

STRATEGIC MONITORING GUIDANCE DOCUMENT



STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

AND

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION 1

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STRATEGIC MONITORING GUIDANCE DOCUMENT

1.0 INTRODUCTION

Connecticut's Aquifer Protection Program, or wellhead protection program, is designed to "ensure a plentiful supply of public drinking water for present and future generations" by protecting major water supply wells in sand and gravel aquifers. Connecticut law requires water suppliers to determine the boundaries of Aquifer Protection Areas around these wells through the "Level B" and "Level A" mapping process. The law also requires the Connecticut Department of Environmental Protection (CTDEP) to adopt land use regulations and procedures for local program management. In addition, the CTDEP must adopt regulations to protect groundwater quality from the potential impacts of agriculture. The program requires municipalities to conduct a land use inventory, designate an aquifer protection agency, and adopt local regulations.

This Guidance Document for Strategic Monitoring outlines and describes steps for the design and implementation of a key tool for aquifer protection: strategic monitoring. Strategic monitoring provides early-warning detection of contaminants that could migrate from points of release in the Aquifer Protection Area to the production wells and that could potentially impact water quality.

The document is divided into two parts. The first section provides an introduction to Connecticut's aquifer protection program; an overview of aquifer protection, strategic monitoring and contaminant hydrogeology; and a description of a pilot strategic monitoring case study. The second section describes all aspects of the design and implementation of a strategic monitoring program. This section is divided into ten tasks, illustrated by 24 exhibits containing examples from the case study. Supporting information is contained in the appendices, including a glossary of terms (Appendix 1) and sources of additional information (Appendix 2).

This document is intended for use by both the water system owner and the engineering consultant. The design and implementation of a strategic monitoring program requires familiarity with contaminant hydrogeology, monitoring well installation, and analytical sampling. Some water systems have the staff and resources to complete all or part of the steps necessary to design a monitoring program. Other water systems will choose to hire a consultant.

STRATEGIC MONITORING AND CONNECTICUT'S AQUIFER PROTECTION AREA PROGRAM

Arising out of concern for the increasing incidence of contamination of public groundwater supply sources, the Connecticut General Assembly passed Public Act 88-324, which was codified as §22a-354a through 354bb of the Connecticut General Statutes. This act established the Aquifer Protection Area program to identify critical water supply areas for large (serving over 1,000 people) wellfields in stratified drift and to protect them from pollution by managing land use within these critical areas.

Two levels of mapping were required by the statute to define the critical areas for protection around Connecticut's water supply wellfields: "Level B" is a preliminary mapping of the contributing areas and Recharge Areas of the wellfields and Level A Mapping is a refinement of Level B Mapping. Level B mapping was designed to be completed quickly with minimal site-specific information, and at low cost. Under Level A mapping, detailed site-specific information is collected for each wellfield and incorporated into a groundwater model of the aquifer. The model is then used to predict the Area of Contribution and Recharge Area under drought conditions. Once approved by the CTDEP, the Level A Mapping (consisting of the Area of Contribution and Recharge Area) must be adopted as an Aquifer Protection Area.

There are numerous regulatory and non-regulatory tools for managing and protecting these groundwater resources. Regulatory tools include: land use restrictions, performance standards, strategic monitoring, septic system upgrades, toxic and hazardous materials handling procedures, and many more. Non-regulatory tools include: conservation

easements, household hazardous waste collection, public education, and Aquifer Protection Area contamination contingency plans.

In Connecticut, regulation of land uses on property within the Aquifer Protection Area, designed to minimize the potential for contamination of the water supply well, must be established and enforced by the municipality. The design and implementation of a strategic groundwater-monitoring program within the Aquifer Protection Area will further strengthen protection of the wellfield.

To assist with the development of the above regulations and to set forth guidance for strategic monitoring, the CTDEP obtained a grant from the U.S. Environmental Protection Agency (EPA) through Section 319 of the Clean Water Act to fund a Pilot Strategic Monitoring Demonstration Project to be completed by Atlantic Geoscience Corporation. The Crystal Water Company's Hopkins Wellfield in Killingly, Connecticut, was selected as the site for the Case Study. The project included the following elements:

1. A case study documenting the design and implementation of a Strategic Monitoring Network for the Crystal Water Company's Hopkins Wellfield in Killingly, Connecticut.
2. A guidance document providing guidance for the design and implementation of an Aquifer Protection Area Strategic Monitoring Program appropriate for Connecticut's valley-fill aquifers.

This Guidance Document fulfills element 2 above and includes examples and highlights from the Case Study, element 1 above (1999, Atlantic Geoscience Corporation).

PRINCIPLES OF STRATEGIC MONITORING AND AQUIFER PROTECTION

In Connecticut, strategic monitoring will be required within the Aquifer Protection Area. Connecticut has set forth the procedures for delineation of Aquifer Protection Areas through its Level A Mapping requirements (Section 22a-354b-1 of the Connecticut General Statutes). The requirements include detailed, site-specific data collection for each well or wellfield. The data are used to create a numerical two- or three-dimensional groundwater flow model. The model is used to determine the Area of Contribution and Recharge Area under a simulated drought condition. Two example delineations of the Level A areas and the resulting Aquifer Protection Areas are shown in Figure 1.

Aquifer Protection Area Definitions

Connecticut's definition of an Aquifer Protection Area is:

"...any area consisting of wellfields, areas of contribution and recharge areas, identified on maps approved by the commissioner of environmental protection pursuant to sections 22a-354b to 22a-354d, inclusive, within which land uses or activities shall be required to comply with regulations adopted pursuant to section 22a-354o by the municipality where the aquifer protection area is located"¹

Definitions for the principal elements of Level A Mapping are as follows; these elements are also illustrated in Figure 2.

" 'Area of Contribution' [AOC] means the area where the water table is lowered due to the pumping of a well and groundwater flows directly to the well."

" 'Area of Influence' [AOI] means the land area that directly overlies and has the same horizontal extent as the part of the water table or other potentiometric surface that is perceptibly lowered by the withdrawal of water. The area of influence delineated by the use of modeling shall be that area of land in which the water table or potentiometric surface is lowered by at least 0.5 feet."

" 'Recharge Area' [RAE] means the area from which groundwater flows directly to the area of contribution."

¹ Connecticut General Statutes sections 22a-354h

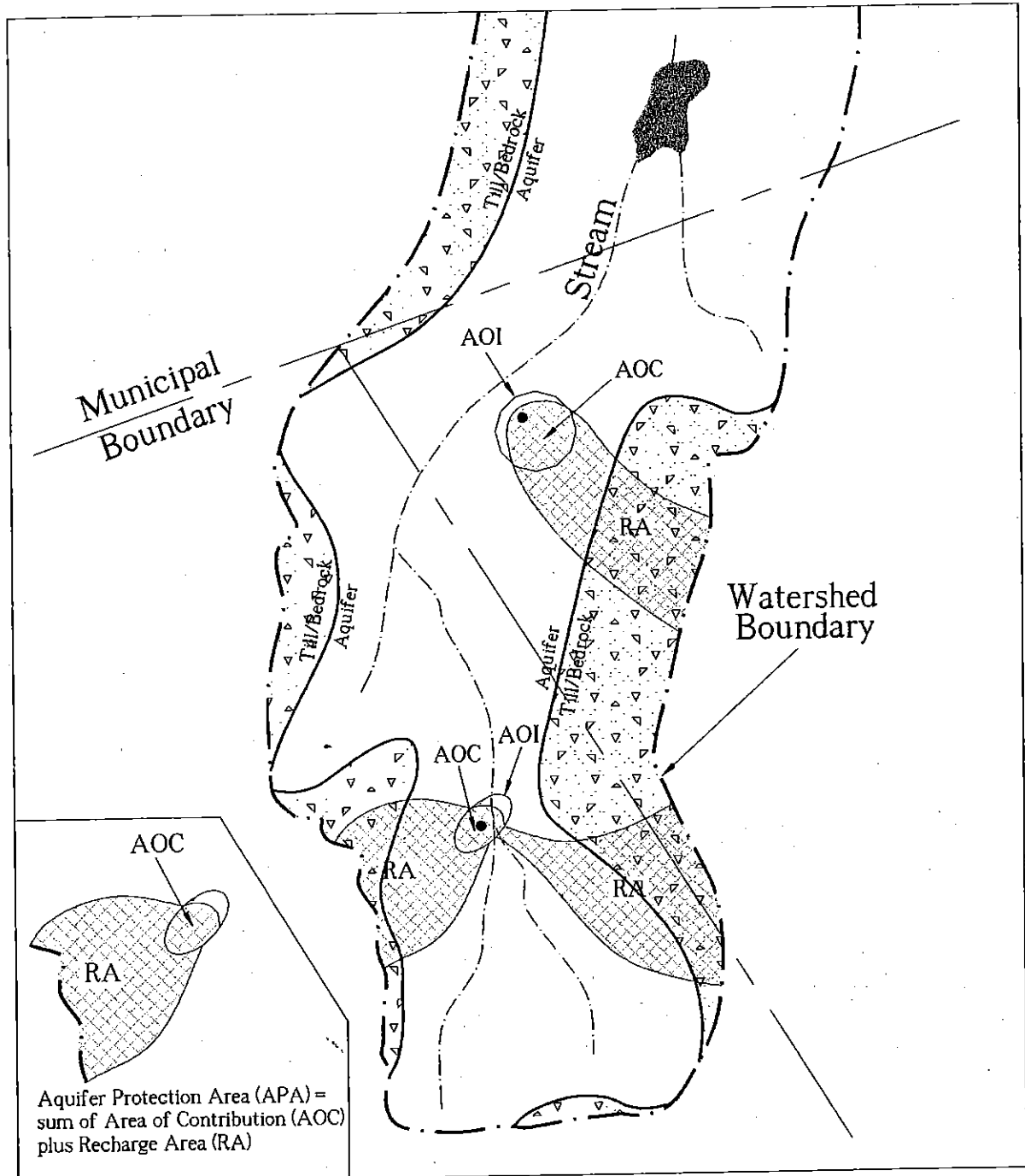
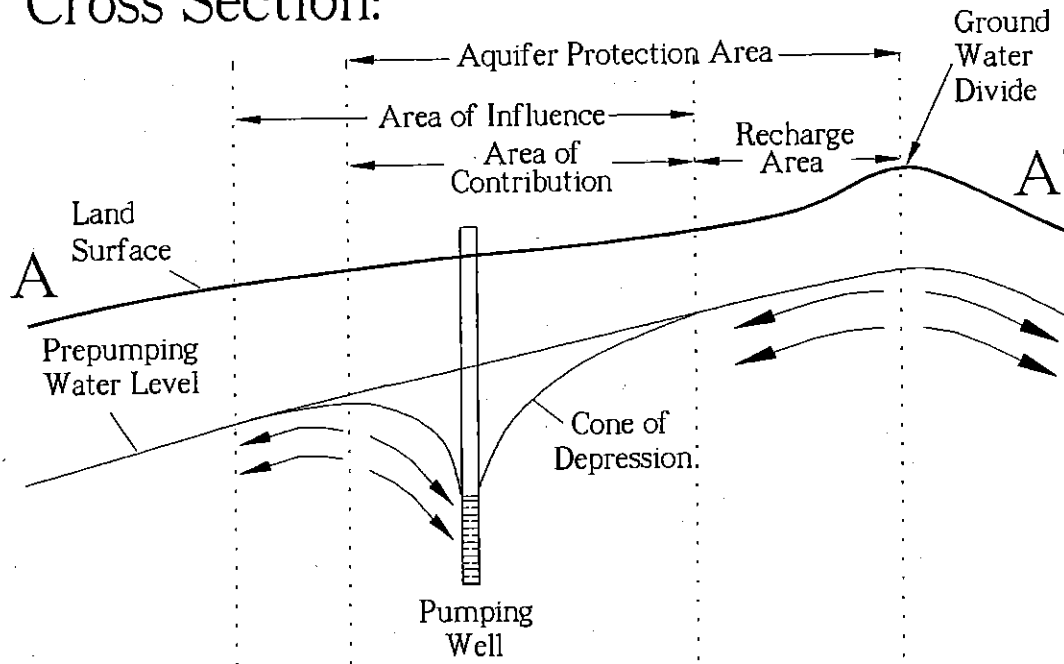


Figure 1. Schematic of Regional Aquifer with
Aquifer Protection Area Delineations
(adapted from Witten and Horsely, 1995)

Cross Section:



Plan View:

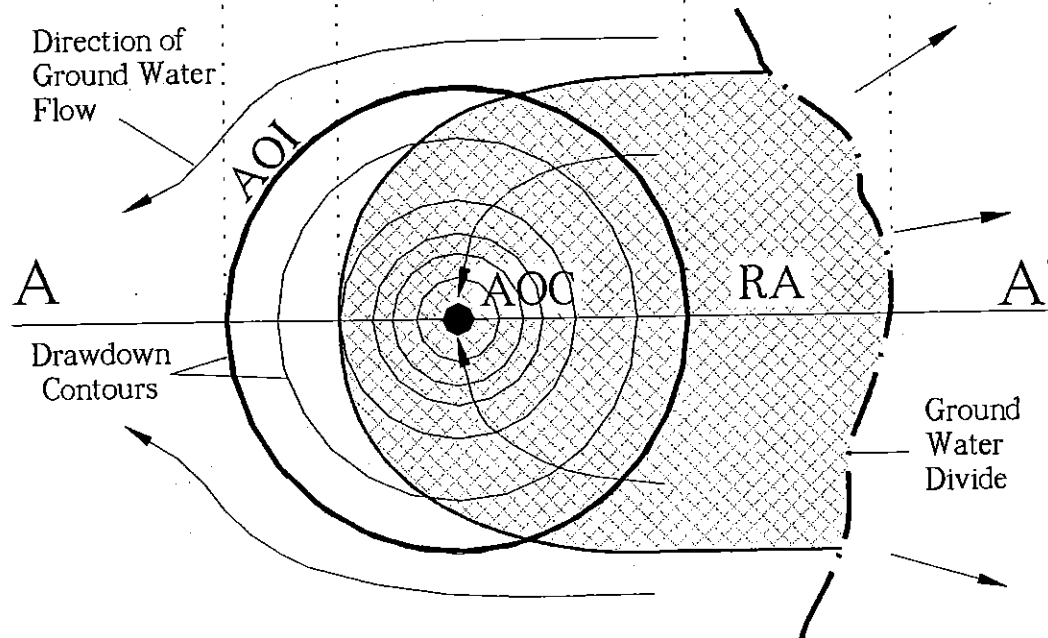


Figure 2. Schematic of Aquifer Protection Area
(adapted from Witten and Horsely, 1995)

Primary Goals and Elements of a Strategic Monitoring Program

Strategic monitoring represents a key aquifer protection tool that provides early-warning detection of contaminants that could migrate from points of release within the Aquifer Protection Area to production wells and potentially impact water quality. The monitoring program provides the information needed to initiate mitigative actions if contaminants are detected at concentrations that could potentially impact the quality of water at the production wells.

In short, strategic monitoring provides the ability to:

- Monitor trends in aquifer water quality;
- Detect a contaminant plume, its direction and velocity; and
- Plan the appropriate response, including remediation and production well shut-down

Primary Elements of a Strategic Monitoring Program:

1. Monitoring Well Network
2. Sampling Plan
3. Sampling Procedures
4. Data Management System
5. Regular Evaluation of Program

Goals of a Strategic Monitoring Program:

1. Design a *sampling network* to monitor, in priority order, land-use activities that present the greatest potential threat to groundwater quality;
2. Develop a *sampling plan* that minimizes costs, while maximizing the range of detectable contaminants and available reaction time (to initiate remedial actions);
3. Develop *sampling procedures* that are simple, cost effective, and technically sound and that minimize sampling-related biases and ensure data integrity;
4. Design a *Data Management System* that facilitates accurate and efficient record keeping and provides a tool to assist in the identification and evaluation of trends and of statistically significant departures from background water-quality conditions;
5. Advocate a monitoring program that can realistically be implemented by the water supplier, from the perspective of costs, staff resources, technical difficulty....etc; and
6. Establish a regular *monitoring program evaluation system*, thereby ensuring that all of the elements of the program are effective and reflect the changing environmental and operational conditions.

The five primary elements of a strategic monitoring program are listed here and discussed in detail in the following sections of this guidance document.

The specific goals of a strategic monitoring program are detailed below, including the purpose of each element.

BRIEF OVERVIEW OF CONTAMINANT HYDROGEOLOGY

This section is intended to briefly highlight some of the mechanisms and factors controlling contaminant transport that should be considered when designing a strategic monitoring program. Behavior of contaminants in the subsurface is highly complex and cannot be adequately covered here; thus, the reader needing additional information should consult the additional sources listed in Appendix 2.

The design of a strategic monitoring network requires knowledge of the location of potential contaminant sources, the possible specific contaminants that could be released and an understanding of the mechanisms that control their movement in the subsurface. This knowledge greatly enhances the ability to predict whether contaminants could migrate to the wellhead and increases the likelihood that monitoring wells can be located to intercept those contaminants effectively. The prediction of contaminant migration is made difficult by the often highly variable nature of materials that comprise the aquifer and the peculiarities of each individual contaminant relative to its movement through porous media.

In order to start evaluating and predicting contaminant migration, one must assess the following:

1. The type of contaminant and its physical characteristics;
2. The primary transport mechanisms for the contaminant; and
3. The effects of local stratigraphy on the fate and transport of the contaminant.

Contaminant Types and Characteristics

Table 1. Summary of Contaminant Characteristics and Transport Mechanisms	
Characteristics	Toxicity
	Mobility
	Persistence
	Solubility
	Density
	Vapor Pressure
	Partition Coefficient
Physical Transport Mechanisms	Advection
	Dispersion
	Molecular Diffusion
Chemical/Biological Transport Mechanisms	Sorption and Desorption
	Biodegradation
	Hydrolysis
	Volatilization
	Co-solvent Effects
	Redox (Oxidation and Reduction)
Reactions	Dissolution/Precipitation
	Ion Exchange

Contaminants can generally be broken into three types:

1. Synthetic organics: volatile organic compounds (VOCs), semi-VOCs, pesticides, PCB's
2. Inorganics: nutrients (nitrogen, phosphorus), heavy metals, others (sodium, chloride)
3. Pathogens: protozoa, bacteria, viruses

Contaminant characteristics (Table 1) include: toxicity, solubility, density, mobility, and persistence. Toxicity is the degree to which a chemical produces a harmful biological effect. It should be noted that toxicity levels are not known for all chemicals nor are they absolute. Solubility and density are important characteristics that help determine the type of transport mechanism that controls the distribution and mobility of contaminants. Persistence refers to whether a contaminant undergoes chemical, biological or radioactive degradation or whether it does not react with the soil or groundwater. Vapor pressure reflects the volatility of a compound and partition coefficient characterizes the compound's distribution in two phases.

Contaminants can be divided into three general types according to their density relative to water: floaters, mixers, and sinkers (Figure 3). Contaminants characterized by low solubility in water will partition out into a density-based separation as either "sinkers" or "floaters". High solubility constituents, such as inorganics, will mix with the groundwater and migrate via advection, dispersion and diffusion, and hence are called "mixers".

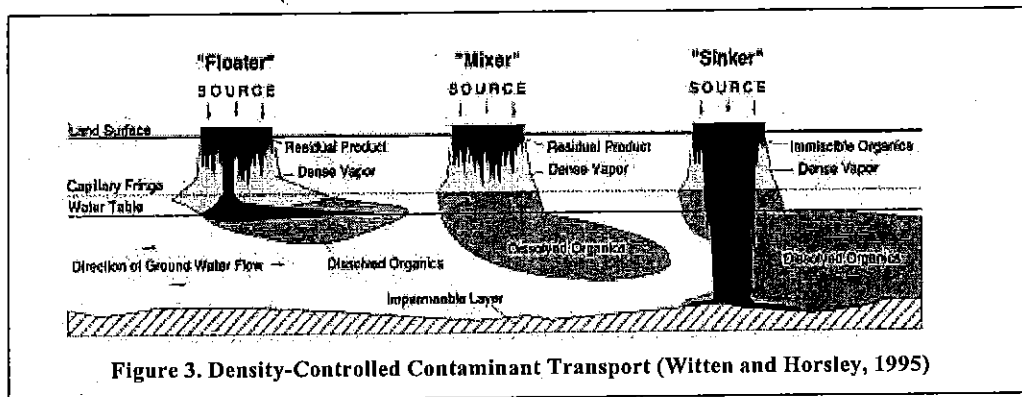


Figure 3. Density-Controlled Contaminant Transport (Witten and Horsley, 1995)

Some Hydrogeologic Controls Over Transport

Confining layers¹

- the low-permeability nature of confining layers can reduce the likelihood of migration and the travel time of contaminants between unconfined & confined aquifers
- contaminants can flow across a confining layer if:
 - the potentiometric head in the upper aquifer differs from that in the lower aquifer, and
 - the confining layer is naturally leaky, or breaches exist in the confining layer (manmade or natural)
- thus confining layers can either protect one aquifer from contamination by the other or, if leaky, can allow cross-contamination of the aquifers
- a head gradient between upper and lower aquifer can be induced by pumping of a well in the lower aquifer, possibly resulting in migration of contaminants across the confining layer, if conditions discussed above exist.

Aquifer materials²

- molecular diffusion may be more dominant in fine-grained materials and low flow velocities
- plume shape and aquifer materials:
 - with higher flow velocities, the plume tends to be more elongated than at lower flow velocities
 - with higher hydraulic conductivity, the plume tends to be more elongate; with lower hydraulic conductivity the plume tends to stay more compact

Surface Water¹

- under pumping conditions, surface water can 1) act as a boundary to flow, 2) be subject to induced infiltration, or 3) cause underflow from the opposite side of the surface water body; in the latter two cases, the surface water body and areas across the surface water body should be considered potential sources of contamination

¹USEPA, 1987, Guidelines for Delineation of Wellhead Protection Areas, Office of Water, Washington DC, EPA 440/6-87/010
²Palmer, C.M., 1996, Principles of Contaminant Hydrogeology, Lewis Publishers, New York

Primary Transport Mechanisms

Contaminants can move through an aquifer by several physical transport mechanisms. Advection is the movement of a solute at the average linear velocity of groundwater. Dispersion is the spreading of a solute over a greater area than would be predicted by the groundwater vectors due to mechanical dispersion and molecular diffusion. Mechanical dispersion refers to spreading due to deviations in the velocity of groundwater as it moves through porous media. Molecular diffusion accounts for the dilution of the solute by non-contaminated groundwater.

In addition to physical transport mechanisms, chemical and biological mechanisms can affect contaminant movements. Various chemical and biological mechanisms that result in chemical transformation and biological breakdown are included in Table 1.

The Effects of Local Stratigraphy on the Fate and Transport of Contaminants

The development of a conceptual hydrogeologic model for groundwater flow is a critical precursor to determining contaminant transport mechanisms and flowpaths. Aquifer boundaries, subsurface stratigraphy and external stresses play an important role in the fate and transport of contaminants. In addition, the following aspects of the hydrogeologic system should be evaluated:

- unsaturated zone thickness
- vertical head gradients
- confining and semi-confining layers
- surface water bodies
- "impermeable" boundaries (bedrock)

- focused recharge (injection wells, lagoons, detention basins...)
- preferential flow zones (buried stream channels, karst conditions, fracture flow,...)
- ambient groundwater quality (e.g., pH and Eh strongly affect the susceptibility of groundwater contamination by metals).

Developing a conceptual model for the fate and transport of contaminants in Connecticut requires an understanding of the State's glaciated terrain. Connecticut's most prolific aquifers occupy primarily shallow valley-fill deposits of meltwater-sorted materials overlying sedimentary or crystalline bedrock. Typically, aquifers are flanked by till and bedrock uplands along the valley walls. The most important source of recharge to the aquifer is from precipitation falling both directly on the aquifer and indirectly on the adjacent till and bedrock uplands, resulting in runoff to the aquifer. Connecticut's valley-fill aquifers represent a significant groundwater resource due to the transmissive quality of the stratified drift aquifer materials combined with the hydraulic connection with streams flowing through the valley. Physical transport mechanisms for groundwater contaminants in this setting include advection, dispersion,

and molecular diffusion, with advection being the predominant mechanism for many soluble contaminants. Contamination plumes typically move slowly, by advection, through sand/gravel aquifers and become elongated in the flow direction. Factors such as low contaminant solubility, a density significantly greater or less than water, dispersion, absorption onto sand grains, and biodegradation can modify the typical advection plume.

All sand and gravel deposits are underlain by bedrock (although other unconsolidated materials such as glacial till may intervene). Most bedrock in Connecticut is relatively impermeable, except where the rock is cut by fractures or other structures. These fracture zones form highly discrete flow paths through the rock. Contaminant transport in fractured bedrock is inhomogeneous and often anisotropic, with each setting presenting unique characteristics. The potential exists for fractured bedrock to either receive contaminants from, or discharge contaminants to, overlying sand and gravel.

PILOT STRATEGIC MONITORING PROGRAM CASE STUDY: CRYSTAL WATER COMPANY'S HOPKINS WELLFIELD

The Crystal Water Company's Hopkins Wellfield, in Killingly, Connecticut, was selected as the site for a Pilot Demonstration Project to evaluate the process of designing and implementing a strategic monitoring program. Examples from the Crystal Water Company's Pilot Project, completed by Atlantic Geoscience Corporation, are used throughout this Guidance Document to illustrate the various steps outlined herein.

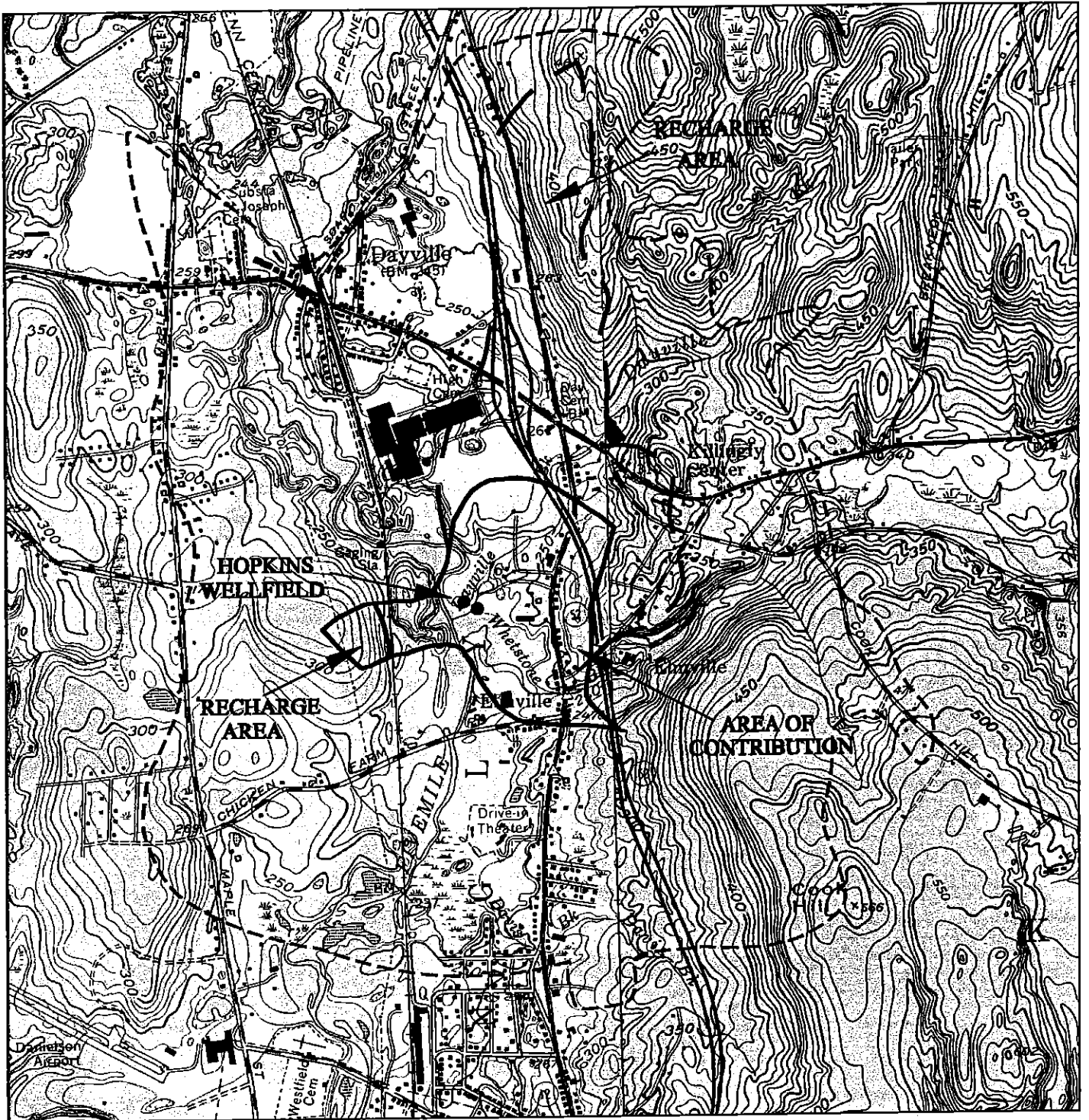
The Crystal Water Company (CWC) provides drinking water to customers in the Dayville section of Killingly, Connecticut. The CWC developed the Hopkins Wellfield during the early 1980's to provide the additional water demanded by their growing customer base. The Hopkins Wellfield, composed of two gravel-packed production wells (designated PW2 and PW3), is adjacent to the Fivemile River and south of the Village of Dayville in Killingly, Connecticut (Exhibit 1).

The Hopkins wellfield is located in a well-developed area with a number of industrial and commercial establishments. Several of these local businesses have reported releases of petroleum or hazardous materials. As a result of past and current land uses in the vicinity of the wellfield, low levels of contaminants have historically been detected in the wellfield and monitoring wells. Between 1994 and 1997 PW3 was offline due to low-level MTBE contamination.

The design of the strategic monitoring network was based, in part, on the Level A Mapping Study for the Hopkins Wellfield completed by Whitman & Howard, Inc., of Wellesley, Massachusetts (1995). This study consisted of a hydrogeological investigation of the wellfield and vicinity and an aquifer test to determine the hydraulic coefficients of the aquifer. In addition, a numerical groundwater flow model was designed, calibrated, and verified and used to predict the Area of Contribution and Recharge Area to the wellfield under "Level A Conditions". Products and results from the Level A report were used where appropriate in the Strategic Monitoring Program design to minimize costs and duplication of effort.

2.0 SUGGESTED TASKS FOR DESIGNING AND IMPLEMENTING A STRATEGIC MONITORING PROGRAM

The following section describes the suggested tasks for the design and implementation of a strategic monitoring program. Throughout this portion of the document, case study examples are included as exhibits to help illustrate the steps described herein.



EXPLANATION

- PRODUCTION WELL
- LEVEL A AREA OF CONTRIBUTION
- LEVEL A RECHARGE AREA
- - - - LEVEL B AREA

Exhibit 1. Site Map

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999

TASK 1: IDENTIFY CONTAMINATION THREATS

The purpose of a contamination threats analysis is to identify and prioritize point and non-point sources of potential contamination, and to determine potential contaminant types, volumes, and most likely modes of release. This information is critical to the development of a monitoring program tailored to the specific threats at a particular site.

Identifying the specific origin of contamination detected in monitoring or production wells is not necessary to design a strategic monitoring program, although it may be an outcome of careful evaluation of data collected during the design. However, identifying the location of existing and potential sources of contamination within the Aquifer Protection Area is critical to the design of the monitoring network. The analysis is completed in a four-step process, as outlined in the subtasks below:

1. Prepare base map
2. Obtain land-use inventory data
3. Review municipal, state, and federal agency data
4. Perform windshield survey

Prepare Base Map

The first step in the project is the creation of a base map illustrating the major hydrological and cultural features in the area. This step facilitates the mapping of potential contamination threats and their locations relative to the wellfield.

A base map can be synthesized from a number of sources: digital map data layers available from the CTDEP's Geographical Information System Program; the Level A Mapping study; tax maps; and reports covering the site area. At a minimum, the site should be shown on a USGS 7 1/2 minute topographic map. Aerial photography can also be used to supplement mapping obtained from digital databases or from the USGS topographic maps.

The base map should show the following elements, supplemented by information gathered in subsequent tasks:

- project site
- individual production wells in wellfield
- Level A Area of Contribution and Recharge Area
- surface water (streams, lakes, ponds)
- major roads

Exhibit 2 describes the development of the site map shown in Exhibit 1.

Steps to Design a Strategic Monitoring Program

1. Identify contamination threats
2. Evaluate and prioritize contamination threats
3. Assess contamination migration pathways to production well(s)
4. Design monitoring well network
5. Design sampling plan
6. Submit proposed monitoring well network and sampling plan to CTDEP
7. Install new monitoring wells
8. Develop water quality monitoring data management system
9. Begin monitoring program
10. Evaluate monitoring program

Exhibit 2. Site Map Development

Figure 1 (Danielson, CT and East Killingly, CT) uses two USGS 7-1/2 minute topographic quadrangle maps as a base and shows the location of the Hopkins Wellfield (wells PW2 and PW3), the Level A Area of Contribution and Recharge Area, and the Level B Area. Subsequent figures in the Case Study added digital data obtained from the CTDEP's Geographic Information Systems Program (GISP), as well as data developed for the case study project.

Obtain Land-Use Inventory Data

A land-use inventory is mandated under Section 22a-354e of the Connecticut General Statutes. The inventory provides a comprehensive accounting of high-risk land uses within the Level B area. In section VI of the "Guidelines for Land Use Mapping over Public Drinking Water Aquifers" (CTDEP Water Management Bureau, 1991), the CTDEP identifies the land use categories to be mapped (Appendix 3). Section VII of the same document describes which "Higher risk activities and facilities listed by land use category" are to be discretely labeled on the map.

Land-Use Inventory data for the Level B area can be obtained from the municipality or the CTDEP. It should be noted

that the Land Use Analysis is completed for the Level B area, which typically is larger than the Aquifer Protection Area. Typical products of the inventory include:



1. a map classifying land uses of all parcels within the Level B area;
2. mapped (and numbered) locations of high-risk land uses (Exhibit 3);
3. and a listing of high-risk land uses (keyed to the map) detailing owner's name, address, type of business or activity, tax map, block and parcel number.

Once completed, the mapped land use classifications and individual high-risk uses are digitized by the Map and Geographic Information Center (MAGIC), with CTDEP's Environmental and Geographic Information Center, and are available on disk for a nominal fee MAGIC. The Land-Use Inventory should form the starting point for the identification of contamination threats within the Level A Recharge Area and Area of Contribution. This information should be supplemented by a windshield survey to further characterize the nature and location of potential contamination threats.

Review Municipal, State, and Federal Agency Data

Information on potential contamination sites is available from various municipal, state and federal agencies (Appendix 4). Most of the available data from these sources concerns "regulated sites", sites that are under an order to complete investigations, conduct compliance monitoring, and/or perform remediation to mitigate contamination thought to originate at the site. The following types of sites should be identified within the Aquifer Protection Area: Resource Conservation and Recovery Act (RCRA) sites, Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) sites, and National Priorities List (Superfund) sites. In addition, the individual CTDEP caseworkers that oversee activities at state-regulated sites may be contacted in order to confirm the status of each site and to obtain additional information regarding ongoing monitoring programs and site investigations. Documented releases are listed on the CT Bureau of Waste Management's Spill Incident database.

Appendix 5 includes a listing of "Potential Sources of Groundwater Contamination" that is useful for evaluating the types of contaminants by land use activity (EPA/625/R-93/002). Appendix 6 lists "Potentially Harmful Components of Common Household Products" (same source).

Several private vendors offer standard site assessment reports consisting of data on contamination risk sites within a certain radial distance of the subject site. These vendors search state and federal databases for information on USTs, LUSTs, RCRA generators, Toxic Release Inventory System sites, Site Remediation Orders, and more. Where adequate address data is available, the sites can be plotted onto a site map. This can be an efficient way to gather contamination threat data quickly for \$150 to \$250. Names of such vendors can be obtained from a search on the Internet under "environmental site assessment".

In the event that the Aquifer Protection Area includes part of a surface-water body, then the surface-water body may be a potential contamination threat. Thus discharges to that body should be identified. The CTDEP published a series of documents useful for evaluating discharges to surface water bodies: The Leachate and Wastewater

Discharge Sources maps for Connecticut's river basins (CTDEP, 1988). The CTDEP can also supply a list of National Pollution Discharge Elimination System (NPDES) permits identifying the regulated and monitored discharges in the vicinity of the site. Individual NPDES permits can then be obtained and reviewed for specific information on the nature of the discharges and monitoring programs. USGS surface water-quality stations on various rivers can provide the data needed to evaluate a river's ambient water quality.

Windshield Survey Form

DATE: _____ PROJECT: _____
 YOUR NAME: _____ CLIENT: _____
 CO/AFFILIATION: _____ ADDRESS: _____
 WEATHER CONDITIONS: _____

SITELANDOWNER NAME: _____
 APPROXIMATE DISTANCE FROM SITE: _____

LOCATION MAP: ADDRESS: _____

GENERAL DESCRIPTION: _____

NATURE OF PROPERTY:

RESIDENTIAL: _____ INDUSTRIAL: _____
 COMMERCIAL: _____ AGRICULTURAL: _____
 GOVERNMENT: _____ RECREATIONAL: _____
 ABANDONED LOT: _____ OTHER: _____

NOTES: _____

POTENTIAL SOURCES OF CONTAMINATION:
 (Indicate the number of sources next to the appropriate category & describe)

ABANDONED WATER WELL _____	INJECTION WELL _____	
ABOVE GROUND STORAGE TANK _____	LANDFILL/DUMP _____	
AIRPORT _____	MINE _____	
ANIMAL FEEDLOT _____	MUNICIPAL SEWAGE LINE _____	
ARTIFICIAL RECHARGE _____	OIL/GAS WELL _____	
AUTO SALVAGE YARD _____	QUARRY _____	
CEMETERY _____	RAILROAD _____	
CESPOOL _____	SEPTIC TANK _____	
CHEMICAL STORAGE (BARRELS, ...) _____	SERVICE STATION DISPOSAL WELL _____	
DRAINAGE WELL/CANAL _____	SEWAGE PLANT SLUDGE DISPOSAL _____	
DUMPSTER _____	STREAM (LAKE, RIVER) _____	
ELECTRICAL TRANSFORMER _____	UNDERGROUND STORAGE TANK _____	
FERTILIZER/PESTICIDE APPL _____	WAREHOUSE _____	
GOLF COURSE _____	WATER WELL _____	
GRAIN STORAGE _____	OTHER _____	
HIGHWAY _____	OTHER _____	
HOLDING POND/LAGOON _____	OTHER _____	

NOTES: _____

EVIDENCE OF LEAKS/SPILLS, IMPROPER HANDLING/DISPOSAL OF HAZ. MATERIALS OR PETROLEUM PRODUCTS: _____

* STAINED GROUND, STRESSED VEGETATION, UNUSUAL OR UNPLEASANT ODOR

Perform Windshield Survey

A site reconnaissance ("windshield survey") of the project area should be conducted to confirm the location and land use activities within the Aquifer Protection Area. Such a survey serves to verify land uses and on-site activities at potential sources of contamination, as described in the land-use inventory, and identify any additional activities of particular interest to the subject wellfield. Observations should include: the approximate age of structures; the presence of fuel storage tanks; the type of fuels, chemicals, wastewater, and other potential contaminants that might be used, stored, or disposed of onsite; the use and storage of heavy equipment; and any activities that use or generate potential contaminants.

TASK 2: EVALUATE AND PRIORITIZE CONTAMINATION THREATS

This task involves organizing all the information gathered in Task 1, by tabulating and mapping the potential contaminant sites. The nature of potential groundwater contaminants at each site is then evaluated, relative to their fate and transport characteristics, and then potential contamination threat sites are prioritized to assist in designing the monitoring well network.

Summarize Contamination Threats

Once information on high-risk land uses and potential contamination threats has been gathered and verified in the field, it is useful to tabulate this data using forms. Threats should be numbered in the table so they can be mapped on a site map for efficient cross-referencing. The table should also include accompanying information on types of operation, location, contaminants stored/generated, contamination incidents, remedial actions and regulatory status. The last column in the table shows a code representing the risk to groundwater quality (risk categories A – E, discussed in the next section) and the land-use category of the property (for example "Industrial"). The table could also include a code describing the type of contaminants (i.e. floater, mixer or sinker) that would also appear on the map (coded by symbol, label or color). This would assist in evaluating the contaminant pathways likely taken by each contaminant.

Contamination Threats Form									
SITE NO.	SITE NAME & ADDRESS	TYPE OF OPERATION	PROXIMITY TO WATER CO.	CONTAMINANTS STORED/GENERATED	CONTAMINATION INCIDENTS	REMEDIAL ACTIONS	REGULATORY STATUS	REFERENCES	RISK TO GROUNDWATER QUALITY & LAND USE CATEGORY*

* Risks and land use categories from draft "Ranking Land Use Categories by Their Risk to Groundwater Quality" (CT DEP, 1997).

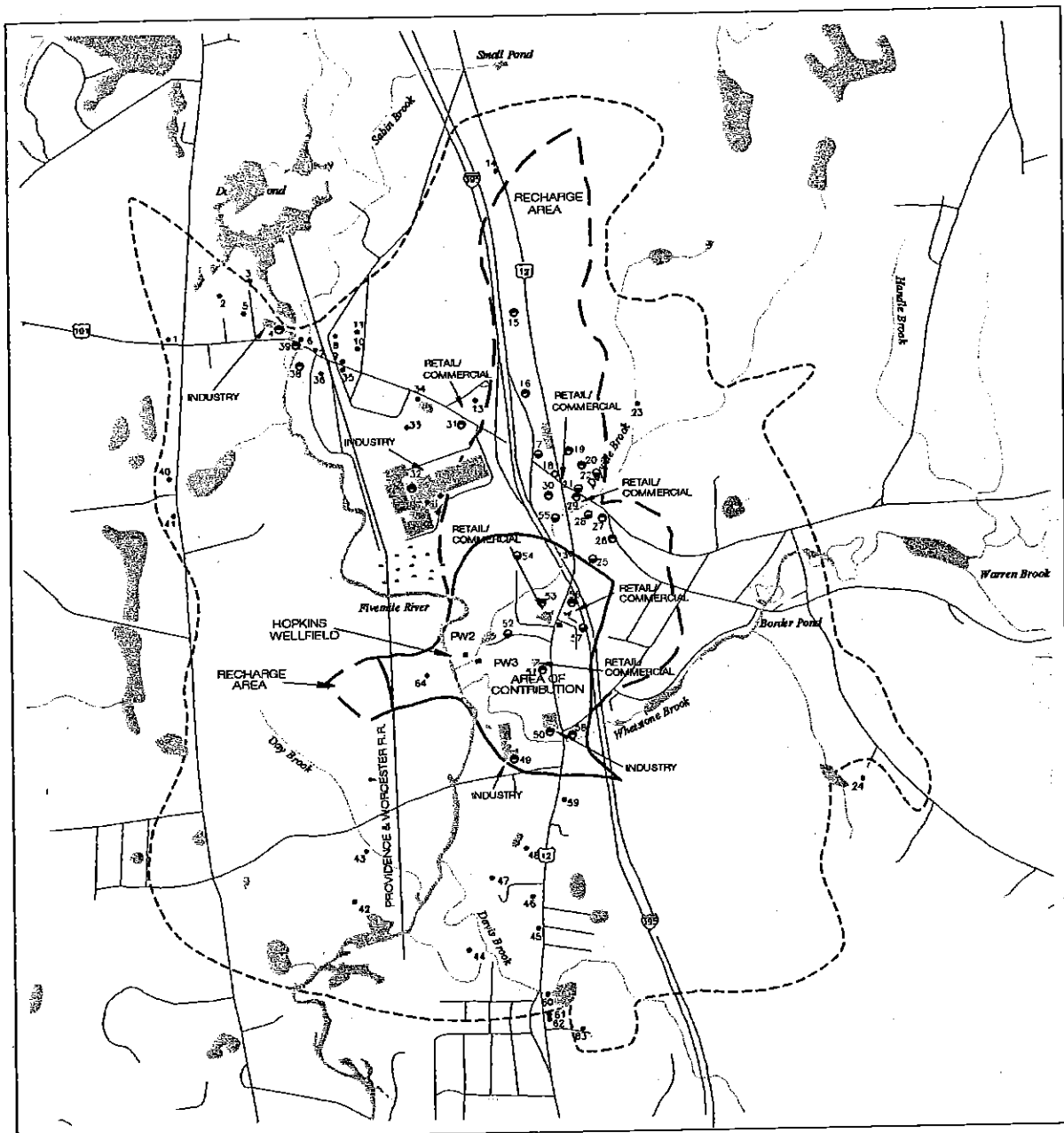
A map should be developed that shows the following:

- Recharge area
- Area of Contribution
- All numbered potential contamination threats
- Roads
- Hydrography
- Production wells

Exhibit 4 provides an example of such a map. The map includes all the above features and also shows three risk-to-groundwater-quality categories (C, D, and E) as different colors/symbols. The methodology for determining potential contaminant risk categories is discussed in the next section.

Prioritize Contamination Threats

This step provides a method of evaluating potential and existing contamination threats to determine locations with a high likelihood of releasing (or having released) significant quantities of petroleum or hazardous materials to the ground and groundwater. Potential contamination threats within the AOC and Recharge Area can be prioritized using the "Ranking of Land Use Categories by Their Risk to Groundwater Quality" (Table 2, CTDEP, pers. Comm., 1997). This risk category system is used by the CTDEP to evaluate land uses within Aquifer Protection Area's and categorizes land uses into five groups from "A" (least risk to groundwater quality) to "E" (highest risk to groundwater quality). The risk category chosen for each threat is indicated both in the potential contamination threats form and map. Exhibit 5 describes the application of this method to the case study. Potential contamination threats should be categorized using this system.



EXPLANATION

- | | |
|------------------------------|--|
| ROADS | BUILDING |
| HYDROGRAPHY | POTENTIAL CONTAMINANT THREAT SITE FOR RISK CATEGORIES C (MODERATE RISK) TO CATEGORY E (MOST RISK) |
| LEVEL A AREA OF CONTRIBUTION | 47 ● CATEGORY A OR B (LEAST RISK) |
| LEVEL A RECHARGE AREA | 18 ○ CATEGORY C (MODERATE RISK) |
| LEVEL B AREA | 54 ○ CATEGORY D |
| PRODUCTION WELL | 51 ○ CATEGORY E (MOST RISK) |

Exhibit 4. Potential Contamination Threats

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999

Table 2. Ranking of Land Use Categories by Their Risk to Groundwater Quality

LEAST RISK

A.

1. Water company owned land
2. Designated, passive recreation open space
3. Federal, state, local, private parks and forests
4. Private land managed for forest products
5. Developed recreational use, public parks

B.

1. Field Crops – permanent pasture, hay crops, corn, vegetables
2. Low Density residential – (>2 acre lots)
3. Churches, Municipal Offices

C.

1. Agricultural Production – dairy, livestock, poultry, nursery, tobacco crops, orchards
2. Golf Course
3. Medium Density Residential – (1/2 to 1 acres lots)

D.

1. Institutional Uses – schools, hospitals, nursing homes, prisons
2. High Density Housing – (<1/2 acre lots)
3. Commercial – with nothing more than sewage discharges

E.

1. Retail Commercial – gasoline and automotive service stations, dry cleaners, photo processors, medical arts, furniture strippers, beauty shops, junk yards, machine shops, radiator repair shops, printing businesses
2. Industrial – manufacturing, processing, research facilities
3. Waste disposal – lagoons, landfills, bulky wastes

MOST RISK

(Source: CTDEP)

Exhibit 5. Prioritizing Contamination Threats

All the potential contamination threats for the Hopkins Wellfield were reviewed and classified "A" to "E" according to the "Ranking of Land Use Categories by Their Risk to Groundwater Quality". All the numbered sites identified in the Killingly Aquifer Land Use Analysis (1995) were at least Category C sites and most were Category E sites. Sites with documented releases were automatically classified as category E sites. Exhibit 4 identifies those potential contamination threats ranked as Category C, D and E.

Pilot Strategic Monitoring Case Study, Atlantic Geoscientific Corporation, 1999

TASK 3: ASSESS CONTAMINANT MIGRATION PATHWAYS TO PRODUCTION WELL(S)

The purpose of assessing contaminant and migration pathways is to assist in designing a monitoring network capable of intercepting contaminants migrating from potential contaminated sites toward the wellfield to provide an early warning system for the water supplier. Development of a conceptual model that describes hydrogeologic controls on contaminant movement is the first step, followed by the assessment of contaminant migration pathways. Once migration pathways are delineated, the travel time for contaminants to reach the production well(s) can be estimated.

Critical groundwater flowpath and geologic cross-section information will be used to plan the locations and screened intervals for groundwater monitoring devices. The installation of new devices will be used to supplement existing monitoring systems to provide as comprehensive a monitoring network as possible within budgetary constraints. Travel-time estimates of potential contaminants will help formulate the sampling frequencies.

Develop Conceptual Hydrogeologic Model for Contaminant Movement

A conceptual hydrogeologic model should be developed to determine the existence of hydraulic boundaries, areally extensive stratigraphic units, or strong vertical gradients that could control the migration of contaminants. Knowledge of these conditions is essential to optimize the design of a monitoring network that will intercept potential contamination approaching the wellfield from upgradient sources.

The important elements that should be addressed and described in a conceptual hydrogeologic model are listed below. The Level A report for the wellfield should contain a conceptual hydrogeologic model describing the movement of groundwater through the aquifer for the purpose of constraining the design of the computerized groundwater flow model. This conceptual model can form the basis for a conceptual model for contaminant movement. Exhibit 6 summarizes the conceptual hydrogeologic model for the case study site.

Elements of a Conceptual Hydrogeologic Model for Contaminant Movement

- Aquifer boundaries
- Aquifer recharge and discharge mechanisms
- Aquifer materials and stratigraphy
- Groundwater flow directions and gradients
- Nature of non-aquifer materials (bedrock, till, clay)
- Groundwater-surface water interaction
- Saturated thickness
- Presence of areally-extensive confining layers
- Implications of above on contaminant movement

Simple geologic cross-sections drawn approximately parallel and perpendicular to the direction of groundwater flow or more complex three-dimensional block diagrams facilitate visualizing subsurface conditions and can yield useful information for estimating contaminant migration pathways. The following data for the Level A study are useful in developing a conceptual hydrogeologic model: cross-sections, well logs, historical water level data, model design information, and the Level A model results.

Exhibit 6: Conceptual Hydrogeologic Model Summary

The Hopkins Wellfield withdraws water from an unconfined, stratified-drift, valley-fill aquifer composed of sand and gravel interbedded with fine-grained sand and silt. Glacial till, present below the aquifer and along its margins to the east and west, consists of poorly-sorted sand, silt, and gravel with some clay and boulders. The till forms the base of the stratified-drift aquifer. The saturated thickness of the stratified drift at the wellfield is approximately 60 feet. Bedrock has been mapped as the metamorphic rocks of the Scituate Granite Gneiss. The bedrock surface forms a trough trending roughly north-south beneath the Fivemile River. Depth to bedrock at the wellfield is approximately 75 feet.

In the immediate vicinity of the production wells, drilling data indicate that the aquifer is primarily sand and gravel. The Level A numerical model simulates the aquifer as a homogeneous unit by assigning a hydraulic conductivity value of 250 feet/day to the aquifer. To the north, east, and south of the wellfield, logs from wells that penetrate the aquifer commonly reveal lenses or layers of coarse gravel; several other wells encountered a layer of silt. Subsurface data indicate that the gravel and silt layers are localized lenses and are not continuous. This area of the aquifer was simulated in the Level A model by assigning a hydraulic conductivity value of 10 feet/day to the silt unit.

The aquifer that supplies the wellfield is stratified drift under water table, or unconfined, conditions. The water table generally mirrors the ground surface; groundwater flows westward from the till and bedrock highlands on the east edge of the valley towards the Fivemile River, which serves as the regional groundwater discharge zone. Nearby Whetstone Brook appears to be a losing stream that recharges the aquifer during high water periods. The distribution of modeled heads under Level A pumping conditions suggests there are no significant vertical hydraulic gradients in the Hopkins Wellfield AOC except very close to PW2. Observed potentiometric data, under operational pumping conditions, and the Level A model simulations are consistent with this conclusion.

In summary, aquifer stratigraphy and groundwater flow patterns in the vicinity of the wellfield suggest that groundwater moves at approximately the same rate throughout the entire thickness of the aquifer material. Based on the reported aquifer properties, there do not appear to be any areally extensive confining layers interbedded within the sand and gravel or strong vertical gradients that would significantly alter contaminant migration pathways from their potential origins to the production well screens.

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Estimate Critical Groundwater Flow Paths and Travel Times

A critical groundwater flow path is a preferred contaminant migration pathway, or flow line, from a high-priority contamination threat to the wellfield under "Level A conditions". Level A regulations mandate that the model simulate "Level A conditions", achieved by 180 days of pumping with no recharge to the aquifer. An evaluation of the distribution of hydraulic head under modeled Level A conditions, and a subsequent determination of groundwater flow paths and travel times under the same conditions, should be completed in this task.

Travel times along flow paths, sometimes translated into capture zones using a time-of-travel criterion, provide a basis for establishing the sampling frequencies for the monitoring wells. The capture zone is the land area contained inside the circle formed by connecting the particle location generated by running the model backwards for a chosen time-of-travel. For example, a series of capture zones can be delineated representing 90-day, 180-day and 365-day times-of-travel. Monitoring wells placed near the 90-day capture zone boundary would be sampled every 45 days, wells near the 180-day capture zone would be sampled at least quarterly, etc. In order to provide adequate early-warning detection of contaminants, the sampling frequencies for a given monitoring well should be approximately one half of the time-of-travel for a contaminant to move from the monitoring well to the wellfield.

Several options exist to determine groundwater flow paths and travel times under Level A conditions. The options include the performance of a more simplified, traditional flownet analysis and manual calculation of travel times, or post-processing of Level A groundwater flow data with a particle-tracking model. These two options are described below.

While one could justify using "average" pumping conditions to determine groundwater flow paths, the use of Level A drought condition results in a worst-case scenario whereby the greatest number of flow paths terminate at the production well(s). The modeled head distribution under these conditions produces flow lines that converge at the wellfield. Flow lines under modeled *average ambient* conditions usually differ substantially from those under *Level A conditions*.

Flow Net Analysis

A flow net is "a set of intersecting equipotential lines and flow lines representing two-dimensional steady flow through porous media" (Fetter, 1994). Once a flow net is completed, flow paths originating from any point can be drawn perpendicular to the equipotential lines, allowing one to determine whether flow lines originating from high-priority threats terminate at the wellfield.

First, a horizontal flow net should be developed using modeled output of heads under Level A conditions. This entails the following steps:

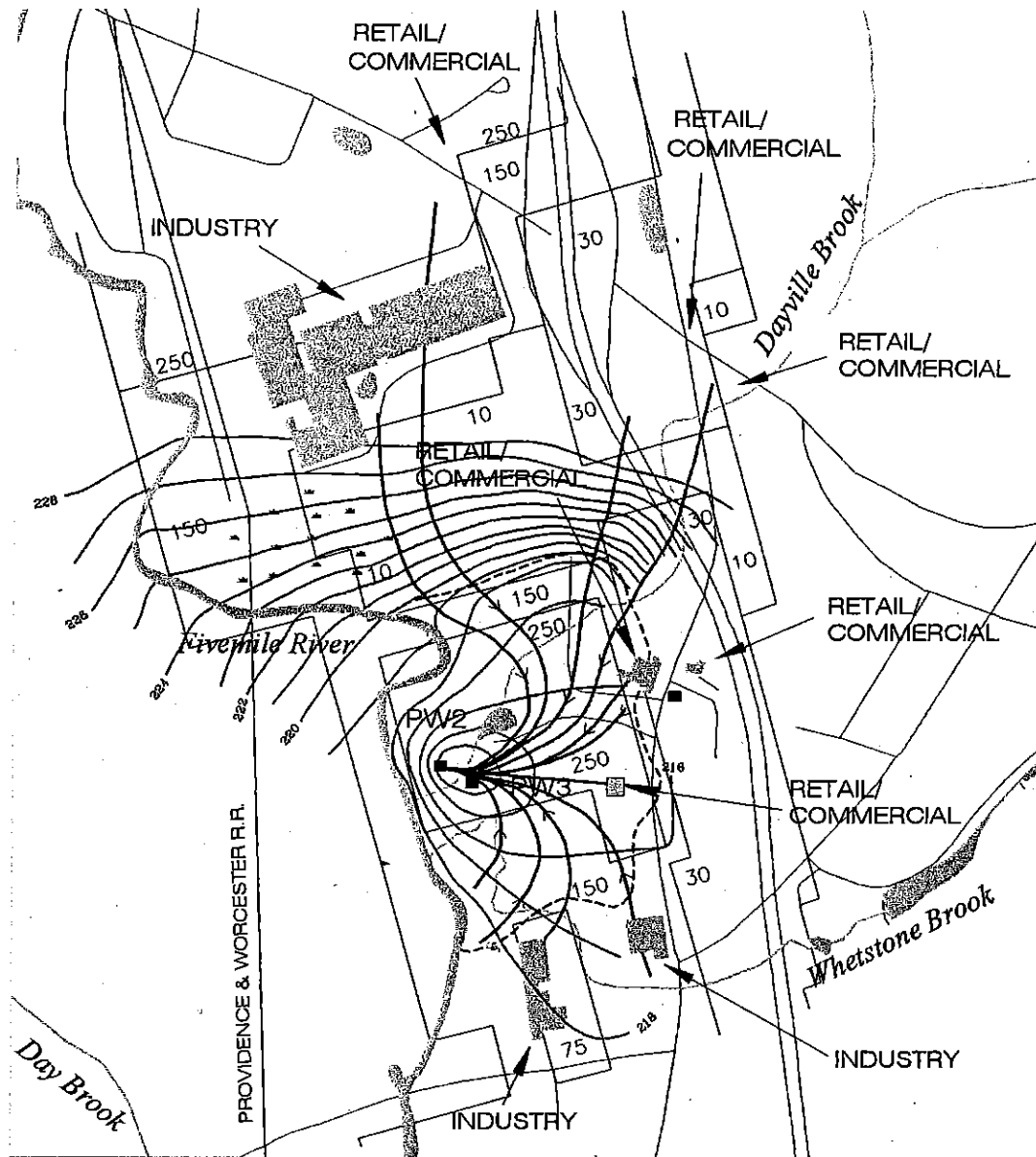
1. Plot a map with contoured and posted modeled heads
2. Choose high-priority potential contamination threats as origination points for flow paths
3. Draw "critical groundwater flow paths" from (2) to the wellfield staying perpendicular to the contours (equipotential lines).

Exhibit 7: Flow Path Delineation Using Flow Net Analysis

Our approach to delineating contaminant flow paths took into account two observations. First, the conceptual hydrogeologic model suggests that there are no significant vertical gradients capable of altering contaminant migration pathways. Second, after evaluating and prioritizing the potential contamination, it was evident that potential contaminant flow paths to the production wells originate from many directions. We decided to 1. complete a horizontal flow net analysis of the modeled head distribution under Level A conditions and 2. delineate critical groundwater flow paths from selected higher risk contaminant sources located in a circle around the wellfield.

This procedure yielded an array of flow lines that converge at PW2. Exhibit 8 shows the estimated contaminant migration pathways from selected higher risk contaminant sources, along with the modeled layer 1 hydraulic heads used to delineate the flow paths.

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.



EXPLANATION

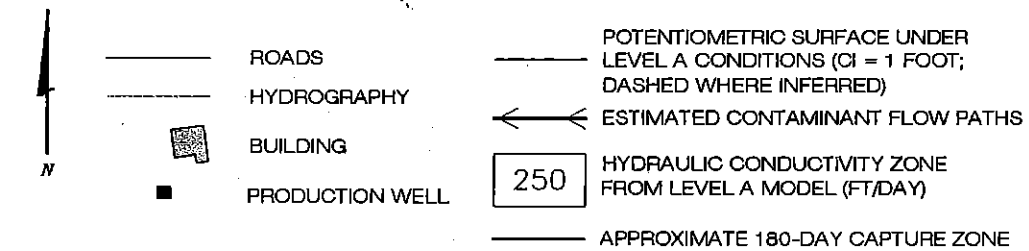


Exhibit 8. Potential Contaminant Flow Paths and Capture Zone

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999

To evaluate flow paths in the vertical dimension, geologic cross-sections developed as part of Task 3 should be used to identify zones of enhanced hydraulic conductivity within the stratified drift. Variability in hydraulic conductivity with depth may play a predominant role in controlling the distribution of hydraulic head, and thus contaminants. If sufficient data exists, observed or modeled hydraulic head data along the geologic cross sections can be posted and used to draw flow paths in the vertical dimension. The Level A mapping studies include geologic cross-sections that can be used for this evaluation. Additional cross-sections can also be drawn along suspected critical flow paths when not available in the Level A Mapping. Exhibit 7 describes the development of potential contaminant flow paths for the case study site shown in Exhibit 8.

The manual calculation of travel times involves application of the equation below to calculate the time-of-travel along a flow line:

$$\text{Travel time} = (d \times \emptyset) \div (K \times i)$$

where K = hydraulic conductivity (feet per day)

i = hydraulic gradient (unitless),

\emptyset = effective porosity, and

d = distance from potential release points to the wellfield along the flow path (feet).

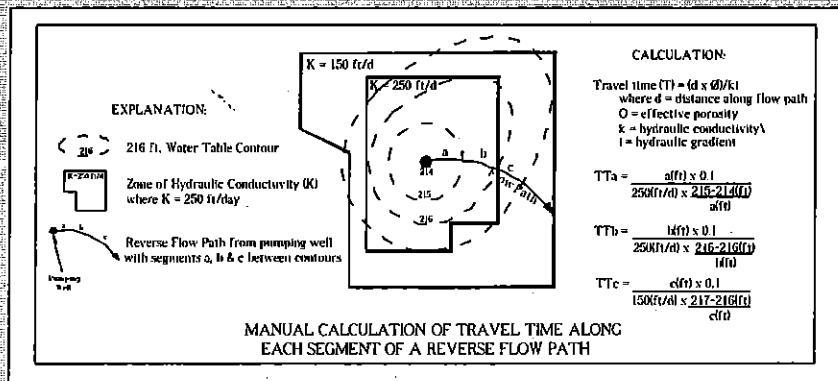
It should be noted that computed travel times are approximate due to the uncertainties associated with modeled heads used to generate the flow paths and the hydraulic parameters used in the travel-time calculations along each flow path. The application of this method for the case study to estimate travel times along critical contaminant flow paths is discussed in the Exhibit 9.

Exhibit 9. Manual Calculation of Travel Times

Values for K , i , and \emptyset were obtained from the Level A model (Whitman & Howard, 1995). A value of 0.1 was used as an approximation of effective porosity, based on the specific yield selected for the Level A model. The modeled layer 1 K zones were overlaid on the contaminant migration pathways (Exhibit 10). Gradients were calculated in segments between 1 foot water level contours along each flow path as:

$$1 \text{ foot} \div \text{distance between contours}$$

Discrete travel times along the flowpath were then calculated for each zone of hydraulic conductivity. These travel times were summed up starting from the center of the wellfield until 180 days was reached. The 180-day capture zone of the Hopkins Wellfield is based on 180 days of travel along each contaminant flow path (Exhibit 10). The 180-day capture zone is a somewhat irregularly shaped area that varies from approximately 900 to 1,500 feet from the wellfield.



Pitts Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Particle Tracking

Particle tracking using computer codes allows the user to delineate particle flow paths, thus facilitating visualization of the flow field. These codes are generally used as post-processors to groundwater flow models to check for errors, as well as to delineate the flow system and its recharge and discharge areas. Particle tracking is also useful for determining contamination sources and delineating capture zones. Particles are introduced at the wellhead and tracked in reverse (reverse particle tracking) to determine their origin. The upgradient boundaries of the capture zone are determined by the selected time-of-travel

A variety of models are available ranging from more simplified analytical and semi-analytical programs to complex numerical codes. Water companies typically hire a consultant to complete modeling because of the computer and technical expertise required. Appendix 2 contains additional references concerning the selection of computer codes.

As described above, particle tracking should be performed under Level A conditions. Thus, the particle tracking simulation should be based on conditions at the end of the 180-day drought scenario.

The procedure is described below:

1. Choose an analytical, semi-analytical, or numerical particle-tracking model.
2. Use modeled head output at the end of the Level A simulation (180 days with no recharge) as starting heads or appropriate data representing these conditions.
3. Choose either a transient or steady state simulation. Each option requires that the model be close to or at steady-state conditions at the end of 180 days.
4. Place particles around the perimeter of the AOC or at high-priority threat sites.
5. Run model the forward to trace their flow paths.
6. Choose a time-of-travel criterion (e.g., 180 days, 365 days, 5 years).
7. Run the model in reverse to trace the location of the particles at the time-of-travel criterion.

Evaluate Potential Surface Water Quality Influence

Surface watercourses often act as sources of recharge under pumping conditions. If a surface water body of poor water quality is located within the Area of Contribution, its threat potential may be high. If the surface water body is located within the Recharge Area, it may also provide a component of the wellfield's recharge. In this case, the Level A report should be reviewed and a determination made as to the potential for induced infiltration from the surface water body. This evaluation will determine whether and where surface water monitoring points should be included in the monitoring network.

TASK 4: DESIGN MONITORING NETWORK

The objective of this task is to design a monitoring network that supplements existing monitoring systems. The goal is to monitor, in priority order, land-use activities that are deemed to present the greatest likely threat of water quality impairment of production well water and to provide early-warning detection of contaminants. The proper placement of monitoring wells provides the ability to: 1) monitor trends in aquifer water quality; 2) detect a contaminant plume, its direction and velocity; and 3) plan the appropriate response, including remediation and production well shutdown. The monitoring network should be as comprehensive as possible within budgetary constraints. The following sections describe the steps for designing a monitoring network.

Evaluate Existing Monitoring Programs

The identification of existing monitoring programs is important in determining where ongoing monitoring can provide adequate early-warning of contamination and where additional monitoring wells are needed to close gaps in the existing monitoring programs. Contamination sites within the Recharge Area that are under state or federal oversight

control should be evaluated to determine the adequacy of any existing water quality monitoring programs in the context of the project objectives. If existing monitoring programs are deemed inadequate, a request for modification of the facility sampling program can be made.

Information on existing monitoring programs at regulated sites can be obtained from the CTDEP and the US EPA Region 1. Additional documents can be requested from these agencies to confirm monitoring well locations and construction details, and to obtain boring logs, sampling schedules, and analytes. Shown here is an example of a form detailing the type of information that is useful for evaluating existing monitoring programs.

Locate and Design Monitoring Network

Existing Monitoring Program Form					
A. WITHIN AREA OF CONTRIBUTION					
SITE NAME & ADDRESS	SAMPLING FREQUENCY	WELLS SAMPLED	ANALYTES SAMPLED	SIGNIFICANT DETECTIONS	REGULATORY STATUS

B. WITHIN RECHARGE AREA (AND OUTSIDE AREA OF CONTRIBUTION)					
SITE NAME & ADDRESS	SAMPLING FREQUENCY	WELLS SAMPLED	ANALYTES SAMPLED	SIGNIFICANT DETECTIONS	REGULATORY STATUS

The design of the monitoring network is the result of a combination of factors: 1) *technical criteria* that identify "ideal well sites" to optimize the interception of contaminants in a timely fashion and provide adequate early-warning to the water supplier and 2) *logistical factors* that may limit the available sites and result in modifications to the "ideal well sites". Technical criteria may be sacrificed in some cases due to logistical considerations; for instance legal and physical access to the preferred well sites may not always be available.

A monitoring network for strategic monitoring can include various kinds of monitoring stations such as:

- surface water sampling stations
- riverbank piezometers
- micro wells
- conventional 2-inch PVC monitoring wells
- multiport sampling devices
- nested monitoring well or piezometer pairs

The subsurface materials, physical access to the site, range of expected contaminants and project budget are some of the factors that will determine the appropriate choice of monitoring stations.

Guidelines for Locating Monitoring Stations

Technical Criteria:

- prioritize monitoring station locations to intercept contamination migration from the highest risk land uses;
- locate monitoring stations at a distance from the production well(s) such that the planned sampling frequency (ideally half the time-of-travel) provides adequate early warning of potential contamination;
- locate monitoring stations to have overlapping monitoring well capture zones, maximizing the likelihood of intercepting contaminants along likely pathways;
- locate monitoring station clusters where needed so that the screens taken can adequately cover the aquifer thickness (ideally, 10 feet of screen for every 20 or 30 feet of aquifer thickness).

Logistical Factors:

- use existing monitoring wells and ongoing compliance monitoring programs, where feasible;
- adhere to permit requirements (wetlands, filling...);
- provide physical access for drilling, monitoring and sampling;
- comply with legal access arrangements (owner's permission, rights of way, liability...).

Exhibit 10 and Exhibit 11 describe the approach taken to designing a monitoring network for the case study site.

Exhibit 10. Monitoring Network Design

The monitoring network for the Hopkins Wellfield consists primarily of 2-inch PVC monitoring wells. The network was divided into two categories of wells:

Category 1. Monitoring wells to be sampled by the water company.

Wells in this category include existing wells and new monitoring wells installed as part of this project to be sampled by the water company. Potential upgradient threats consist of risk category C, D, or E sites. These wells are considered high-priority and thus sampled by the water company.

Category 2. Monitoring wells already sampled by neighboring facilities under ongoing compliance monitoring programs.

Wells in this category are currently sampled by neighboring facilities under their on-going compliance monitoring programs. Selected water-quality data and reports from wells in this category will be obtained and integrated into the monitoring program.

Once well sites were prioritized on a map, the property owners were contacted, given information about the monitoring program, and asked for permission to conduct a site walkover to stake well locations. In one case the owner could not be reached, thus planned well locations were moved to an adjacent lot. Atlantic Geoscience Corporation conducted the site walkover and staked well locations in May 1997. Physical conditions such as buildings, grades, and soil conditions were also taken into account. Adjustments were made in well locations in several cases to allow drilling access.

The local Inland and Watercourses Commission regulates clear-cutting, sub-grade disturbance, filling, culverting and discharge of pollutants within 200 feet of wetlands. Atlantic Geoscience Corporation provided the Commission with a letter detailing the drilling activities and a map showing proposed drilling locations. The Commission ruled that drilling could proceed if sediment and erosion control measures were employed. Property owners were again contacted and asked to check the staked locations and grant permission for drilling and long-term sampling.

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Property Access and Agreements

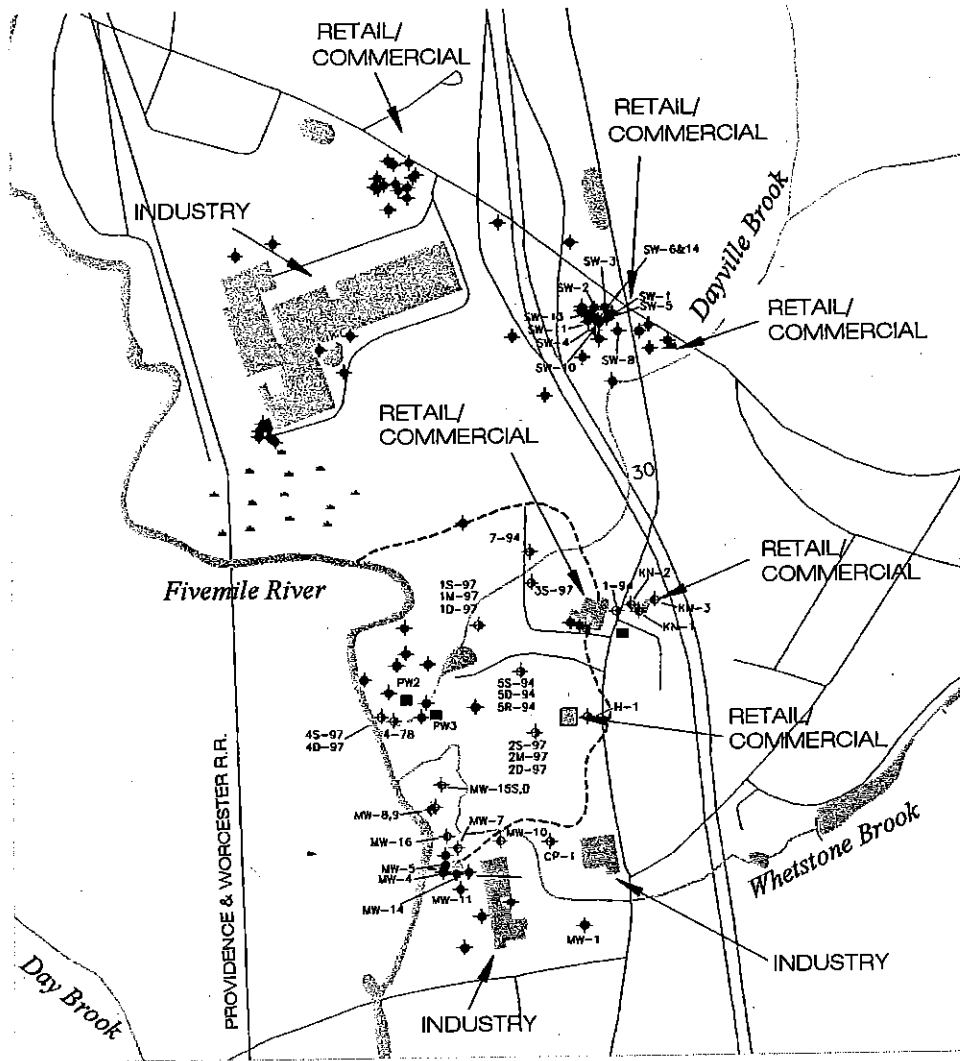
The ideal situation is to design a monitoring network where all the existing and/or proposed monitoring wells are on the water company property, thereby bypassing any need for special permission to access neighboring properties for drilling and sampling. If this is not possible, a mechanism is needed to formalize an agreement with neighbors to carry out the monitoring program using wells on their property.

One approach is to draft a simple letter agreement. The sample letters here address two situations:

1. permission to access and sample *existing* monitoring well(s)
2. permission to install and sample *new* monitoring well(s)

If a more formal agreement is desired, then other options are available such as a deeded easement (in perpetuity) or a lease to access the property for a specified duration of time. Regardless of the type of agreement, the following elements should be included in writing:

- brief description of the monitoring program
- description of existing or proposed wells to be accessed or installed
- reason for entrance to property and what activities will take place
- frequency and duration of entrance to property
- special arrangements such as transfer of keys, advance notification, parking, sharing water quality results, etc.



EXPLANATION

- ROADS
 - HYDROGRAPHY
 - - - - - APPROXIMATE 180-DAY CAPTURE ZONE
 - BUILDING
 - PRODUCTION WELL
- MONITORING WELL NETWORK:
- ⊕ CATEGORY 1 WELLS (sampled by Water Company)
 - ⊕ CATEGORY 2 WELLS (sampled by facility owner)
 - ⊕ ADDITIONAL EXISTING WELLS IN VICINITY



Exhibit 11. Monitoring Well Network

Example of a Property Access Permission Letter to Drill and Sample New Well(s)

To Whom It May Concern:

The (water company) is currently designing a monitoring well network for the purpose of tracking background water quality of the aquifer and providing early warning detection in the event that changes in water quality could affect our production wells. As you may know, we have monitored water quality at several wells that we plan to sample on a regular basis to achieve the goals of the project as stated.

We would very much appreciate your permission so that we may install monitoring well/s on your property to include in our network. The proposed locations are shown on the attached map. We would be willing to move the locations somewhat to accommodate your needs. With your permission we would install the wells using a truck or track-mounted drill rig and, once completed, return the area to its original condition. A representative of the (water company) would come onto your property several times throughout the year to measure water levels and take water samples. We anticipate that this process would take between one and two hours each time.

Thank you very much for your attention to this request and assistance in this matter. If you are willing to grant the permission requested, would you please sign where noted below and return the enclosed permission to us. If you have any questions regarding the project do not hesitate to contact me at _____.

Sincerely,

(water company representative)

I hereby grant permission to (water company) and their representatives to install monitoring well/s on my property and to subsequently enter my property for purposes of monitoring water levels and collecting water samples at the above well(s).

Hereunto duly authorized:

Signature

Date

Please print name and title

Example of a Property Access Permission Letter to Sample Existing Well(s)

To Whom It May Concern:

The (water company) is currently designing a monitoring well network for the purpose of tracking background water quality of the aquifer and providing early warning detection in the event that changes in water quality could affect our production wells. As you may know, we have monitored water quality at several wells, which we plan to sample on a regular basis to achieve the goals of the project as stated.

During the course of this study, it has come to our attention that a well identified as (well id) is located on your property. We would very much appreciate your cooperation so that we may include the well in our network. With your permission a representative of the (water company) would come onto your property several times throughout the year to measure water levels and take water samples. We anticipate that this process would take between one and two hours each time.

If you are willing to provide us permission to utilize your monitoring well for the purposes stated above, we will adhere to any protocols that you may require. With regard to physical access to the well, we would need to obtain a key to the lock that is currently on the well or replace your lock with ours. In the latter case we would return your lock to you.

Thank you very much for your attention to this request and assistance in this matter. If you are willing to grant the permission requested, would you please sign where noted below and return the enclosed permission to us. If you have any questions regarding the project do not hesitate to contact me at _____.

Sincerely,

(water company representative)

I hereby grant permission to (water company) and their representatives to enter my property for the purposes of monitoring water levels and collecting water samples at the above well(s).

Hereunto duly authorized:

Signature

Date

Please print name and title

TASK 5: DESIGN SAMPLING PLAN

A sampling plan should describe all field and analytical aspects of a simple, cost effective and technically sound monitoring program. This includes the selection of sampling equipment, analytical test methods, sampling frequencies, sampling procedures, and quality assurance measures. A properly designed monitoring program will: 1) maximize the range of detectable contaminants; 2) minimize costs; 3) increase the available reaction time to initiate remedial action; and 4) promote data integrity by developing detailed procedural guidance through the use of forms and checklists. A sampling plan form is useful for organizing information relevant to each monitoring well.

Sampling Plan Form								
MONITORING WELL	PROPERTY OWNER OF RECORD *	TAX MAP & PARCEL NO. *	POTENTIAL UPGRADIENT THREATS		KNOWN OR LIKELY CONTAMINANTS OF CONCERN	ANALYTES	EPA METHOD OF ANALYSIS	MONITORING FREQUENCY
			KNOWN RELEASE	HIGH-RISK REGULATED LAND USE **				

* Tax map, parcel number, & property owner of record at location of well
 ** These land uses are proposed to be regulated under Connecticut General Statutes 22a-354i and represent categories C, D & E from "Ranking of Land Use Categories by their Risk to Groundwater Quality", CTDEP, 1997.

Develop Technical and Cost Evaluation of Water Quality Sampling Systems

Options for water quality sampling systems should be carefully evaluated. First a technical and cost comparison of purging and sampling equipment is suggested. Second, the choice of equipment can be made based on this comparison and balancing the four objectives outlined below:

1. technical integrity of the equipment and samples;
2. adherence to overall goals of the monitoring program;
3. "ease of use" ; and
4. time and expense of sample procurement.

Commonly used sample collection methods to be evaluated might include: positive displacement bladder pumps; suction pumps (peristaltic or centrifugal); gas-drive devices; positive displacement pumps (submersible); and bailers. The technical integrity of the equipment should be evaluated by determining: compatibility with low-flow purging and sampling protocols; potential to mix the water column, introduce turbidity, or degas the sample; decontamination procedures; ease-of-use; and logistical considerations (power supply, method of transport, water depth limit).

Exhibit 12 includes such an evaluation of 1) peristaltic pumps, 2) variable rate submersible pumps, 3) non-variable rate submersible pumps, and 4) bailers. An added component of the evaluation was whether the pump would be dedicated to a well or used on multiple wells with decontamination procedures between wells.

Exhibit 12. Technical Comparison of Purging and Sampling Equipment

	NON-DEDICATED PERISTALTIC PUMP & DEDICATED TUBING	DEDICATED NVR SUBMERSIBLE PUMP & TUBING	DEDICATED BAILER	NON-DEDICATED VS SUBMERSIBLE PUMP & TUBING	DEDICATED VS. SUBMERSIBLE PUMP & TUBING
GENERAL					
Depth Limit	within suction (20 - 25 feet)	up to 50 feet	none	none	none
Cleanliness of water	not important	problematic if dirty	not important	problematic if dirty	problematic if dirty
Pump rate	up to 0.15 gpm	up to 2.5 gpm	approx 0.15 gpm	up to 5 gpm	up to 5 gpm
TECHNICAL ADVANTAGES					
Low flow/Low stress	Yes	Yes		Yes	Yes
no decon. required	Yes	Yes	Yes		Yes
TECHNICAL DISADVANTAGES					
Degassing of sample	Yes		Yes		
Turbidity Increase			Yes		
Mixing of water column			Yes	Yes	
Other		cannot control pump rate	measurement of indicator parameters while bailing not	gas-powered generator presents potential for VOC contamination	gas-powered generator presents potential for VOC contamination
LOGISTICAL ADVANTAGES					
Ease of use	Yes	Yes	Yes		
reliability of equipment	Yes		Yes		
faster purge time possible				Yes	Yes
LOGISTICAL DISADVANTAGES					
water depth limit	Yes (20 - 25 ft)	Yes (50 ft)			
complicated equipment				Yes	Yes
reasonable potential for equipment malfunction		Yes		Yes	Yes
Other		need to cool 5 minutes for every 15 minutes of operation	can be physically demanding to bail well	heavy equipment to move (pump, converter, generator)	heavy equipment to move (converter, generator)

NVR = Non-Variable rate; VR = Variable rate
Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

A cost comparison between rental and/or purchase of the sampling equipment needed for each option should be completed. Exhibit 13 presents cost comparisons in annual cost per well; annual cost per 14 wells at 4 sample rounds per year for 1 year; and annual cost per 14 wells at 4 sample rounds per year for 5 years.

Exhibit 13. Cost Comparison of Purging and Sampling Equipment

Cost Category	Rent Peristaltic Pump, Purchase Dedicated Tubing	Purchase NVR Dedicated Purge Pump and Tubing	Purchase Dedicated Bailer	Rent Non-Dedicated VR Submersible Pump, Purchase Tubing	Purchase Dedicated VR Submersible Pump and Tubing
Cost Per Well					
rental rate/week	\$60			\$250 (pump, generator & converter)	\$140 (generator)
one-time purchase (misc. items)	\$100 (battery)	\$225 (battery, & reel)	\$114 (reel & bracket)	\$157 (battery)	\$1444 (converter)
purchase dedicated equipment	\$225 (battery, weights, person)	\$252 (pump & tubing)	\$157 (bailer & NVR)		\$732 (pump & tubing)
Cost Per 14 Wells, 4 Sample Rounds Per Year					
rental	\$840			\$3,500	\$800
one-time purchase (misc. items)	\$1,400	\$3,150	\$1,598	\$2,200	\$19,912
purchase dedicated equipment	\$3,150	\$3,528	\$2,163		\$10,248
other				\$630	
TOTAL	\$8,540	\$10,278	\$3,761	\$6,330	\$30,960
Cost Per 14 Wells, 4 Sample Rounds Per Year for 5 Years					
rental	\$4,200			\$17,500	\$4,000
one-time purchase (misc. items)	\$1,400	\$3,150	\$1,598	\$2,200	\$19,912
purchase dedicated equipment	\$3,150	\$3,528	\$2,163		\$10,248
other				\$3,150	
TOTAL	\$12,800	\$16,778	\$5,761	\$23,850	\$34,160

* Purchase 1 length of non-dedicated tubing per sample round.
 NVR = Non-Variable rate; VR = Variable rate
Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Identify Appropriate Water Quality Parameters

Each monitoring point in the network should be sampled and analyzed for those chemical contaminants most likely to be intercepted by the production well(s). For each monitoring point, a list of likely contaminant types should be developed. This list will be largely dictated by the types of priority contaminants identified in Task 1 and might be refined as successive sampling rounds are completed. The list should also consider historical and current land uses upgradient of the production wells along the critical groundwater-flow pathways.

Once the list of potential contaminant types for each monitoring point is completed, appropriate analytical methods can be chosen. The analytes will likely not be the same for all the points, since potential contamination threats vary among sites. Table 8 provides a form to summarize these data for each point.

In consideration of the nature of contaminants expected at each monitoring point, and recognizing the expense associated with water quality analysis in the long term, the use of water quality indicator parameters should be evaluated. For example, if an ionic contaminant is expected, conductivity might be an effective indicator measurement. Similarly, if the contamination threat is a gasoline station, total petroleum hydrocarbons might be an appropriate water quality indicator. In addition, indicator parameters such as nitrate, total organic carbon, and chemical oxygen demand should also be evaluated.

Exhibit 14. Analytical Method Details

SAMPLE PARAMETER	EPA METHOD	NO. OF CONTAINERS PER SAMPLE	CONTAINER VOLUME	CONTAINER TYPE	SAMPLE MATRIX	PRESERVATION METHOD	MAXIMUM HOLDING PERIOD
VOCS	524.2	3*	40 ml	glass VOC vial	water	6N HCL, cooled	14 days
Pb - total	200.9 Graphite Furnace	1	250 ml	plastic	water	nitric acid, unfiltered cooled	6 months
Cr - total	200.7 ICP	1	250 ml	plastic	water	nitric acid, unfiltered cooled	6 months
pesticides	525.2	1	1000 ml	amber glass	water	6N HCL, cooled	14 days
herbicides	531.1	1	40 ml	amber glass	water	1.2 ml monochloroacetic acid buffer, cooled	14 days
nitrate	353.2	1	125 ml	plastic	water	cooled	48 hours

* Does not include trip blank vials

Plur Strategic Monitoring Case Study, Atlantic Cleasence Corporation, 1999

Managing the array of analytical methods, sample bottles, preservation procedures, and holding times for a typical sampling round is critical to the success of the data collection effort. Exhibit 14 shows an approach to summarizing these data to facilitate organization and sample collection.

Assess Required Sampling Frequency

The range of expected groundwater flow rates (and associated contaminant migration rates), and the spatial relationships of the

contamination threat, monitoring point and wellhead should be evaluated to determine recommended sampling frequencies. For example, if a conservative estimate of contaminant migration rates from the monitoring point to the wellhead indicates a travel time of 30 years, it would not be necessary to monitor that device every six months. Similarly, if a conservative estimate of migration rates indicate that a contaminant could move from the monitoring device to the wellhead within a month, then monitoring that point every six months would not provide any lead time for corrective measures in the event a contaminant were detected.

The frequency of sampling also varies among the wells in the network, depending on the location of the monitoring well relative to the wellfield and the estimated travel time for contaminants to migrate from potential sources to the production wells. For example, monitoring points might be sampled according to the following schedule:

- biannual sampling of wells within the 365-day capture zone; and
- quarterly sampling of wells within the 180-day capture zone.

Develop Sampling Protocols and Procedures

In this step, specific methods are developed for the procurement and handling of water quality samples. The primary objective of defining protocols and procedures is to optimize the consistency and integrity of the water quality data generated at each monitoring point. It is critical that the data be collected and handled with extreme care and consistency, since sample results are usually the sole basis for actions taken at a site. In addition, the data can be legally challenged and thus should be of the highest integrity.

Sampling protocols and procedures (sometimes called "SOPs") provide the best tool for ensuring data integrity. Strict adherence to the SOPs may make challenges to the data or data collection procedures less likely. The use of forms and checklists is often an efficient way to standardize and document these procedures and make sure they are followed. Appendix 7 includes an example of an SOP and forms used by Atlantic Geoscience Corporation in the Pilot Strategic Monitoring Case Study.

- Elements of a Sampling SOP**
- Hydrologic measurements
 - Purging
 - Sample collection
 - Sample filtration and preservation
 - Field measurements
 - Quality control samples
 - Sample storage and transport

While SOP's ensure proper sample procurement, the integrity of the analytical data is ensured by a Quality Assurance program. The purpose of a QA program is to document the procedures and criteria that will help facilitate the analysis of representative groundwater samples and the generation of valid, defensible laboratory data. A Quality Assurance program typically includes procedures for the collection of various quality control (QC) checks in the form of duplicate samples and sample blanks. These samples are prepared and submitted to the analytical laboratory as "blind" samples not identified as quality control samples. The QA plan should detail the number and type of QC samples to be collected, as well as criteria for validation of the analytical results.

QAQC Terms and Concepts

Accuracy is the degree of agreement between a measurement and an accepted reference of true value as determined by the analysis of blank spikes and/or spiked samples.

Precision is a measure of the mutual agreement among individual measurements and is determined by the analyses of laboratory duplicates.

Trip blanks are required for the purpose of demonstrating that containers and samples are not contaminated in transit. A trip blank consists of a volatile organic compound sample container filled with organic-free water that is maintained with the other sample containers prior to, during, and following sample collection. Typically one trip blank for each day of sample collection is prepared and submitted for VOC analysis.

Equipment blanks are required for the purpose of demonstrating that non-dedicated sampling equipment has not caused contamination of the field samples. If non-dedicated equipment is used to collect samples from one or more monitoring wells, one equipment blank should be collected using rinsate from the equipment after decontamination is complete.

Duplicates of groundwater samples are collected for the purpose of assessing the consistency of the overall sampling and analytical program. The duplicates are collected at the frequency of one duplicate per round of sampling and are submitted for analysis of the same parameters.

The precision criterion for duplicates is typically set at 20 percent. If this criterion is not met, the laboratory should be notified and, if samples are within the holding time, they should be re-analyzed. In addition, the laboratory should take measures to ensure that the precision criteria are met in the future.

Exhibit 15 summarizes various QC samples that were collected for each sampling round and the method of analysis of each sample. Exhibit 16 provides an explanation for the fictitious sample numbers reported to the laboratory. Careful documentation of fictitious QC sample identification is critical to proper data validation.

Develop Action Plan

An action plan represents a set of steps and guidelines to be followed in the event that contaminants are detected or long-term trends in the data change. A note of caution should be made here relative to the detection of contaminants. Detections are often the result of contamination due

TYPE OF SAMPLE	FREQUENCY OF SAMPLE	EPA METHOD
Trip Blank	1 per VOC cooler per day	EPA 524.2 (VOC's)
Equipment Blank*	1 per non-dedicated pump and tubing	EPA 524.2 (VOC's), 200.9 (Pb), 200.7 (Cr), 353.2 (nitrate), 525.2 & 531.1 (pesticides)
Duplicate	1 per round of samples**	EPA 524.2 (VOC's), 200.9 (Pb), 200.7 (Cr), 353.2 (nitrate), 525.2 & 531.1 (pesticides)
matrix spike/matrix spike duplicate	1 per round of samples**	EPA 524.2 (VOC's)

* Equipment blank only collected if using non-dedicated purging or sampling equipment
 ** 1 per round of samples; one duplicate per complete round of sampling from all wells in network

Exhibit 15. Quality Control Sampling Requirements
 Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

to invalid sample collection or laboratory analysis procedures. Thus any time sample results contain questionable or high contaminant levels, the water company should resample from the monitoring point.

An action plan should include the following elements:

1. minimum detection level thresholds for "action"
2. statistical trend thresholds for "action"
3. protocols for confirmation of detection
4. action to be taken upon confirmation of detection, for example
 - report results to appropriate local and state agencies
 - cleanup/remediation procedures
 - immediate modification of operations (reduce or cease pumping production well(s), etc.)
 - evaluate monitoring program (sampling frequency, analytical methods, monitoring network, etc.)

SAMPLE ID*	ANALYTES	METHOD OF ANALYSIS	SAMPLE DESCRIPTION**
MW-13	Pb, Cr	200.9, 200.7	duplicate for 112-97
MW-14	VOC	524.2	duplicate for 5R-94
MW-15	pesticides, herbicides, nitro	525.2/531.1/533.2	duplicate for 48-97
MW-16	pesticides, herbicides	525.2/531.1	distilled spring water regurgitated as an air-exposure sample; direct-pour; near H-1
MW-17	VOC	524.4	distilled spring water regurgitated as an air-exposure sample; vial filled by direct-pour near H-1
MW-18	VOC	524.2	distilled spring water for tubing blank
MW-19	VOC	524.2	pump rinse; after cleaning with ALCONOX before sampling (1-)
Blank	VOC	524.2	trip blank

* Use field/lab well ID
 ** Describe sample, for example duplicate for MW-1, or add (air) blank from a removable pump, or note, field blank prepared by pouring water through new air-line tubing

Exhibit 16. Quality Control Sample Record
 Pilon Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Exhibit 17. Action Plan

1. Upon initial detection of a contaminant at or above 20% of the CTDPH MCL or Action Level:
 - immediately resample to confirm results.
2. Upon observing a consistent increase in contaminant levels (two or more results equal to or greater than 150% relative percent difference) and concentrations at or above 20% CTDPH MCLs or Action Levels:
 - re-evaluate the monitoring program
3. If confirmed results are at or above 50% of MCLs or Action Levels:
 - inform owner of upgradient potential contamination source(s), if known;
 - determine whether spill/leak occurred;
 - consider modifying production well pumping rate;
 - re-evaluate the monitoring program
4. If confirmed results are above MCL's or Action Levels:
 - report these results immediately to CTDEP Permitting, Enforcement and Remediation Division;
 - consider modifying production well pumping rate;
 - inform owner of upgradient potential contamination source(s), if known;
 - determine whether spill/leak occurred;
 - consider initiating cleanup/remediation
 - re-evaluate the monitoring program.

Re-evaluation of the monitoring program might result in the following modifications:

- increase the sampling frequency at the subject monitoring point and/or at neighboring monitoring points in order to establish the contaminant concentration trend; and/or
- add new monitoring points to the monitoring network.

Pilon Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

The action plan developed for the Case Study (Exhibit 17) incorporated the trend and risk analyses protocols inherent to the data management system (discussed later in Task 8). The trend and risk analysis can assist in determining what steps are warranted if minimum detection levels are not exceeded but trends indicate a steady increase in contaminant levels.

TASK 6: PREPARE AND SUBMIT PROPOSED MONITORING WELL NETWORK DESIGN AND SAMPLING PLAN TO CTDEP

A plan should be prepared summarizing activities and results from Tasks 1 through 5 and submitted to the CTDEP. A history of the subject wellfield should be included describing any detected contaminants in the production well(s) or monitoring well(s). The purpose of the plan submission is to solicit input from the CTDEP and its staff relative to designing the most effective monitoring program.

TASK 7: INSTALL MONITORING POINTS AND SAMPLING SYSTEMS

The planning stage of the drilling phase involves several elements. Utility clearance is required before drilling to avoid hitting buried or overhead utilities, thereby posing a danger to on-site personnel, cutting off utilities, and incurring fees and/or fines. Site access should be discussed with the driller, preferably in an on-site meeting. Adequate access may require tree clearing, road building, filling or other measures to facilitate access of large, heavy drilling equipment to the flagged drilling sites. These site preparation activities may require permitting (as discussed in Exhibit 11 regarding the Inland and Water Courses Commission), permission, or inspection by governing bodies or landowners. Lastly, a health and safety plan should be completed to protect all on-site workers by promoting accident prevention and providing information on hospitals and other health care facilities.

A scope of work should be carefully prepared that details all aspects of the boring and monitoring well installation, including:

Exhibit 18. Subsurface Data Summary

Monitoring Well	Location (Distance to Production Well - ft.)	Boring Depth (ft bgs)	Screen Interval (ft bgs)	Well Diameter (in)	Depth to Water (ft bgs)	Total Saturated Thickness (ft)	Sample Pump Type	Tubing Inlet (in oga)
PW2	234	NA	55-70	1.6	15	70	sampling port	
PW3	234	NA	59-74	1.6	19	70	sampling port	
15-97	780	15	4-14	2	4	11	peristaltic	9
1M-97	780	45	15-45	2	4	41	peristaltic	39
1D-97	780	89	17-87	2	6	83	peristaltic	82
25-97	1,080	23	13-23	2	10	4	peristaltic	18
2M-97	1,080	34	28-39	2	20	18	peristaltic	33
2D-97	1,080	81	45-55	2	20	41	peristaltic	30
3S-97	1,000	25	15-25	2	11	44	peristaltic	20
43-97	158	15	4-14	2	6	8	peristaltic	9
4D-97	158	59	83-93	2	6	87	peristaltic	86
4-78	158	NA	37-42	2.6	6	250	peristaltic	36.5
5S-94	500	NA	15-25	2	20	70	peristaltic	20
5D-94	500	NA	59-69	2	20	70	peristaltic	64
5R-94	500	NA	88-95	1.6	20	70	peristaltic	106.5
7-94	1,080	NA	89-79	2	13	65	peristaltic	74
1-94	1,300	NA	7-17	2	14	15	peristaltic	12
CP-1	1,000	NA	20-30	2	19	70	peristaltic	25
H-1	880	NA	30-40	2	31	60	submersible	35

NOTES
 1. All constructed with a 2 PVC Blank base at a 4-in. casing; protective casing; well depth column indicates boring depth (for raw water).
 2. As measured in December, 1997.

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

- number of borings and monitoring wells
- expected boring depths and subsurface conditions
- monitoring well design (casing and screen materials, screen length, annulus seal, filter pack material, surface completion and development)
- source of water for drilling and well development
- drilling method (most common methods for monitoring well installation are cable tool; flight and hollow stem auger; and rotary)
- storage and disposal of contaminated cuttings or fluids
- decontamination procedures
- formation sampling
- boring log and well construction documentation
- special provisions to prevent contamination of the site by operation or maintenance of drilling equipment (including refueling)

There are several important procedures that should take place during drilling and thus should be negotiated in advance with the driller. First, procedures for the storage and disposal of contaminated drill cuttings, drill fluids, development water, and purge water should be agreed upon. If contaminated materials (cutting or fluid) are encountered, the driller must temporarily store those materials until proper disposal is arranged. Contaminated cuttings can be stored between impermeable tarps or in drums. Contaminated fluids must be stored in drums. Second, decontamination of equipment and tools is critical to maintaining the integrity of the well installations as well as the sample collection effort. Decontamination is critical both before mobilizing onto the site, as well as between individual well installations on the site. Third, the procedure for formation sampling should be specified to ensure that representative samples are collected. Sampling typically takes place using a split-spoon sampler, Shelby tube, or coring device. The frequency of sampling, typically every 5 feet, should also be decided. Lastly, a system for boring log documentation and reporting is needed. Many drillers provide samples in labeled jars as well as a boring log describing the subsurface conditions and the monitoring well construction details. Once data on the subsurface conditions at each well are obtained, it can be summarized in tabular form as shown in Exhibit 18.

The selection of a drilling company must be done carefully, considering several factors. First, the drilling company should be experienced not only with the installation of borings and monitoring wells, but should have such experience at contaminated sites and under similar subsurface conditions that are expected at the site. Second, a detailed proposal from the driller should reflect that the driller understands all aspects of the project (as described in the scope of work), has accounted for all supplies and requirements, and has provided a careful cost estimate. Third, the driller should demonstrate adequate insurance and bonding coverage.

Monitoring points/wells should be surveyed to provide both horizontal control for accurate mapping purposes and vertical elevations for determination of accurate water level elevations.

Once monitoring points/wells are in place and developed, sampling systems can be installed. Regardless of the type of sampling system, the intake should be at the screen mid-point. Permanent tubing or pumps installed in the well should be carefully set at the proper depth. Documentation of all installations, including photographs, should be kept for future reference.

TASK 8: WATER QUALITY MONITORING DATA MANAGEMENT SYSTEM

The purpose of a data management system is to provide a mechanism to store water quality data, to facilitate data analysis, and to determine statistically significant departures from background conditions. Such a system facilitates accurate and efficient record keeping and provides a tool to assist in the identification and evaluation of statistically significant departures from background water quality conditions.

Develop and Institute Internal Record-Keeping System

When designing a data management system, the "end user" should be identified; this will determine the type and complexity of the system. The "end user" is the entity (water company staff, hydrogeologist, consultant, etc...) who will maintain the system and complete the data entry and evaluation.

The basic elements of a data management system include:

1. Data validation procedures
2. Procedures for entry of monitoring data
3. Mechanism to summarize data by individual sampling round, including:
 - Contaminant detections above mdl (minimum detection level)
 - MCL (maximum contaminant level) exceedances
4. Mechanism to summarize data over multiple sampling rounds, including:
 - Time versus concentration graphs of selected analytes
 - Statistical trend analysis
 - Graphical trend analyses

Data validation refers to checking that all proper laboratory procedures were followed in the course of determining analytical results. For quality assurance, laboratory data should be validated before results are entered into the data management system. Basic data validation steps should be developed, as well as actions that should be taken if data validation criteria are not met. The table below includes the data validation procedures developed for the case study project.

The ideal data management system allows the user to store not only analytical data for each sample round, but to document important information regarding the collection of samples. This would include the static water level; duration, volume and rate of purging; sampler name; equipment used; decontamination procedures; notes on site and/or monitoring well conditions; QC sample explanation; and information on usual conditions or non-standard procedures. This information can be critical to the data validation process, for example to determine whether questionable detections resulted from contamination by equipment.

**Sample of a
Laboratory Data Validation SOP**

Date of Validation: _____
 Data Validated by: _____
 Samples procured from: _____
 Sample Round ID: _____
 Sampling Dates: _____
 Samples Submitted to Laboratory: _____
 Laboratory: _____
 Analytes: _____
 Sampler/Affiliation: _____

DATA VALIDATION CRITERIA	ACTION TAKEN IF CRITERIA NOT MET*
1. LABORATORY ANALYTICAL METHODS ARE IN COMPLIANCE WITH PLANNED METHODS	✓ CONFIRM ANALYTICAL METHODS WITH LAB ✓ CONFIRM VALIDITY OF TEST RESULTS FROM THE UNPLANNED TEST PROCEDURES ✓ - CLARIFY METHODS FOR NEXT SAMPLING ROUND
2. NUMBER OF LABORATORY REPORTS EQUAL TOTAL NUMBER OF SAMPLES SUBMITTED	✓ CONFIRM NUMBER OF SAMPLES COLLECTED AND SUBMITTED WITH FIELD RECORDS AND CHAIN-OF CUSTODY ✓ CONFIRM NUMBER OF SAMPLES COLLECTED, SUBMITTED AND ANALYZED WITH LAB ✓ CLARIFY NUMBER OF SAMPLES FOR NEXT SAMPLING ROUND ✓ - DETERMINE WHETHER FIELD OR LAB PROCEDURES SHOULD BE MODIFIED
3. TIME-OF-COLLECTION TO TIME-OF-ANALYSIS (OR EXTRACTION) IN COMPLIANCE WITH HOLDING PERIOD(S)	✓ CONFIRM EXCEEDENCE OF HOLDING PERIOD(S) WITH LABORATORY ✓ DETERMINE WHY HOLDING PERIOD(S) WAS(WERE) EXCEEDED AND HOW FIELD OR LAB PROCEDURES SHOULD BE MODIFIED TO ASSURE COMPLIANCE ✓ - INVALIDATE SAMPLE RESULTS & EVALUATE IMPACT OF DATA OMISSION
4. LAB PRECISION AND ACCURACY ARE WITHIN SPECIFIED CRITERIA FOR THE TEST METHOD USED	✓ CONFIRM ACCURACY & PRECISION RESULTS AND CRITERIA WITH LAB ✓ SECURE LAB'S COMMITMENT THAT THEY WILL TAKE MEASURES TO ENSURE THAT CRITERIA ARE MET IN THE FUTURE ✓ - INVALIDATE SAMPLE RESULTS & EVALUATE IMPACT OF DATA OMISSION
DATA VALIDATION CRITERIA	ACTION TAKEN IF CRITERIA NOT MET*
5. TRIP BLANK SAMPLE RESULTS SHOW NO CONTAMINATION	✓ CONFIRM TRIP BLANK RESULTS WITH LAB ✓ DETERMINE POSSIBLE SOURCES OF CONTAMINATION WHILE EMPTY CONTAINERS OR SAMPLES IN TRANSIT ✓ EVALUATE REMAINING SAMPLE RESULTS AND EVIDENCE FOR EXPOSURE TO SAME CONTAMINANTS(S) ✓ - INVALIDATE VOC SAMPLE RESULTS FOR SAMPLES ACCOMPANIED BY CONTAMINATED TRIP BLANK**
6. EQUIPMENT RINSATE SAMPLE RESULTS SHOW NO CONTAMINATION	✓ CONFIRM EQUIPMENT BLANK RESULTS WITH LAB ✓ FOR SAMPLES THAT CAME INTO CONTACT WITH CONTAMINATED EQUIPMENT, IDENTIFY EVIDENCE FOR CONTAMINATION BY THE SAME ANALYTES & DETERMINE WHETHER SUBSEQUENT RESULTS ARE INVALID ✓ - MODIFY SAMPLING, DECONTAMINATION OR OTHER PROCEDURES TO PREVENT FUTURE CONTAMINATION BY EQUIPMENT

- * Additional actions(s) regarding use of sample results if Data Validation criteria not met:
- a. Re-analyze samples if within hold times
 - b. Re-sample wells and re-analyze
 - c. Invalidate sample results
 - d. Make use of data as-is with appropriate notation regarding data validation criteria
- ** Detection of VOC's in trip blank (as in any sample) can also be due to contamination of lab equipment by detection of VOC's in a previous sample; internal lab QC checks using matrix spike/matrix spike duplicates should detect such contamination

A data management system should facilitate analysis of data by individual sampling round, as well as tracking data through time. For example, a standard format for analysis of individual sampling rounds is a table that summarizes all data for a sampling round with MCL exceedances shown in bold. Long-term analysis is facilitated by graphs that track the concentration of one or more analytes over time. Regression can be used to develop best-fit lines or curves to examine trends in the data and evaluate departures from historic conditions. Exhibit 19 describes the data management system developed for the site, which consists of four linked Microsoft Excel® spreadsheets.

Exhibit 19 - Data Management System Description

Data Management System Structure: The data management system was comprised of four Microsoft Excel™ files containing multiple spreadsheets. For simplicity, these files are referred to as Database 1, Database 2, Database 3 and Database 4. Only one spreadsheet file requires raw data entry; the other database spreadsheets are either linked automatically or require a simple copy command of data from one spreadsheet to the other. The purpose of each file is as follows:

- Database 1 contains quarterly spreadsheet "forms" for active data entry of each quarterly sampling round.
- Database 2 automatically reformats data from Database 1 for plotting in Database 3.
- Database 3 displays plots of specific contaminants over time for selected wells.
- Database 4 contains data suitable for trend and risk analysis of individual wells.

Short-term trend analysis: Two simple calculations were incorporated in database 4 to provide a quick indicator of *short-term* trends in the data and the risk posed to the wellfield by changes in the water quality of samples from monitoring wells. First, the relative percent difference (RPD) between the current and previous concentration of an analyte at a well is calculated as:

$$RPD = ((\text{current conc.} - \text{last conc.}) / \text{last conc.}) \times 100$$

While concentrations can increase or decrease by a significant percent from one round to the next (revealed in the RPD), this change can be put into context by applying a second calculation: determining the concentration relative to the Action Level (or MCLs). For example, if ethylbenzene levels increase from 0.5 to 1.0 µg/l, this represents a 200% increase. However, the CTDPH Action Level for this contaminant is 700 µg/l. This 200% increase in ethylbenzene only represents an increase from .07% to 0.14% of the Action Level.

Long-term trend analysis: The plots created in Database 3 assist with the trend analysis of *long-term* data. Statistical trend lines (using linear, exponential, or logarithmic curves) are included on the graphs to help evaluate trends in the data and departures from historic conditions. A regression line was fit to each analyte choosing from among linear, exponential, and logarithmic curve fitting. The curve with the best fit, measured by the highest r^2 value, was chosen. The r^2 value is a statistical measure of the "goodness-of-fit" of the curve and varies from 0 (poor fit) to 1.0 (perfect fit).

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Coordinate Data Exchange with CTDEP

Data collected as part of a strategic monitoring program are of interest not only to the water company, but also to the CTDEP's Water Management Bureau. These water-quality data can reveal the conditions of Connecticut's water resources and help shape policy aimed at curbing groundwater pollution. Therefore, sharing the results of the monitoring program is encouraged. The CTDEP recommends that water suppliers planning a strategic monitoring program contact the Planning and Standards Division of the Water Management Bureau to work out the details of such a data exchange.

TASK 9: BEGIN MONITORING PROGRAM

At this point the water supplier is ready to initiate the sampling program. The steps, described in the previous sections, are as follows:

1. Notify landowners of plans to enter property for sampling; obtain permission and required keys;
2. Purchase or rent needed equipment for purging and sampling; check equipment operation and calibrate;
3. Organize/tabulate analytical methods and QC samples for each well;
4. Notify laboratory of sampling; schedule pickup and drop-off of bottles; obtain bottles and appropriate preservatives; label bottles in advance of field sampling;
5. Collect field forms and SOP's, including chain-of-custody forms, purging and sampling forms; purging and sampling SOP's; equipment manuals; QC sample forms;
6. Complete sample collection following all procedures;
7. Submit samples to laboratory using proper preservation procedures, staying within maximum holding times and accompanied by proper chain-of-custody forms; and
8. Upon receipt of data, complete data validation and enter into data management system.

If a consultant will be hired to complete sample collection, the water supplier should provide the consultant with the sampling plan, relevant site maps, and all other documentation pertinent to the steps outlined above.

TASK 10: ONGOING EVALUATION OF MONITORING PROGRAM

Strategic Monitoring Program Evaluation Form

I. Evaluation of Critical Data

Monitoring Program Water Quality Results: _____

Leaks & spills: _____

New land uses: _____

Site access issues: _____

Water quality from regulated sites in the APA: _____

Changes in the status of regulated sites in the APA: _____

II. Budgetary & Resource Considerations

Staff Resources: _____

Costs: _____

III. Evaluation of Monitoring Program (note modifications to monitoring program where appropriate)

Monitoring Network: _____

Analytes and Sampling Schedule: _____

Sample Collection Methods and Equipment: _____

QA Procedures: _____

Data Management System: _____

Action Plan: _____

Designing and maintaining a monitoring program is an ongoing and evolving process. The monitoring program is composed of many elements, including the monitoring well network, analytical methods, sampling schedule, sample collection methods and equipment, QA procedures, and data management. Many factors affect the initial design, as well as the evolution of the monitoring program. The interrelationship between these components and the evolving monitoring program are shown in Figure 4.

The most important factor in evaluating the monitoring program is observed trends in the water quality collected during the program. In addition, there are "external" factors

associated with neighboring sites, such as the occurrence of leaks and spills, new land uses, site access, and changes in the water quality and status of regulated sites in the Level A area. Furthermore, a monitoring program is constrained by business considerations such as costs and staff resources.

Evaluation of a monitoring program can be organized according to the form shown. The components of a complete monitoring program evaluation are discussed in the following sections.

Evaluation of Critical Data

In this task, water quality data, land uses and contamination incidents are evaluated to determine whether there are trends in groundwater quality or new risks posed to the aquifer that would warrant modifying the monitoring program. Such "critical data" to be evaluated are discussed below.

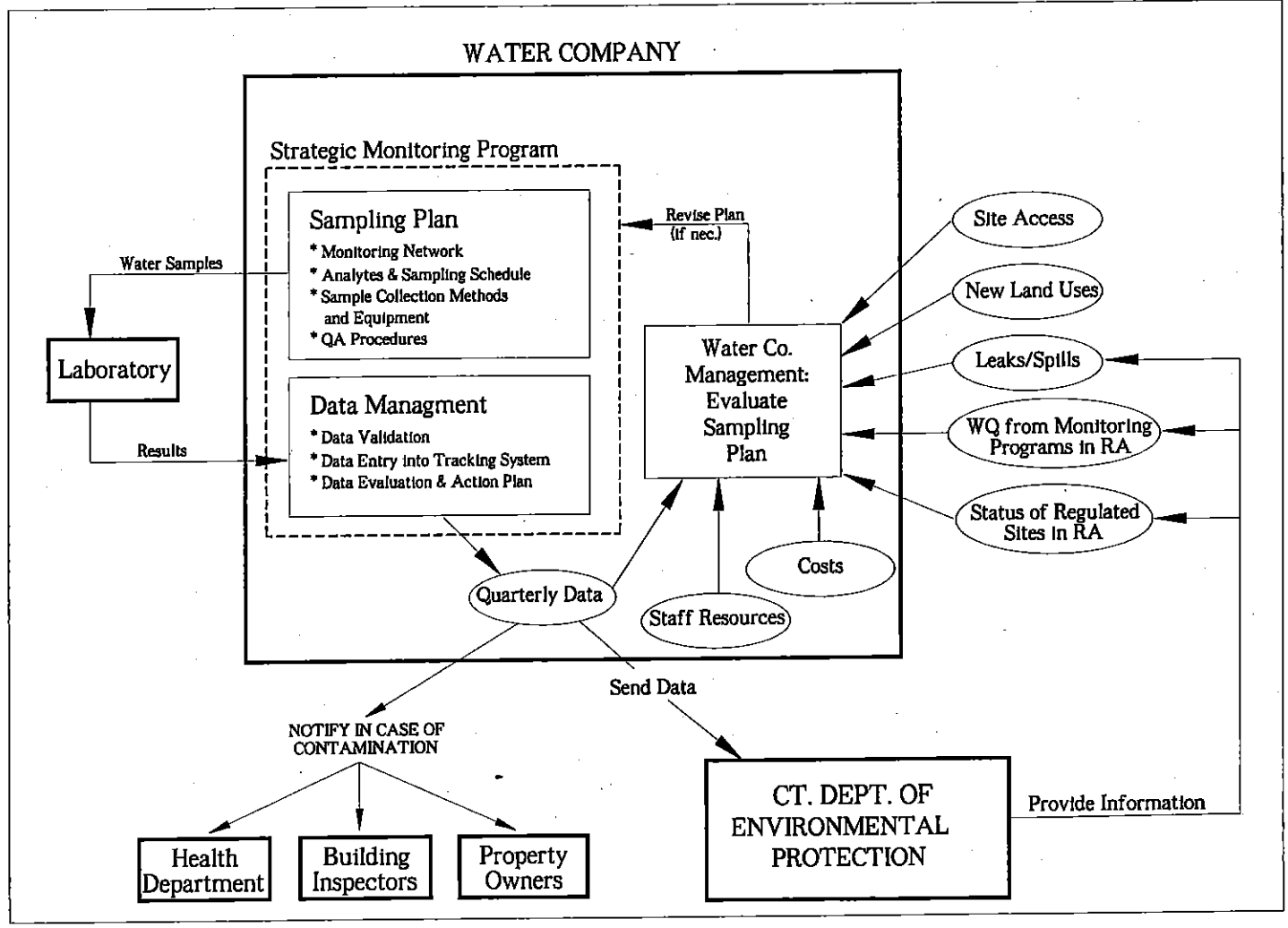
Monitoring Program Water Quality Results

This step includes an evaluation of contaminant levels (both newly detected and those above MCL or action levels), evidence for changes in the concentration or position of contaminants, and overall trends in the long-term data. Exhibit 20 shows the use of regression to produce best-fit curves for some contaminants in a production well.

Leaks And Spills

Evidence for leaks or spills, such as spill incident reports obtained from the CTDEP, should be evaluated to determine whether they pose any threat to the supply well(s).

Figure 4. Flow Diagram of Ongoing Monitoring Program Evaluation



Production Well 2 Primary Contaminant Levels

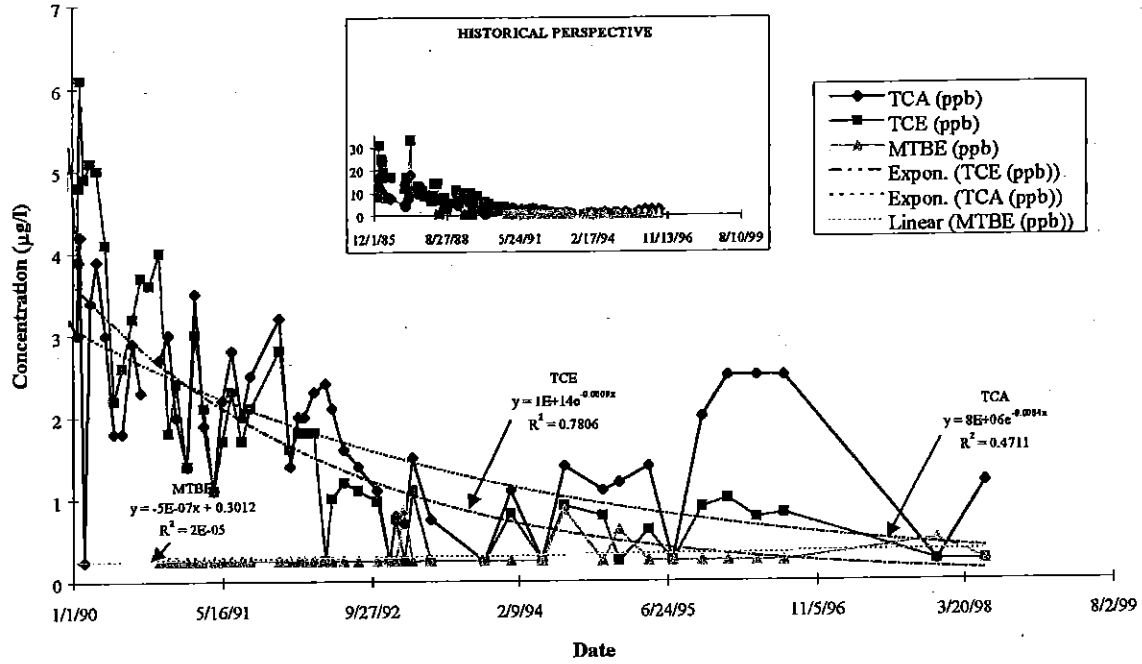


Exhibit 20. Historic Water Quality Trends

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999

New Land Uses

Observations relative to changes in activities on area parcels should be recorded. Activities of concern would include those that involve the use, storage, generation or on-site disposal of contaminants. Information gathered in the windshield survey described in Task 1 could be updated by a brief reconnaissance effort. Local municipal planning offices can be contacted to determine whether changes in zoning regulations have occurred or are anticipated.

Site Access Issues

Any problems with access to monitoring points for sampling should be recorded and addressed here. For example, a lack of snow removal from parking areas can make access to flush-mount monitoring wells difficult. Coordination between the water company representatives and the appropriate parties responsible for snow removal would be warranted in this case.

Water Quality from Regulated Sites in the Aquifer Protection Area

Water quality data obtained from regulated sites in the Aquifer Protection Area should be evaluated to determine whether there are significant changes in the concentrations of contaminants or in the monitoring program itself that would warrant modifications in the water company's program. For instance, the concentration of a particular constituent might reach levels of concern that justify increasing the frequency of sampling at monitoring wells between the regulated site and the water company's production well(s). Likewise, long-term data from the regulated site might indicate that a contaminant of concern has dropped below detection levels, allowing the water company to drop that constituent altogether from the list of sample analytes.

Changes in the Status of Regulated Sites in the Aquifer Protection Area

In the context of strategic monitoring, changes in the status of a regulated site would include any change that signaled either an improvement or worsening in water quality conditions attributable to on-site activities. A change in the site status include any number of steps taken by the state, such as imposition of an ORDER, initiation of a site investigation, change in site priority, or modification in the imposed monitoring program. Such changes in status might warrant modification in the water company's monitoring program. For example if the regulated site succeeded in obtaining approval from the CTDEP to reduce the number of monitoring points, the frequency of monitoring or the constituents for analysis and the water company had reason to be concerned about the adequacy of the revised monitoring program. In response, the water company might chose to take measures to compensate for the scaling-down of the regulated monitoring program, such as adding monitoring points, expanding analytes, or increasing sampling frequencies.

Budgetary and Resource Considerations

Exhibit 21. Monitoring Program Cost Estimates: Analytical Costs

<i>Plan #1:</i>							
Parameter	Price Per Sample*	Number of Wells Sampled Quarterly **	Total Number of Quarterly Samples Per Year	Number of Wells Sampled Biannually	Total Number of Biannual Samples Per Year	Total Number Sampled In One Year	Cost Per Year
VOCs (624-2)	\$150.00	13	52	5	10	62	\$9,300
Pb	\$20.00	4	16	0	0	16	\$320
Cr	\$20.00	4	16	0	0	16	\$320
Nitrate	\$15.00	4	16	0	0	16	\$240
TOTAL:							\$10,180

<i>Plan #2:</i>							
Parameter	Price Per Sample*	Number of Wells Sampled Quarterly **	Total Number of Quarterly Samples Per Year	Number of Wells Sampled Biannually	Total Number of Biannual Samples Per Year	Total Number Sampled In One Year	Cost Per Year
VOCs (624-2)	\$150.00	10	40	8	16	56	\$8,400
Pb	\$20.00	4	16	0	0	16	\$320
Cr	\$20.00	4	16	0	0	16	\$320
Nitrate	\$15.00	4	16	0	0	16	\$240
TOTAL:							\$9,280

<i>Plan #3:</i>							
Parameter	Price Per Sample*	Number of Wells Sampled Quarterly **	Total Number of Quarterly Samples Per Year	Number of Wells Sampled Biannually	Total Number of Biannual Samples Per Year	Total Number Sampled In One Year	Cost Per Year
VOCs (624-2)	\$150.00	7	28	1	2	30	\$4,500
VOCs (602-2)	\$100.00	4	16	7	14	30	\$3,000
Pb	\$20.00	4	16	0	0	16	\$320
Cr	\$20.00	4	16	0	0	16	\$320
Nitrate	\$15.00	4	16	0	0	16	\$240
TOTAL:							\$8,380

* prices are approximate and do not include discounts
 ** Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

A monitoring program must be evaluated like any other business expense by asking: "What are the costs and benefits of the program?" In this task the costs of the program are estimated. Primary costs include: 1) analytical laboratory fees, 2) equipment rental or purchase, and 3) labor for administration and execution of the monitoring program.

These primary costs should be evaluated to determine whether there are potential savings. Cost savings can be achieved through numerous means, including: reducing the number of monitoring points and/or the sampling frequency; reducing the number of parameters tested; choosing less expensive analytical methods; modifying the type of equipment rented or purchased; and generally increasing the efficiency of sample collection.

Exhibit 21 details analytical costs for three monitoring plan scenarios. The three scenarios were developed during the monitoring program evaluation completed after three rounds of data were collected

and analyzed. These plans differ in the number of wells sampled and the frequency of sampling. Thus analytical costs differ and can be weighed against the benefits of each plan.

Exhibit 22 summarizes labor requirements and equipment cost estimates. In the case of the peristaltic pump, rental and purchase options are compared.

Exhibit 22. Monitoring Program Cost Estimates - Labor and Equipment

Labor Estimates:

	Sample Collection:	Data Entry
Each Quarterly Round:	4 days X 8 hrs/day = 32 hours	8 hours
Per Year:	128 hours	32 hours

Equipment Estimates:

Equipment	Rental/Purchase	Quantity	Rate	Price Per Quarter	Annual Total
Peristaltic Pump	Rental	2	\$95/week	\$190	\$760
Peristaltic Pump	Purchase	2	\$800 - \$1000/pump		\$1600 - \$2000 one-time cost
Battery	Purchase	1	\$100		\$100 one-time cost

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Modification of Monitoring Program Elements

In this task the basic elements of the monitoring program are modified, if warranted, based on the evaluation of critical data as well as budgetary and resource considerations described above.

The monitoring network encompasses all monitoring points (monitoring wells, surface water points, micro wells, etc.) whose water quality data are to be tracked and evaluated as part of the strategic monitoring program. Thus, the network consists of points sampled by the water company and may include some points on neighboring parcels sampled for ongoing compliance monitoring. The following describes how various elements of the monitoring program can be modified.

Monitoring Network

As described in Task 4, the monitoring points that comprise the monitoring network 1) should be chosen to monitor, in priority order, land-use activities which are deemed to present the greatest likely threat of water quality impairment of production well water and 2) should be located so as to optimize the interception of contaminants in a timely fashion to provide adequate early-warning to the water company. The monitoring network may require modification as conditions in the aquifer protection area evolve, i.e., leaks or spills, land use changes, new contamination is detected, or the status of a regulated site changes. This might include substituting one monitoring point for another, adding or removing points, or installing new points.

Analytes and Sampling Schedule

For the most part, the sampling results will determine whether the analytes, analytical method, or sampling schedule should be modified. For example, if for an entire year no lead is detected at one or more wells, the water company might choose to drop lead testing from these wells altogether or reduce the frequency of lead testing. New activities in the recharge area, such as leaks, spills or changing land use, can also justify modifying the selection of analytes, analytical methods, or frequency of sampling to better detect changes in water quality of the aquifer attributable to these new activities. Likewise, the trend analysis feature in the data management system may indicate that levels of a particular analyte are suddenly significantly higher than background conditions, requiring an increase in the sampling frequency.

Sample Collection Methods and Equipment

Modification to sample collection methods might include adjusting procedures for: equipment decontamination; calibration and use; well purging; collection of water quality indication parameters; sample procurement; handling of bottle preservation; labeling, shipping, and chain-of-custody. Equipment modifications might include: examining whether to rent, lease, or buy equipment; choosing the type of equipment; or selecting the equipment manufacturer and source. Choices regarding equipment should balance the need for data of high integrity as well as affordable, reliable, and easy-to-use equipment.

QA Sampling Procedures

The purpose of QAQC sampling is to ensure the integrity of the analytical data and the consistency of the overall sampling and analytical program. All QA sampling procedures should be evaluated including: the number and source of QA samples (trip blanks, equipment blank duplicates...); procedures for collecting equipment blanks (which equipment, what analytical method...); and sample identification.

Data Management System

The Data Management System procedures should be evaluated (data validating, entry, manipulation, graphing, and trend and risk analysis) as well as its overall effectiveness as an organizational tool. The Data Management System should provide a mechanism to efficiently track long-term water-quality data and to determine whether there are significant departures from the historic "background" water quality record. Departures might indicate increased contamination and justify an evaluation of the overall monitoring program.

Action Plan

The action plan details steps for handling the detection of contaminants as well as decisions regarding the monitoring program once trends in the data are confirmed. In summary, the plan outlines the decision-making process for protecting the water supply in the event that contamination is detected or suggested from data trends. Modifications to the plan fall into one of two categories: the definition(s) of the "occurrence" that triggers action (threshold contamination levels, trend criteria...) or the action(s) taken (emergency contacts, on-site operational actions, changes to the monitoring program, etc.).

Exhibit 23 . Recommended Long Term Monitoring Plan: Three Options

MONITORING WELL	ANALYTES	EPA METHOD OF ANALYSIS	PLAN #1	PLAN #2	EPA METHOD OF ANALYSIS	PLAN #3
			MONITORING FREQUENCY	MONITORING FREQUENCY		MONITORING FREQUENCY
Hopkins Wellfield PW2 or PW3	VOCs	524.2	quarterly	quarterly	524.2	quarterly
	nitrate		annually	annually		annually
	metals		every 3 yrs	every 3 yrs		every 3 yrs
IS-97	VOCs, Pb, Cr	524.2, 200.9, 200.7	quarterly	biannually	502.2, 200.9, 200.7	biannually
IM-97	VOCs, Pb, Cr	524.2, 200.9, 200.7	quarterly	quarterly	502.2, 200.9, 200.7	quarterly
ID-97	VOCs, Pb, Cr	524.2, 200.9, 200.7	quarterly	quarterly	524.2, 200.9, 200.7	quarterly
2S-97	VOCs	524.2	quarterly	biannually	502.2	biannually
2M-97	VOCs	524.2	quarterly	quarterly	502.2	quarterly
2D-97	VOCs	524.2	quarterly	quarterly	524.2	quarterly
3S-97	VOCs	524.2	biannually	biannually	502.2	biannually
4-78	VOCs, nitrate	524.2, 353.2	quarterly	quarterly	524.2, 353.2	quarterly
4S-97	VOCs, nitrate	524.2, 353.2	quarterly	quarterly	502.2, 353.2	quarterly
4D-97	VOCs, nitrate	524.2, 353.2	quarterly	quarterly	524.2, 353.2	quarterly
5S-94	VOCs	524.2	quarterly	biannually	502.2	biannually
5D-94	VOCs	524.2	quarterly	quarterly	524.2	quarterly
5R-94	VOCs	524.2	quarterly	quarterly	524.2	quarterly
7-94	VOCs	524.2	biannually	biannually	502.2	biannual
1-94	VOCs	524.2	biannually	biannually	524.2	biannually
CP-1	VOCs	524.2	biannually	biannually	502.2	biannually
H-1	VOCs	524.2	biannually	biannually	502.2	biannually

NOTES

Plan #2 differs from Plan #1 in frequency of sampling wells IS-97, 2S-97, & 3S-94
 Plan #3 differs from Plan #2 by substituting EPA Method 502.2 for 524.2 in selected wells

Pilot Strategic Monitoring Case Study, Atlantic Geoscience Corporation, 1999.

Exhibit 23 summarizes three monitoring program options that were generated based on an evaluation of the case study monitoring program. Cost estimates for each option are shown in Exhibit 22.

3.0 CONCLUSION

There are numerous regulatory and non-regulatory tools for managing and protecting groundwater resources. Connecticut law requires the delineation of Aquifer Protection Areas and the adoption of land use regulations and procedures for local aquifer protection. Strategic monitoring is a key tool for aquifer protection. If properly designed and implemented, strategic monitoring provides early-warning detection of contaminants that could migrate from points of release in the Aquifer Protection Area to the production wells and potentially impact water quality. The specific goals of strategic monitoring are as follows:

1. Design a *sampling network* to monitor, in priority order, land-use activities that present the greatest potential threat to groundwater quality;
2. Develop a *sampling plan* that minimizes costs, while maximizing the range of detectable contaminants and available reaction time (to initiate remedial actions);
3. Develop *sampling procedures* that are simple, cost effective, and technically sound and that minimize sampling-related biases and ensure data integrity;
4. Design a *Data Management System* that facilitates accurate and efficient record keeping and provides a tool to assist in the identification and evaluation of trends and of statistically significant departures from background water-quality conditions;
5. Advocate a monitoring program that can realistically be implemented by the water supplier, from the perspective of costs, staff resources, technical difficulty....etc; and
6. Establish a regular *monitoring program evaluation system*, thereby ensuring that all of the elements of the program are effective and reflect the changing environmental and operational conditions.

The monitoring program provides the information needed to initiate mitigative actions if necessary. In short, strategic monitoring provides the ability to: 1) monitor trends in aquifer water quality; 2) detect a contaminant plume, its direction and velocity; and 3) plan the appropriate response, including remediation and production well shut-down.

The design and implementation of a strategic monitoring program requires familiarity with contaminant hydrogeology, monitoring well installation, and analytical sampling. Some water systems have the staff and resources to complete all or part of the steps necessary to design a monitoring program. Other water systems will choose to hire a consultant. This document is intended for use by both the water system owner and the engineering consultant and describes steps for the design and implementation of a strategic monitoring program.

Designing and maintaining a monitoring program is an ongoing and evolving process. The program should be evaluated on a regular basis to make sure it meets the goals of strategic monitoring and adjusts to a variety of changing conditions. The most important condition to evaluate is the observed trend in the water quality of the aquifer. Additional conditions include the occurrence of leaks and spills, new land uses, site access, and changes in the status of regulated sites in the Level A area. A monitoring program is also constrained by business considerations such as costs and staff resources. Once these conditions are identified, the Water Company can evaluate and modify the program elements including the monitoring network, analytes and sampling schedule, sample collection methods and equipment, QA procedures, data management system, and action plan.

The Crystal Water Company's Hopkins Wellfield, in Killingly, Connecticut provides an example of an implemented strategic monitoring program. The Hopkins Wellfield is located in a well-developed area with a number of industrial and commercial establishments. As a result of past and current land uses in the vicinity of the wellfield, low levels of contaminants have historically been detected in the wellfield and monitoring wells. Thus strategic monitoring is a critical tool for the Crystal Water Company by providing the framework for documenting and tracking water quality trends in an aquifer that houses numerous known and potential contamination threats.

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Appendix 1. Glossary of Terms ¹

Accuracy. The degree of agreement between a measurement and an accepted reference of true value as determined by the analysis of blank spikes and/or spiked samples.

Advection. The movement of a constituent at the average linear velocity of groundwater.

Area of influence. The land area that directly overlies and has the same horizontal extent as the part of the water table or other potentiometric surface that is perceptibly lowered by the withdrawal of water. The area of influence delineated by the withdrawal of water. The area of influence delineated by the use of modeling shall be that area of land in which the water table or potentiometric surface is lowered by at least 0.5 feet.

Aquifer. A geologic formation, group of formations or part of a formation that contains sufficient saturated, permeable materials to yield significant quantities of water to wells and springs.

Aquifer protection area. Any area consisting of well fields, areas of contribution and recharge areas, identified on maps approved by the commissioner of environmental protection pursuant to sections 22a-354b to 22a-354d, inclusive, within which land uses or activities shall be required to comply with regulations adopted pursuant to section 22a-354o by the municipality where the aquifer protection area is located.

Area of contribution. The area where the water table is lowered due to the pumping of a well and groundwater flows directly to the well.

Bedrock. A general term for the consolidated (solid) rock that underlies soils or other unconsolidated surficial materials.

Biodegradation. The process whereby concentrations of contaminant are reduced through chemical reaction catalyzed by microorganisms.

Capture zone. The lateral area inside a time-of-travel isochron (contour of equal time).

Cone of depression. A depression of the potentiometric surface in the shape of an inverted cone that develops around a well which is being pumped.

Confined aquifer. An aquifer saturated with water and bounded above and below by beds having a distinctly lower hydraulic conductivity than the aquifer itself.

Confining bed. A layer of rock adjacent to an aquifer that hampers the movement of water into or out of the aquifer.

Contaminant. An undesirable substance not normally present or an unusually high concentration of a naturally occurring substance in water or soil.

Contamination. The addition to water of contaminants, preventing the use or reducing the usability of the water. Sometimes considered synonymous with pollution.

Density. A property of a chemical or compound equal to its mass per unit volume.

Dispersion. The spreading of a constituent over a greater area than would be predicted by the groundwater flow vectors due to mechanical dispersion and molecular diffusion.

Dissolution. The dissolving of a compound in water according to the compound's solubility.

Drawdown. The decline in groundwater level at a point caused by the withdrawal of water from an aquifer.

Duplicate. A Quality control sample for the purpose of assessing the consistency of the overall sampling and analytical program.

Equipment blank. A Quality control sample for the purpose of demonstrating that non-dedicated sampling equipment has not caused contamination of the field samples.

Groundwater. Water in the saturated zone that is under a pressure equal to or greater than atmospheric pressure.

Groundwater divide. A ridge in the water table or potentiometric surface from which ground water moves away at right angles in both directions. The line of highest hydraulic head in the water table or potentiometric surface.

Groundwater recharge. The process of water addition to the unsaturated zone or the volume of water added by this process.

Appendix 1. Glossary of Terms¹

- Hydraulic conductivity.** The capacity of a rock to transmit water; expressed as the volume of water that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.
- Hydraulic gradient.** The slope of the water table or potentiometric surface; that is, the change in water level per unit of distance along the direction of maximum head decrease. Determined by measuring the water level in several wells.
- Hydrogeology.** The science dealing with the occurrence of groundwater, its utilization, and its functions.
- Hydrolysis.** The reaction of hydrogen, hydroxyl radicals or water molecules interacting with organic compound depending on the pH and polarity of the reaction site on the molecule.
- Ion Exchange.** The reversible exchange of ions contained in a compound for different ions in solution.
- Level A conditions.** The prescribed drought conditions for Level A model predictive simulations, primarily 180 days with no aerial recharge.
- Level A mapping.** A methodology to map the Area of Contribution and Recharge Area of wellfields, as required pursuant to Section 22a-354b-1 of the Connecticut General Statutes.
- Level B mapping.** A methodology to map the locations of existing and potential well fields, as required pursuant to Section 22a-354b of the Connecticut General Statutes, as well as the preliminary delineation of wellfield contributing and recharge areas.
- Mechanical dispersion.** Spreading of a constituent due to deviations in the velocity of groundwater as it moves through porous media.
- Mobility.** The ability of a compound to move through soils, sediment, aquifers and surface.
- Molecular diffusion.** The transport of a constituent in the direction of decreasing concentration of the constituent, resulting in the its dilution by non-contaminated groundwater.
- Non-point source.** A source originating over broad areas, such as areas of fertilizer and pesticide application and leaking sewer systems, rather than from discrete points.
- Oxidation/Reduction.** The liberation of electrons (oxidation) and reactions that consume electrons (reduction).
- Partition coefficient.** A measure of the distribution of a compound in two phases, expressed as a concentration ratio.
- Point source.** Any discernable, confined, or discrete conveyance from which contaminants are or may be discharged, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, container, rolling stock, or concentrated animal feeding operation.
- Potentiometric surface.** An imaginary surface representing the level to which water will rise in a well.
- Precipitation.** The formation of solid minerals from super saturated dissolved materials in water.
- Precision.** A measure of the mutual agreement among individual measurements and is determined by the analyses of laboratory duplicates.
- Quality Assurance (QA).** A policy of documented measurement procedures and quality control checks which validate the reliability of a data set.
- Quality Control (QC).** Procedures or samples that provide statistical measure of data integrity and are described in a QA program.
- Recharge area.** The area from which groundwater flows directly to the area of contribution.
- Saturated zone.** The zone (below the unsaturated zone) in which interconnected openings contain only water.
- Solubility.** The degree and ease to which a chemical or compound will dissolve in water.
- Sorption.** The attachment of a portion of the dissolved phase of a substance to a solid by electrochemical or thermodynamic processes such as cation exchange or by absorption.
- Specific yield.** The amount of water yielded (i.e., from a water-bearing material) under the influence of gravity.

Appendix 1. Glossary of Terms¹

Steady-state condition. A condition in which the amount of water flowing into a defined volume of the aquifer is equal to the amount flowing out of that volume. Under steady state flow conditions the head distribution in an aquifer is constant over time.

Stratified drift aquifer. A predominantly sorted sediment laid down by or in meltwater from glaciers and includes sand, gravel, silt and clay arranged in layers.

Till. An unsorted and unstratified mixture of clay, silt, sand, gravel, and boulders deposited directly by glaciers.

Time of travel. The amount of time it takes for groundwater or a contaminant to flow from a point in the well's recharge area to the well.

Toxicity. The degree to which a chemical or compound produces a harmful biological effect, as measured using a variety of criterion including short-term (acute) lethal effects and long-term (chronic) adverse effects.

Transient flow condition. A condition in which the amount of water flowing into a defined volume of the aquifer is equal to the amount flowing out of that volume plus or minus some amount of water held in the volume as storage. Under transient flow conditions the head distribution in an aquifer varies as a function of time.

Transmissivity. The capacity of an aquifer to transmit water; equal to the hydraulic conductivity times the aquifer thickness.

Trip blank. A Quality control sample for the purpose of demonstrating that containers and samples are not contaminated in transit.

Unconfined aquifer. An aquifer that contains both an unsaturated and a saturated zone (i.e., an aquifer that is not full of water).

Unsaturated zone. The zone between the land surface and the regional water table. Generally, water in this zone is under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure.

Vapor pressure. The pressure exerted by a vapor when it is in equilibrium with the liquid from which it is derived.

Volatilization. The transport of a compound from the liquid to the vapor phase at a given temperature.

Water table. The level in the saturated zone at which the water is under pressure equal to the atmospheric pressure.

Wellfield. The immediate area surrounding a public drinking water supply well or group of wells.

Wellhead. The portion of a well that extends above ground.

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Appendix 3. Guidelines for Land Use Mapping Over Public Drinking Water Aquifers

October 1991

GUIDELINES FOR LAND USE MAPPING OVER PUBLIC DRINKING WATER AQUIFERS

I INTRODUCTION

All municipalities containing stratified drift aquifers used for public drinking water supply by utilities serving more than 1000 people are required, pursuant to Connecticut General Statutes 22a-354e, to conduct an inventory of existing land uses in critical areas surrounding public water supply wells. A land use inventory is also required for the area around proposed wells identified in approved water supply plans. The purpose of these inventories is to identify those land uses that may pose threats to groundwater quality, and thus to existing or potential public drinking water supplies.

It is important that municipalities adhere to the following guidelines to ensure that the information gathered is adequate for aquifer protection and is consistent statewide. As aquifers often cross political boundaries, a compatible information base will help municipalities work together to protect their drinking water supplies. An added benefit of following these guidelines is that the information will eventually become part of the State's computerized Geographic Information System and will be helpful for other aspects of environmental planning and regulation.

Staff from DEP's Natural Resources Center and Bureau of Water Management are available to help clarify any confusion concerning these inventory guidelines and, where possible, to help with technical difficulties. If you have any questions, please call one of the following people:

Bob Hust, Bureau of Water Mgmt., inventory technique	566-3496
Diane Mayerfeld, Bureau of Water Mgmt., general information	566-7049
Kristina Sacks, Natural Resources Center, information format ...	566-3540
Fred Banach, Bureau of Water Mgmt., general information	566-7049
Jim Murphy, Bureau of Water Mgmt., general information	566-3496

II OTHER SOURCES OF ASSISTANCE

Municipalities may find that their Regional Planning Organization or Regional Health District can assist them with the land use inventory. They may either contract to do the actual work, or provide information and technical assistance. Midstate Regional Planning Agency and Central Connecticut Regional Planning Agency both have ARC/INFO geographic information systems which are compatible with DEP's system. Municipalities within these two planning areas may be able to have the regional planning agencies enter data, but all municipalities should check with DEP first.

Also, some water utilities may have conducted local land use surveys, which may prove helpful. If you do not know a contact person in the utility operating the wells in your municipality, please call the Natural Resources Center's water use program at 566-3540. Municipalities that have their own

water departments may want to delegate the land use inventory to the water department staff.

III SEQUENCE OF EVENTS

1. Water company performs Level B mapping of the aquifer. (This mapping, roughly identifies the extent of the area directly contributing ground water to the public supply wells.)
2. DEP approves the Level B map
3. DEP enters the Level B delineations into the State's Geographic Information System (GIS)
4. DEP adopts aquifer protection regulations (draft regulations to be published by July 1991, final regulations expected early in 1992)
5. Within 3 months of approval of the Level B map and adoption of aquifer protection regulations by the State, the municipality must designate an existing board or commission as the Aquifer Protection Agency. The Aquifer Protection Agency will be responsible for seeing that the land use inventory is performed.
6. DEP provides a base map to the municipality
7. The municipality (or contractor) conducts the land use inventory
8. The municipality submits the completed land use map and index to DEP or a participating regional planning organization for data entry, no more than one year after authorization of the local land use agency, receipt of the base map from DEP, or adoption of aquifer protection regulations by the State, whichever is later.
9. DEP enters the mapped information into the DEP's GIS and returns the land use map to the municipality
10. Water company completes Level A mapping (This mapping should be completed by July 1995 for most wellfields)
11. DEP approves the Level A map
12. The municipality designates Aquifer Protection Areas
13. The municipality adopts protective regulations for the Aquifer Protection Areas
14. The municipality implements its aquifer protection program
15. The municipality periodically updates the land use inventory

DEP will provide two maps to each affected municipality, showing the following items:

A. Base Map (on mylar, at a scale of 1 inch - 1,000 feet or 1:12,000)

1. Municipal boundaries
2. Boundaries of the area to be inventoried (the Initial Setback Area and Recharge Area for the wells in the aquifer as delineated by approved Level B mapping done by the utility) and the active wells

¹Municipalities are encouraged to proceed with forming an aquifer protection agency and conducting the land use inventory before DEP's land use regulations for aquifers are finalized.

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3. Roads, highways, and railroads from the most recent USGS topographic map
4. Surface water bodies and streams
- B. Potential Pollution Source Information ("Risk Information") Map (on paper, at a scale of 1 inch = 1,000 feet or 1:12,000)
 1. Sewered areas (sanitary, not storm) over the aquifer as entered in GIS
 2. Landfills
 3. Other waste disposal areas or potential pollution sources as entered in GIS
 4. State Department of Transportation salt storage and highway maintenance facilities
 5. State Department of Environmental Protection owned property as entered in GIS (if available)
 6. Pipelines, transmission lines, and airports shown on the most recent USGS topographic map

In addition, DEP will provide a listing of known commercial underground storage tanks in the town.

The first copy of both maps will be provided free of charge; additional copies may be obtained from the Natural Resources Center at cost.

Please correct and complete the information provided by DEP on the Potential Pollution Source Information Map, and map the land use categories and high risk uses specified below on the Base Map. The information contained in the Potential Pollution Source Information Map is compiled from several sources and is quite likely to be incomplete or inaccurate.

Unless the municipality requests otherwise, DEP will print the base map at a scale of 1:12,000 (1"=1000'). Municipalities should do their final mapping on the base map provided by DEP. Towns with dense, complex land use or existing maps at a larger scale may prefer to use a larger scale than 1:12,000 for field mapping. All the Risk Information maps will be printed at 1:12,000 and will cover the same area as the base map.

Submission of Xerox or blue-ray copies of either map is not acceptable, as the distortion that inevitably accompanies reproduction causes errors when the mapped information is digitized into the computerized geographic information system. Even folding the base map can introduce inaccuracies into the spatial information. Municipalities may, however, want to perform draft or field mapping on copies of the base map.

IV DESIGNATION OF A BOARD OR COMMISSION TO ACT AS AQUIFER PROTECTION AGENCY

Every municipality for which a Level B map has been completed must authorize an existing board or commission to act as an aquifer protection agency. Examples of existing boards which might be authorized to act as aquifer protection agencies include the planning commission, inland wetlands commission, and zoning board. This aquifer protection agency must be authorized no more than 3 months after DEP has adopted aquifer protection regulations and approved the Level B mapping for the municipality. The

aquifer protection agency will be responsible for overseeing the land use inventory, as well as adopting land use regulations for the aquifer protection area. See Connecticut General Statutes 22a-354e and 22a-354o.

V LAND USE INVENTORY GUIDELINES

Area to be mapped: Land uses must be mapped for the "Initial Setback Area" and "Recharge Area" shown on the base map provided by DEP. Mapping in the area beyond the delineated aquifer is optional.

Map units:

General Land Use Categories: Land use types should be mapped as areas by land use category. Any land use category covering five (5) acres or more should be shown. (Five acres is approximately equal to a half inch square on a 1:12,000 scale map.) Municipalities are welcome to map in greater detail, down to two acre units. Usually, lots or land parcels will be under one type of use. Where very large parcels have several use types, all the use types covering 5 acres or more should be shown.

Often, certain areas within a municipality will have a mixture of land use types; for example, residential and commercial uses are commonly mixed along old State highways. In determining how to map such mixed areas, the municipality must use its judgement. The important criterion is to ensure that the map indicates all potential threats to ground water quality. Where land use types are evenly mixed, the area may be shown as such, e.g., mixed commercial/residential. If one land use clearly predominates, the area should be mapped as the dominant land use type. If an area is shown as mixed use, it may be coded on the map by striping the two colors and/or by indicating both letter codes. Areas under construction should be classified by their anticipated use. Vacant or abandoned development should be classified by its former use (often, potential contaminants remain at commercial and industrial sites, even after the business has gone).

High Risk Uses: Certain activities that pose higher risks to ground water quality are listed at the end of these guidelines. Such facilities and activities should be mapped as numbered points and identified by business name, type, and address in an attached index. Although this information may be difficult and time-consuming to collect, it will be very helpful in implementing regulations required by the Aquifer Protection Act. It will also be used by DEP to assign facility inspection priorities.

VI GENERAL LAND USE CATEGORIES TO BE MAPPED

Land use categories to be mapped are listed below. Briefly, the overall categories are: open space, residential areas, agricultural lands, commercial use, institutions, industrial areas, utilities, transportation areas, and waste disposal sites. These land use types are listed in general order of increasing risk to groundwater quality. Every land use type may, however, encompass both high and low risk examples.

Major land use categories printed in boldface below should be mapped to at least a 5 acre level of detail and may be mapped down to a 2 acre level of

detail. Municipalities may also map some or all of the subcategories indicated; however, such detail is optional. The list of higher risk activities to be mapped as points follows in Section VII. Different land use categories should be indicated on the map by color and/or letter codes. Suggested codes are given below. We recommend use of color codes because they are visually effective and clearly show the boundaries between land use types. If letter codes alone are used, each area separated by roads or other boundaries should be labeled.

Open Space (code = OS; color = true green, Prismacolor 910)

1. Water utility owned land or dedicated natural area (areas with a long term legal guarantee for management that poses few or no threats to groundwater) (code = OS-1)
2. Undeveloped open space (eg., passive recreation/wildlife areas, forest land, meadows, wetlands and water bodies, and many state parks and forests. Such sites generally pose few threats to groundwater, but they may be subject to future development) (code = OS-2)
3. Landscaped parks or open spaces (including cemeteries, golf courses, playing fields, public gardens, and city parks; management of such areas may result in groundwater pollution) (code = OS-3)

Residential Areas (code = R; color = yellow ochre, Prismacolor 942)

1. Low density (fewer than 2 dwelling units per acre) (code = R-1)
2. Medium density (2 to 8 dwelling units per acre) (code = R-2)
3. High density (more than 8 dwelling units per acre) (code = R-3)

Agricultural Lands (code = A; color = apple green, Prismacolor 912)

Permanent pastureland, hayfields, row crops, orchards, nurseries, christmas tree plantations, greenhouses, animal husbandry (livestock, dairy, poultry, etc.)

Commercial (code = C; color = scarlet lake, Prismacolor 923)

Retail, trades, and services; includes most offices and stores, as well as service businesses

Institutional (code = INS; color = true blue, Prismacolor 903)

Public buildings and facilities, government offices including the municipal hall, libraries, churches, schools, prisons, hospitals, fire stations, public works garages, etc.

Industrial (code = I; color = purple, Prismacolor 931)

1. Lower risk industry (no materials processing, just assembly; no bulk storage of chemicals or scrap, or onsite disposal) (code - I-1)
2. Resource extraction (rock quarrying, sand and gravel excavation) (code - I-2)
3. Higher risk industry (any industry involving materials processing or primary manufacturing; especially chemical, metal plating, finishing, or other processing, and machining) (code - I-3)

Utilities (code - U; color - coal gray light, Prismacolor 967)

Power stations, water supply treatment facilities, etc.

Transportation (code - T; color - coal gray dark, Prismacolor 965)

Airports, highway maintenance facilities and municipal garages, rail stations and yards, bus terminals, and large areas dedicated as interstate highways and associated rights of way.

Waste Disposal, Treatment or Handling (municipalities should review and correct DEP's information) (code - W; color - pink, Prismacolor 929)

Landfills, transfer stations
Bulky wastes
Sewage treatment and sewage sludge disposal
Special waste, such as septage and industrial waste
Hazardous waste
Recycling processing area
Junk or salvage yards
Historic and closed waste sites of all kinds
Resource recovery facility

VII HIGHER RISK ACTIVITIES AND FACILITIES, listed by land use category

The activities listed below are to be mapped as numbered points on the base map, with business name, type, and address shown in an attached index. Please use an "X" to show the location of the high risk use, with the center of the X on the center of the use. Where many high risk uses are concentrated in a small area, such as an industrial park, they may be shown collectively and then listed separately in the index. The listing by land use category below is intended to provide a general guide; any use related to or similar to those listed should also be identified. These uses may occur in any of the land use areas. Where known, include higher risk commercial and even manufacturing and industrial activities, such as car repair, that may occur in residential areas as customary home occupations. Where known, former high risk sites (such as gas stations, mills, and factories) should be mapped as high risk points and labelled as vacant in the index.

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Open space - higher risk activities include:

- o golf courses (map as areas, rather than points)
- o cemeteries (map as areas, rather than points)

Residential - higher risk activities include:

- o unsewered high and moderate density residential development (map as areas, rather than points)
- o certain home occupations (see higher risk commercial uses listed below)

Agricultural - higher risk activities include:

- o nurseries and greenhouses (DEP is responsible for conducting the inventory of other agricultural uses around the well)

Commercial - higher risk activities include:

- o all automotive sales or services (any car, truck, bus, recreational vehicle, marine, or heavy equipment facility) including gas and service stations, body and general repair shops, dealerships, rental or leasing operations, washes, etc.
- o machine shops
- o junk or salvage yards
- o certain retail trades including: fuel oil distributors or dealers, lumber yards, hardware stores, auto and home supply stores, garden centers, department stores, mobile home dealers heavy construction businesses
- o personal and repair services including: dry cleaners; launderers and laundromats; lawn care businesses; beauty shops; photo processors; equipment rental; pharmacies; printers; funeral parlors and crematories; medical, dental, and veterinary offices; furniture strippers and finishers; reupholsterers; electrical, radio, and television repair; appliance, lawnmower, and small engine repair; heating and cooling equipment service; pesticide applicators and exterminators; etc.
- o research or testing laboratories
- o large uncovered parking areas (more than 100 spaces), parking garages with open roofs
- o underground fuel and chemical storage

Institutional - higher risk activities include:

- o garages and vehicle or equipment service areas
- o fuel storage and dispensing facilities
- o salt storage areas
- o hospitals
- o secondary schools and colleges with workshops or laboratories
- o prisons

Manufacturing and Industrial - higher risk activities include:

- o All manufacturing and processing facilities except: simple assembly involving no processing, and warehousing of durable goods (no chemicals)
- o warehousing, storage, or distribution of: chemicals; fertilizers; pesticides and allied products; petroleum, coal, and other fuels; and hazardous materials
- o mining (rock quarries and sand and gravel excavation)

Utilities - higher risk activities include:

- o electric power generation
- o oil or chemical pipelines

Transportation - higher risk activities include:

- o airports
- o highway maintenance facilities, including road salt storage
- o truck, rail, or bus terminals, stations, or maintenance facilities

Waste Disposal - all waste disposal sites should be identified as higher risk activities, including:

- o mixed waste landfills
- o solid waste transfer stations
- o bulky waste landfills
- o sewage treatment plants, sewage sludge disposal
- o special waste, such as septage and industrial waste
- o hazardous waste
- o recycling processing center
- o junk and salvage yards
- o resource recovery facilities
- o historic and closed waste sites of all kinds

This list contains only the more common higher risk uses, and municipalities may want to develop a more comprehensive inventory, if possible. Any activity involving the handling, use, storage, or disposal of large quantities of solvents, petroleum products, pesticides, or hazardous chemicals constitutes a higher risk activity. For more information on possible higher risk uses, municipalities may refer to Appendix 2 of the 1989 Aquifer Protection Task Force Report to the Legislature or to lists of higher risk uses compiled by various organizations, available from the Planning and Standards Division of the Bureau of Water Management in DEP.

VIII SUGGESTED INFORMATION SOURCES AND INVENTORY METHODOLOGIES

There are several possible ways for determining the locations of higher risk activities. Communities are urged to combine several approaches, rather than relying completely on one source or method.

- o Windshield survey - Although driving through town and visually noting higher risk uses is fairly time-consuming, this technique is

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generally acknowledged to be the most reliable and complete method for identifying land uses.

- o Municipal officials, especially sanitarians or health inspectors, building inspectors, fire marshals, planners, and zoning enforcement officials - can help identify or confirm land use variances and higher risk activities, including certain commercial or industrial home occupations in residential areas.
- o Water utility or municipal water department inspectors and managers - are often aware of higher risk uses threatening water supplies.
- o Emergency Response Plan - Under the Federal Superfund Amendments and Reauthorization Act (SARA Title 3), facilities that manufacture, use, and/or store hazardous materials are required to report to the local Emergency Planning Committee and local fire department. Reporting is required to aid municipalities in emergency response planning for the possibility of fires or spills involving such materials. The businesses identified in these Emergency Response Plans will almost all prove to be higher risk activities.
- o DEP's Leachate and Wastewater maps and reports - The Natural Resources Center of DEP maintains maps showing known sources of leachate and wastewater in the State. These maps are arranged by major drainage basin and are available from the Natural Resources Center for \$2.50 each (tel: 566-7719).
- o Underground Storage Tank Inventory - The Waste Management Bureau, Underground Storage Program in DEP maintains a statewide inventory of non-residential underground fuel, petro-chemical, and waste oil tanks (all gas tanks and other tanks containing more than 2000 gallons). Data sheets showing addresses of each known underground storage tank are available from the DEP. Such underground storage tanks constitute a threat to the aquifer in themselves and are often also indicators of businesses posing other threats to groundwater.
- o Aerial photographs - Aerial photos are most helpful when interpreted by people with air photo experience.
- o Yellow pages.
- o Connecticut Directory of Manufacturers (available from State of Connecticut Labor Department, \$20 plus postage and handling) and quarterly updates. This source only lists industrial facilities.
- o Chamber of Commerce industry and commerce listings.
- o Regional Planning Organizations - may have information from previously conducted inventories.

- o Local tax records - The usefulness of this information source varies by municipality, depending on how the information is filed and kept.
- o The Industrial Permits and Enforcement Section of the Bureau of Water Management of DEP keeps records by town of its facilities inspections - These records, referred to as P5 files, may be consulted at DEP. Check with the department for the date of the most recent inspections in your town.

IX PRODUCT TO BE DELIVERED TO DEP

One Base Map, showing:

- o general land uses
- o point locations of higher risk activities and facilities

Again, this information shall be mapped on the base map provided to the municipality by DEP. Xerox or blue-ray copies are not acceptable (see p. 2). DEP may refuse to enter information from copied maps into its geographic information system.

Boundaries between general land use categories should be shown in black ink in lines no wider than 1 millimeter or 1/16th of an inch.

Land use categories should be differentiated by color, letter, or number codes. Color is preferred and may be combined with letter or number codes. The legend must be completed to clearly explain all the symbols and codes used on the map. A suggested coding system is presented below:

- OS -- open space (color = true green, Prismacolor 910)
 - OS-1 -- permanently protected open space
 - OS-2 -- undeveloped open space, may or may not have some protection
 - OS-3 -- landscaped open space
- R -- residential areas (color = yellow ochre, Prismacolor 942)
 - R-1 -- low density residential
 - R-2 -- medium density residential
 - R-3 -- high density residential
- A -- agricultural lands (color = apple green, Prismacolor 912)
- C -- commercial areas (color = scarlet lake, Prismacolor 923)
- INS -- institutional lands (color = true blue, Prismacolor 903)
- I -- industrial areas (color = purple, Prismacolor 931)
 - I-1 -- lower risk industry
 - I-2 -- resource extraction
 - I-3 -- higher risk industry
- U -- utilities (color = coal gray light, Prismacolor 967)
- T -- transportation areas (color = coal gray dark, Prismacolor 965)

W -- waste disposal, treatment, or handling (color - pink, PrismaColor 929)

Higher risk activities and facilities shall be indicated by number (clearly distinguishable from any number codes used to show general land use categories).

One Index, showing

- o the names, addresses, and types of higher risk activities indicated on the base map. The higher risk activities shall be listed in order of the numbers by which they are identified on the base map.

One Corrected and Completed Potential Pollution Source Information Map (optional)

In correcting this map, please cross out incorrect boundaries, names, or locations and add new information. Use a distinctively colored pen or pencil to make the corrections as clear as possible.

Please send your completed maps and index to:

Fred Banach
Div. of Planning and Standards
Water Management Bureau, DEP
122 Washington Street
Hartford, CT 06106

Maps should be rolled and sent in a tube. Folded or creased maps can become distorted and result in inaccurate digitizing of information.

X UPDATES

The Aquifer Protection Act requires businesses in the Aquifer Protection Area to notify the municipality of changes of ownership or use. Towns should record these changes on their index of high risk activities. Every 5 years, municipalities should also update the general land use map of the Aquifer Protection Area.

Appendix 4. Connecticut Sources of Information on Potential Contamination Sites

SOURCE	DESCRIPTION	FEE
CTDEP; Bureau of Water Management; Permitting, Enforcement & Remediation; 860-424-3705	CERCLIS List Site Investigation & Remediation Status List National Priorities List (NPL) List CT State Priority List Spill Incident Report	
CTDEP; Bureau of Waste Management; Pest., PCB, UST & Terminal Division; UST Enforcement; 860-424-3374	Documented Leaky Underground Storage Tank (LUST) Sites Underground Storage Tank (UST) List	
CTDEP; Bureau of Waste Management; 860-424-3023	Inventory of Hazardous Waste Disposal Sites	
CTDEP; Bureau of Water Mgmt.; Planning & Standards; Resource Modeling; 860-424-3020	Permit Expiration Table	
Town Planning Department	Land Use Inventory	no
CTDEP; Natural Resource Center.; GIS Section; 860-424-3540	Digital GIS data including: land use info., Level B & Level A Mapping, hydrography, roads, Town boundaries, ...	yes
CT DEP Public Files Room; 860-424-4180	Site -specific monitoring programs, water-quality results, and remediation status	no
USGS; Water Resources Division; 860-240-3060	Water quality monitoring on selected surface water bodies	no
CTDEP; Water Mgmt.; Planning & Standards; Mon. Assess. & Lake Mgmt.; 860-424-3020	Water quality monitoring on selected surface water bodies	no
Level A Mapping Report, Town or Water Company	Hydrogeologic information, recharge area(s) for production well(s), direction of groundwater flow,	no
CTDEP; Maps & Publications; 860-424-3540	Leachate and Wastewater Discharge Sources Map & Inventory (published by basin) Protecting Connecticut's Water-Supply Watersheds: A Guide for Local Officials; Land-Tech Consultants, 1993.	\$3/basin \$10
US EPA Region I J.F. Kennedy Federal Building, Boston, MA 02203-2211; 617-565-3420	Federal List of facilities and generators who treat, store or dispose of hazardous materials.	
CTDEP; Water Mgmt.; Planning & Standards; Municipal Facilities; 860-424-3020	Information on large septic systems (>5000 gal.)	
Department. of Public Health; Water Supply Section; Engineering; 860-509-7333	Investigations into impacted public water supplies; Orders to close water supplies;	no
Town Health Department	Information on septic systems and private wells	no

Appendix 5. Potential Sources of Ground Water Contamination

Table 4-4. Potential Sources of Ground Water Contamination

Source	Health, Environmental, or Aesthetic Contaminant ^{1,2,3}
NATURALLY OCCURRING SOURCES	
Rocks and soils	<i>Aesthetic Contaminants:</i> Iron and iron bacteria; manganese; calcium and magnesium (hardness) <i>Health and Environmental Contaminants:</i> Arsenic; asbestos; metals; chlorides; fluorides; sulfates; sulfate-reducing bacteria and other microorganisms
Contaminated water	Excessive sodium; bacteria; viruses; low pH (acid) water
Decaying organic matter	Bacteria
Geological radioactive gas	Radionuclides (radon, etc.)
Natural hydrogeological events and formations	Salt-water/brackish water intrusion (or intrusion of other poor quality water); contamination by a variety of substances through sink-hole infiltration in limestone terrains
AGRICULTURAL SOURCES	
Animal feedlots and burial areas	Livestock sewage wastes; nitrates; phosphates; chloride; chemical sprays and dips for controlling insect, bacterial, viral, and fungal pests on livestock; coliform ⁴ and noncoliform bacteria; viruses
Manure spreading areas and storage pits	Livestock sewage wastes; nitrates
Livestock waste disposal areas	Livestock sewage wastes; nitrates
Crop areas and irrigation sites	Pesticides; ⁵ fertilizers; ⁶ gasoline and motor oils from chemical applicators
Chemical storage areas and containers	Pesticide ⁵ and fertilizer ⁶ residues
Farm machinery areas	Automotive wastes; ⁷ welding wastes
Agricultural drainage wells and canals	Pesticides; ⁵ fertilizers; ⁶ bacteria; salt water (in areas where the fresh-saltwater interface lies at shallow depths and where the water table is lowered by channelization, pumping, or other causes)
RESIDENTIAL SOURCES	
Common household maintenance and hobbies	<i>Common Household Products:</i> ⁸ Household cleaners; oven cleaners; drain cleaners; toilet cleaners; disinfectants; metal polishes; jewelry cleaners; shoe polishes; synthetic detergents; bleach; laundry soil and stain removers; spot removers and dry cleaning fluid; solvents; lye or caustic soda; household pesticides; ⁹ photochemicals; printing ink; other common products <i>Wall and Furniture Treatments:</i> Paints; varnishes; stains; dyes; wood preservatives (creosote); paint and lacquer thinners; paint and varnish removers and deglossers; paint brush cleaners; floor and furniture strippers <i>Mechanical Repair and Other Maintenance Products:</i> Automotive wastes; ⁷ waste oils; diesel fuel; kerosene; #2 heating oil; grease; degreasers for driveways and garages; metal degreasers; asphalt and roofing tar; tar removers; lubricants; rustproofers; car wash detergents; car waxes and polishes; rock salt; refrigerants
Lawns and gardens	Fertilizers; ⁵ herbicides and other pesticides used for lawn and garden maintenance ¹⁰
Swimming pools	Swimming pool maintenance chemicals ¹¹
Septic systems, cesspools, and sewer lines	Septage; coliform and noncoliform bacteria; ⁴ viruses; nitrates; heavy metals; synthetic detergents; cooking and motor oils; bleach; pesticides; ^{9,10} paints; paint thinner; photographic chemicals; swimming pool chemicals; ¹¹ septic tank/cesspool cleaner chemicals; ¹² elevated levels of chloride, sulfate, calcium, magnesium, potassium, and phosphate
Underground storage tanks	Home heating oil
Apartments and condominiums	Swimming pool maintenance chemicals; ¹¹ pesticides for lawn and garden maintenance and cockroach, termite, ant, rodent, and other pest control; ^{9,10} wastes from onsite sewage treatment plants; household hazardous wastes ⁸

Appendix 5. Potential Sources of Ground Water Contamination

Table 4-4. Potential Sources of Ground Water Contamination (continued)

Source	Health, Environmental, or Aesthetic Contaminant ^{1,2,3}
MUNICIPAL SOURCES	
Schools and government offices and grounds	Solvents; pesticides; ^{9,10} acids; alkalis; waste oils; machinery/vehicle servicing wastes; gasoline and heating oil from storage tanks; general building wastes ¹³
Park lands	Fertilizers; ⁶ herbicides; ¹⁰ insecticides ⁹
Public and residential areas infested with mosquitoes, gypsy moths, ticks, ants, or other pests	Pesticides ^{5,9}
Highways, road maintenance depots, and deicing operations	Herbicides in highway rights-of-way; ^{5,10} road salt (sodium and calcium chloride); road salt anticaking additives (ferric ferrocyanide, sodium ferrocyanide); road salt anticorrosives (phosphate and chromate); automotive wastes ⁷
Municipal sewage treatment plants and sewer lines	Municipal wastewater; sludge; ¹⁴ treatment chemicals ¹⁵
Storage, treatment, and disposal ponds, lagoons, and other surface impoundments	Sewage wastewater; nitrates; other liquid wastes; microbiological contaminants
Land areas applied with wastewater or wastewater byproducts	Organic matter; nitrate; inorganic salts; heavy metals; coliform and noncoliform bacteria; ⁴ viruses; nitrates; sludge; ¹⁴ nonhazardous wastes ¹⁶
Storm water drains and basins	Urban runoff; gasoline; oil; other petroleum products; road salt; microbiological contaminants
Combined sewer overflows (municipal sewers and storm water drains)	Municipal wastewater; sludge; ¹⁴ treatment chemicals; ¹⁵ urban runoff; gasoline; oil; other petroleum products; road salt; microbial contaminants
Recycling/reduction facilities	Residential and commercial solid waste residues
Municipal waste landfills	Leachate; organic and inorganic chemical contaminants; wastes from households ⁸ and businesses; ¹³ nitrates; oils; metals
Open dumping and burning sites, closed dumps	Organic and inorganic chemicals; metals; oils; wastes from households ⁸ and businesses ¹³
Municipal incinerators	Heavy metals; hydrocarbons; formaldehyde; methane; ethane; ethylene; acetylene; sulfur and nitrogen compounds
Water supply wells, monitoring wells, older wells, domestic and livestock wells, unsealed and abandoned wells, and test hole wells	Surface runoff; effluents from barnyards, feedlots, septic tanks, or cesspools; gasoline; used motor oil; road salt
Sumps and dry wells	Storm water runoff; spilled liquids; used oil; antifreeze; gasoline; other petroleum products; road salt; pesticides; ⁵ and a wide variety of other substances
Drainage wells	Pesticides; ^{9,10} bacteria
Well pumping that causes inter-aquifer leakage, induced filtration, landward migration of sea water in coastal areas; etc.	Saltwater; excessively mineralized water
Artificial ground water recharge	Storm water runoff; excess irrigation water; stream flow; cooling water; treated sewage effluent; other substances that may contain contaminants, such as nitrates, metals, detergents, synthetic organic compounds, bacteria, and viruses.
COMMERCIAL SOURCES	
Airports, abandoned airfields	Jet fuels; deicers; diesel fuel; chlorinated solvents; automotive wastes; ⁷ heating oil; building wastes ¹³
Auto repair shops	Waste oils; solvents; acids; paints; automotive wastes; ⁷ miscellaneous cutting oils
Barber and beauty shops	Perm solutions; dyes; miscellaneous chemicals contained in hair rinses
Boat yards and marinas	Diesel fuels; oil; septage from boat waste disposal areas; wood preservative and treatment chemicals; paints; waxes; varnishes; automotive wastes ⁷

Appendix 5. Potential Sources of Ground Water Contamination

Table 4-4. Potential Sources of Ground Water Contamination (continued)

Source	Health, Environmental, or Aesthetic Contaminant ^{1,2,3}
Bowling alleys	Epoxy; urethane-based floor finish
Car dealerships (especially those with service departments)	Automotive wastes; ⁷ waste oils; solvents; miscellaneous wastes
Car washes	Soaps; detergents; waxes; miscellaneous chemicals
Camp grounds	Septage; gasoline; diesel fuel from boats; pesticides for controlling mosquitoes, ants, ticks, gypsy moths, and other pests; ^{5,9} household hazardous wastes from recreational vehicles (RVs) ⁸
Carpet stores	Glues and other adhesives; fuel from storage tanks if forklifts are used
Cemeteries	Leachate; lawn and garden maintenance chemicals ¹⁰
Construction trade areas and materials (plumbing, heating and air conditioning, painting, paper hanging, decorating, drywall and plastering, acoustical insulation, carpentry, flooring, roofing and sheet metal, wrecking and demolition, etc.)	Solvents; asbestos; paints; glues and other adhesives; waste insulation; lacquers; tars; sealants; epoxy waste; miscellaneous chemical wastes
Country clubs	Fertilizers; ⁶ herbicides; ^{5,10} pesticides for controlling mosquitoes, ticks, ants, gypsy moths, and other pests; ⁹ swimming pool chemicals; ¹¹ automotive wastes
Dry cleaners	Solvents (perchloroethylene, petroleum solvents, Freon); spotting chemicals (trichloroethane, methylchloroform, ammonia, peroxides, hydrochloric acid, rust removers, amyl acetate)
Funeral services and crematories	Formaldehyde; wetting agents; fumigants; solvents
Furniture repair and finishing shops	Paints; solvents; degreasing and solvent recovery sludges
Gasoline services stations	Oils; solvents; miscellaneous wastes
Golf courses	Fertilizers; ⁹ herbicides; ^{5,10} pesticides for controlling mosquitoes, ticks, ants, gypsy moths, and other pests ⁹
Hardware/lumber/parts stores	Hazardous chemical products in inventories; heating oil and fork lift fuel from storage tanks; wood-staining and treating products such as creosote
Heating oil companies, underground storage tanks	Heating oil; wastes from truck maintenance areas ⁷
Horticultural practices, garden nurseries, florists	Herbicides, insecticides, fungicides, and other pesticides ¹⁰
Jewelry/metal plating shops	Sodium and hydrogen cyanide; metallic salts; hydrochloric acid; sulfuric acid; chromic acid
Laundromats	Detergents; bleaches; fabric dyes
Medical institutions	X-ray developers and fixers; ¹⁷ infectious wastes; radiological wastes; biological wastes; disinfectants; asbestos; beryllium; dental acids; miscellaneous chemicals
Office buildings and office complexes	Building wastes; ¹³ lawn and garden maintenance chemicals, ¹⁰ gasoline; motor oil
Paint stores	Paints; paint thinners; lacquers; varnishes; other wood treatments
Pharmacies	Spilled and returned products
Photography shops, photo processing laboratories	Biosludges; silver sludges; cyanides; miscellaneous sludges
Print shops	Solvents; inks; dyes; oils; photographic chemicals
Railroad tracks and yards	Diesel fuel; herbicides for rights-of-way; creosote for preserving wood ties
Research laboratories	X-ray developers and fixers; ¹⁷ infectious wastes; radiological wastes; biological wastes; disinfectants; asbestos; beryllium; solvents; infectious materials; drugs; disinfectants (quaternary ammonia, hexachlorophene, peroxides, chlornexade, bleach); miscellaneous chemicals

Appendix 5. Potential Sources of Ground Water Contamination

Table 4-4. Potential Sources of Ground Water Contamination (continued)

Source	Health, Environmental, or Aesthetic Contaminant ^{1,2,3}
COMMERCIAL SOURCES (continued)	
Scrap and junk yards	Any wastes from businesses ¹³ and households; ⁸ oils
Sports and hobby shops	Gunpowder and ammunition; rocket engine fuel; model airplane glue
Above-ground and underground storage tanks	Heating oil; diesel fuel; gasoline; other petroleum products; other commercially used chemicals
Transportation services for passenger transit (local and interurban)	Waste oil; solvents; gasoline and diesel fuel from vehicles and storage tanks; fuel oil; other automotive wastes ⁷
Veterinary services	Solvents; infectious materials; vaccines; drugs; disinfectants (quaternary ammonia, hexachlorophene, peroxides, chlornexade, bleach); x-ray developers and fixers ¹⁷
INDUSTRIAL SOURCES	
Material stockpiles (coal, metallic ores, phosphates, gypsum)	Acid drainage; other hazardous and nonhazardous wastes ¹⁶
Waste tailing ponds (commonly for the disposal of mining wastes)	Acids; metals; dissolved solids; radioactive ores; other hazardous and nonhazardous wastes ¹⁵
Transport and transfer stations (trucking terminals and rail yards)	Fuel tanks; repair shop wastes; ⁷ other hazardous and nonhazardous wastes ¹⁵
Above-ground and underground storage tanks and containers	Heating oil; diesel and gasoline fuel; other petroleum products; hazardous and nonhazardous materials and wastes ¹⁶
Storage, treatment, and disposal ponds, lagoons, and other surface impoundments	Hazardous and nonhazardous liquid wastes; ¹⁶ septage; sludge ¹⁴
Chemical landfills	Leachate; hazardous and nonhazardous wastes; ¹⁶ nitrates
Radioactive waste disposal sites	Radioactive wastes from medical facilities, power plants, and defense operations; radionuclides (uranium, plutonium)
Unattended wet and dry excavation sites (unregulated dumps)	A wide range of substances; solid and liquid wastes; oil-field brines; spent acids from steel mill operations; snow removal piles containing large amounts of salt
Operating and abandoned production and exploratory wells (for gas, oil, coal, geothermal, and heat recovery); test hole wells; monitoring and excavation wells	Metals; acids; minerals; sulfides; other hazardous and nonhazardous chemicals ¹⁶
Dry wells	Saline water from wells pumped to keep them dry
Injection wells	Highly toxic wastes; hazardous and nonhazardous industrial wastes; ¹⁶ oil-field brines
Well drilling operations	Brines associated with oil and gas operations
INDUSTRIAL PROCESSES (PRESENTLY OPERATED OR TORN-DOWN FACILITIES)¹⁸	
Asphalt plants	Petroleum derivatives
Communications equipment manufacturers	Nitric, hydrochloric, and sulfuric acid wastes; heavy metal sludges; copper-contaminated etchant (e.g., ammonium persulfate); cutting oil and degreasing solvent (trichloroethane, Freon, or trichloroethylene); waste oils; corrosive soldering flux; paint sludge; waste plating solution
Electric and electronic equipment manufacturers and storage facilities	Cyanides; metal sludges; caustics (chromic acid); solvents; oils; alkalis; acids; paints and paint sludges; calcium fluoride sludges; methylene chloride; perchloroethylene; trichloroethane; acetone; methanol; toluene; PCBs
Electroplaters	Boric, hydrochloric, hydrofluoric, and sulfuric acids; sodium and potassium hydroxide; chromic acid; sodium and hydrogen cyanide; metallic salts
Foundries and metal fabricators	Paint wastes; acids; heavy metals; metal sludges; plating wastes; oils; solvents; explosive wastes

Appendix 5. Potential Sources of Ground Water Contamination

Table 4-4. Potential Sources of Ground Water Contamination (continued)

Source	Health, Environmental, or Aesthetic Contaminant ^{1,2,3}
Furniture and fixtures manufacturers	Paints; solvents; degreasing sludges; solvent recovery sludges
Machine and metalworking shops	Solvents; metals; miscellaneous organics; sludges; oily metal shavings; lubricant and cutting oils; degreasers (tetrachlorethylene); metal marking fluids; mold-release agents
Mining operations (surface and underground), underground storage mines	Mine spoils or tailings that often contain metals; acids; highly corrosive mineralized waters; metal sulfides
Unsealed abandoned mines used as waste pits	Metals; acids; minerals; sulfides; other hazardous and nonhazardous chemicals ¹⁶
Paper mills	Metals; acids; minerals; sulfides; other hazardous and nonhazardous chemicals ¹⁶ ; organic sludges; sodium hydroxide; chlorine; hypochlorite; chlorine dioxide; hydrogen peroxide
Petroleum production and storage companies, secondary recovery of petroleum	Hydrocarbons; oil-field brines (highly mineralized salt solutions)
Industrial pipelines	Corrosive fluids; hydrocarbons; other hazardous and nonhazardous materials and wastes ¹⁶
Photo processing laboratories	Cyanides; biosludges; silver sludges; miscellaneous sludges
Plastics materials and synthetics producers	Solvents; oils; miscellaneous organics and inorganics (phenols, resins); paint wastes; cyanides; acids; alkalis; wastewater treatment sludges; cellulose esters; surfactant; glycols; phenols; formaldehyde; peroxides; etc.
Primary metal industries (blast furnaces, steel works, and rolling mills)	Heavy metal-wastewater treatment sludge; pickling liquor; waste oil; ammonia scrubber liquor; acid tar sludge; alkaline cleaners; degreasing solvents; slag; metal dust
Publishers, printers, and allied industries	Solvents; inks; dyes; oils; miscellaneous organics; photographic chemicals
Public utilities (phone, electric power, gas)	PCBs from transformers and capacitors; oils; solvents; sludges; acid solution; metal plating solutions (chromium, nickel, cadmium); herbicides from utility rights-of-way
Sawmills and planers	Treated wood residue (copper quinolate, mercury, sodium bazide); tanner gas; paint sludges; solvents; creosote; coating and gluing wastes
Stone, clay, and glass manufacturers	Solvents; oils and grease; alkalis; acetic wastes; asbestos; heavy metal sludges; phenolic solids or sludges; metal-finishing sludge
Welders	Oxygen, acetylene
Wood preserving facilities	Wood preservatives; creosote

¹In general, ground water contamination stems from the *misuse and improper disposal* of liquid and solid wastes; the *illegal dumping or abandonment* of household, commercial, or industrial chemicals; the *accidental spilling* of chemicals from trucks, railways, aircraft, handling facilities, and storage tanks; or the *improper siting, design, construction, operation, or maintenance* of agricultural, residential, municipal, commercial, and industrial drinking water wells and liquid and solid waste disposal facilities. Contaminants also can stem from *atmospheric pollutants*, such as airborne sulfur and nitrogen compounds, which are created by smoke, flue dust, aerosols, and automobile emissions, fall as acid rain, and percolate through the soil. When the sources listed in this table are used and managed properly, ground water contamination is not likely to occur.

²Contaminants can reach ground water from activities occurring on the land surface, such as industrial waste storage; from sources below the land surface but above the water table, such as septic systems; from structures beneath the water table, such as wells; or from contaminated recharge water.

³This table lists the most common wastes, but not all potential wastes. For example, it is not possible to list all potential contaminants contained in storm water runoff or research laboratory wastes.

⁴Coliform bacteria can indicate the presence of pathogenic (disease-causing) microorganisms that may be transmitted in human feces. Diseases such as typhoid fever, hepatitis, diarrhea, and dysentery can result from sewage contamination of water supplies.

⁵Pesticides include herbicides, insecticides, rodenticides, fungicides, and avicides. EPA has registered approximately 50,000 different pesticide products for use in the United States. Many are highly toxic and quite mobile in the subsurface. An EPA survey found that the most common pesticides found in drinking water wells were DCPA (dacthal) and atrazine, which EPA classifies as *moderately toxic* (class 3) and *slightly toxic* (class 4) materials, respectively.

⁶The EPA National Pesticides Survey found that the use of fertilizers correlates to nitrate contamination of ground water supplies.

Appendix 5. Potential Sources of Ground Water Contamination

⁷Automotive wastes can include gasoline; antifreeze; automatic transmission fluid; battery acid; engine and radiator flushes; engine and metal degreasers; hydraulic (brake) fluid; and motor oils.

⁸Toxic or hazardous components of common household products are noted in Table 3-2.

⁹Common household pesticides for controlling pests such as ants, termites, bees, wasps, flies, cockroaches, silverfish, mites, ticks, fleas, worms, rats, and mice can contain active ingredients including naphthalene, phosphorus, xylene, chloroform, heavy metals, chlorinated hydrocarbons, arsenic, strychnine, kerosene, nitrosamines, and dioxin.

¹⁰Common pesticides used for lawn and garden maintenance (i.e., weed killers, and mite, grub, and aphid controls) include such chemicals as 2,4-D; chlorpyrifos; diazinon; benomyl; captan; dicofol; and methoxychlor.

¹¹Swimming pool chemicals can contain free and combined chlorine; bromine; iodine; mercury-based, copper-based, and quaternary algicides; cyanuric acid; calcium or sodium hypochlorite; muriatic acid; sodium carbonate.

¹²Septic tank/cesspool cleaners include synthetic organic chemicals such as 1,1,1 trichloroethane, tetrachloroethylene, carbon tetrachloride, and methylene chloride.

¹³Common wastes from public and commercial buildings include automotive wastes; rock salt; and residues from cleaning products that may contain chemicals such as xylenols, glycol esters, isopropanol, 1,1,1-trichloroethane, sulfonates, chlorinated phenols, and cresols.

¹⁴Municipal wastewater treatment sludge can contain organic matter; nitrates; inorganic salts; heavy metals; coliform and noncoliform bacteria; and viruses.

¹⁵Municipal wastewater treatment chemicals include calcium oxide; alum; activated alum, carbon, and silica; polymers; ion exchange resins; sodium hydroxide; chlorine; ozone; and corrosion inhibitors.

¹⁶The Resource Conservation and Recovery Act (RCRA) defines a hazardous waste as a solid waste that may cause an increase in mortality or serious illness or pose a substantial threat to human health and the environment when improperly treated, stored, transported, disposed of, or otherwise managed. A waste is hazardous if it exhibits characteristics of ignitability, corrosivity, reactivity, and/or toxicity. Not covered by RCRA regulations are domestic sewage; irrigation waters or industrial discharges allowed by the Clean Water Act; certain nuclear and mining wastes; household wastes; agricultural wastes (excluding some pesticides); and small quantity hazardous wastes (i.e., less than 220 pounds per month) generated by businesses.

¹⁷X-ray developers and fixers may contain reclaimable silver, glutaldehyde, hydroquinone, phenedone, potassium bromide, sodium sulfite, sodium carbonate, thiosulfates, and potassium alum.

¹⁸This table lists potential ground water contaminants from many common industries, but it does not address all industries.

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Appendix 6. Potentially Harmful Components of Common Household Products

Table 3-2. Potentially Harmful Components of Common Household Products

Product	Toxic or Hazardous Components
Antifreeze (gasoline or coolants systems)	Methanol, ethylene glycol
Automatic transmission fluid	Petroleum distillates, xylene
Battery acid (electrolyte)	Sulfuric acid
Degreasers for driveways and garages	Petroleum solvents, alcohols, glycol ether
Degreasers for engines and metal	Chlorinated hydrocarbons, toluene, phenols, dichloroperchloroethylene
Engine and radiator flushes	Petroleum solvents, ketones, butanol, glycol ether
Hydraulic fluid (brake fluid)	Hydrocarbons, fluorocarbons
Motor oils and waste oils	Hydrocarbons
Gasoline and jet fuel	Hydrocarbons
Diesel fuel, kerosene, #2 heating oil	Hydrocarbons
Grease, lubes	Hydrocarbons
Rustproofers	Phenols, heavy metals
Car wash detergents	Alkyl benzene sulfonates
Car waxes and polishes	Petroleum distillates, hydrocarbons
Asphalt and roofing tar	Hydrocarbons
Paints, varnishes, stains, dyes	Heavy metals, toluene
Paint and lacquer thinner	Acetone, benzene, toluene, butyl acetate, methyl ketones
Paint and varnish removers, deglossers	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 naphtha
Laundry soil and stain removers	Hydrocarbons, benzene, trichloroethylene, 1,1,1-trichloroethane
Other solvents	Acetone, benzene
Rock salt	Sodium concentration
Refrigerants	1,1,2-trichloro-1,2,2-trifluoroethane
Bug and tar removers	Xylene, petroleum distillates
Household cleansers, oven cleaners	Xylenols, glycol ethers, isopropanol
Drain cleaners	1,1,1-trichloroethane
Toilet cleaners	Xylene, sulfonates, chlorinated phenols
Cesspool cleaners	Tetrachloroethylene, dichlorobenzene, methylene chloride
Disinfectants	Cresol, xylenols
Pesticides (all types)	Naphthalene, phosphorus, xylene, chloroform, heavy metals, chlorinated hydrocarbons
Photochemicals	Phenols, sodium sulfite, cyanide, silver halide, potassium bromide
Printing ink	Heavy metals, phenol-formaldehyde
Wood preservatives (creosote)	Pentachlorophenols
Swimming pool chlorine	Sodium hypochlorite
Lye or caustic soda	Sodium hydroxide
Jewelry cleaners	Sodium cyanide

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

Appendix 7. Example of a Standard Operating Procedure

SAMPLING STANDARD OPERATING PROCEDURES

1. PROCEDURES FOR LOW-FLOW SAMPLING WITH PUMP¹

The main steps are outlined below. Start with least contaminated well.

A. Before Day of Sampling:

1. Sound well bottom.
2. Calculate screen depth interval.
3. Determine pump rate that achieves drawdown of less than 0.3 feet.
4. Decontaminate water-level probe between wells.

B. Day of Sampling:

1. To avoid disturbing particulates, complete a round of water levels before sampling; record water levels and measuring point in logbook.
2. Calibrate field water quality instruments at the beginning of each sampling day (see section 3)
3. Position a clean 4-foot square sheet of plastic on the ground around the well over which to work.
4. Wearing gloves, install tubing and/or pump equipment and slowly lower until intake is positioned at selected depth.
5. Measure water level again before starting pump.
6. Purge well; if using an adjustable rate pump, adjust pump rate to achieve minimal drawdown (preferably <0.3 feet); water level should not drop to the intake level; (target pump rate is 0.1 - 0.4 l/min).
7. Every 5 minutes measure water levels (using an electric water level probe) and pumping rate (using a bucket graduated for volume measurement).
8. Monitor indicator parameters every 3 to 5 minutes by placing probes in a clean container of the purge water. Stabilization is considered complete when three consecutive readings are within the following limits:
 - turbidity & DO: 10%
 - SC, temperature: 3%
 - pH: +/- 0.1 unit
9. Purge volume should be > drawdown volume plus extraction tubing volume. If well is dewatered, allow well to recover and collect sample.
10. Collect samples from discharge line of pump:
 - Label sample containers.
 - Collect VOCs first; keep tubing full of water; allow some overflow of sample to achieve a convex meniscus on the vial; close the cap of the vial tightly; invert the vial and tap it several times to check for trapped air; reject any vials containing air bubbles.
 - Sample for remainder of parameters.
 - Add preservatives to the appropriate samples unless bottles have already been prepared; place filled containers in cooler.
 - Complete chain-of-custody and sample record.
11. Remove equipment from well:
 - If using dedicated submersible pump and tubing, secure tubing to well head.
 - If using portable peristaltic pump with dedicated tubing, detach tubing from pump and secure tubing to well head.
12. Decontaminate equipment:
 - If using dedicated submersible pump and tubing, no decontamination is required.
 - If using portable peristaltic pump with dedicated tubing, no decontamination is required.

¹ Adapted from EPA Region I SOP #0001 "Low Stress (low-flow) Purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells", July 30, 1996.

Appendix 7. Example of a Standard Operating Procedure

- Decontamination is required of any non-dedicated equipment (non-dedicated submersible pump, non-dedicated tubing, field instrument probes) that comes into contact with samples.
 - Decontamination procedure: potable water rinse, non-phosphate detergent wash, potable or distilled/de-ionized water rinse, isopropyl alcohol rinse, distilled/de-ionized water rinse.
13. Rinse field water quality equipment with distilled/de-ionized water
 14. Standardization and instrument drift checks at the end of each sampling day (see section 3)
 15. Document all steps and times in logbook.
 16. Lock well.

2. PROCEDURES FOR SAMPLING WITH A DEDICATED BAILER

The main steps are outlined below. Start with least contaminated well.

A. Before Day of Sampling:

Same as 2A above

B. Day of Sampling:

1. Position a clean 4-foot square sheet of plastic on the ground around the well over which to work.
2. Wearing clean gloves, remove wrapper from the dedicated bailer.
3. Measure a piece of dedicated nylon rope long enough to reach the selected intake depth and attach this rope to the bailer with a secure knot.
4. Lower the bailer gently to the selected intake depth.
5. Withdraw the bailer from the well, holding the rope to prevent from touching the ground.
6. Pour the water from the bailer into a bucket graduated for purge water volume measurement.
7. Repeat this operation until the correct purge volume as been withdrawn.
8. Field water quality parameters will be measured from the bucket into which the purge water is poured. Measurement and stabilization of these parameters is achieved as described in 2.B.8 above.
9. Sample can be collected when field parameters have stabilized or three well volumes have been evacuated, whichever comes first. Lower the bailer slowly into the column of water and gently pull the bailer out.
10. VOC sampling:
 - Slowly push the VOC sampler tip into the lower end of the full bailer until the sample begins to flow from the discharge tube.
 - Lift a clean VOC vial around the discharge tube and fill the vial, allowing some overflow to achieve a convex meniscus on the sample vial. Close the cap of the vial tightly.
 - Invert the vial and tap it several times to check for trapped air. Reject any vials containing air bubbles.
11. Remove the VOC sampler tip and fill the remainder of the sample bottles from the top of the bailer.
12. At no time should the bailer touch the ground or any surface other than the inside of the well or the gloved hands of field sampling personnel.
13. Secure bailer inside well with rope and lock well head.

3. INSTRUMENT CALIBRATION AND DRIFT CHECKS

Calibration of each instrument will be performed at the beginning of each sampling day. Field sampling staff will perform a two-point calibration of the pH meter and one-point calibrations of the conductivity and D.O. meters. The Hach turbidimeter calibration will be checked two times daily using three secondary standards (composed of silicon gel and metal oxide) in accordance with manufacturer's instructions.

Standardization checks will be performed at the conclusion of each sampling day. Instrument drift will be checked by analyzing a standard at the conclusion of each sampling day.

General technical specifications and calibration procedures for the field water quality instruments are attached in the Field Water Quality Instrument SOP.

Appendix 7. Example of a Standard Operating Procedure

4. CRITERIA FOR SELECTION OF TUBING OR PUMP INTAKE DEPTH

Each well will be sounded to confirm the well depth. The target intake depth will be the center of the well screen. If a build up of silt in the bottom of the well will interfere with the proper placement and operation of a submersible pump, the intake will be placed three feet below the top of the screen. Monitoring wells with significant amounts of silt will be periodically developed to remove the accumulated sediment. If excessive amounts of silt are encountered, the well will be purged and sampled using a dedicated bailer (as discussed below).

5. SAMPLE IDENTIFICATION, TRANSPORTATION, AND CHAIN-OF-CUSTODY

Sample containers will be labeled in advance of sampling with the sample date, location (well identifier), sampler's initials, and project name.

Written sample custody procedures will be followed whenever samples are collected, transferred, stored, analyzed, or destroyed, in order to trace possession and handling of a sample from collection to disposal. Accountability for a sample begins when the sample is taken from the well. Each sample will be accounted for with the use of sample labels, and chain-of-custody forms, a record of sample collection, and field data notebooks.

The following chain-of-custody procedures will be implemented by the field staff:

- Entries in the field notebook and chain-of-custody form will be made in ink. Documentation of each sample must be completed at the time of sampling.
- The original copy of the chain-of-custody must accompany the samples at all times after collection, until receipt at the analytical laboratory. A copy of the chain-of-custody form will be kept by the field staff until filing at the office.
- When the possession of samples is transferred, the individuals relinquishing and receiving the samples will sign, date, and note the time on the chain-of-custody form.
- If samples are shipped, strict chain-of-custody is violated. However at the discretion of the project manager the procedures can still be followed, with one modification: the field staff will note the courier name and airbill number on the chain-of-custody form. The field staff will keep a copy of the airbill.

6. EQUIPMENT LIST

Equipment for Low-flow Sampling Using Pump

- Pump constructed of stainless steel or Teflon (submersible centrifugal or peristaltic).
- Power source (marine battery).
- Dedicated tubing: 1/4 or 3/8 inch ID (pharmaceutical-grade silicone tubing around rotor head of peristaltic pump; Teflon-lined polyethylene for submersible pump).
- Flow rate measurement equipment (graduated cylinder or bucket and stop watch).

Equipment for Sampling Using Bailer

- Dedicated Teflon bailer.
- Dedicated drop-line for bailer.
- VOC adapter tip for bailer.

Additional Equipment

- Water level probe (accuracy =0.01 feet).
- Decontamination materials if needed (non-phosphate detergent, distilled/de-ionized water, isopropyl alcohol).
- Sample bottles, labels, cooler, and ice packs.
- Sample preservatives (unless added by lab).

Appendix 7. Example of a Standard Operating Procedure

- Well construction data (maps, well construction reports, data from previous sampling round).
- Logbook.
- Quality Assurance Plan.
- Well purging and sampling forms.
- Chain-of-Custody.
- Well keys.
- Bolt cutters.
- Field water quality equipment: pH, Dissolved Oxygen, Turbidity, Specific Conductance, Temperature.
- Standards for field calibration.
- Gloves and plastic sheets (4-foot square to lay on ground)

7. FORMS

The following forms are attached:

1. **Analytical Method Details:** to record details regarding each analytical method (the type and number of containers, matrix type, preservation method, holding period) and which wells are sampled for each analytical method
2. **QC Sample Form:** to record information regarding each QC sample (duplicate sample, field blank, equipment blank, trip blank) including fictitious id's and sample description
3. **Water Sample Record:** to record all information regarding the purging and sampling each well
4. **Chain-of-Custody Record:** to record all parties who handle samples from collection to disposal

WATER SAMPLE RECORD FORM

PROJECT NAME: _____	PROJECT NO. _____
LOCATION: _____	WELL IDENTIFICATION CODE
SAMPLE IDENTIFICATION NO.: _____	

ELEVATION DATA

DATE: _____	TIME: _____	WELL DIAMETER (inches): _____
DEPTH (ft)	+ CORRECTION	= TRUE DEPTH
WATER LEVEL	+	WATER COLUMN HEIGHT: _____ (feet)
BOTTOM OF WELL	+	GAL/FT x 3: _____
MEASURING POINT: TPS / PVC		VOLUME TO BE PURGED: _____ (gallons)
INSTRUMENT: _____		
COMMENTS: _____		

WELLHEAD CONDITION

(circle items where appropriate; cross out if not applicable)

GENERAL CONDITION: GOOD / NEEDS REPAIR	IS WELL PLUMB? Y / N
PROTECTIVE STEEL CASING: GOOD / CRACKED / BENT / LOOSE / NONE	LOCK: GOOD / BROKEN / NONE
WELL NO. VISIBLE? Y / N	RUST AROUND CAP? Y / N
WELL CAP: GOOD / BROKEN / NONE	PVC RISER: GOOD / DAMAGED / NONE
RAIN WATER BETWEEN STEEL AND PVC CASINGS? Y / N	CONCRETE COLLAR: GOOD / CRACKED / NONE
EVIDENCE OF PONDING AROUND WELL? Y / N	EVIDENCE OF: RODENTS / INSECTS / NONE
GOPHER-TYPE HOLES AROUND COLLAR? Y / N	CURB BOX: Y / N (key is: HEX / PENT)
COMMENTS: _____	CURB BOX GASKET: GOOD / REPLACE

PURGE DATA

(circle items where appropriate; cross out if not applicable)

START TIME: _____	PURGE DEVICE: DEDICATED / NON-DEDICATED
END TIME: _____	DEVICE TYPE: BAILER / PERISTALTIC / SUBMERSIBLE / BLADDER
PURGED TIME: _____	COMMENTS: _____
PUMP RATE: _____ (gpm)	WELL YIELD: HIGH / MODERATE / LOW / DRY
VOLUME PURGED: _____ (gallons)	

SAMPLE DATA

DATE: _____	TIME: _____	SAMPLER: _____	CONTAINERS	QUANTITY	PRESERVATIVES
SAMPLE DEPTH: _____ (ft) WEATHER: _____					
SAMPLING METHOD: BAILER / PERISTALTIC / CENTRIFUGAL					
BAILER TYPE: 2"SS / 1.25"SS / SHORT SS / 2"PVC / OTHER					
BAILER CABLE: DEDICATED / NON-DEDICATED					
FILTERED IN FIELD: N Y / @WELLHEAD / @VEHICLE					
FILTRATION METHOD: PRESSURE / VACUUM / SYRINGE					
PUMP ID NO.: _____ FILTER ID NO.: _____					
FIELD DECON: BAILER / FILTER / TUBING / OTHER / NONE					
WATER APPEARANCE (COLOR, ODOR, ETC.): _____					

INSTRUMENT CALIBRATION

pH METER	pH	mV	T
pH 4 buffer			
pH 7 buffer			
pH 10 buffer			

SPECIFIC CONDUCTIVITY (cal. soln. / meas cal. soln.)	
cell constant: 1,413 umho/cm / _____	= _____
temp. correction (f): cal. soln. temp = _____	f = _____

FIELD PARAMETERS

INSTRUMENT #	SAMPLE TEMPERATURE	SPECIFIC CONDUCTIVITY	INSTRUMENT #
pH		cell constant X temp. corr. (f) X measured SC =	
		X X	@ 25 C

NOTE: SC CALCULATION BASED ON TEMP. AT THE TIME OF MEASUREMENT

