (WAT-PS-10-01) Assigning Groundwater Assessment Criteria for Pollutant Inputs provides details of the standards that can be used to assess this impact.

2.3.2 The exact requirements of a Stage 3 assessment are complex and site-specific, and thus cannot be prescribed in this guidance. It should only be undertaken by professionals with demonstrable qualifications and experience in groundwater risk assessment.

2.3.3 In most cases this stage requires a detailed quantitative risk assessment based on numerical pollutant fate and transport modelling. The type of numerical model to be used depends on site specific circumstances but examples include ConSim, P20, and/or Modflow. The assessment also needs to take account of any changes to graveyard design implemented to minimise pollutant loading (Annex 2).

2.3.4 Where proposed sites are extensions to existing burial grounds, the existing site may provide an analogue to aid the risk assessment process if the ground conditions and proximity to sensitive receptors on both sites are similar.

2.3.5 The detailed quantitative risk assessment should include ammoniacal nitrogen, which is the principal contaminant of concern to the water environment from burials. Risks from other contaminants such as metals, formaldehyde, and microbial pathogens should also be taken into consideration if a sensitive receptor is very close (within the standoff distances presented in Box 1).

2.3.6 The risk assessment should be undertaken using a Source-Pathway-Receptor approach. The main risk factors are a) the number of people buried per year, b) proximity to receptors such as rivers and drinking water sources, c) the depth to water table and the permeability of soil above the water table, and d) the nature of groundwater flow below the water table. Factors (a) to (c) form the basis of the criteria set out in Box 1 and Box 2 of this guidance.

2.3.7 The detailed quantitative risk assessment will require to be supported by a more detailed intrusive site investigation and an extended period of prior monitoring of both groundwater levels and quality. The scope of the additional investigation and monitoring should be designed taking into account the environmental setting of the site. As a minimum, SEPA will expect:

- At least three monitoring boreholes extending at least 3m below the maximum lair depth. The boreholes must be surveyed in to Ordnance Datum to permit interpretation of the groundwater flow regime.
- At least one year of monthly monitoring of groundwater levels.
- At least three baseline water quality rounds (analytical suite to include: pH, electrical conductivity, chloride, ammoniacal nitrogen, nitrate) for groundwater, and if applicable, surface water.

At sites with complex hydrogeology or in close proximity to sensitive receptors, the investigation and monitoring requirements may be greater than the minimum described above. It is suggested that the proposed scope of additional investigation be submitted to SEPA for comment prior to commencing the works on site.

2.3.8 It is in the best interest of the applicant to provide sufficient information in their planning application to enable us to make an informed and timely response. Submissions should include the form in Annex 1, along with the results of the stage 3 assessment and all supporting evidence.

2.4 Burial of Cremated Remains

2.4.1 Cremation burials usually pose a lesser risk to the water environment than conventional burials. Cremated remains should not be interred below the water table. It is preferable, but not essential, to maintain >1m between the planned depth of the buried cremated remains and the annual maximum water table. Standoff requirements from water features (see Box 1) should be maintained.

2.4.2 An average spacing of at least 0.5m between individual cremated remains is recommended. At the discretion of the Local Authority the burial depth may be less than a metre.

2.4.3 If urns are used, SEPA recommended the urns are composed of either inert (e.g. ceramic) or biodegradable (e.g. wood) materials.

2.5 SEPA Objections

2.5.1 We will object to proposals which:

- do not meet the site suitability requirements outlined in Stage 1, 2, or 3 (as appropriate).
- do not provide the summary table provided in Annex 1 along with necessary supporting information.

2.5.2 For the duration of cemetery use it is considered good practice to maintain a groundwater level and groundwater quality monitoring programme, to confirm that the site is not having a detrimental impact on the water environment. Such a monitoring programme is however not a compulsory planning requirement and will not be requested by SEPA.

ANNEX 1: SITE SUITABILITY CHECKLIST

Site Name:	
NGR of centre of site:	
PCS No: **[to be completed by SEPA]**	
Area of site (hectares)	
Burial rate (per year)	
Maximum depth of burial and method of body containment (m)	
Author:	
Date:	

Criteria **Stage 1 Assessment**	**Y/N**	**Details**	**Location in report where more details can be found**
1. Will burials be within 250m of potable groundwater abstractions; namely any spring, well or boreholes used as a source of drinking water?			
2. Will burials be within 50m of any other springs, wells or boreholes?			
3. Will burials be within 50m of any watercourse (loch, wetland, burns etc)?			
4. Will burials be within 10m of any field drain?			

5. Will any burials be within an area of known or probable shallow mine workings?			
6. Is the development located within an area designated as Contaminated Land?			
7. Is the development located on land prone to flooding?			
Stage 2 Assessment			
8. Is there any rock outcropping at surface or exposed in investigations to at least 1m below the planned base of the lairs?			
9. Is the soil exposed by the investigations “coarse SAND”, “GRAVEL” or coarser?			
10. Is there >1m between the planned base of the lairs and the annual maximum water table?			
Stage 3 Assessment (if required): Please provide a summary of the results of the more detailed assessment of ground conditions and/or of changes to the design of the cemetery to minimise pollutant loading			**Location in report where more details can be found**

ANNEX 2: OPTIONS FOR CEMETERY DESIGN TO MINIMISE POLLUTANT LOADING

Where the cemetery does not meet the requirements specified above the developer could consider modifying the design to meet these requirements. This section provides some guidance on possible modifications that could be undertaken to address some of these issues.

Option 1: Only use the parts of the site which meet the suitability criteria

Many sites suffer from constraints related to topography or groundwater levels. These constraints in effect define a restricted envelope of ground suitable for burial use and therefore the suitability of various areas of the site for multiple, single or no burial.

If a portion of the site is not suitable for burials the entire site need not necessarily be rejected. Internal zoning of the site according to site conditions may be appropriate as shown in Figures A1 and A2.

Option 2: Increase the depth to groundwater by land raise

Land raise is the most obvious of the solutions where available sites exhibit groundwater levels that are only marginally too high or where soil thickness is a limitation. This should not be confused with burial mounds which will not routinely be considered (a mound erected over the dead on an individual basis).

If a land raise option is under consideration, the implications for local flood risks must be assessed.

Materials used must be inert and should meet the permeability criteria specified in Box 2.

Figure A1: Restricted development due to groundwater level constraint

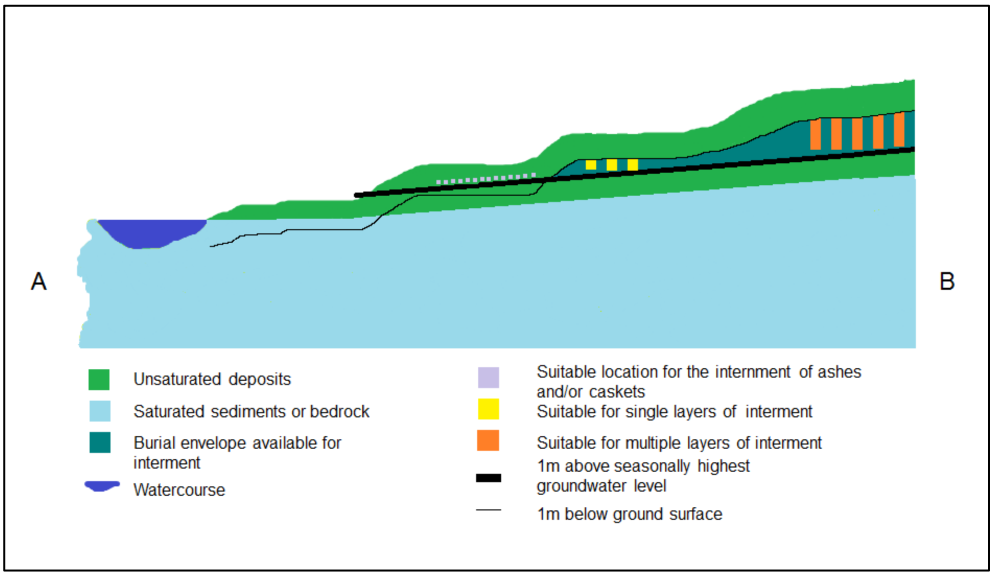
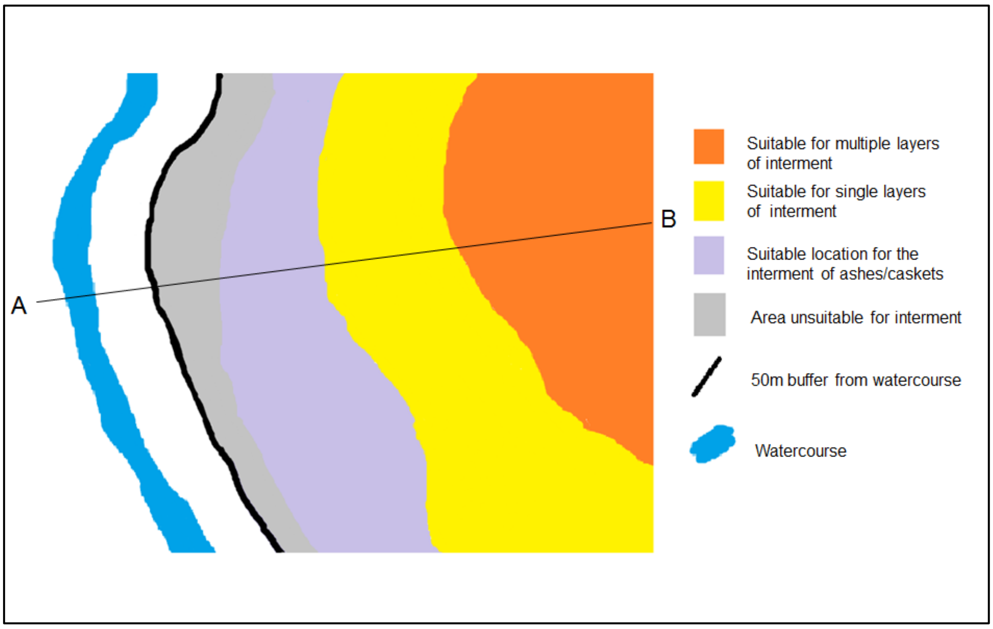


Figure A2: Zoned development appropriate to Figure A1



Option 3: Increase the depth to groundwater through passive drainage

Developers should note that passive drainage options may only rarely provide a viable development option. The cost of getting the assessment wrong may be high.

This methodology can however be applied where groundwater levels are marginally too high, rendering the site unsuitable. Where present this methodology utilises underlying permeable strata and artificial drains to lower the groundwater level to a point where the site meets the criteria outlined in Box 2.

Only sustainable passive drainage should be considered an appropriate drainage design. Soils within the footprint area may need to be engineered and homogenised to remove preferential flow pathways and the permeability requirements outlined in Box 2 should be applied. It is recommended that a numerical model be used to demonstrate the viability of the design. This should fully consider the local three-dimensional flow regime, including any vertical component of groundwater flow from the underlying soils or bedrock aquifer.

For the duration of cemetery use it is considered good practice for cemetery managers to maintain a discharge quality monitoring programme, to ensure that no consequential pollution of the environment occurs.

It is suggested that drainage maintenance, and financial provision for treatment, should be agreed by prior arrangement with the planning authority.

Option 4: Reduce pollutant loading

In many areas where conventional cemetery developments and burials are not possible or portions of a cemetery development site are unsuitable for normal development, alternative burial methodologies may prove appropriate for use either on their own or in conjunction with other measures.

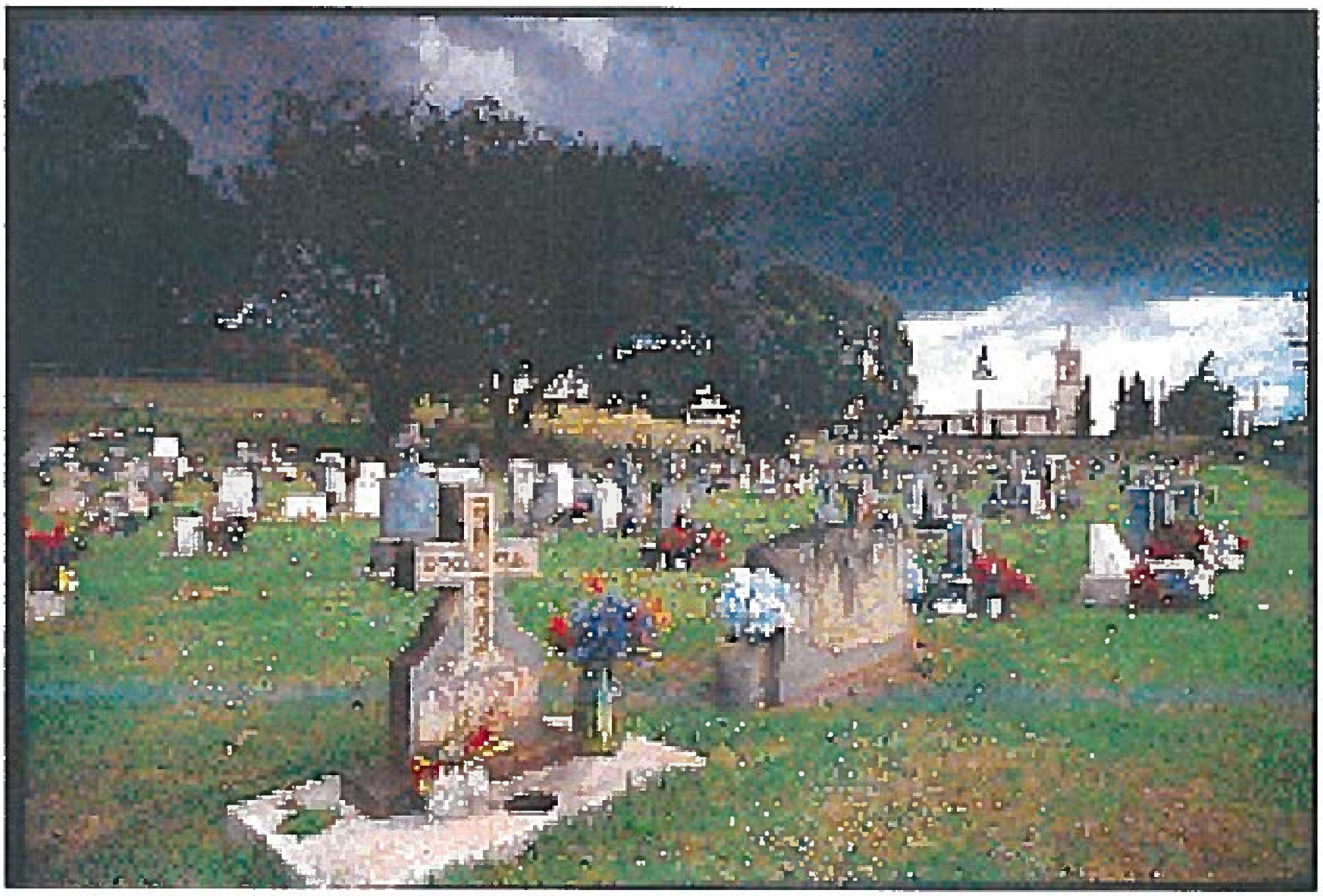
Burial chambers: Where soils are thin, groundwater levels shallow or the permeability of the strata too high, the use of burial chambers built of durable and impermeable materials may be considered (Suitable concrete may be C35A as defined in BS EN 1992-3:2006 or better). In these instances there is no need to demonstrate the potential for natural attenuation within the materials below the burial chamber.

Where the type of burial chamber proposed comprises fully sealed units, the potential for groundwater contamination would no longer be a consideration. This means the requirements in Box 2 can be disregarded.

Mother Jones

Dead in the Water

JOHN COOK JANUARY/FEBRUARY 1999 ISSUE



As navel-gazing Baby Boomers begin the last leg of their march toward the great yonder, it's no surprise that the business of death is coming under increased scrutiny. The popular reissue last year of *The American Way of Death*, Jessica Mitford's classic 1963 investigation of the funeral industry, as well as the rise of the do-it-yourself, "natural death" movement, suggest that boomers will not go gently into that good night.

Embalming involves filling the deceased's arteries and body cavities with formaldehyde (usually a 2 percent solution), which, although it makes a fine preservative, is a known carcinogen. What's more, the EPA regulates it as hazardous waste. If a funeral home discarded, say, 3.5 gallons of the stuff — roughly the amount needed to embalm the average adult — the EPA could slap it with a fine.

According to Kelly Smith of the National Funeral Directors' Association, embalming is "the rule of thumb" for the approximately 2 million bodies buried each year in the United States. That means we bury somewhere in the neighborhood of 7 million gallons of hazardous waste annually. Has anyone ever looked closely at what happens to all that formaldehyde? Not really.

EPA groundwater expert Kevin McCormack says that in the 1980s a White House groundwater task force considered cemeteries as one potential pollution source, but determined that the possibility of formaldehyde leaching from graves was not a major risk. "The level of concern was low," he says. But, he concedes, so was the amount of data. "We did no field research on [our] own," McCormack says. "I think we looked at some studies."

This scarcity of data gives some water quality experts pause. "Most technical people are very concerned about it," says Carl Hauge, chief hydrogeologist for the California Department of Water Resources. Hauge notes that arsenic, a popular embalming agent in the 19th century, has been showing up in groundwater in some areas, and many experts believe cemeteries are a contributor to the problem. If so, Hauge says, "then you'd expect that formaldehyde is going to be showing up, too. But as long as it isn't being detected, nobody really worries about it."

Of course, it's hard to detect something you're not looking for. EPA guidelines for municipal water authorities don't recommend testing for formaldehyde, and nobody in the U.S. is systematically monitoring groundwater near cemeteries. Even if formaldehyde did show up in drinking water, local agencies wouldn't know whether it posed a threat to human health — the EPA has not set a standard for how much formaldehyde is too much. Given its carcinogenicity, says one EPA drinking water official, the question of whether it stays inside graves or finds its way into the water supply is a good one, although he notes it would be a highly localized problem.

In Canada, Ontario's Ministry of the Environment conducted just such a study in 1992 and found low levels of formaldehyde, but said there was little cause for concern. The same year in Britain, however, researchers found an extremely high concentration (8.6 milligrams per liter) of formaldehyde in seepage water entering a freshly dug grave.

So is it really a threat? Scott Hill, water director for Riverton, Utah, believes it could be. In 1997, he unsuccessfully opposed a plan to build a new cemetery directly uphill from the city's wells because of concerns about formaldehyde. "A degree of hazard is there," Hill says. "Rainwater will carry contaminants with it."

Steel vaults, used in many states to encase coffins, may reduce risk. Still, no one knows how long leached formaldehyde lasts in soil, meaning that any potential health risks might not show up for decades. "Will the vaults last five years? A hundred years? I don't know," says Julie Weatherington-Rice, an environmental consultant who has studied arsenic in groundwater.

"[Formaldehyde] is going to show up," she says. "But it's going to take a while. We're probably drinking great-grandmother Maude right now more than we are someone who died last Saturday night."

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February 14, 2018

VIA EMAIL

Crystal Vanuch, Chairman
Stafford County Planning Commission
1300 Courthouse Road
Stafford, Virginia 22554

Re: Reconsideration of the Cemetery Ordinance adopted last year

Dear Ms. Vanuch:

This letter is being sent in advance of the meeting of the Planning Commission's Cemetery Subcommittee, scheduled for tomorrow, February 15, 2018. The Planning Commission was tasked by the Board of Supervisors on October 3, 2017 to review the changes in the County's cemetery ordinance enacted in December, 2016. Such review was requested based on concerns expressed by the AMAA (All Muslim Association America) that the additional setbacks adopted in 2016 would prohibit establishment of a new cemetery. AMAA members will be in attendance at tomorrow's meeting, and look forward to discussing their recommendations with the members of the committee.

The concerns involve new provisions inserted in the 2016 amendment to the Zoning Ordinance that exceed the existing State law. At all times pertinent to this issue, State law required a cemetery to be located a minimum of 250 yards (750 feet) from any residence that is not separated from the cemetery by a public highway. If the cemetery and the residence are separated by a state highway, the buffer or separation requirement is reduced to 250 feet. Most of the language approved as part of the 2016 amendment incorporates language from the State Code, but one new clause with two requirements exceeds the existing state law. AMAA recommends amendment of the new language to bring it in compliance with the State Code, as shown below:

Proposed Amendment

4. No cemetery shall be established within nine hundred (900) feet of any <u>property owned by any city, town or water company, upon which or a portion of which are now located driven wells from which water is pumped or drawn from the ground in connection with the public water supply</u>. ~~No cemetery shall be located within nine hundred (900) feet of any private well used as a drinking water supply.~~

Members of the AMAA (some of whom are residents of Stafford County) attended a Planning Commission meeting last year to express their concerns about these issues. Tomorrow's meeting with be the first time since then that the cemetery committee has met.

These increased buffers were not supported by the County's Environmental Health office during the Planning Commission's 2016 review. In an e-mail dated June 21, Tommy Thompson stated that "In my professional opinion and, according to the Regulations, if there is at least 100 feet of separation distance between the existing bored well and the proposed cemetery, there should be no public health problem created by a cemetery being installed."

The increased buffers were also not supported by Planning Director Jeff Harvey, who in fact recommended adoption of the same 100 foot buffer standard between a cemetery and a private well, as shown in the e-mail dated August 25, 2016. Retaining the 750 foot separation requirement currently in State law, or 250 feet when the uses are separated by a State highway, far exceeds the scientific recommendations of our local officials, and complies with State law.

Virginia Code Section 57-26 regulates cemeteries. It does not authorize a locality to impose more than a 700' buffer between a private well and a cemetery, or a 250' buffer if the two uses are separated by a state road. It also does not authorize a locality to impose a buffer restriction involving a perennial stream that flows to a terminal reservoir. Instead, the State language references land owned by a city, town, or water company which contains "driven wells". The language adopted in the 2016 amendments to the Cemetery Ordinance is far broader than authorized by the State Code.

Our research could not find any other local jurisdictions that imposed restrictions on the location of cemeteries that exceed the standards established by State law. Instead, control is limited to determination of the appropriate zoning districts for cemeteries.

Sincerely,

Debrarae Karnes

cc: Planning Commission
Jeff Harvey
Kathy Baker
AMAA

Anthony D. Toigo

From:	Thompson, Tommy (VDH) <Tommy.Thompson@vdh.virginia.gov>
Sent:	Tuesday, June 21, 2016 11:22 AM
To:	Anthony D. Toigo; Jeff A. Harvey
Cc:	Kathy C. Baker; Piraino, Violet (VDH); McCord, Brent (VDH)
Subject:	RE: Well water concerns on Garrisonville Road.

Our office has not been contacted. So, here are my comments!

I looked in our files and it appears that the well installed on this property was installed sometime around August or September 1977. The type of well that was typically installed at that time is a Class III C bored well. However, our records are incomplete concerning this well.

Virginia Private Well Regulations require a 50' minimum separation distance between an existing Class III B (drilled and grouted 50'+ with cement) and a cemetery. Typically these type wells (drilled) were not routinely installed in this time frame to serve private residences such as this one. However, these type wells are routinely installed today to serve private residences.

The Regulations require a 100' minimum separation distance between an existing Class III C Bored Well (bored with concrete casings and 0'-20' of cement grout). This is the type well that was routinely installed in this time period. Bored wells are no longer installed in Stafford to serve private residences as a source of drinking water.

In my professional opinion and, according to the Regulations, if there is at least 100' of separation distance between this existing bored well and the proposed cemetery, there should be no public health problem created by a cemetery being installed.

The local environmental office of the health department is not involved in the issuance of permits for cemeteries. Jeff Harvey's office is being contacted with this email so that they can see what our Regulations say and what our opinion is.

Let me know if I can be of further assistance.

From: Anthony D. Toigo [mailto:AToigo@staffordcountyva.gov]
Sent: Monday, June 20, 2016 9:29 AM
To: Jeff A. Harvey
Cc: Kathy C. Baker; Thompson, Tommy (VDH)
Subject: RE: Well water concerns on Garrisonville Road.

Jeff,

Thank you very much!

Anthony D. Toigo
Citizen Action Officer
Stafford County Board of Supervisors
Office of the County Administrator
Phone: (540) 658-4159
Email: atoigo@staffordcountyva.gov

RE: cemeteries and well water

McCord, Brent (VDH) <Brent.McCord@vdh.virginia.gov>

Wed 12/6/2017 2:32 PM

To: CLARK LEMING <LEMINGANDHEALY1@msn.com>;

Ms. Karnes,

I am not aware of wells that have been contaminated from adjacent cemeteries. The local Health Depts. permit private wells that serve private residences through the Private well regulations. We (local Health Dept) require newly constructed drinking water wells pass a standard water potability test that tests for a general type of bacteria known as Coliform. The water sample must be absent of Coliform bacteria in order for the local health Dept. to issue a well inspection report and approve the well for use. Most types of Coliform bacteria are not harmful, but some types are harmful (pathogenic). If a well fails this type of test due to the presence of Coliform bacteria it does not allow us to determine the source of the contamination and generally cannot determine where the source of contamination originated with this type of testing. Most time a failed Coliform test does not necessary indicate the source water is unsuitable, but some bacteria has gotten into the well or distribution system by some method. We generally would have the owner perform a onetime batch chlorination of the well and after a period of time flush the chlorine from the well and retest. A safe well water source will then deliver a water sample with satisfactory test results. The private wells regulations table 3.1 consider a cemetery a source of pollution and depending on the class of well designates a 100 ft. or 50 ft. horizontal separation distance between the well and cemetery.

The VDH Office of Drinking Water regulates public water wells and community water systems. http://www.vdh.virginia.gov/drinking-water/

I am not aware of a method to search our electronic database for well contamination related to sources of contamination since we generally do not have an ability to identify the pollution source of a private well that may be contaminated or not pass the potability test. Rarely do we have properly constructed wells that fail the standard Coliform water potability test.

It may be useful to identify some Churches in the area that have a cemetery and well on the property and note the separation distance and see if they are getting suitable well water sample test results. Some of these Churches that have a well as a source of drinking water have a daycare and are monitored by the Office of Drinking Water since they are classified as a Non-transient non-community (NTNC) water supply. I would contact the Culpeper regional office of Drinking water (540-829-7340) as they may be able to provide a listing that can searched. There is a listing of waterworks in Virginia monitored by ODW that you could search for a church with a well. You could filter by the counties in this immediate area. You can find it at http://www.vdh.virginia.gov/drinking-water/information-for-consumers/listing-of-waterworks-and-owners/

I am away from my office today, but can be reached by cell if necessary. 540-369-5184.

Brent McCord
Environmental Health Manager
Rappahannock Area Health District
1320 Central Park Blvd., Suite 300
Fredericksburg, VA 22401
Off. # 540-322-5933
Fax# 540-785-3407

Attachment 5
Page 4 of 13

Marcia C. Hollenberger

From:	Jeff A. Harvey
Sent:	Thursday, August 25, 2016 3:36 PM
To:	Wendy Maurer
Cc:	crystal vanuch (cvstaffordplanning@gmail.com); Keith C. Dayton; Mike T. Smith; Kathy C. Baker; Daniel J. Wisniewski
Subject:	RE: Cemetery Ordinance

Wendy:

We understand your concern. We looked at the 100 foot separation from a private well as a defendable standard. It is the maximum distance that the Health Department requires. State code provisions for cemeteries have a separation requirement from municipal wells but, there is no separation requirement from private wells. The Health Department standards are more restrictive.

Thanks,

Jeff

From: Wendy Maurer
Sent: Thursday, August 25, 2016 2:35 PM
To: Jeff A. Harvey
Cc: crystal vanuch (cvstaffordplanning@gmail.com); Keith C. Dayton; Mike T. Smith; Kathy C. Baker
Subject: Re: Cemetery Ordinance

Jeff,

I have serious heartburn that we are protecting public wells more than private wells. I don't care what the health department is willing to accept. If we won't let dead bodies around wells of water that is treated why would I allow it for untreated water?

Wendy

Sent from my iPhone

On Aug 25, 2016, at 2:27 PM, Jeff A. Harvey <JHarvey@staffordcountyva.gov> wrote:

> Wendy and Crystal;
>
> I am writing to follow-up on our previous conversations about changes to the cemetery ordinance. Please find attached draft ordinance text that I plan on discussing at the September 7th CEDC meeting. During preparation of the amendment, it was discovered that Chapter 8 of the County Code does not conform with State Code and should be repealed in its entirety. All of the cemetery related regulations except for entering a cemetery at night is being moved to the zoning ordinance. Of significant note is the proposed restrictions on burials. No burial would be permitted within 900 feet of a terminal reservoir or a perennial stream that flows to a terminal reservoir. This is similar to state code regulations that prohibit a cemetery within 300 yards of a municipal water well. Also, there would be no burials within 100 feet of any private well used for a water supply. This falls in line with Health

Department requirements. The minimum size of a cemetery is kept at 25 acres. The maximum size of 300 acres is from state code.

Please let me know if you have questions.

Thanks,

Jeffrey A. Harvey, AICP
Director of Planning and Zoning
Stafford County, Virginia
1300 Courthouse Road
P.O. Box 339
Stafford, VA 22555-0339
540-658-8668

<2016-08-25 Cemetery Ordinance (dw edits).docx>

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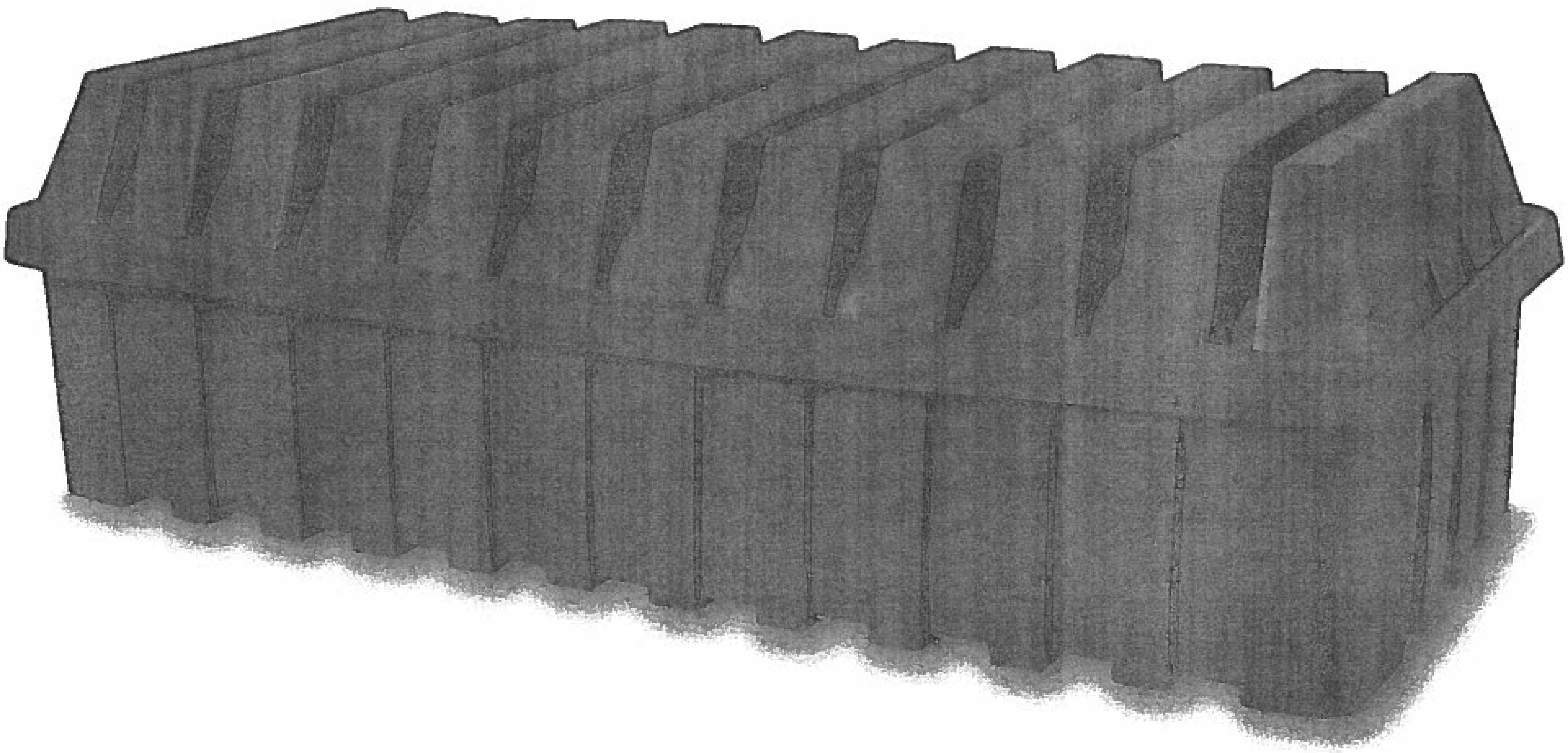

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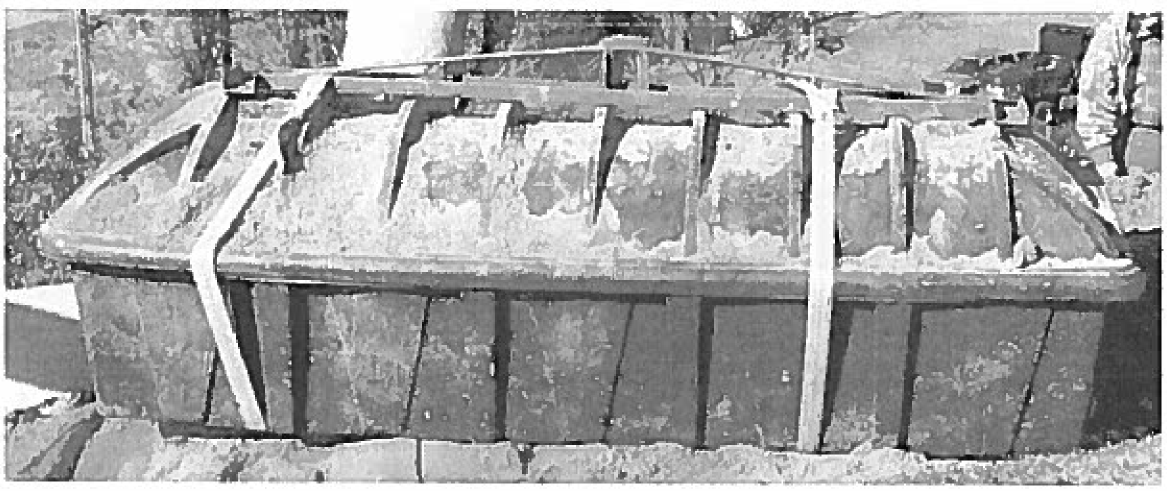
Sent from my Verizon, Samsung Galaxy smartphone

-------- Original message --------
From: mike@austinandbarnesfuneralhome.com
Date: 12/5/17 5:00 PM (GMT-05:00)
To: casketsalesinc@bellsouth.net
Subject: Polyliner

This is for Lauren.

This is a poly liner that had been buried for 12 years. It was completely intact, no damage. With a good bath it would look like new.

Mike



Jeff A. Harvey

From:	crystal vanuch <cvstaffordplanning@gmail.com>
Sent:	Sunday, December 03, 2017 10:12 AM
To:	Jeff A. Harvey
Cc:	Darrell E. English; Tom C; Daniel J. Wisniewski
Subject:	Fwd: Upcoming Free Lance-Star article regarding StaffordCountyCemetery regulation
Attachments:	Response to Kristin Davis.docx; ATT00001.htm

Jeff and fellow PC cemetery subcommittee members-

Please see below email from a resident in rockhill. I am sending along based on his request.

Jeff, would you mind providing these to have available for committee members to make part of the record on Wednesday's meeting?

Thanks so much,

CV

Sent from my iPhone

Begin forwarded message:

> **From:** Glenn Patterson <gpatterson01639@gmail.com>
> **Date:** December 3, 2017 at 9:56:03 AM EST
> **To:** Crystal Vanuch <cvstaffordplanning@gmail.com>
> **Cc:** "kdavis@freelancestar.com" <kdavis@freelancestar.com>
> **Subject: RE: Upcoming Free Lance-Star article regarding StaffordCountyCemetery regulation**
>
> Commissioner Vanuch,
>
> I learned on Thursday that Kristin Davis of the Free Lance-Star intended to write another article regarding the hearing process that is taking place with respect to Stafford County's cemetery ordinance. Since I felt that her September 19th article presented a completely biased and unbalanced viewpoint of what has transpired, I reached out to her and offered to provide her with some input from a different perspective than that of the AMAA. She replied to me a couple of hours later with a series of questions which I gave careful consideration to prior to providing her with my response. I sent Ms Davis my reply less than 24 hours later only to find in her reply yesterday that her deadline had already passed and she would be unable to include my input in her article. I'm more than a little unhappy with Ms. Davis, since she could easily have informed me that she was working on a deadline which would have provided me with an opportunity to reply in a timeframe which she could work with. I've just finished reading her latest article and I at this point I don't believe that Ms. Davis is interested in balanced reporting or journalistic integrity but would rather be a shill for the AMAA instead. Perhaps that sells more papers.
>
> The reason I'm contacting you is because I believe that Ms. Davis' questions, although biased, were reasonable and I answered them honestly. If it's possible, I0'd like to have her questions and my responses entered into the public record at Wednesday evenings cemetery subcommittee meeting. I've included all correspondence between myself and Ms. Davis to provide you with the full background and have attached an MS Word file with her questions and my responses. In the interest of fairness, I have copied her on this message.

Sincerely,

Glenn Patterson
8 Skywood Ct

From: Davis, Kristin
Sent: Saturday, December 2, 2017 10:13 AM
To: Glenn Patterson
Subject: RE: Upcoming Free Lance-Star article regarding StaffordCountyCemetery regulation

Hi Glenn,

Thank you for these responses. Unfortunately, I cannot get them into Sunday's story because my deadline has passed and the story was placed on the page Friday afternoon.

However, I will be covering the Planning Commission's Wednesday meeting and following this topic as it goes along, so I feel certain I can include many of your comments in upcoming stories. I thought your comments especially about how you served your country to protect everyone's rights was especially poignant – and how it wouldn't matter what cemetery was going in across the street, you'd still be opposed to it.

Please feel free to call or email anytime.

Thank you,

Kristin

From: Glenn Patterson [mailto:gpatterson01639@gmail.com]
Sent: Friday, December 1, 2017 7:35 PM
To: Davis, Kristin
Subject: RE: Upcoming Free Lance-Star article regarding Stafford CountyCemetery regulation
Importance: High

Ms Davis,

I have taken your questions and put them into a MS Word document which is attached. I did this to make it a bit easier to separate your questions from my responses. Please let me know if you have any difficulty in reading them in Word format and I can send them as plain text.

I've tried to be as complete as possible but, if I've left anything unclear, please don't hesitate to send follow-up questions. I think it's extremely important that your readership get a balanced picture of this issue. I firmly believe that your September 19th article was lacking in that regard.

Sincerely,

Glenn Patterson
8 Skywood Ct.

Stafford, VA 22556
(703) 595-2777

From: Davis, Kristin
Sent: Thursday, November 30, 2017 8:03 PM
To: Glenn Patterson
Subject: RE: Upcoming Free Lance-Star article regarding Stafford CountyCemetery regulation

Hi Mr. Patterson,

Thank you for reaching out. If you'd like to weigh in on any of these questions, I'd be glad to hear from you, since you are also a neighbor of the cemetery that was proposed.

I sent these questions to Mr. Silver, but again, if you'd like to respond as another neighbor who is also concerned about well water quality, then I'd be glad to quote you.

1. Do you recall how you heard about the cemetery that was planned across the street from you?

2. Have you had any other concerns about the safety of your drinking water, or was it the planned cemetery that first got you thinking about the issue?

3. Do you recall what it was about a cemetery that made you concerned about contamination? Had you heard about other cases in which cemeteries had created a problem for people who got their water nearby?

4. I understand that water stands in your yard after heavy rains and that you were concerned about contamination a cemetery might pose, which I've included in my story. That's pretty self-explanatory, but is there anything else you want to add about your concerns?

5. Are you satisfied with the new ordinance?

6. The association that wanted to build the cemetery is a Muslim organization and has suggested that if it was a Christian cemetery, there would have been no issues. Does the religion of those buried in the cemetery have anything to do with your concerns? (To be clear, I have seen or heard nothing to suggest this, but since it was brought up, I wanted to make sure you at least had the opportunity to respond.)

Thank you again. I appreciate your time and willingness to respond.

Kristin

From: Glenn Patterson [gpatterson01639@gmail.com]
Sent: Thursday, November 30, 2017 5:17 PM
To: Davis, Kristin
Cc: Dave Silver
Subject: Upcoming Free Lance-Star article regarding Stafford County Cemetery regulation

Ms Davis,

I spoke with my neighbor David Silver a short while ago and he indicated that you had contacted him regarding an article which you will be writing soon. I know that Dave has been pretty busy lately and may be for some time in the near future. If you have specific questions which you'd like answered, I may be able to assist you in that. Please reply to this message with any questions you may have and I will try to respond expeditiously.

Thank you

Glenn Patterson
8 Skywood Ct
Stafford, VA 22556

Project Name: Code Amendment for Merchant's Capital Tax Date Presented to the CEDC: July 10, 2018

Current Situation

- On October 17, 2017 in a unanimous vote the Stafford County BOS passed the Resolution on legislative issues for the Commonwealth's General Assembly. Within that Resolution was the following:
- Taxation--Tax Rate for Distribution Companies to "Petition the General Assembly for the creation of a new sub-category within the merchant's capital tax category to give localities the option to set a lower tax rate for distribution companies."
- This past session the General Assembly enacted § 58.1-3510.02 in regards to the Merchant Capital Tax (MCT). The new law allows:
  - The separation from MCT of wholesaler who's inventory is located in structure of 100,000 square feet or more.
  - A local unit of government may levy a tax of such inventory at a different rate than others MCT

Proposed End State

- Consideration by the Board of Supervisors to consider lowering the MCT for such size facilities (August\September BOS meeting)

Request for the CEDC Committee/Board of Supervisors

- Staff would like to brief the CEDC on the use of this legislation to further the goals and objectives of our Economic Development Strategy, interest in Stafford as a hub of high-value, high-volume warehouse\distribution facilities, and hypothetical examples of the use of this incentive.
- Our briefing is for discussion and input from the CEDC for clarity on bringing to the Board at a future meeting

Benefits to the County

- Statement for purposes of business attraction that Stafford is open and encourages large-scale warehouse and distribution projects.
- Put on record and notice for potential interested developers that Stafford is encouraging these projects.

Due to the limited time for CEDC Meetings, please limit the salient points of your presentation to this single slide. Backup slides may be submitted for additional reference but may or may not be reviewed during the presentation. We ask that presenters limit their presentations to 10 minutes or less.

STAFFORD Virginia

Project Name: Code Enforcement Procedures

Date Presented to the CEDC: July 10, 2018

Current Situation

- Zoning Technicians enforce Chapter 28 of the County Code which is the Zoning Ordinance. They also inspect and process violations for tall grass (Chapter 24), accumulation of trash (Chapter 21), and the keeping of inoperative vehicles on private property (Chapter 15)
- Enforcement is on a complaint basis
- Complainants may leave their name or may remain anonymous
- We currently accept anonymous complaints which comprise approximately 20% of all complaints received

Proposed End State

- Identify the Committee's preference on anonymous complaints

Request for the CEDC Committee/Board of Supervisors

- Review of Comparative Localities
- Determine whether or not to continue to accept anonymous complaints

Benefits to the County

- Anonymous complaints allow the public to refer violations to the County without fear of retaliation from the violator
- Anonymous complaints may allow a citizen to use the County as a means to antagonize a neighbor, removal of this option would allow the County to optimize staff time for legitimate complaints

Due to the limited time for CEDC Meetings, please limit the salient points of your presentation to this single slide. Backup slides may be submitted for additional reference but may or may not be reviewed during the presentation. We ask that presenters limit their presentations to 10 minutes or less.

George Washington's Boyhood Home

Comparison Chart

Jurisdiction	**Zoning Violation**	**Trash Violation**	**Inoperative Vehicle**	**Anonymous Complaints**
Stafford – Civil penalties	Notice to comply, 30 days, court*	Notice to comply, 14 days , remove trash, bill violator	Notice to comply, 15 days, towed, billed for cost, dispose of after additional 21 days notice	Yes
Prince William – Criminal and Civil penalties	Criminal, Notice to comply, 30 days, court*	Civil, Notice to comply, 30 days, court*	Civil, Notice to comply, 30 days, court*	No
Spotsylvania – Criminal penalties	Notice to comply, 30 days, court*	Notice to comply, 7 days, court*, class 2 misdemeanor	Notice to comply, 14 days, court*, class 1 misdemeanor	Yes except overcrowding
Albemarle – Civil and criminal penalties	Notice to comply, 30 days, Court	Notice to comply, Remove trash, bill violator	Notice to comply, remove vehicle and dispose of after reasonable notice	No
Fauquier – Civil penalties	Notice to comply, 30 days, court*	Notice to comply, 30 days, court*	Notice to comply, 30 days, court*	Yes
Loudoun – Civil penalties	Notice to comply, 30 days	10 days to comply	10 days to comply, issue ticket	No
Hanover – Criminal penalties	Notice to comply, 30 days, court*	Notice to comply, 30 days	Notice to comply, 30 days, Court*	No

*Jurisdiction works with the violator to achieve compliance, court proceedings are only pursued if the violator does not show acceptable progress towards compliance.

Current Zoning Enforcement Procedures

Complaint is received via mail or phone call, information needed in complaint

- Nature of complaint
- Address of occurrence
- Name of complainant if provided

Assigned to appropriate inspector

The information is entered into the Hansen tracking system

- Date of complaint
- Address of complaint
- Details of complaint

The property is then researched –

- Zoning
- Approved zoning case
- Proffered conditions
- Approved use permit
- Approved site plans etc.
- Previous zoning violations

A site visit is performed to confirm violation and take photos

- Violations must be observed by officer in order to give legal testimony in court if necessary.
- The officer may enter the property and go to the front door. Whatever he sees from that vantage is evidence.
- The officer may not enter property if “no trespassing” signs are posted, but may observe from the road or from adjacent property with permission of the owner(s).
- The officer shall take pictures for evidence.
- Any conversation with the property owner/occupant is also evidence and shall be documented.
- All information is entered into the existing file in the Hansen system.

If a violation is observed, the inspector will contact the property owner either by phone, email or in person to discuss the violation and how to correct it.

If contacted and the property owner states the violation will be corrected, the inspector will scheduled a site visit for one week from that date of contact to verify compliance.

If compliance is not observed on this site visit, a notice of violation (NOV) is issued. It will be sent to the property owner and/or the tenant of the property via certified mail or service by the Sherriff. The NOV states 30 days to correct the violation or appeal** the order.

The inspector will also update the complainant on status of their complaint.

A re-inspection of the site is made once a week by the enforcement officer until the thirty (30) day compliance date. If the site is in compliance, the case is closed.

If the owner/occupant has not achieved compliance*, the case will be turned over to the county attorney to pursue legal action.

* Should the owner/occupant contact the officer to request additional time, the issue is discussed with the Zoning Administrator to determine the best action at that time. Additional time may be granted if all parties involved think the violation will be eliminated if additional time is given.

**Appeals of zoning violations are heard by the Board of Zoning Appeals

If you have any questions, please call Melody Musante, Deputy Zoning Administrator, 540-658-8668.

Current Inoperable Vehicle Enforcement Procedures

Complaint is received via mail or phone call, information needed in complaint

- Nature of complaint
- Address of occurrence
- Name of complainant if provided

Assigned to appropriate inspector

The information is entered into the Hansen tracking system

- Date of complaint
- Address of complaint
- Details of complaint

The property is then researched

- Zoning
- Prior code violations

A site visit is performed to confirm violation and take photos

If violation is observed, notice is sent to property owner

The inspector will schedule a site visit 8 days from that date of contact to verify compliance.

Perform compliance inspection. If vehicle(s) have not been removed, The Board of Supervisors, through its agents or employees, may remove any such inoperable vehicle after 15 days' notice by certified mail or personal delivery.

If the Board decides to have the vehicle removed. The bill is received from the towing company, processed by staff and sent to the property owner for payment. If the bill is not paid by the property owner, it is then assessed on the real estate tax bill

Information in Hansen is updated as activity is performed.

**** Note: Planning and Zoning Staff has not been authorized by the Board of Supervisors to tow inoperable vehicles from private property at this time. Each issue may be considered on a case by case basis. Staff will work with the violator to encourage compliance before bringing the issue to the Board.*

Current Trash Violation Enforcement Procedures

Complaint is received via mail or phone call, information needed in complaint

- Nature of complaint
- Address of occurrence
- Name of complainant if provided

Assigned to appropriate inspector

The information is entered into the Hansen tracking system

- Date of complaint
- Address of complaint
- Details of complaint

The property is then researched –

- Zoning
- Acreage of property
- Previous complaints

A site visit is performed to confirm violation and take photos

If violation is observed, notice is sent to property owner

The inspector will scheduled a site visit 8 days from that date of contact to verify compliance.

Perform compliance inspection, if trash is not removed, the inspector will schedule a contractor to remove the trash

Bill is received from the contractor, processed by staff and sent to the property owner for payment. If the bill is not paid by the property owner, it is then assessed on the real estate tax bill

Information in Hansen is updated as activity is performed

Current Grass Violation Enforcement Procedures

Complaint is received via mail or phone call, information needed in complaint

- Nature of complaint
- Address of occurrence
- Name of complainant if provided

Assigned to appropriate inspector

The information is entered into the Hansen tracking system

- Date of complaint
- Address of complaint
- Details of complaint

The property is then researched –

- Zoning
- Occupied or vacant
- Acreage of property

A site visit is performed to confirm violation and take photos

If violation is observed, notice is sent to property owner

The inspector will scheduled a site visit 8 days from that date of contact to verify compliance.

Perform compliance inspection, if grass is not cut, the inspector will schedule a contractor to the grass cut grass

Bill is received from the contractor, processed by staff and sent to the property owner for payment. If the bill is not paid by the property owner, it is then assessed on the real estate tax bill

Information in Hansen is updated as activity is performed

Project Name: Short Term Rentals

Date Presented to the CEDC: July 10, 2018

Current Situation

- Approximately 70 dwellings within the county are currently advertised for short term rentals – Airbnb, Homeaway, VRBO, etc.
- The zoning ordinance does not currently provide for short term rentals in dwellings
- Short term rentals are defined in State Code as lodging for less than 30 days
- Short term or transient rentals are only permitted in hotel/motel structures and approved bed and breakfast inns

Proposed End State

- Property owners will be aware of regulations in the zoning ordinance
- Notices of violation will be issued for non-compliance
- Residential neighborhoods will not be impacted by transient rental occupation

.

Request for the CEDC Committee/Board of Supervisors

- State Code allows for the locality to regulate the short term rental of property in residential zones through general land use and zoning authority
- If Committee does not recommend changes, we recommend a pro-active strategy to achieve compliance with the current regulations
  - Notify properties on rental lists by mail of regulations
  - Issue notice of violation of non-compliance
  - Monitor properties on rental sites

Benefits to the County

- Transient rentals will be located within the hotels, motels and bed and breakfast establishments
- Residential neighborhoods will not be impacted by transient rental occupation
- Proper collection of taxes will be ensured

Due to the limited time for CEDC Meetings, please limit the salient points of your presentation to this single slide. Backup slides may be submitted for additional reference but may or may not be reviewed during the presentation. We ask that presenters limit their presentations to 10 minutes or less.