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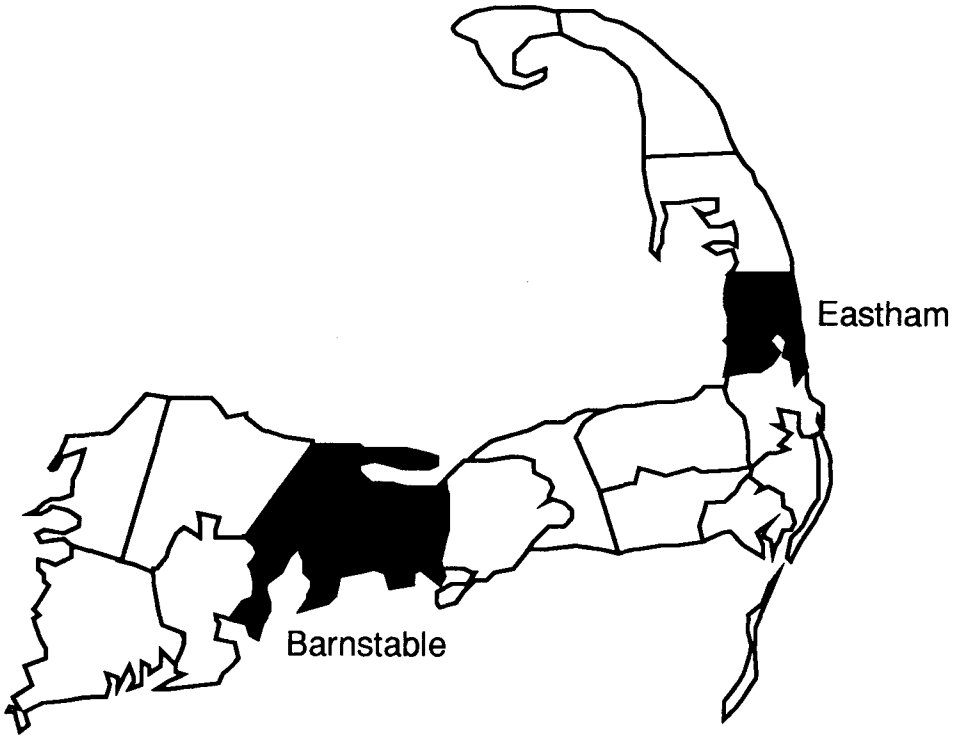
THE CAPE COD AQUIFER MANAGEMENT PROJECT (CCAMP)

Executive Summary



CCAMP WAS UNDERTAKEN BY:

U.S. ENVIRONMENTAL PROTECTION AGENCY, REGION I
U.S. GEOLOGICAL SURVEY, MASSACHUSETTS DISTRICT OFFICE
MASSACHUSETTS DEPT. OF ENVIRONMENTAL QUALITY ENGINEERING
CAPE COD PLANNING AND ECONOMIC DEVELOPMENT COMMISSION

IN COOPERATION WITH:

THE TOWN OF BARNSTABLE AND THE TOWN OF EASTHAM

SEPTEMBER 1988

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THE CAPE COD AQUIFER MANAGEMENT PROJECT (CCAMP)

EXECUTIVE SUMMARY

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SEPTEMBER 1988

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

DATE: November 22, 1988

SUBJECT: Distribution of Cape Cod Aquifer Management Project Reports

FROM: Robert E. Mendoza, Chief
Ground Water Management and Water Supply Branch, Region 1

TO: Ground Water Office Directors
EPA Regions 2-10

Enclosed please find a full set of reports from the Cape Cod Aquifer Management Project (CCAMP). This has been a two year cooperative project between federal, state, regional and local agencies concerned with developing a comprehensive, resource based approach to ground water protection. Although the work took place in Massachusetts, I believe there are numerous institutional issues and opportunities, as well as new techniques and methods for evaluating ground water protection measures, which are applicable throughout the Country.

The CCAMP project has provided us with many insights into wellhead protection efforts which may be applicable in your region as well. The technical reports, including the Guide to Contamination Sources in Wellhead Protection Areas and the Mass Balance Nitrogen Loading Model were written to help local governments specifically in their protection efforts. The GIS report has certainly been of use within our office in helping to identify opportunities and problems associated with the technology. I think it will also be helpful to states and regional agencies considering such an investment.

If you have any questions or would like to discuss this project further, please give me a call.

Executive Summary

The Cape Cod Aquifer Management Project (CCAMP) was initiated in September, 1985 for the purpose of examining the effectiveness of the way in which the groundwater resource was being protected. Concerns surrounded the fact that since 1960, over 100 public water supplies in Massachusetts were contaminated from a variety of sources, and the trend was toward steadily increasing occurrences. CCAMP was designed as an intergovernmental project with the participating agencies being: U.S. Environmental Protection Agency, Region I (EPA); Massachusetts Department of Environmental Quality Engineering (DEQE); Cape Cod Planning and Economic Development Commission (CCPEDC); and the U.S. Geological Survey (USGS).

Cape Cod was chosen as the focus of the project because of its regional attributes - common hydrological and geographical characteristics, as well as its sole source aquifer. In addition, an abundance of technical information on thegroundwater resource existed for the Cape, and it was readily available.

CCAMP participants began their work with the following suppositions:

(1) Prevention not correction is the proper groundwater management approach

(2) The present institutional arrangement for protecting groundwater was ineffective due to a fragmented regulatory process

(3) A comprehensive resource - based approach to groundwater management, rather than individual source by source controls, was the preferred method

(4) Greater knowledge and improved data is required at the local level for land use decision-making

The Study Area

CCAMP chose the towns of Barnstable and Eastham to test and advance these suppositions. They were selected as the specific study area because they represent the spectrum of problems facing Cape Cod communities. Barnstable, a large, highly developed town with extensive public water supplies exemplifies the challenge facing much of Cape Cod - balancing inappropriate land use decisions of the past (and present) with existing and future water supply needs. To a large degree, groundwater protection in

Barnstable must become dependent on risk management analyses. An approach that controls existing sources of contamination and clearly identifies and provides special attention for the highest risk activities should be adopted. With this in mind, CCAMP's efforts in Barnstable focused on resolution of land use/water supply conflicts.

Eastham is a rural community removed from population centers and totally dependent on private wells and on-site wastewater disposal systems. Small lot zoning in all residential sections of town has caused attention to focus on a potential need for public water. Although Eastham has completed no long range planning, it does not approach the array and magnitude of groundwater protection issues confronting Barnstable, and has greater flexibility in controlling and siting inappropriate land use activities. Considering Eastham's situation, CCAMP concentrated on providing technical assistance to help the town better comprehend its environmental condition, so that practical groundwater protection goals could be met.

Resource - Based Approach

A central theme of this project was that programs at the federal, state and local levels of government designed to protect groundwater tend to focus on individual sources of potential contamination without an awareness of all other possible sources. Moreover, work is often conducted without a full understanding of the resource that requires protection. Controlling pollution at the source is important, but environmental agencies must never lose sight of the nature of the resource to be protected and then designing proper programs to accommodate the need . CCAMP strived for establishing new institutional arrangements among levels of government, and producing unique management tools so that a truly resource-based approach to groundwater protection could be implemented. Using Barnstable and Eastham as the laboratory, the project attempted to refine the way groundwater is managed on Cape Cod.

Several years ago hydrogeologists searching for ways to streamline the areas in need of intensive protection, developed the Zone of Contribution (ZOC), or the aquifer area that directly feeds the public supply well. DEQE refers to this area as Zone II and EPA calls it the Wellhead Protection Area. CCPEDC was a pioneer in this area delineating all the ZOCs for the Cape's public supply wells in 1983. The protection of ZOCs is not without hydrogeologic complexities and political and economic liabilities however. One problem is that several hydrogeologic assumptions must be made to delineate ZOC boundaries. As an estimate, these boundaries are open to debate and revision. A second problem is that the ZOC often contains sources of contamination.

Prevention techniques are still highly experimental, but they are developing rapidly. Promising innovative measures are emerging such as land use planning models that indicate if development will result in an overload of certain contaminants. A realistic prevention strategy is premised on determination of the level of risk that is acceptable, i.e., the levels of contaminants that will be tolerated and those that are considered excessive. Different types of measures are appropriate for different potential sources. It may be sufficient to limit the density of certain land uses, while prohibitions may be required for others. In the same way, certain contaminants are highly mobile and require other types of controls.

The resource-based approach is an attempt to both refine and advance a prevention-oriented philosophy. It features the following components:

(1) Thorough characterization of the aquifer system so that the ZOC for the public well can be delineated as accurately as possible.

(2) A comprehensive inventory of all potential sources of contamination located within the ZOC.

(3) Assessment of the federal, state and local controls in place for the regulation of all sources.

(4) A strategy for protecting the well based upon relative risk from individual sources, cumulative impacts from several sources, and possible future problems from potential sources.

The findings, recommendations and management tools that follow describe CCAMP's attempt to facilitate implementation of the resource-based approach to groundwater protection.

Resource Characterization

Because of the extreme importance of precisely portraying the aquifer system so that accurate ZOCs could be delineated, CCAMP concentrated much of its work in this highly technical area. Project participants worked closely with Barnstable town planners to help them understand their town's groundwater system and how to protect it. CCAMP produced a detailed map showing the shape and elevation of the water table for the eastern half of Barnstable and part of the neighboring town of Yarmouth (which contains areas of recharge to Barnstable wells). In addition to portraying its ZOCs, this water table map will be invaluable to the town as it investigates future contamination sites, decides

where to locate various land uses and sites new public wells. CCAMP emphasized the importance of understanding water levels and flow direction in an aquifer - it is a prerequisite for any groundwater study and the first step in resource-based management. The project provided its approach to water table mapping and detailed the methodology in its full report.

As mentioned previously, several hydrogeologic assumptions must be made to delineate ZOC boundaries which makes them vulnerable to debate and revision. Such a situation exists in Barnstable where both CCPEDC and a consulting firm have mapped the town's ZOCs. While the two maps present similar delineations they are distinctly different. They are difficult to compare in detail however, because different input data were used during modeling. CCAMP concluded that either method can yield an approximate ZOC delineation, but that the need for credibility demands the development of standard criteria. Further, input data are subject to judgmental variation, and perhaps manipulation, which can seriously alter the resultant delineations. The most sensitive of these factors are: recharge rate, withdrawal rate, and initial water table conditions. There is a definite need to establish standard criteria for assigning values to these factors and for assigning aquifer transmissivity as well.

CCAMP also observed that analytical techniques such as those used in Barnstable are useful for preparing initial, simplified estimates of the impacts from pumping, however they are incapable of simulating complex aquifer conditions. Analytical techniques do not account for multiple withdrawal and recharge points, boundary conditions, spatial and directional variation of aquifer properties and recharge, multilayered aquifer systems, and partially-penetrating wells. Numerical models, however, can integrate these variables yielding a higher level of confidence in modeling predictions. A demonstration of three-dimensional groundwater modeling was recommended by CCAMP to add critical knowledge to the aquifer characterization process.

As a result, a three dimensional modeling project was approved and cooperatively funded by USGS, DEQE, CCPEDC and the Massachusetts Department of Environmental Management (Division of Water Resources). The project will be completed in 1989 and contains the following objectives:

(1) Demonstrate the use of the USGS modular three-dimensional groundwater flow model to delineate recharge areas to wells under a range of recharge and pumping conditions.

(2) Describe the data acquisition requirements and costs for the demonstration models so they can be used to compare the relative benefits and costs of this approach with

other analytical approaches.

(3) Prepare a plan for model verification with future water level data to enable further evaluation and refinement of the models.

(4) Apply the models to existing conditions in Barnstable and planned future development conditions in Eastham.

Land Use Inventory

Important relationships exist between the types of land uses that occur within a Zone of Contribution to a public well and the quality of water pumped from that well for public use and consumption. Certain land uses, although conforming with local zoning, have the potential to contaminate groundwater. Therefore, local officials and water purveyors need a complete inventory of information concerning land use characteristics in order to achieve water resource management goals. CCAMP adopted the land use inventory as a basic element of the resource-based approach, and undertook an intensive land use study within one ZOC in Barnstable. The inventory was comprehensive, including the identification of underground storage tanks, toxic and hazardous material storers and class V injection wells among others. Field surveys were used to confirm information and identify potential contaminant sources, such as the location of injection wells. By characterizing all existing land uses and resulting risks to the groundwater, it was possible to evaluate the effectiveness of existing management programs and to design a more integrated protection strategy that addresses those land uses posing the greatest threats.

The ZOC that CCAMP studied surrounds nine public supply wells, six future wells and presently provides 31% of the town's water. It encompasses 3650 acres within two towns - Barnstable and Yarmouth, and is the most highly developed commercial area on Cape Cod. It was chosen because it presents a groundwater management scenario representing the greatest threat of potential contamination imaginable. The methodology used for the prototype effort has been well documented and was recently implemented for a ZOC in the town of Chatham. A townwide land use inventory and management analysis is planned for Truro and it is hoped that many more will be conducted both on and off Cape Cod.

Management Tools

Contamination from nitrates is one of the most widespread threats to groundwater quality on Cape Cod. Nitrate acts as a conservative chemical species in groundwater because it is not sorbed by aquifer materials. The principal mechanism by which nitrate is attenuated is through dilution. It has also been demonstrated

that nitrate is an indicator of the presence of other anthropogenic contaminants.

CCAMP reviewed and found inadequate the current guideline of limiting one house per acre as a protective measure against exceeding the nitrate standard. As a result, the project developed an approach for evaluating the cumulative impacts of nitrogen-contributing land uses on drinking water quality. This nitrogen loading methodology was created to allow town planners and land managers an opportunity to recognize the level of incremental development that will cause nitrate concentrations in municipal wells to exceed planning goals or health-based standards. If used properly this model provides a technical basis for evaluating future development strategies and comparing trade-offs between various land uses within ZOCs.

Another valuable tool developed by CCAMP to provide usable technical information to assist in groundwater management, is a guide to sources of contamination. This handbook contributes background information on common land uses and their associated contaminants for use in the development of sound wellhead protection strategies. Detailed information on 18 contaminant classes and 35 common land use categories is provided. The guide covers: the threat each land use may pose, key examples of products that contain particular contaminants, common usages and the fate of the contaminants in soils and groundwater. It also contains information on best management practices that should be encouraged for each land use.

The guide will assist local officials as they attempt to site land uses in sensitive areas including ZOCs. A handy accompanying matrix will allow for immediate assessment of which land uses provide the greatest threat to groundwater; the nature of that threat, the contaminants involved, their toxicity and mobility in groundwater. This will help determine those businesses that should be prohibited or strictly controlled by aquifer protection bylaws. The guide will also assist in the investigation of sources of groundwater contamination.

Cape Cod is rich in hydrologic, geologic and environmental data, particularly contamination-source data, in mapped and tabular formats, and CCAMP added significantly to the wealth of available information. The need to screen large amounts of these data quickly and accurately for the purpose of determining potential risks to water supplies from existing and potential contamination sources became evident early in the project. It was agreed that Geographic Information System GIS technology would provide the advanced data handling, manipulation,and display capabilities necessary to facilitate the required analysis.

As a result, a cooperatively funded project between USGS, DEQE and CCPEDC using GIS technology was initiated with the major

objectives being:

(1) To analyze and illustrate spatial relations between land use, well sites, and existing and potential contamination sources.

(2) To establish a comprehensive data base for the study area and provide a template for a potential Capewide geographic information system.

The project concentrated on the development of a digital data base for the same Barnstable ZOC that was examined through the land use inventory, and for a portion of Eastham. However, the heart of the GIS effort revolved around the development of a series of risk assessment scenarios intended to demonstrate the powerful application capabilities of the technology. The scenarios that have been portrayed are:

(1) Identification of potential risk to public supply wells from complete development

(2) Application of the nitrogen loading formula

(3) Ranking of risk from underground storage tanks

(4) Ranking of landfills for clean up

(5) Screening for a potential stump dump site

(6) Management issues within an intertown ZOC

(7) Implication of a one-half mile radius around a well versus a delineated ZOC

(8) Siting of a one million gallon per day public well

GIS should provide the focal point for a truly inter-governmental regulatory approach to groundwater management in the future. As with the other management tools, GIS maps will be especially useful to local officials as they make critical land use decisions. The following figures illustrate examples of GIS products produced as part of the demonstration project. First GIS was employed to generate professional quality maps of pertinent ground water related data as shown in Figure 1. Subsequently, it was utilized to undertake, and display the results of the risk asssessment scenarios described. Figure 2 illustrates one of the factors considered in the ranking of risks posed by underground storage tanks.

POTENTIAL GROUNDWATER CONTAMINATION SOURCES, AND ZONES OF CONTRIBUTION

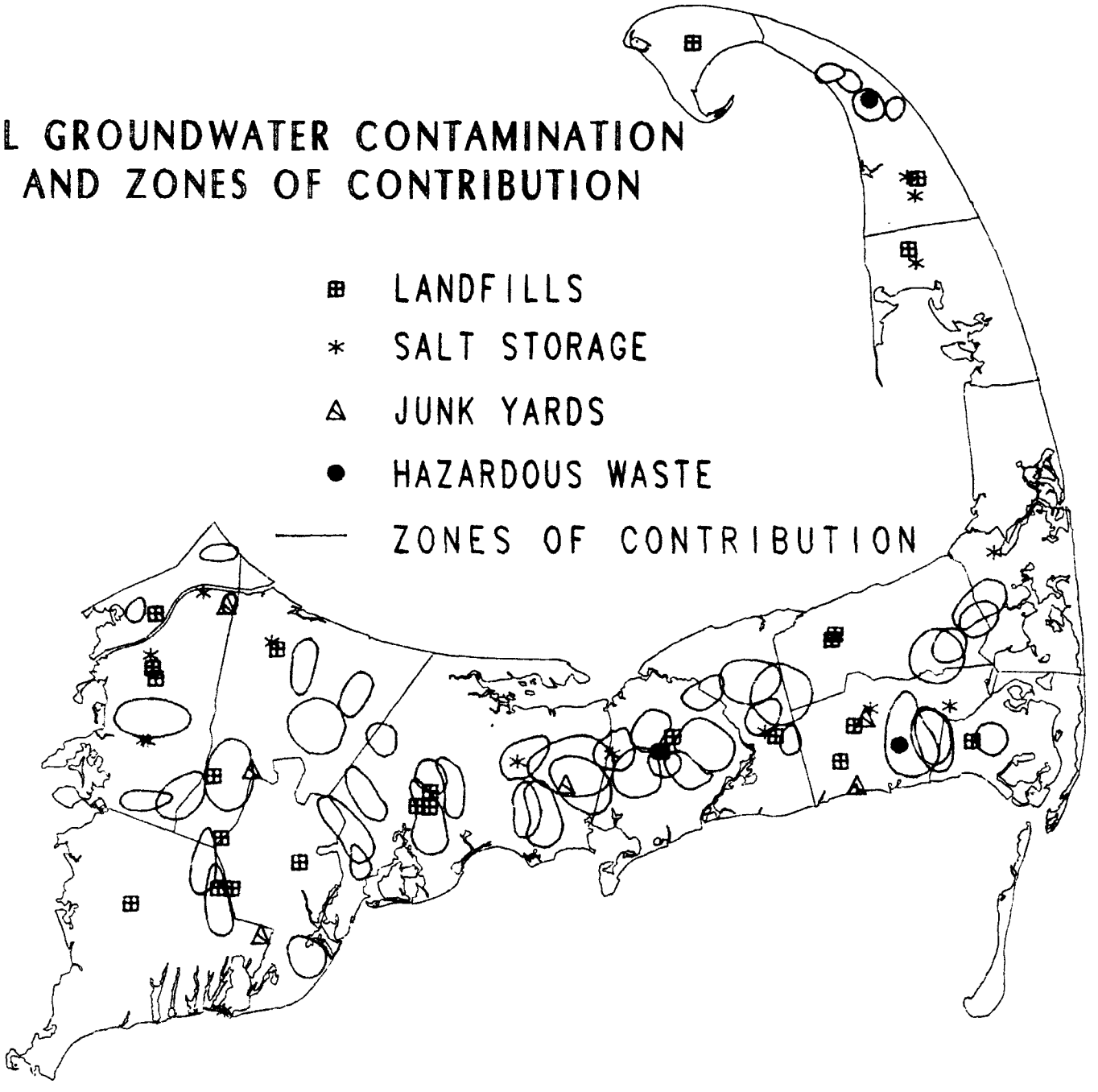
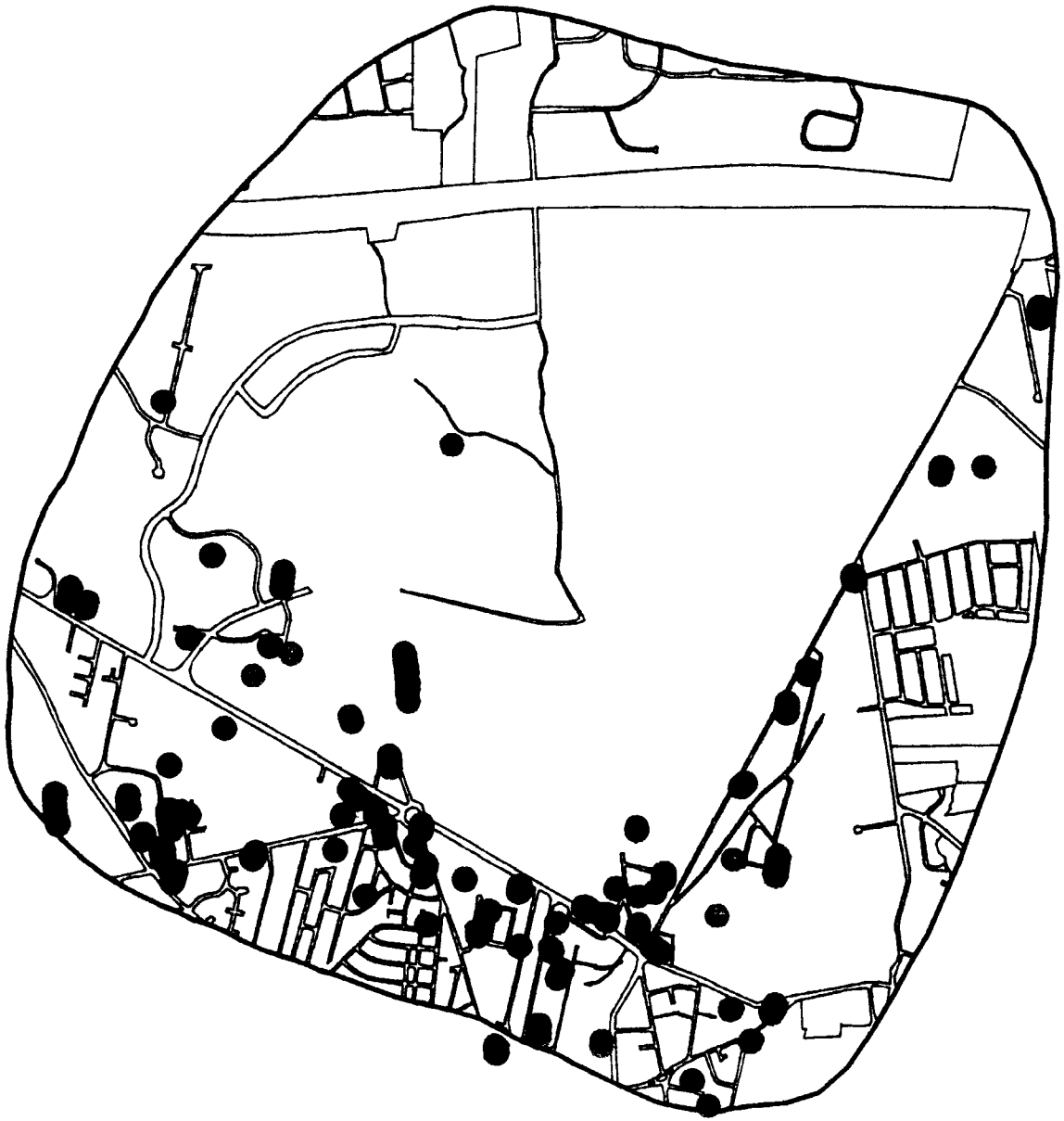


Figure 1

UNDERGROUND STORAGE TANKS WITHIN THE BARNSTABLE ZONE OF CONTRIBUTION



AGE OF UNDERGROUND STORAGE TANKS

- < 20 YEARS
- ≥ 20 YEARS

ROADS

Figure 2

Institutional Change

One of CCAMP's initial suppositions was that the present institutional arrangement for protecting groundwater is ineffective due to a fragmented regulatory process. An investigation of procedures and regulations presently being implemented by agencies at the federal, state and local level clearly supports this supposition. A leading problem concerns the common bureaucratic approach of managing groundwater on a program by program basis. This tends to narrow the management focus and results in an emphasis on individual sources of contamination rather than the resource itself. Another major problem is the serious lack of communication between levels of government that erodes the necessary coordination which must continuously exist to insure effective management.

CCAMP produced extensive sets of recommendations intended to strengthen the protection afforded groundwater by existing programs. These cover the following program areas:

- Landfills
- Groundwater Discharge Permits
- Groundwater Classification
- Construction Grants
- Septic Systems
- Septage and Sludge
- Water Supply Planning
- Toxic and Hazardous Materials
- Pesticides
- Underground Storage Tanks
- Private Wells

Several recommendations have already been implemented particularly by the lead regulatory agency, DEQE. CCAMP participants hope that all recommendations are seriously considered for implementation and phased into the operating programs of the relevant local, regional, state and federal agencies. The most critical programmatic issues that should receive immediate attention are included here.

DEQE, working closely with regional and local agencies, should strive for the delineation of Zone II areas (Zones of Contribution) for all the state's public water supplies. CCAMP's GIS project graphically displayed the inadequacy of using a generalized half mile radius as an interim measure. Delineation of the ZOC is the basic building block for the resource-based approach to groundwater protection and a truly effective program demands that it be done as accurately as possible. EPA should expand this effort throughout New England.

Incorporation of the resource-based approach into all groundwater related regulatory programs is a necessary goal for all levels of

government. Major progress has been made in this area as both EPA and DEQE have begun to order their priorities according to whether a specific activity is inside or outside of a ZOC. Some towns on Cape Cod have been particularly aggressive in regulating land uses within ZOCs. However, much more needs to be accomplished beginning with the adoption of an anti-degradation policy by DEQE. The inclusion of such a provision within the state's groundwater classification system and the banning of certain categorical discharges in ZOCs should be immediately pursued.

The control of all potential sources of contamination, especially those within ZOCs, is a basic component of resource-based management and an area that CCAMP has found deficient. Cape Cod is replete with small discharges that receive no regulation by federal or state agencies either because they are beyond the agency's purview, below a threshold level, or due to resource constraints, too low a priority to be addressed. It is of paramount importance that local agencies fill the void and regulate these smaller activities such as residential underground storage tanks, car washes, machine shops, automotive garages, etc. It is especially important to insure that small quantities of hazardous waste are collected and disposed of properly. The land use inventory is the management tool that local government should use to comprehend the activities it needs to regulate.

A program area that must be upgraded is the state's requirements for the subsurface disposal of sanitary waste, better know as Title 5. Title 5 has not kept pace with other groundwater programs administered by DEQE. Developers, skilled in recognizing the loopholes in the program, are placing a tremendous burden on town governments, most of which are ill-equipped to deal effectively in such matters. For example, the inability of Title 5 to regulate the cumulative pollution impact to public supply wells created by dense development, may eventually force the closure of many public wells. Moreover, the ability of Title 5 to deal effectively only with the threat of bacterial contamination, and not the dangers from nutrients and volatile organic compounds, may have long-term negative effects on public and private wells in addition to other valuable resources.

An area that has not received enough attention from any level of government is the protection of private wells. Presently, there are no state or federal laws or regulations in effect that protect private wells as there are for public water supplies. Although Title 5 requires a septic system's leaching facility to be at least 100 feet from a well, there is no set back requirement for a well from a septic system. Theoretically, it could be sited five feet away. Clearly, research into the siting of private wells, as they relate to septic systems and other sources of contamination, must be pursued. As with public wells, local and regional groundwater flow conditions and the delineation of Zones of Contribution should be the focus of attention.

State and local agencies unquestionably have the largest roles in groundwater protection, yet CCAMP discovered a serious lack of communication and coordination between them. Policies are misinterpreted, intentions are not understood, and the result is usually confusion, delays and further distrust. Regional Planning Agencies (RPAs), who are familiar with both levels of government, must assume a liaison role. The DEQE should utilize RPAs as agents of the state in making the proper contacts with the towns and insuring that the correct messages are being received. This will result in a more comprehensive management process devoid of many needless time delays.
In addition to a lack of coordination between state and local levels, CCAMP found major coordination problems within town government. A fragmented governmental process caused by autonomous local boards and a critical absence of leadership has caused groundwater management to suffer in several Cape towns. CCAMP did observe one town in which the Board of Selectmen appointed a water quality advisory committee, with the full authority of the Selectmen, to coordinate all groundwater activities in town. The committee has had superb results and should serve as a model for other towns.

The present institutional framework that leaves local government with the principal responsibility for making well-informed land use decisions must be upgraded significantly, as it is not working effectively. CCAMP has shown that transferring good technical information from federal and state agencies to the local level is very important, but it only represents a partial solution. A truly comprehensive approach, that treats groundwater as a regional resource not respectful of town boundaries, is also required. The creation of a regional land use agency with the necessary regulatory authority to help towns manage the ongoing land use crisis on Cape Cod is a viable approach and should receive serious consideration.

In conclusion, CCAMP was a successful prototype project because it demonstrated:

(1)The importance of a resource-based approach to groundwater protection.

(2)The effectiveness of administrative and scientific personnel from each level of government working together in a cooperative process.

(3)The value of developing creative management tools to insure informed decision-making.

(4)The need to transfer technical information in a usable form from federal and state agencies to local groundwater managers.

Now it is important for each of the participating agencies and others to take the findings and recommendations developed by CCAMP and implement them on a wider scale.

CAPE COD AQUIFER MANAGMENT PROJECT (CCAMP)

DOCUMENTS AVAILABLE

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(An asterisk indicates documents not included in the final report.)

Except as otherwise noted, all CCAMP documents listed below will be available from the National Technical Information Service (NTIS) after October 1, 1988. Contact NTIS directly at the following address:

National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161
(703) 487-4650

General

*1 "Cape Cod Aquifer Management Project Description". November 1985.

2 "Cape Cod Aquifer Management Project: Final Report". 1988. (Final Report includes the following item numbers from this CCAMP list of documents: 5-11; 15; 18-20)

*3 "The Cape Cod Aquifer Management Project: A Multi-Agency Approach to Groundwater Protection" by T. Gallagher and S. Nickerson. July 1986. In Proceedings of the Third Annual Eastern Regional Ground Water Conference, NWWA, Springfield, MA. pp. 116-135. Available from your technical library or from the National Water Well Association, 6375 Riverside Drive, Dublin, OH 43017.

*4 "A Resource-Based Approach to Groundwater Protection" by Lee Steppacher and Tara Gallagher. May 1988. Environment, Volume 30(4), pp.4,45. (Available from your technical library).

Institutional Recommendations (Items 5-12 available from NTIS as a package):

5 Cape Cod Aquifer Management Project Recommendations, Enhanced Groundwater Protection in Landfills. August 1986.

6 Cape Cod Aquifer Management Project Recommendations, Construction Grants, Groundwater Discharge Permit Program,

and Groundwater Classification. December 1986.

7 Cape Cod Aquifer Management Project Recommendations, Water Supply Planning. December 1986.

8 Cape Cod Aquifer Management Project Recommendations, Underground Storage Tank. October 1987.

9 Cape Cod Aquifer Management Project Recommendations, Septage Management. December 1987.

10 Cape Cod Aquifer Management Project Recommendations, Hazardous Materials Use and Disposal. December 1987.

11 Cape Cod Aquifer Management Project Recommendations, Private Well Protection. October 1987.

12 Cape Cod Aquifer Management Project Recommendations, Pesticide Recommendations. January 1988.

Technical Documents

*13 "Nitrate Loading in Municipal Wellhead Protection Areas" by M. Frimpter, J. Donohue, and M. Rapacz. February 1988. 50 pp. (Provides managers with an easily understood methodology and the relevant associated data for application of this formula.).

*14 "Guide to Contamination Sources for Wellhead Protection" by K. Noake. 1988. 75 pp. (This handbook provides detailed information on common land uses and associated contaminants and their environmental fate.).

15 "Water-Table Elevations: Eastern Barnstable, Massachusetts, May 11-13, 1987." by D. Heath and E. Mascoop. October 1987.

*16 "Locating Available Water-Table Observation Wells". October 1987. (Describes methodology to follow for developing a water-table map utilizing existing observation wells.)

*17 "Demonstration of the Use of Three Dimensional Groundwater Flow Modeling and Particle Tracking to Delineate Zones of Contribution to Public Supply Wells, Cape Cod, MA" by USGS. Available May 1, 1990. (Three-year study suggested by CCAMP utilizing numerical modeling in Barnstable and Eastham.). (Available in 1990 from the Books and Open-Files Reports Section; Box 25425, Federal Center; Denver, Colorado 80225.)

Items 18-20 will be available as a package from National Technical Information Service (NTIS) after October 1, 1988.

18 "Evaluation of Approaches to Determine Recharge Areas for Public Supply Wells " CCAMP Aquifer Assessment Committee.

April 1986. (Summarizes the group's evaluation of Zone II delineations in the study area.)

19 Hydrogeologic Considerations of Zone of Contribution Methods Used by Cape Cod Planning and Economic Development Commission and SEA Consultants, Inc. For Public Supply Wells in Barnstable, Massachusetts". May 1986. (Detailed examination of necessary data for Zone II delineation and discussion of methods of data reduction.)

20 "Quality Assurance of Groundwater Models Through Documentation" by John Donohue, IV. June 1986. (Discusses the necessary documentation which should accompany all groundwater modeling efforts.)

Zone II Inventory

*21 "Cape Cod Aquifer Management Project: Land Use Risks, Impacts on Water Quality, and Methods of Analysis" by Gabrielle Belfit. May 1987. Presented at the American Water Resources Symposium on Monitoring, Modeling and Mediating Water Quality, in Syracuse, N.Y., 14 pp. (Available from your technical library)

*22 "The Management of Toxic and Hazardous Materials in a Zone of Contribution on Cape Cod" by Tara. Gallagher and Lee Steppacher. July 1987. In Proceedings of the FOCUS on Eastern Regional Ground Water Issues: A Conference, July 14-16, 1987, Burlington, Vt. pp. 13-41. (Available from your technical library)

Geographic Information Systems (GIS)

*23 "Demonstration of a Geographic Information System for Ground Water Protection" edited by Lee Steppacher. October, 1988.

*24 USGS Open File Report - "Assessing Risk to Water Quality at Public Water Supply Sites, Cape Cod, Massachusetts" by Julio Olimpio, Elizabeth Flynn, and Saiping Tso. In Preparation (Available after October 1, 1988 from the USGS, Books and Open-Files Reports Section, Box 25425, Federal Center, Denver, Colorado 80225.)

Bibliography

*25 "CCAMP Bibliographies: Publications and Maps" compiled by EPA Region 1 Library. May 1988. EPA 901/3-88-002.