AQUIFER-PROTECTION STUDY OF BARNES AQUIFER FOR EASTHAMPTON, MASSACHUSETTS

Ward S. Motts

Hydrogeologist

Amherst, Massachusetts

January 1990

CONTENTS

FIGURES, APPENDIX AND ATTACHMENTS

INTRODUCTION

General Statement

The present study was made for the Town of Easthampton in conjunction with Alexandra Dawson, Environmental Lawyer. I conducted a hydrogeologic study focusing on recommendations for aquifer protection; whereas, Attorney Dawson studied the legal implications of aquifer-protection strategies and prepared recommendations to Easthampton for implementing the recommendations. Alexandra Dawson and this author worked closely together prior to the submittal of the July 17 memo to the Town (Dawson, 1989). Consequently, we are in agreement with most of the memo recommendations and the few of which there are minor disagreements are discussed further in this report.

The quality and quantity of Easthampton's ground-water supply are in long-range jeopardy because of (1) low recharge, (2) increased urban development in the town, and (3) no protective silt or clay bed south of Plain Street to prevent rapid and unimpeded flow of contaminants with little attenuation into the main aquifer supplying Easthampton wells. Fortunately, there are the following natural and social conditions that serve to protect the aquifers: (1) the thick clay bed that protects the important Lower Aquifer north of Plain Street, (2) the rapid flow of water through Easthampton's aquifers that provides a natural flushing action, and (3) numerous hydrologic studies of the aquifers, providing an increasing background of important information for Easthampton's aquifers. Nevertheless, Easthampton must maintain constant vigilance including periodic monitoring to save the aquifer from serious quality and quantity impairment.

The author greatly appreciates the support and full cooperation of Michael Tautznik and other members of the Easthampton Planning Board; of Roland Laramie, Town Engineer and Peter Klejna, former Town Planner; and of Christopher Curtis, Pioneer Valley Regional Planning Commission. I am grateful for the productive discussions regarding the project held with Attorney Dawson and Dr. James Hall, colleagues of the author. Thanks are given to Dennis McInerney for his good work in helping prepare and draft the illustrations.

Goals and Scope of Study

The complete goals and scope of this investigation are described in the memo of February 27, by Motts and Dawson (1989). The major goals of Motts were to determine the quality and quantity stressing of the Barnes Aquifer and to recommend ways of alleviating these stresses by specific land-use controls and other measures. One of the major contributions of this study is a computer program to establish contaminated travel-rate zones which show how long it takes for contaminants to reach specific town wells. Dr. James Hall, hydrology computer expert, participated in this part of the study. Another contribution not in the original proposal is the establishment of time-contaminant zones for the Lovefield Street well. It is unfortunate that the hydrology and recharge areas of this well, which is an important source of water for Easthampton, were not adequately studied in previous studies.

HYDROGEOLOGY

Barnes Aquifer System

The Easthampton production wells (Lovefield Street Well, Nonotuck Park Wells, and Hendrick Street Wells) all obtain their water supply from the Barnes Aquifer System. The Barnes Aquifer System extends from the Westfield River, north through Holyoke and Westhampton, into Easthampton. The system occurs in thick stratified drift which fills a deep trench caused from glacial erosion. South of Plain Street in Easthampton the Barnes Aquifer is generally unconfined but in places it consists of an Upper Aquifer and a Lower Aquifer separated by silt beds. North of Plain Street, the major part of the aquifer is confined by almost impermeable lake beds. Consequently, the Barnes Aquifer in Holyoke, Southampton and Easthampton consists of two flow systems: (1) a series of small local systems comprises the Upper Aquifer in which precipitation percolates into the aquifer and flows directly toward surface-water bodies, and (2) a deeper flow system comprising the Lower Aquifer in which precipitation percolates into the Barnes Aquifer south of Plain Street, flows north beneath the confining layer and eventually discharges in the Oxbow and the Manham River (IEP, 1988).

Broad Brook drains both the shallow and deeper parts of Barnes Aquifer. In relation to Easthampton wells, any part of the recharge area feeding Barnes Aquifer can be called either a "direct" or an "indirect" recharge area. The direct recharge area of a well is defined as directly contributing to the well discharge; therefore, contamination impacting a direct recharge area would move through the ground-water zone unimpeded to the well. On the other hand, contamination impacting an indirect recharge area moves through the aquifer to a stream, travels in the stream, and recharges into the direct recharge area where it moves directly to the wells. The shallow and deeper parts of the Barnes Aquifer are indirect in many places because ground water flows into Broad Brook before the brook recharges the direct recharge area. These processes were recognized by IEP (1988, p. 39), who made this statement: "It is possible that a portion of a surface water flow from Broad Brook becomes induced recharge through the stream bed and enters the deep aquifer due to pumping of the Hendrick Street wellfield. The amount of induced recharge from Broad Brook cannot be estimated based on available data."

Of course it is important in regard to aquifer protection to understand whether a locality is a direct or an indirect recharge area. Not only can contamination be intercepted at the surface in an indirect area, but also many contaminants are attenuated as they move through areated surface water. The surface- and ground-water interactions are complex between Barnes Aquifer and Broad Brook. For example, many recharge areas are indirect during normal flow and climatic conditions; however, during drought, low flow, and/or heavy pumping conditions, the Brook can dry up and the original indirect recharge area can become a direct area. The surface water/ground water relationships between Broad Brook and Barnes Aquifer should be studied in greater detail in future hydrogeologic studies of Easthampton.

Details of many aspects of the hydrogeology of the Barnes Aquifer System are presented in IEP (1988) and Wehran Engineering Corporation (1988).

Amount of Natural Recharge to Barnes Aquifer and Its Relation to Safe Yield

Safe yield may be defined as the amount of water an aquifer will produce with a given well spacing without depleting the aquifer, causing the encroachment of poor quality water, or causing surrounding environmental damage. Pumping more water than is naturally recharging Barnes Aquifer would not only deplete the aquifer, but also could cause the following negative effects: (1) dewatering parts of the confined aquifer may result in aquifer collapse combined with a reduction in aquifer yield or land surface subsidence, (2) reversal of ground-water heads between the Upper and Lower Aquifers, resulting in downward migration of surficial contaminants (road discharge, etc.) and pollution of the artesian Lower Aquifer, and (3) lowering of levels in the Upper Aquifer resulting in negative environmental impacts including dewatering or "drying up" portions of Broad Brook (see IEP, 1988).

The IEP report uses the term "perennial yield" for safe yield (as used in this report) and relates it to the amount of natural recharge entering the Barnes Aquifer system. This natural recharge, also called ground-water outflow, is the amount of precipitation that enters the aquifer system and flows to the discharge area. IEP calculated the natural recharge in two ways: (1) by the "Connecticut Method" developed by the U.S. Geological Survey in Connecticut, and (2) by an estimate of recharge from precipitation falling on the unconfined portion of the stratified drift part of the aquifer. The natural recharge calculated by the first method is 7.1 ft^3/sec or 5 mgd, and by the second method is 5.8 ft^3/sec or 3.7 mgd.

The first method (Connecticut method) is the most accurate, primarily because the second method did not include recharge from the till and bedrock. However, the IEP calculations using the Connecticut method were not completely correct in two respects: (1) the total recharge area of Barnes Aquifer extends further south than indicated by IEP, which provides greater recharge to Easthampton wells, and (2) IEP did not consider withdrawals from Holyoke municipal wells or from private wells, which decreases the available recharge to Easthampton wells. The total discharge from the Holyoke Coronet and Pequot Wells in 1984 was about 75,000 gpd (gallons per day). The author, Motts (1985) determined that the southern boundary area of Barnes Aquifer and its recharge area extends to Pequot Ponds as shown on Fig. 1. The infiltration into this indirect recharge area, not included on this IEP map, moves into the deeper Barnes Aquifer and then into Broad Brook, where it eventually again enters the direct recharge area of the aquifer in Easthampton. Also the IEP Zone 3 boundary was slightly altered west of Pomeroy Street to better conform to drainage boundaries, thereby slightly increasing the size of Zone 3 at this location.

The total recharge to the Easthampton part of the Barnes Aquifer should be calculated with greater precision in future studies. However, because the incorrect calculations of IEP discussed above tend to cancel each other, their value of 5 mgd as calculated by the Connecticut method may be correct in the general order of magnitude. This indicates that the natural recharge to the Easthampton aquifer system is close to the total withdrawal by Easthampton wells during times of drought, low flow conditions. For example, while the average ground water outflow was calculated to be 5 mgd, the 7 years equalled or exceeded in 10 years is .85 x 5 mgd or 4.25 mgd and the long-term minimum is approximately .4 x 5 mgd or 2.00 mgd. In 1980, the total withdrawal from Easthampton wells was 3.23 mgd. Therefore, the difference between natural recharge and withdrawals by Easthampton wells for average climatic conditions is 5 mgd - 3.23 mgd or 1.77 mgd (about 1.8 mgd); and for 7 years in 10 is 4.25 mgd - 3.23 mgd or 1.02 mgd (about 1.00 mgd). During the long term minimum (a severe drought similar to that of 1960-1965) Easthampton would be pumping more than the natural recharge, 3.23 mgd - 2.00 mgd or 1.23 mgd (about 1.20 mgd).

The above discussion indicates not only the importance for Easthampton to more closely monitor the indirect, direct and total recharge to their wells, but also the necessity to adapt strict but reasonable water conservation measures.

IMPORTANCE OF WATER CONSERVATION

As indicated in the previous section of this report, the Barnes Aquifer system becomes severely stressed when the natural recharge decreases and/or the ground water withdrawals increase. During a long-term drought, pumping 3.23 mgd from the aquifer would result in a withdrawal of more than 1 mgd over the amount of natural recharge. Such severe stressing of the aquifer could have serious negative environmental effects, including reversal of heads between the upper and lower artesian aquifers and land subsidence. Another effect of this quantity stressing is to induce poor quality water containing iron and manganese from distant parts of the aquifer and from the deeper bedrock zones.

Conservation of water is an effective way of increasing the amount of water in aquifer storage. A study was made in Marin County, California of ways of alleviating the effects of the severe 1980 drought in that state. The study found that a community can decrease the amount of water consumed through conservation (1) by about 50 percent with stringent measures but with considerable community discomfiture, (2) by about 25 to 30 percent from moderate measures with minor community discomfiture, and (3) by 15 to 20 percent from minor measures and virtually no community discomfiture or negative impact on the community.

Because of the importance of water conservation to Easthampton, the author recommends that Town boards adopt the following measures:

(1) Establishment of a committee that can examine water conservation measures for Easthampton.* The committee could consider the following measures:

A. Metering for all water users.

B. Adoption of a contingency plan for strict conservation measures if well withdrawals exceed 4 mgd.

C. Recommendations for decreasing domestic consumption of water; for example, the amount of water applied to lawns, low discharge showerheads and toilets that discharge sufficient but smaller amounts of water than prevailing types.

D. Recommendations for decreasing industrial consumption of water: conferences can be held with industrial executives regarding conservation strategies. It can be pointed out

---

*Such a committee could examine measures for aquifer and surface-water protection that include consideration of steps for protection of Nashawannuck Pond recommended by Baystate Environmental Consultants (1988).

that some industries such as the Gillette Company adopted a program that not only conserved water but also resulted in considerable financial savings for the company. For this, the Gillette Company earned the Massachusetts Audubon Society Audubon "A" Award. By a closed loop system, Texas Instruments, Inc. in Attleboro, Massachusetts, reduced water consumption by 1.2 mgd since 1980, and saved $8.6 million from 1980-1988 (Attachment 1).

E. Examination of "Residential Water Use" by Milne (1979) for other ways of conserving water that may be applicable and useful for Easthampton.

(2) Establishment of a public-education program designed to inform Easthampton residents of the environmental and economic value of water conservation and of protecting natural resources. In addition to media coverage, presentations to town boards, town organizations, and local schools may be effective.

SOURCES OF CONTAMINATION TO BARNES AQUIFER SYSTEM OUTSIDE EASTHAMPTON

One of the goals of this investigation is to obtain and plot contamination sources impacting the Barnes Aquifer System outside of Easthampton in Holyoke and Southampton. IEP (1988) plotted sources of contamination within Easthampton on base maps with a scale of 1:25,000. Wehran Engineering Corporation (1988) plotted contamination sources in Southampton which have been transferred by this author to Easthampton base maps with the above scale (Fig. 1). The Pioneer Valley Regional Planning Commission is now locating sources of contamination in Holyoke which can be transferred to the Easthampton maps.

COMPUTER PROGRAM DELINEATING TIME CONTAMINANT ZONES

An important contribution of this study is the establishment of travel-time contours which show the length of time for water to travel to each of the Easthampton wells. Dr. James Hall, a hydrology computer expert, performed the computer modeling part of this study. His report on the computer model is presented in Appendix 1. The travel-time contours were generated using a random-walk mass transport computer model that simulates pollutants transport in an inverted head/velocity field. The model was developed by Thomas Pricket and used in some localities including Dade, Broward, and Palm Beach Counties, Florida (Johnson and others, 1985). Some of the basic data collected by IEP (1988) for their MODFLOW model was utilized for our time-contaminant zone model; however, the MODFLOW data has the limitations discussed in Appendix 1.

Our time-contaminant zone model simulates the three Easthampton wells pumping simultaneously at optimum rates: Lovefield Well at 1.5 mgd, Nonotuck Park Wells at 1.5 mgd, and Hendrick Street Wells at 4.3 mgd (Fig. 2). Computer runs were prepared for each well pumping separately; however, all the wells pumping together produces the greatest drawdown and most rapid flow conditions in the Aquifer. Fig. 2 shows travel-time contours for 100, 180, 360, 720 and 1800 days. A particle of water at a given contour, say the 100 day contour, would take 100 days to reach the well at the abovementioned rates. The contours enclose "travel-time envelopes"; for example, any pollutant (such as one from an oil spill) would take more than 100 days but less than 180 days to reach the well if the spill occurred between the above-mentioned contours.

The model is based on the movement of water from convective transport. In some cases, actual time of pollutant movement may be slower than model calculations because of the "retardation effect," which is the reaction of the pollutants with other pollutants, with the surrounding sediment, and by other processes. Therefore, the model is conservative, that is, it represents the most rapid or minimum time that a contaminant would reach the well.

The time-contaminant zone model has resulted in the following five benefits for our aquifer protection study:

(1) The model allows us to make specific recommendations for time-contaminant zones close to municipal wells. For example, it may be wise to first implement the recommendations regarding buried oil tanks made by the author and Dawson (1989) within the 180 day time contaminant zone. All potential sources of contamination within this zone should be carefully evaluated.

(2) In case of an accidental toxic spill, the model allows us to calculate the time it will take the contaminants to reach the well. This will help the town to adopt the most efficient procedures for spill cleanup, including mobilization of drill rigs, the time-frame necessary for analysis of laboratory samples, and the optimum placement of scavenger wells in the contaminated plume.

(3) The model provides us with the recharge area of each pumping Easthampton well. In case one of the wells becomes polluted,

knowledge of the contribution area of the well can give valuable insight regarding the nature and source of contamination. (Also see the discussion of this topic in Appendix 1 by Dr. Hall.)

(4) The model furnishes information for the optimum placement of monitoring wells (see next section of this report).

(5) Finally, we are provided with data regarding the velocity of ground-water flow through the aquifer, which is the "flushing rate" of the aquifer. The model shows that the Barnes Aquifer in the Easthampton-Holyoke-Southampton area has a rapid flushing rate. This has a positive and negative side. The positive side is the rapid removal of contaminants that may enter the ground-water flow systems from an accidental spill or for some other reason. The negative side is the rapid transmission of contaminants toward the wells after a spill, allowing only a short time for cleanup operations.

STRATEGIES AND RECOMMENDATIONS FOR PROTECTING EASTHAMPTON'S GROUND WATER SUPPLIES

The following strategies and recommendations are designed to protect the Barnes Aquifer System, which supplies the Nonotuck Wells, Hendrick Street Wells, and Lovefield Street Well. The author and Attorney Dawson have discussed together many of these recommendations, which are presented in Dawson, 1989. Because the recharge area of Barnes Aquifer System extends into Southampton and Holyoke, recommendations will also be made regarding the latter towns.

Zoning

The author recommends two-acre zoning in till and bedrock (Zone 3), and one-acre zoning in stratified drift (Zone 2) for Easthampton and Southampton. These are similar to recommendations that I made for Holyoke (Motts, 1985) where the above zoning density will prevent build-up of sodium greater than 20 ppm, a limit recommended by the American Heart Association for persons with heart or circulatory problems. Keeping the level of sodium less than 20 ppm will also keep concentrations of nitrates within public health limits (40 ppm). In Easthampton, the two-acre zoning in bedrock and till will reduce the risk of erosion on the steep slopes.

Our recommendation for cluster zoning (see Dawson, 1989) will enhance aquifer protection for two reasons: (1) The greater amount of open space covered by natural landscape has less pavement and impermeable cover, resulting in greater amounts of natural recharge and less polluted wastewater runoff. (2) Cluster zoning readily allows the construction of holding ponds or "recharge pits" through which runoff can return to the aquifer.

Methods of Increasing Recharge to Barnes Aquifer

Because of the low amount of natural recharge to Barnes Aquifer discussed in a previous section, it is important to discharge as much precipitation and runoff as possible into the subsurface. This can be accomplished by (1) reduction of impervious cover, (2) discharge of stormwater into holding ponds, and (3) artificial-recharge methods.

Reduction of Impervious Cover

We recommend a maximum of 10 percent impervious cover; however, an increase from 10 percent to 20 percent could be allowable with special permission in small lots (see Dawson, 1989, pp. 1, 2).

Holding Ponds for Stormwater Runoff

Holding ponds can be specially designed to renovate stormwater runoff. The renovation occurs within man-made wetlands or wetland-like ecosystems which are called biofilters. The description of these renovation systems in holding ponds is discussed by D.L. Ferlow and J.B. Ferlow, 1988, in Attachment 2.

Artificial Recharge Methods

Artificial recharge may be defined as any process by which the natural infiltration rate is increased from surface to groundwater or from one aquifer to another. Artificial recharge (AR) augments the amount of water in aquifer storage through increasing the natural movement of surface water into the subsurface by construction methods, by water spreading, or by artificially changing natural conditions. AR methods in Easthampton would utilize large spring runoffs by recharging part of the water that would normally discharge out of Easthampton in flood flows. AR methods are expensive; therefore, they should be considered only as long-term alternative if severe drought conditions and/or excessive pumping threatens the aquifer. Motts (1983) discusses the different kinds of AR methods that could be implemented in Massachusetts, some of which would be applicable to Easthampton.

Monitoring Recommendations

Monitoring recommendations may be subdivided into the categories of ground-water quality, potentiometric surface, and surface water (Broad Brook) discharge.

Ground-Water Quality Monitoring

As indicated previously in this report, ground-water quality monitoring will play an important role in long-term protection of Easthampton's ground water supply. The proposed monitoring wells shown on Figure 2 are located with the purpose of protecting the water supply of Lovefield Street, Hendrick Street, and Nonotuck Wells and of testing the water quality under a residential area south of Plain Street where Chem Lawn, Fox and other lawn applications are applied.

The monitoring wells protecting the municipal wells were located with the help of the time-contaminant zones which show the direction of ground-water movement toward the wells. The 180-day travel time contour was chosen for the location of the wells (Fig. 2). Sampling the monitoring wells twice a year will give maximum protection of the municipal wells.

Wells 1 and 2 are located to protect Lovefield Street Wells from the east and south respectively, and Wells 3 and 4 protect Nonotuck Park Well from the south and southwest. It will be noted that Well 3, which will also protect Hendrick Street Well field, is the existing monitoring well cluster 1-87 installed by IEP (1987, Plate 1). The other monitoring well cluster 2-87 (Well 8) installed by IEP is not in the main ground water flow toward Nonotuck Well and therefore should not be sampled on a regular periodic basis. Wells 3, 5 and 6 are located to protect Hendrick wells from the south and west respectively. It should be noted that the flow of I_3 could be diverted into either the Nonotuck Park Wells or the Hendrick Street Wellfield, depending on the amount of their respective pumping rates.

A suggested list of analytical parameters to be sampled twice yearly is shown on Table 1 and yearly shown on Table 2.

Table 1
Analytical Parameters Sampled Twice Yearly

BOD	nitrate	mercury*
pH (field and laboratory)	ammonia	color
specific conductance	COD	odor
sodium	arsenic*	turbidity
chloride	barium*	iron
alkalinity	cadmium*	manganese
hardness	chrome (total)*	
purgeable organic compounds, including TCEs, acetone, and benzene	copper*	
	lead*	
oil and grease	nickel*	

*If not present, these parameters can be sampled annually or every two years.

Table 2
Parameters Sampled Annually

EDB and DBCP	organophosphorus pesticide scan
temik	chlorinated pesticides
carbonate pesticide scan	sampling should include scan for 1,2 dichloropropane

It is recommended that the key constituents such as sodium, nitrates, chloride, specific conductance and others be plotted on a graph of concentration vs. time. Then if the contaminants show a continuous increase with time, there may be a need to establish contamination control measures. If, for example, sodium and chloride show a progressive increase and their source is from deicing salts, steps can be taken to reduce the application of these salts to Easthampton roads.

Monitor Well 7 will be located in a residential area south of Plain Street where Chem Lawn, Fox and other toxic lawn applications are used. If the ground water shows an increase in the toxic contaminants due to the application of these chemicals, the following course of action is recommended.

(1) The residents will be informed that the chemicals they are applying to their lawns are causing deterioration of water quality and on a voluntary basis are asked to use other, non-toxic chemicals.

(2) If the toxic contaminants continue to rise, more intensive media coverage and public education forums can be given. Discussions can be held with individual house and lawn owners.

(3) If the contaminants continue to rise after Step 2, the town can adopt more stringent measures, including enforcement by fines and other methods.

When the monitor wells are drilled, a geologist should be present to supervise the work, log the cuttings, and take split spoon samples of representative subsurface units. Cuttings should be collected and with the split spoon samples studied in the laboratory and office. On the basis of the field and laboratory studies, additional wells should be located, drilled and screened in each water-productive horizon. More than one well at a site is called a well cluster. There will generally be only two wells in each cluster--a shallow well penetrating the Upper Aquifer and a deeper well penetrating the Lower Aquifer. However, three wells or more may be required at some clusters if interfingering silt beds subdivide the aquifer into discrete units. Each monitoring well should be completely developed, that is, test pumped until the discharge is sediment-free. Such development is necessary because each monitor well should have good well efficiency, i.e., any change in aquifer level is immediately reflected by a change of water level in the well. The well drilling methods described by IEP (1988, p. 16) can be used during future drilling. It may be advantageous to use the services of the drilling company which did the work for IEP because they are acquainted with the geology and sediment types in Easthampton.

Monitoring of Ground-Water Levels

When water samples are taken from the monitoring wells, it is recommended that water level measurements be taken of all shallow and deep wells. The water levels should be plotted against time, on graphs known as "hydrographs." The hydrographs will show the long-term trends of the water levels and indicate if the heads of the deeper artesian aquifer are lowering to dangerous levels below the shallow levels. If this is the case, reversal of flow can occur between the shallow and deep aquifer along with other negative effects discussed in a previous section of this report. Therefore, remedial steps can be taken if the hydrographs show the above-mentioned long-term trends.

Monitoring the Surface Flows of Broad Brook

Maintaining the flow of Broad Brook is important in regard to aquifer protection for two reasons: (1) Some of the flow of Broad Brook returns to the Barnes Aquifer through channel infiltration which provides an important source of ground-water augmentation to the aquifer. (2) Broad Brook forms a "water-quality drain" in which contamination, especially from the more polluted shallow aquifer, is flushed out of and away from Barnes Aquifer. As long as Broad Brook is flowing, the flushing action continues; when Broad Brook dries up, all the contamination is drawn back into the aquifer and thence moves towards Easthampton wells. The discharges of Broad Brook should be measured during low flow periods in the late summer and fall when there has been no rain for about one week.

Setbacks Along Broad Brook

Regulations for setbacks along Broad Brook are discussed in Dawson, 1989, p. 2. These regulations help protect Barnes Aquifer because of the good hydrologic connection between Broad Brook and the aquifer. In other words, water from the brook can readily percolate to the ground-water zone. If it is politically feasible, I recommend a setback of 75 feet (rather than 50 feet), to be kept in a natural vegetation condition without human alterations.

Subsurface Oil Tanks

The regulations discussed in Dawson (1989, pp. 4-5) regarding buried oil tanks are important for aquifer protection. One large leaky tank of 1000 to 2000 gallons capacity can destroy a drinking water supply. It only takes two or three parts per billion (ppb) of oil to make such a supply undrinkable.

Storage and Use of Hazardous Wastes

The storage and use of hazardous wastes is discussed in Dawson (1989, pp. 5, 6). I recommend one addition to the Dawson recommendation; that is cribbing or some catchment device should be installed below the storage tanks to capture any leakage for pesticides, herbicides, and fertilizers (see third paragraph from bottom of p. 5).

Toxic Spraying Along Railroads, Power Lines, Gas Lines and Road Curbings

Dawson (1989, p. 8) recommends negotiation with Northeast Utilities regarding the amount and types of herbicides this company will use on the utility R.O.W. running through Zone 2. In addition, I recommend disuse of all toxic spraying not only for the Northeast Utilities line, but also for the gas line which crosses part of the town. Easthampton should also examine the practices of the town DPW and the state DPW in regard to spraying curbings along town and state roads to be certain that no toxic sprays are used for this purpose.

Sewers and Water Mains

All new sewers and water mains installed in Easthampton should be designed for leakage prevention. Leakage from sewers can cause pollution of the aquifer, and leakage from the water mains results in loss of water. Water tightness can be engineered in several ways, including a "pipe within a pipe" and specially designed joints. The town should also check the sewer system and the water-main system for leaking pipes by using current technology. I suggest that town board members consult personnel of the Massachusetts Water Resources Authority (MWRA) who have conducted a massive program of locating water-main leaks in Boston.

Contamination from Agriculture and Animal Farming

The Stone and Webster Engineering Corporation (1988) conducted a pesticide study of towns in the Connecticut Valley for the Massachusetts Department of Environmental Protection and sampled water from community users. In Easthampton, four wells were sampled for pesticides and two showed traces of 1,2-dichloropropane which were less than the Massachusetts Interim Drinking Water Guidelines. The depth of water sampled (100 to 140 feet) suggested contamination from a distant source which may be southern Easthampton, Southampton, or Holyoke. Although the amounts of 1,2-dichloropropane were small, the author recommends continued pesticide testing in the monitoring program (see section of this report, "Ground Water Quality Monitoring"). It is noteworthy that the agricultural areas decreased from 1972 to 1985 in Easthampton from 29 percent to 18 percent and in Westhampton from 18 percent to 10 percent. However, the agricultural land use changes for this time period are not known for the Barnes Aquifer recharge area (see "Recommendations for Further Study").

Improper practices in animal farming can pollute aquifers, especially from large quantities of nitrates generated from animal wastes. Consequently, if the water quality monitoring program shows progressive increase of nitrates in Easthampton wells, the animal-management practices at specific farms should be evaluated. Recommendations for animal waste management are also given in Bayside Environmental Consultants (1988, p. 104).

Reducing the Amount of Deicing Salts on Roads

If the monitoring program shows a dangerous rise of sodium and chloride, there should be a reduction of road salt applied to town and state roads. The problem also may be associated with salt-storage practices and/or snow dumping. A statement of the problem and voluntary reductions are recommended as a first step. Such voluntary methods have proven effective for Easthampton in the past. However, if monitoring shows that voluntary methods are not working, more stringent regulations can be applied. Increasing the amount of sand to produce a high sand to low salt ratio is commonly an effective method. It is possible to use only 5 to 20 percent salt in the total sand-salt volume. Alternatives to the use of sodium chloride include: (1) application of calcium chloride--this is more expensive than sodium chloride, and the potential for increasing the hardness to unacceptable levels should be evaluated, and (2) the use of verglimit or of calcium magnesium acetate (CMA)--the latter chemical is also expensive.

Prohibition of Toxic Septic-Tank Cleaners

Some septic-tank cleaners contain highly toxic cleaning fluids that can damage ground water for drinking water purposes. Sales of these cleaners are unlawful in Connecticut, but unfortunately they can be sold in Massachusetts. Therefore, Easthampton, Westhampton and Holyoke should ban the use of the offending cleaners. A complete discussion of the toxic cleaners with brand names is presented by Noss and others (1987).

Purchase of Critical Open Space and Wetlands and Protection of Wetlands

It would be wise to purchase as much open space as economically possible in the recharge area of Barnes Aquifer. Some of the open space could be used for town parks or town recreational areas. Also, the purchase of development rights only and conservation easements should be considered. The purchase of wetlands would have beneficial effects for ground-water protection. Wetlands serve an important role in protecting a ground-water supply because wetland vegetation ingests phosphates, nitrates and other contaminants in ground water and because the organic wetland map absorbs toxic contaminants. Therefore, if the wetlands can't be purchased they should be protected from the kind of development that impairs ground-water supplies.

Regulations Regarding Domestic and Other Private Wells Drilled into Barnes Aquifer

It is important that all domestic and private wells drilled through the Upper Aquifer into the Lower Aquifer not pollute the latter aquifer. This can occur when upper-aquifer water polluted from road discharge and other surficial contaminants seeps along the sides of well casings into the Lower Aquifer. Therefore the well casings should be well grouted at depth and thoroughly capped. Old wells as well as new ones should be inspected to insure proper construction that prevents such cross contamination.

It is recommended that domestic and private well owners have water-quality analyses made at a state certified laboratory for bacteria, viruses, and inorganic constituents to insure that their drinking water does not pose a public health risk.

Prevention of Illegal Dumping

Illegal dumping of solid waste, oil, and hazardous wastes can seriously impair the water quality of Barnes Aquifer. Often the amount dumped at any one time is small; however, the cumulative effect can be large and many small steps can make a big step. For example, some car owners who change their oil do not hesitate to dump the used oil in their back yards, thinking that the small amount can have little effect on the aquifer. However, numerous episodes of "back yard dumping" can progressively impair the aquifer because of the highly toxic nature of petroleum products. Therefore, two steps are recommended: (1) A public education program should inform Easthampton residents of the environmental and economic value of their aquifer and of the serious consequences of illegal dumping. (2) There should be a center for disposal of used oil and of other hazardous wastes at a convenient location in town and at no cost to the disposal users.

Posting Criticial Aquifer Areas

The author recommends posting the area enclosing the 100-day contaminant-time zones around the Lovefield, Nonotuck Park, and Hendrick Street Wells to prevent the passage of trucks containing petroleum products or hazardous wastes through these areas. An accidental spill within a 100-day travel time contour would result in a plume that would impact the well before recovery methods could be implemented. There would be no time to drill test wells, analyze the data, and drill scavenger wells. (Also see discussion of this topic in Dawson, 1989, p. 8.)

Regulations Regarding Removal of Clays and Stratified Drift

The lake clays north of Plain Street should not be mined because they form an important protective cover for the Lower Aquifer which supplies Easthampton's wells. As the clays become thinner from mining, more rapid flow with less attenuation occurs from the polluted Upper Aquifer down into the producing Lower Aquifer. Quarrying and mining of sand and gravel in the unsaturated zone has the negative effect of removing nature's "natural filter" which protects the aquifer by greater attenuation. The thicker the natural filter in the unsaturated zone, the greater the attenuation and purifying effect. A thick unsaturated zone also results in slower downward percolation of contaminated water. If quarrying is allowed, there should be a minimum of ten feet of sand left between the bottom of the quarry and the highest water table, which should be determined in the spring during years of high precipitation.

Contingency Plans for Accidental Spills and Other Aquifer-Threatening Emergencies

Easthampton should have contingency plans in case of an accidental spill or other emergency so that cleanup operations can proceed as rapidly as possible. The town manager and key members of Easthampton town boards should have emergency telephone numbers of Massachusetts DEP personnel, drilling companies, town consultants, and others. Huntley and Associates (1988) present a contingency plan for Belchertown. I recommend that Easthampton boad members obtain a copy of this report to evaluate what approaches and methods in the report may be applicable to Easthampton.

Integration of Aquifer-Protection Recommendations with Those Proposed for the Management of Nashawannuck Pond

Many of the best management practices (BMCs) proposed by Baystate Environmental Consultants (1988, Table 16) for reducing eutrophication and improving the water quality of Nashawannuck Pond will also enhance the aquifer protection of Barnes Aquifer. The BMCs discussed in the above report (pp. 103-112) that are beneficial to Barnes Aquifer include animal waste management, pasture management, conservative tillings, cover cropping, contour farming, nutrient management, pest management, filter strips, grassed waterways, diversions and terraces, extended detention ponds, infiltration trench/basin, porous pavement, oil/grit separation, stormwater in-line storage, and grade stabilization. Some of the above recommendations, if implemented, would improve the water quality of Barnes Aquifer (animal waste management, nutrient management, pest management, filter strips, grassed swales, and oil/grit separation); whereas other implemented recommendations would increase natural recharge to the aquifer (contour farming, diversion and terraces, extended detention ponds, infiltration trench/basin and porous pavement). A program of the Division of Fisheries and Wildlife called the "Adopt-a-Stream" aids in the protection of stream corridors by technical expertise and public education (Baystate Environmental Consultants, 1988, p. 111). The above program would be beneficial to Broad Brook. Also presented in the above report are federal, state and local programs for acquisition of lands for agricultural use and other agricultural land-use programs.

Aquifer-Protection Measures for Holyoke and Southampton

Because the Barnes Aquifer and its recharge area extends into parts of the Towns of Easthampton, Holyoke and Southampton, aquifer protection measures must be taken by all these towns to protect the aquifer from quality and quantity deterioration. The Pioneer Valley Regional Planning Commission and interested parties in the three towns established the Barnes Aquifer Protection Advisory Committee, which will be of great value in long-term protection of the aquifer. All three towns will benefit in protecting Barnes Aquifer, but especially Easthampton, which derives almost all of its water supply from the aquifer. Therefore, it is important for Easthampton to "lead the way" in aquifer-protection measures, some of which are presented in Dawson (1989, p. 9). In addition to the latter recommendations, the toxic septic-tank cleaners that seriously pollute ground-water supplies should be prohibited. Other specific recommendations are discussed for Southampton in Wehran Engineers and Scientists (1987) and for Holyoke in Motts (1985).

RECOMMENDATIONS FOR FURTHER STUDY

Recommendations for further study are (1) a monitoring well program combined with hydrogeologic evaluation of results, (2) an investigation to determine the source of pesticides from agricultural and/or toxic lawn applications in Easthampton's ground-water supplies, (3) plotting and evaluating land-use changes from 1970 to 1985 in aquifer and aquifer-recharge areas of the Barnes Aquifer, and (4) further studies to find more precisely the long-term natural recharge to the aquifer, especially under low-flow drought periods, and to find the interrelationships of Broad Brook and other streams with Barnes Aquifer, including the location of the direct and indirect recharge areas.

Monitoring Well Program

The monitoring well program discussed in a previous section of this report is the key to protecting the quality and quantity of water from Easthampton's municipal wells. The monitoring program should consist of two steps: (1) collecting the samples for analysis at least once a year and preferably twice a year, then plotting the data on quality of water graphs, and (2) analysis of the data by a hydrogeologist or by the Town Engineer to determine if any dangerous trends are developing the could threaten the aquifer. In addition, a short verbal report could be presented to appropriate town boards or to the Aquifer and Surface-Water Protection Committee if such a committee is formed.

Investigation to Determine the Source of Pesticides from Agricultural and/or Toxic Lawn Applications in Easthampton's Ground Water

It would be wise for Easthampton to know the source of the pesticides in the water supplies of their municipal wells (Stone and Webster Engineering Corporation, 1988). If the dichloropropane and other pesticides continue to rise, remedial steps should be taken, perhaps starting with a voluntary program to eliminate use of the toxic chemicals, followed by more stringent measures if the latter program is not effective.

Plotting Land-Use Changes Above Barnes Aquifer and its Recharge Area

The Department of Agriculture, University of Massachusetts, has prepared detailed land-use maps of Massachusetts in 1970 and 1985, based on aerial photography. On the maps are 22 land-use components, including different kinds of farmland, wetlands, wooded areas, and commercial developments. Maps showing land-use changes of Barnes Aquifer and its recharge area may indicate not only some present aquifer concerns, but also land-use changes from 1970 to 1985 that could indicate future problems for the aquifer. The long-range trends could call for appropriate remedial steps by Easthampton, Southampton and Holyoke to insure the protection of Barnes Aquifer.

Studies to Determine More Precisely the Long-Term Natural Recharge and the Direct and Indirect Recharge Areas of Barnes Aquifer

In the section of this report on natural recharge (p. 5), it was pointed out why the precise amount of recharge on a short-term and long-term basis should be determined. For full understanding of the aquifer-recharge mechanisms, both the indirect and direct recharge areas and the detailed relationship between Broad Brook and the aquifer should be determined.

CONCLUSIONS

There are negative and positive aspects regarding the long-range prospects of Easthampton's ground-water supply. The negative aspects are (1) low recharge, (2) increased urban development, and (3) no protective clay or silt bed south of Plain Street. On the other hand, the positive aspects are (1) some natural conditions that serve to protect the aquifer, including the thick clay bed that protects the important Lower Aquifer north of Plain Street where Easthampton Wells are located, and the high velocity of ground-water flow through the aquifer, which tends to rapidly flush out contaminants. (2) The recognition by Easthampton residents of the value of their aquifers and surface-water supplies, as shown by many hydrologic and environmental studies which have provided an increasing background of important technical information. Nevertheless, the ground-water supply of Easthampton is in jeopardy and the town must maintain constant vigilance and promote stringent steps to protect the aquifer from quality and quantity impairment.

The Barnes Aquifer System which provides ground water supplies for Easthampton, Southampton and Holyoke consists in most places of (1) the Upper Aquifer which is polluted in many places by shallow sources including road discharge, and (2) the Lower Aquifer which yields the ground-water supplies of town wells. North of Plain Street, the Upper Aquifer is separated from the Lower Aquifer by a confining bed of lake silt and clay.

Low quantities of natural recharge to the Barnes Aquifer pose potentially serious future problems during low flow drought conditions when Easthampton well withdrawals can exceed the natural recharge. Along with other steps for aquifer protection, Easthampton should consider basic water-conservation measures which can include (1) metering all water users, (2) decreasing domestic and industrial consumption by basic measures which are effective but have minimal user impact, (3) adoption of a contingency plan for strict conservative measures if well withdrawals exceed 4 mgd, and (4) establishment of an aquifer and surface-water protection committee which can examine all steps to protect the surface- and ground-water resources of Easthampton.

An important contribution of this study is the establishment of time-contaminant zones enclosed by travel-time contours which show the length of time for water to travel to each of the Easthampton wells. The time-contaminant zone model has the following benefits for aquifer protection: (1) the model allows us to make specific recommendations such as removal of all buried oil tanks in time-contaminant zones close to municipal wells, (2) in case of an accidental spill of oil or hazardous waste, the model allows us to calculate the time it will take the contaminant plume to reach the well, (3) the model shows the specific recharge area for each pumping well, (4) information from the model allows the optimal placement of monitoring wells, (5) the model shows the flushing rate of Barnes Aquifer, which is rapid.

As the result of this study, the author proposes the following additional steps to protect Easthampton's aquifer:

(1) Zoning. Two-acre zoning is recommended for till and bedrock (Zone 3) and one-acre zoning for stratified drift (Zone 2) in the aquifer and aquifer-recharge areas. Similar zoning recommendations were made in Holyoke and Westhampton.

(2) Methods of increasing recharge to Barnes Aquifer are reduction of impervious cover, holding ponds for stormwater runoff, and artificial recharge methods.

(3) Recommendations are presented for monitoring ground-water quality, ground-water levels, and surface flows of Broad Brook.

(4) Setbacks along Broad Brook that include 75 feet from each side of the stream center line to be kept under natural vegetative conditions without human alteration.

(5) Strict regulations regarding the removal and testing of sub-surface oil tanks.

(6) Regulations regarding the use and storage of hazardous wastes.

(7) Prohibition of toxic spraying along railroads, power lines, gas lines, and road curbings.

(8) Sewers and water mains, if newly installed, should be designed for leakage prevention, and old ones checked for leaks by using current technology.

(9) Recommended procedures to decrease contamination from pesticides due to agricultural and/or toxic lawn applications if the pesticides continue to increase in Easthampton wells. Nitrates also can increae from toxic lawn applications.

(10) Reduction of the amount of deicing salts used on roads.

(11) Prohibition of toxic septic-tank cleaners.

(12) Purchase of critical open space and wetlands and protection of wetlands; purchase of development rights only and conservation easements.

(13) Regulations regarding domestic and other private wells drilled into the Barnes Aquifer.

(14) Prevention of illegal dumping of solid wastes, oil and hazardous wastes.

(15) Posting of critical aquifer areas within the 100-day contaminant-time zone.

(16) Regulations regarding removal of clays and stratified drift.

(17) Contingency plans for accidental spills and other aquifer-threatening emergencies.

(18) Integration of aquifer-protection recommendations with those prepared for the management of Nashawannuck Pond.

(19) Aquifer protection measures for Holyoke and Southampton are presented in this report and in Dawson (1989).

The following four aspects regarding aquifer protection are recommended for further study and work: implementation of a monitoring well program with hydrogeologic evaluation of results; determining the source of agricultural pesticides in Easthampton's ground-water; plotting land-use changes above Barnes Aquifer and its recharge area; and studies to determine more precisely the long-term natural recharge and the direct and indirect recharge areas of Barnes Aquifer.

REFERENCES CITED

Baystate Environmental Consulting, Inc., 1988, Diagnostic Feasibility Study of Nashawannuck Pond: Report prepared for Town of Easthampton and Massachusetts Division of Water Pollution Control, Baystate Environmental Consultants, Inc., East Longmeadow, Massachusetts.

Dawson, Alexandra, 1989, Legal Recommendation for Protecting Aquifer: Memo to Town of Easthampton regarding protection of Barnes Aquifer, memo in files of Selectmen and Town Planner.

Ferlow, D.L. and Ferlow, J.B., 1988, Development Related Storm Runoff Renovation: Report published by Environmental Design Associates, Wilton, Connecticut.

Huntley and Associates, 1988, Hop Brook Drainage Basin, Contingency Plan: Report prepared for the Board of Selectmen, Town of Belchertown, Massachusetts.

IEP, Inc., 1988, Aquifer Land Acquisition Study for Town of Easthampton: Report prepared for Easthampton Board of Public Works.

Johnston, R.C., Dendron, S.A., Morse, C.I., and Prickett, T.A., 1984, Well Field Protection Using Pollutant Transport Modeling: Chapter in Proceedings of Natural Water Works Association, Eastern Regional Conference on Ground-Water Management.

Milne, Murry, 1979, Residential Water Re-Use: California Water Resources Center, University of California at Davis, Report No. 46.

Motts, W.S., 1985, Hydrogeology of West Holyoke and Adjacent Areas: Report for the City of Holyoke, which can be obtained from Health Board, City Hall Annex, Holyoke, Massachusetts.

__________, 1983, Editor, The Feasibility of Increasing Water Supplies and Preventing Environmental Damage by Artificial Recharge in Massachusetts: Water Resources Research Center, University of Massachusetts at Amherst, Publication 132.

__________ and Dawson, A., 1989, Proposal to the Town of Easthampton for an Aquifer Protection Study: Prepared for Aquifer Protection and Zoning Bylaw Revisions submitted to Acting Town Administrator, Easthampton, Massachusetts.

Noss, R.H., Drake, R., and Mossman, C., 1987, Septic Tank Cleaners: Their Effectiveness and Impact on Groundwater Quality: Publication No. 87.3, the Environmental Institute, University of Massachusetts at Amherst.

Stone and Webster Engineering Corporation, 1988, Connecticut River Valley Pesticide Study: Report for the Massachusetts Department of Environmental Quality Engineering, Division of Water Supply, Stone and Webster Engineering Corporation, Boston, Massachusetts

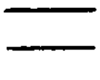
Wehran Engineers and Scientists, 1987, Southampton Aquifer Protection Study: Report for Town of Southampton by Wehran Engineers and Scientists, Burlington, Vermont.

EXPLANATION

Figure 1

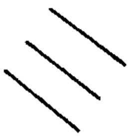
Easthampton pumping well or well field enclosed by 400 foot radius of Zone 1.

Zone 2 as mapped by IEP.

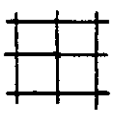


Zone 3 as mapped by IEP.

Altered IEP Zone 2/3 boundary from Motts (1985) and this study.



Supplemental area added to Zone 2 for maximum well protection.



Supplemental area added to Zone 3 for maximum well protection.

Potential Contamination Sources in Easthmapton

Fuel tanks, less than 1000 gallons.

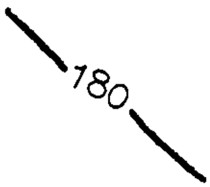
Fuel tanks, 1000-4000 gallons.

Commercial hazardous waste site.

See Wehran Engineers and Scientists (1987) for explanation of citation.

EXPLANATION

Figure 2



Travel-time contours enclosing contaminant-time zones.

Recommended location for new monitoring well.

Existing Monitor Well 3 at IEP Well Cluster 1-87.

Existing Monitor Well 8 at IEP Well Cluster 2-87.

Altered IEP Zone 2/3 boundary from Motts (1985) and this study.

APPENDIX

TIME-ZONE MODELING OF BARNES AQUIFER

James C. Hall
New Hartford, Connecticut

Introduction

A hydrogeologic flow model of the Easthampton valley was created using Aquifer(c). This model was not fully calibrated, but yields acceptable results for the purposes of this study. Groundwater levels on the extreme eastern edge (Mt. Tom range) and in the southwest corner are slightly too high. The results are similar to, although not identical with, the results achieved by IEP, Inc., using the MacDonald-Harbaugh model.

The output of this model was used as the input information for travel time and flow path modeling, using Contrans(c) to perform the necessary computations.

Results of Modeling

(1) The three well (fields) do not interfere with each other at 1 mgd each, the rate which was used in the first part of the simulation. However, at the higher rates used in the second phase, 1.5 mgd for the Lovefield and Nonotuck Park Wells and 4.3 mgd for the Hendrick Street well, considerable interference exists, causing some additional

drawdown in each well when all three are operating versus when each is operating alone. In addition, there is a significant shift in the flow patterns to the Lovefield and Nonotuck Wells caused by the operation of the Hendrick Street Well.

(2) The principal source region of the Lovefield Well is west and somewhat northerly from the well. Results from this region are somewhat uncertain, since the model grid used (covering the same area as the IEP model, but with finer resolution) did not extend a sufficient distance to the north. In addition, the IEP data do not provide sufficient information for full calibration in this area. A significant portion of the water supply for this well comes down the valley from the south, however, on flow lines between the Nonotuck and Hendrick Street Wells and to the west of the Nonotuck Well. This effect increases as the flow from this well increases. In addition, the flow from the Hendrick Street well tends to increase this effect. A comparison of the maps from the two different flow rates demonstrates this. This portion of the aquifer is artesian where it passes beneath the major developed region of Easthampton, but it is conceivable that, under certain conditions, contamination in this area could reach this well.

(3) The principal source area for the Nonotuck Well is to the south and west, originating in the Coleman Road/Gunn Road region (refer to Fig. 2). This well does not draw water from south of Pleasant Street/Phelps Street, nor does it draw water from the east. In fact, as noted above, a certain amount of the down valley flow to the east of this well's influence passes on and is intercepted by the Lovefield Well.

(4) The source area for the Hendrick Street Well is to the south of the well, and extends up into the Mt. Tom range to the east and south to the groundwater divide located near the southern edge of the model grid.

(5) The Lovefield Well pumping alone draws some water from the southern boundary region of the model in the western half. Inasmuch as this well is not contaminated at the present time, but the Hendrick Street Well is, it is apparent that the contamination of the Hendrick Street Well comes from a source in the quadrant extending from the east through to south from the well. An examination of the flow path density, approximately related to the quantity of water drawn from various areas, indicates that the source may be approximately east of the well, between it and the Mt. Tom range or up on the Mt. Tom range above the well.

Travel times for the flows to the various wells and the envelopes of each one's capture zone are delineated on the maps. Five maps are presented, being one for the three wells together at a rate of 1 mgd each, one for the three wells together at 1.5 mgd for Lovefield and Nonotuck and 4.3 mgd for Hendrick Street, and three for each of the wells separately at the higher rate.

A significant feature of the groundwater flow pattern on the western edge of the area is a discharge zone to the Manhan River in the vicinity of the Route 10/West Street intersection. This is an important feature, particularly with regard to the flow to the Lovefield Street Well, and is due to the relatively thin or (reportedly in the IEP material) absent clay cover in this area. This feature is entirely absent from the IEP model, although clearly indicated in their source data. The amount of discharge, and the divide between the portion of the aquifer discharging in this area and the discharge from the Lovefield Well is influenced by the discharge from the Lovefield Well.

Modeling Methods

An initial effort was made to use the results of the IEP modeling to study the travel time and capture envelopes of the three well sites. However, it was found that, due to the limitations of the model used in that study, it was not feasible to do so. These limitations were:

(1) Excessive generalizations and assumptions regarding the permeability of the various formations. The IEP study utilized a strict two layer model. In order to model the variations in transmissivity due to variations in the thickness of the clays, particularly in the center of the valley, they found it necessary to vary the permeability of the major aquifer (their layer 2). Unfortunately, that made it impossible to use their permeability figures to determine velocities, as the variation in permeability which they used is an artifact of the modeling process and not an intrinsic characteristic of the formations.

(2) Complete disregard of the highlands to the east and west. Again, this is partly due to the nature of the model used, which is not capable of handling high relief areas, but is also a result of the traditional notion that till and bedrock areas are not aquifers. This is not necessarily so, and in this instance the travel times are

such that the western slopes of Mt. Tom, the northern end of Whiteloaf Mountain, and the uplands west of the Lovefield Well are within short travel times of the various wells and must be regarded as within Zone II.

(3) Insufficient grid density in the vicinity of the Lovefield Well. This well was not considered in the IEP report, and the grid used in that report did not include sufficient density in that area to permit modeling that well. The grid was augmented by six additional lines of nodes in that area.

(4) Apparent failure to account for thinning of the clay lens to the east and west of the axis of the valley. Although this thinning is clearly indicated on the source materials used by the IEP report, it does not appear, from examination of the input data used, that this thinning was taken into account. This is particularly important in the Route 10/Manhan River area whee, as noted in the Introduction, it was found that significant recharge from the lower aquifer to the river takes place. This also somewhat affects water levels in the northeastern portion of the model. The IEP report indicates some 50 feet of artesian head between their lower aquifer and the Manhan River in the vicinity of the upper end of the Lower Millpond, for example, whereas this present model indicates about 10 feet, which is more reasonable in our judgment considering the thinness of the clay (less than 10 feet) in this area and to the west. In addition, the IEP model claims some 30 feet of artesian head at the Oxbow, which does not seem realistic.

As a result, the area was remodeled using Aquifer(c) which, while not a three-dimensional model and thus not able to model the exchange between the clay and the underlying sands, was better suited to the type of modeling required to determine capture envelopes and travel times. It is not subject to the limitations or problems noted above. The model was calibrated in the valley partially against the IEP model and partially against available well data. In the highlands, the model was partially calibrated against observed streams and wetlands. A complete calibration was beyond the scope of this effort and was not, in any event, required for the travel time/capture envelope portion of the work. As a result, ground water elevations as modelled on Mt. Tom and the western highlands are somewhat too high. Completion of the calibration to create a usable model for predictive work would be possible if the client were interested. This would entail extending the model to the south, to the divide of the lower artesian aquifer, as well as adjustments in the permeabilities of the bedrock strata.

The principal output information for the model is the type of formations present (e.g., coarse or fine sand, gravel, bedrock, clay, etc.), the thickness of the formations, the surface elevations, the presence or absence of surface water (lakes and streams), and the hydrologic characteristics of the various formations. This model derived the clay layer thickness from Plate 5 of the IEP report. Surface elevations and water bodies were taken from the relevant USGS topographic maps. The bottom of the unconsolidated material was taken as 60 feet below sea level (the same as the IEP model) except in the till covered upland areas, where it was set at 5 to 30 feet below the surface, the exact dimension depending on the judgment of the modeler. The bottom in the valley was set in the absence of other information; better calibration could be obtained by using real information from wells, etc. Initial calibration of the hydrogeologic parameters was set using estimated transmissivities and formation thicknesses as reported by IEP. However, it was found that calibration to well tests and ground water level inforation was not possible with permeabilities determined in that manner, andit was necessary to reduce the permeability by approximately a factor of two from those values. The final calibrated permeabilities are within the normal range of permeabilities for formations of this type. However, it was found that the bedrock permeability had to be set to a somewhat lower than expected value. Whle this does not affect the travel times nor the capture zones of the wells as reported here, it should be investigated further in the event full calibration is desired.

No contrast head nodes or other artificial boundary conditions were used for calibration.

Final results of the calibration match available well information from the IEP report within approximately five percent, and create a pattern of water table/surface intersection (wetland areas) which is reasonably similar to reality, except in the upland areas where the levels are a bit high. This indicates that the bedrock permeabilities are a bit low, in line with the observation on the values themselves. Further calibration in these areas might assist materially in solving both problems, particularly coupled with the use of real rather than assumed bedrock elevations in the valley (particularly in the southern end). Extension of the model to the south would assist in raising the piezometric head in this area in spite of higher bedrock permeabilities, and would more closely match reality in this area. Since this area is more than two years' travel time from any of the wells, we believe that the errors in calibration in this area do not affect the results sought in this study.

Flow line and travel time modeling was done using the output of the Aquifer(c) model referred to above. The model was run for a total of eight variations: one set of four with the wells, singly or all together, at 1 mgd; the other set of four with the wells singly or all together at 1.5 mgd for the Lovefield and Nonotuck Wells and 4.3 mgd for the Hendrick Street well. The flow modeling program Contrans(c) was used to do the computations transferring the head outputs and permeability inputs from Aquifer(c) to flow lines and travel paths. Contrans(c) uses the source and head output information from Aquifer(c) to determine the local piezometric gradient and, from it, velocity, using Darcy's Law. Flow lines are automatically back-traced from the vicinity of each well to determine travel time and capture envelope.

Generally, the capture zones delineated by this study are comparable to those outlined by IEP (1988) on their Plate 7 except for the following point: the capture zone for the Nonotuck Park Well does not extend as far to the west as they indicate. This is due to the difference in treatment in the Manhan River Valley, particularly in the vicinity of Route 10, as noted above. It also appears that their drainage divide is incorrect at the southern end of the zone of influence and that the protected area should extend farther west.

TEXAS INSTRUMENTS INCORPORATED ATTLEBORO, MA.

Water Source: Attleboro Municipal Supply	72%
On-Site Wells	28%
Water use in 1980	2.7 mgd
Water use in 1988	1.5 mgd
Increase in water rates since 1980	290%
Increase in sewer rates since 1980	38%
Estimated cost of projects since 1980	$4 million
Estimated water and sewer savings since 1980	$8.6 million

Texas Instruments Incorporated (TI) operates a facility in Attleboro which consists of 19 buildings with approximately 1.5 million square feet of manufacturing area, and employs over 5,000 people. Water quality and supply have always been a concern at TI because production is largely dependent on water use. The major uses of water at TI include the cooling of heat producing manufacturing equipment (non-contact water) and product rinsing (contact water). Before changes were made to the piping structure, non-contact water that had gone through the cooling system was sent directly to the municipal sewer. The most effective water conservation measure has been the recirculation of cooling water.

Instead of a "once-through" system, TI now has a closed loop cooling system to recirculate water. Recirculation was made possible by installing cooling towers to remove heat from water that cooled manufacturing equipment. Water temperature is reduced to the required level and then recirculated to continue the cooling process. Conductivity meters measure water quality and control water blow-down and make-up.

TI reaffirmed its recognition of the value of water as a resource in the late 1970's when it began a comprehensive conservation program. In 1979 a new cooling tower was built with a 4,000 gallon per minute (gpm) flow capacity. This cooling tower allowed recirculation in 3 buildings covering 500,000 sq. feet, including the power plant and boiler room. Two more cooling towers were installed in 1980 and 1981, with flow capacities of 2,000 gpm and 1,200 gpm, respectively. Including the capacity of a cooling tower installed in the early 1970's, TI recirculates a total of 8,400 gpm, or over 4 million gallons per day (mgd) for the minimum 8 hour shift.

In every building accessible to a cooling tower, each machine that needs cooling water is tied into the closed loop system. The challenge at TI is to connect other buildings and other machines to the recirculated cooling system. There is a $100,000 project underway to install a line carrying water from one building to the largest cooling tower and recirculate an additional 50 gpm. In this way, step-by-step progress will be made towards recirculating all on-site cooling water. TI not only recirculates water which cools manufacturing equipment, it also reuses water from the air conditioners that cool the buildings.

TI expended considerable capital and engineering expertise to achieve the level of recirculation that has been reached - over one million gallons of water are saved every day. Obviously, projects with the largest potential water savings will be done first. TI recognized this fact and at the same time saw significant savings potential in other, less "glamorous" or complex projects. Through this realization, projects with small, individual savings but large cumulative effects were completed.

Non-contact steam condensate is captured and returned to the boiler to makeup for water that evaporates. At every point of cooling in the equipment lines, thermal valves regulate the temperature so that there is an on-demand flow of cooling water instead of a continous flow. In 100 restrooms, faucets are equipped with aerators to reduce the water flow by one gallon per minute, and the recently completed fitness building is equipped with low-flow showerheads.

Every employee is involved with water conservation each time he or she turns on the tap. The amount of water saved is not on the same scale as that achieved by recirculation, but it is still a reduction in use. For this reason, employee awareness has been highlighted with the formation of a task force in every building. Employees involved in production read meters on a weekly basis, check valves, and identify problems with equipment. Proper maintenance is necessary to insure that leaks and general disrepair don't elevate water consumption. Other methods being planned to increase employee awareness include articles in the employee newsletter, and the discussion of water use at department meetings.

Recirculation and other measures have a site-wide impact, but various divisions have also taken other steps to reduce water consumption.

Lead Frame Plating Division

Prior to 1981, TI received all of its water from Attleboro's municipal supply. In order to reduce demand on the overextended municipal supply and insure more uniform quality of water used in lead frame plating, on-site wells were sunk. These production wells for plating provide 90% of the water used in lead frame plating processes. The well water is treated by reverse osmosis before being used as process water. After going through the lead frame plating process, 60% of the system water is recycled. Plating engineers hope to eventually reuse 90% of the water flow.

Water leaving the wells is not metered. Use can be estimated based on the reverse osmosis system's maximum capacity of 470,000 gpd. Water sent to the waste treatment plant is metered because TI finds it useful to track various waste streams for maximum conservation potential. The wastewater is generally of a better and more consistent quality, in terms of suspended solids, than water drawn from the wells. The plating engineers would like to utilize this wastewater in their processes to reach their ultimate goal of zero waste discharge.

Another water saving improvement planned for existing lead frame plating is the use of automatic valves to turn off water when the processing line is shut down for any reason. New lines will be equipped with valves to control the flow of individual plating strands (three strands make up one plating line), and each strand will be independently supplied with water on demand. Two of the valve-equipped lines have already been installed.

The costs incurred by the lead frame plating division are as follows:

$700,000	deep well installations
$200,000	reverse osmosis system
$1,500,000-$2,000,000	adjustments to system since 1981,

including sand and carbon filter systems, tanks and internal plumbing, and a rechlorination system.

The savings realized in the lead frame plating division come from two different areas. Waste treatment costs have been greatly reduced since reverse osmosis allows such a large percentage of wastewater to be reused. The other major cost saving is the avoidance of product losses due to fluctuations in water quality from the municipal supply. In the spring and fall, the source of municipal water is changed between surface and well water. Before TI used on-site wells, the company would lose $500,000/week over an 8-10 week period while processes were adjusted to handle variations in water quality. System changes in the lead frame plating division have also led to a higher quality product.

Attleboro Fabrication Cost Center (AFCC)

The AFCC is another plating division at TI that has greatly reduced water consumption. The measures taken highlight the importance of attention to small details in attaining large reductions in water consumption. Conservation measures at the AFCC include:

- Adjusting nozzles on sparging tubes to distribute water more efficiently.
- Replacing stationary rinse system with counterflow system and dragout tank.
- Putting timers on rinse controllers to avoid overuse of water.
- Training plating operators about careful water use.
- Remounting monitoring equipment to give a more accurate measure of water flow. This measure reduced solenoid valves from allowing unnecessary flows.
- Installing flow restrictors where applicable.

Average daily water use in the AFCC has been reduced from 143,000 gpd in 1985 to 83,300 gpd in 1988. The average daily use in January 1989 was 81,000. Throughout this time, production in the AFCC has increased.

Wastewater Treatment Facility

TI recognizes that the true cost of water is not fully communicated by the price charged to have it supplied; the true cost of water includes the price of disposal. As the cost of disposal has escalated, the waste treatment plant at TI has become a more important part of production. Any water that comes in direct contact with the product must be treated before being discharged. Waste treatment staff take monthly readings using portable meters to monitor incoming flows. 480,000 gpd are discharged by the treatment plant. 95% of the treated wastewater is discharged into the Taunton River Basin, with the remainder sent to the municipal sewer system.

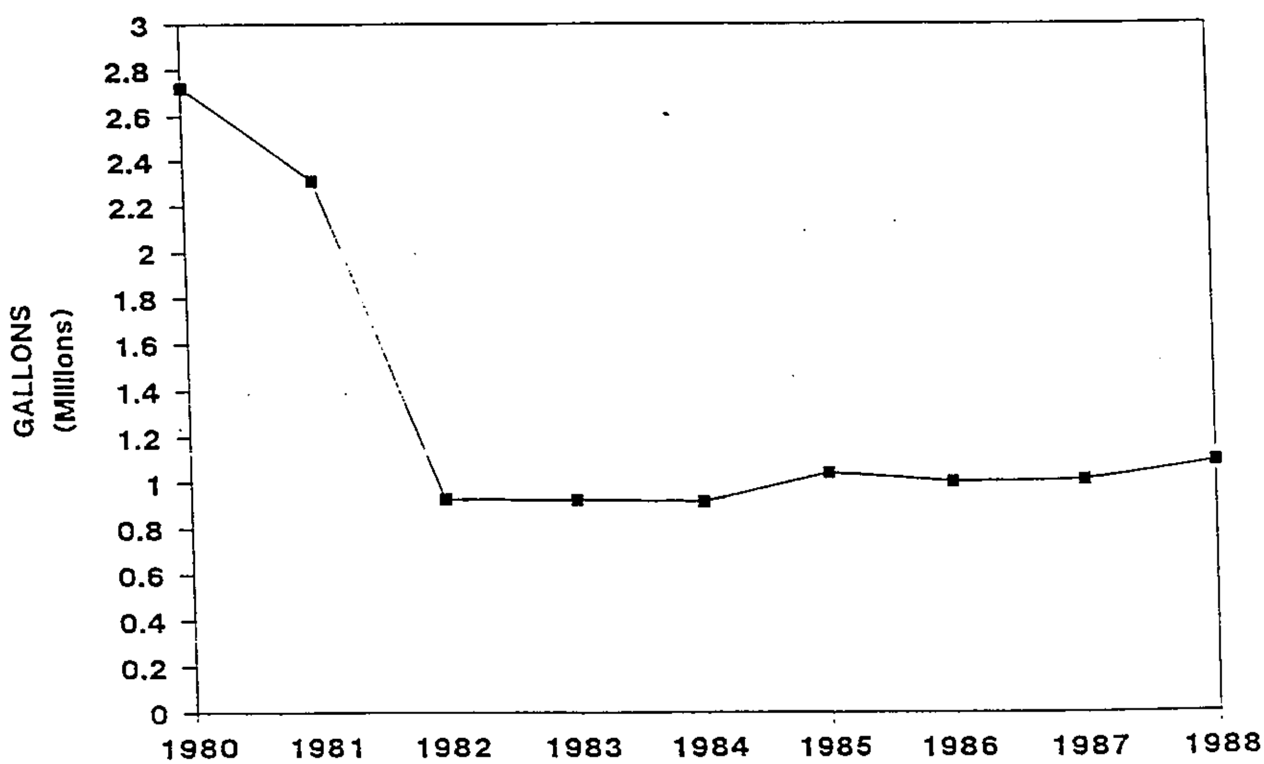
The cost of treatment has quadrupled since 1984 and is currently $2.00/1000 gallons. This price reflects the cost of chemicals and sludge disposal and does not include operating costs. In 1988 TI spent $350,000 on chemical stock to treat wastewater. A further indication of how treatment costs have risen is the operating budget for the wastewater treatment plant; in 1984 the budget was $500,000 and in 1988 it was $3,000,000.

TI invested $10 million in a new treatment system that went on line in late 1987. This system has enabled the treatment plant to produce very high quality wastewater. The treated effluent consistently meets the stringent discharge permit requirements of the EPA Water Quality Criteria. This ensures protection of the most sensitive organisms at the base of the aquatic ecosystem into which TI discharges. In general, the water quality criteria which TI meets are more stringent than drinking water standards. Such high quality wastewater provides TI with the unique opportunity to reuse its treated effluent.

At the present time, the wastewater treatment facility recycles 10% of its effluent for internal applications. These applications include such things as backwash for multi-media filters, housekeeping, cooling, make-up and dilution for chemical treatment solutions, and seal water for centrifugal pumps. Another application to recycle treated effluent is currently under investigation within the Lead Frame Plating Division. If the results of the investigation are positive, the Lead Frame Plating Division could reuse 200,000-250,000 gpd of treated effluent as feedstock to their manufacturing operations. Somewhat further in time, TI has plans to install a cogeneration facility. Installation of this facility would allow reuse of another 50,000 gpd of treated effluent to produce steam in the boilers.

In short, TI is in a very good position with regard to water consumption. The company not only recognized that water supply and pricing would affect its operations, but had the foresight to make changes in their system before the situation became more serious. The management team at TI supported the conservation program and will now reap the benefits of saving over 350 million gallons of water every year. The manager of environmental engineering at Texas Instruments summarized the company's philosophy as one which stresses regulatory compliance, attention to economics, and the development of a sound environmental policy.

TEXAS INSTRUMENTS
DAILY WATER USE



DEVELOPMENT RELATED STORM RUNOFF RENOVATION ©

Donald L. Ferlow and James B. Ferlow

Environmental Design Associates

Wilton, Connecticut 06897

INTRODUCTION

Stormwater runoff from roofs, parking lots and site roadways of suburban and rural landscapes presents a threat for degradation of water quality and habitat value of wetlands and watercourses. While communities have acted to prevent development related runoff increases with storm detention systems, little effort has been made to require systems that may act to renovate runoff. Storm detention can be constructed in a manner that creates the potential for runoff renovation within man-made wetland or wetland-like ecosystems.

Three stormwater runoff renovation systems (biofilters) are reviewed. One, located in Greenwich, Connecticut, along the Mianus River, receives stormwater runoff from a condominium project. The other two, located in Stamford, Connecticut, along the Noroton River, receive stormwater runoff from a corporate office - industrial park development. Each has been excavated from disturbed upland site areas and passes stormwater runoff through the system prior to outfall into the rivers. The biofilters have been designed as naturalistic habitat areas and establish, continue or expand buffer systems adjacent river corridors.

The study attempts to document the value of the man-made biofilter systems in the reduction of silts and sediments, pH levels, nitrates, phosphates and certain heavy metals commonly found in stormwater runoff.

METHODS AND MATERIALS

Biofilter plans were created using principals of wetland system functions. Each was associated with project stormwater management requirements. Although the three biofilters are of slightly different design and construction, they function upon the same principal. Rainfall runs across roofs, pavements and grass areas to points of collection in drain inlets. The inlets (catchbasins) are fitted with sumps which trap and hold the heavier sand and silt materials carried in stormwater runoff. Reinforced concrete piping connects the drain structures and conveys the stormwater to points of outfall into the biofilters. Here the runoff water is slowed, from the faster pipe flow, allowing silt and sediment material to collect on the biofilter floor. The storm runoff moves through the biofilter vegetation and is discharged into the river. Crushed limestone has been added at the points of pipe inflow to help buffer the stormwater and improve pH levels. Heavy vegetation helps to entrap silt, sediment and debris and uptake nutrients from the stormwater. Vermiculite has been introduced into the soil to improve the binding potential for heavy metals within the bottom silts and clays.

Each biofilter was sized predicated upon the available development area and the requirements for stormwater runoff control. Established design guidelines were not available at the time of construction.

The biofilters were excavated to subgrade elevations using normal earth moving equipment. Two were used as temporary sedimentation basins. The biofilter areas were topsoiled (two with a silty loam soil and vermiculite mix) and lined with limestone outfall pads and low flow channels. Soil additives were incorporated into the topsoil and the area was fine graded, seeded and mulched. Plant materials were planted along the fringes, on the side banks and within the wet biofilter bottom. Plants were obtained from nursery sources or were gathered from the local area. Wildflower seeds were collected and disbursed across the biofilters. Watering and weeding was rendered only to the levels necessary to insure the start of growth. From that point forward the biofilter systems were allowed to grow without special care. Plant materials "fight" for survival and dominance.

In 1988 and 1989, the three biofilters have been checked and tested for their effectiveness toward the improvement of development generated stormwater runoff prior to its discharge into the river. In the early Spring of 1989, a natural wetland control was added to the study and tested with the three biofilters.

Visual observations have been made for the deposition of sands, silts and debris carried by the runoff water. pH levels have been tested using a Engineered Systems and Designs LcpH meter. Nitrate, Phosphate, Chromium (hexavalent) and Iron levels have been tested using a LaMotte Chemical Company, MIRL Colorimeter. Tests have been random in nature and conducted from April 1988 to June 1989. Testing has been accomplished during or immediately following rainfall periods in order to obtain water samples from the several stormwater runoff pipes as well as the biofilter basins. Tests have been during light rains, intermittent shower periods and during heavy rainfall events.

DISCUSSION

Biofilter One: This system was constructed in 1984 as part of the stormwater runoff system serving a thirty six (36) unit condominium development in Greenwich, Connecticut. Twenty four (24) units were built in 1984 with the remaining twelve (12) being completed in 1989.

Stormwater runoff from site roads, parking areas, roofs, patios and lawns discharges through the biofilter into the Mianus River, which at this point is classified by the Town as a potential emergency drinking water source. The biofilter area was part of a former land use that included a contractors storage yard and several residential structures with failing septic systems. The 160 +/- foot long biofilter basin was excavated. Elevations were created to have the potential to generate saturated soil conditions for extended periods during the year. Crushed limestone outfall pads and a partial low flow channel were installed. Topsoil was spread across the basin floor and on the side slopes. The area was fine graded, seeded and mulched. Portions of the biofilter were planted with locally collected and nursery grown plant materials.

Areas of the system are generally wet year round and function closely with ground water levels. Several ground water seeps have developed toward the eastern edge and discharge into the main biofilter basin. The limestone lined channel and stone weir structure help direct and control the stormwater runoff as it passes through the biofilter. (See Figure 1)

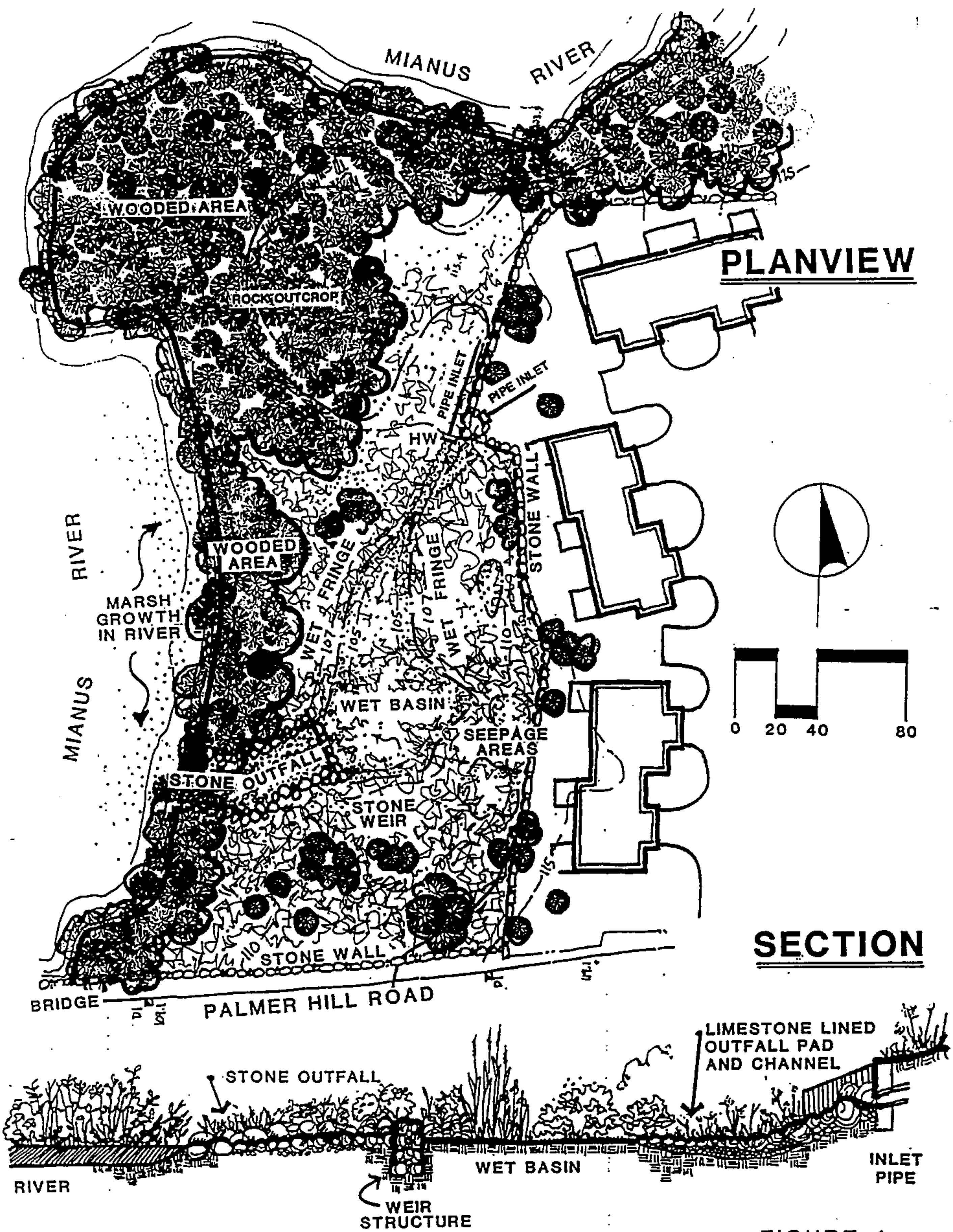


FIGURE 1

eda

BIOFILTER #1

BIOFILTER #1

Growth in the biofilter has been excellent. All of the original woody species, planted in 1984, are present in 1989 and a number of new plant species have pioneered and established growth.

Visual observations during rainfall periods, have noted a reduction in turbidity in the stormwater runoff as it passes across the floor of the biofilter. In addition, varying amounts of water borne "debris" are trapped and held. Storm runoff water is significantly "clearer" as it leaves the biofilter.

Tests for nutrients, certain heavy metals and pH within the storm runoff water passing through the biofilter have documented a change or registered no change toward neutral for pH the majority of the time and reduced or registered no change for levels of Chromium (hexavalent), Iron, Phosphates and Nitrates the majority of the time.

Biofilter Two and Biofilter Three: These systems were constructed in 1984 and 1986 respectively, as part of the stormwater runoff system serving new buildings in an office - industrial park complex in Stamford, Connecticut. Biofilter two was built at the "end" of the site storm piping from a 37 car parking lot, loading dock areas and 650 feet of site access road system. Biofilter three was built at the "end" of the site storm piping from a 163 car parking lot and building entrance area. Piped stormwater runoff outfalls into the biofilters, passes through the systems and discharges into underlying granular soils or into the river. The neighboring community of Darien, Connecticut has a public drinking water wellfield drilled into the underlying aquifer less than a quarter mile downstream of the site. (See Figures 2 and 3)

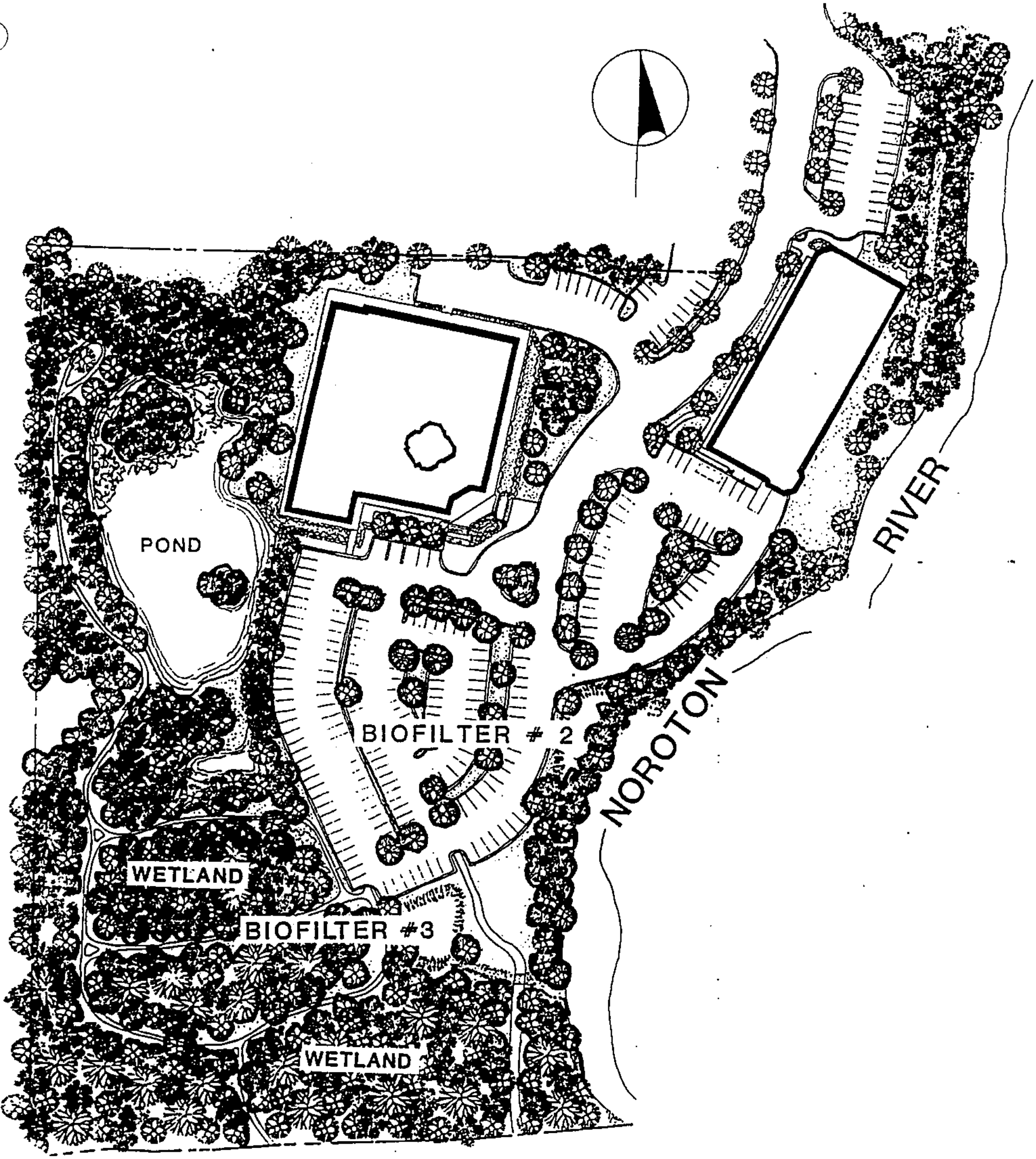
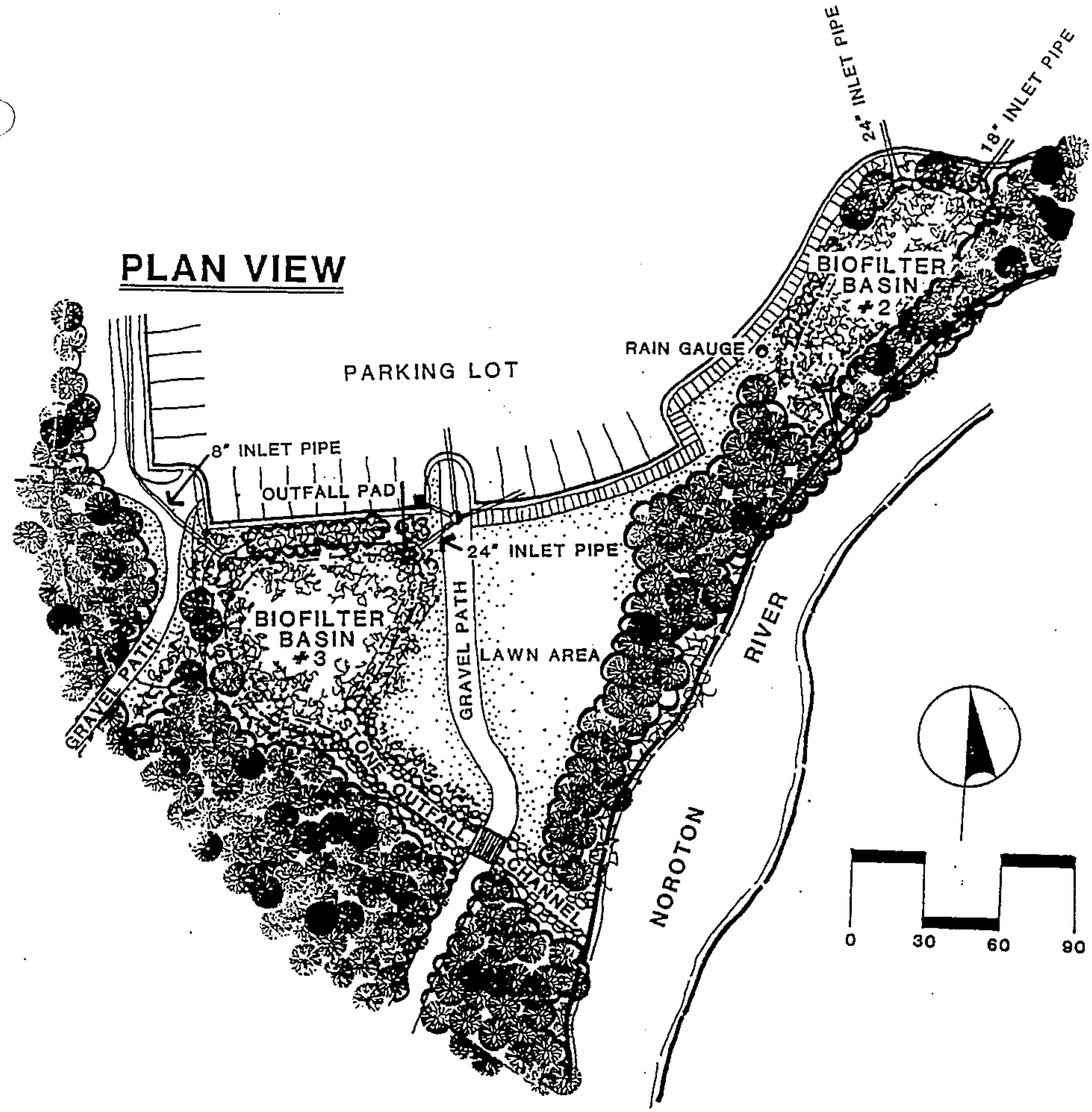


FIGURE 2

BIOFILTER #2 & #3

BIOFILTER #2 & #3



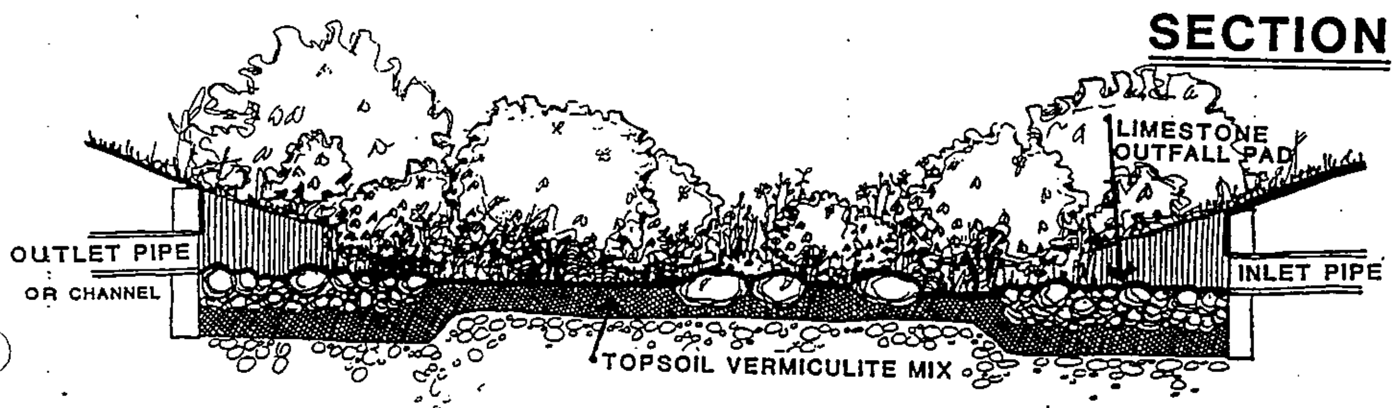


FIGURE 3

BIOFILTER #2 & #3

The biofilter areas were part of a disturbed site with little to no topsoil, gravelly surface conditions and scrub shrub growth containing significant amounts of trash and debris. Biofilter two is 90 +/- feet long and biofilter three is 80 +/- feet long. Each was excavated and was used as a sediment basin during the construction period. The basins were cleaned, topsoiled, fine graded, seeded and mulched. Crushed limestone pipe outfall pads were installed. Vermiculite granules were added to the topsoil mix to increase the potential for binding heavy metals. Locally collected field seed and nursery grown plant materials were planted. Biofilter one is generally wet and functions closely with ground water levels. Biofilter three has been generally dry. In early 1989, portions of the biofilter three floor have been wet, but are anticipated to dry during the summer months as the ground water level drops.

Growth in the biofilters has been excellent. Though some of the individual plants have died or have been overgrown, all of the original woody species, planted in 1984 and 1986, are present in 1989 and a number of new plant species have pioneered and established growth.

Visual observations, during rainfall periods, have noted a reduction in turbidity in the stormwater runoff as it passes across the biofilters. In addition, varying amounts of water borne "debris" are trapped. Stormwater runoff is significantly "clearer" as it leaves the biofilters.

Tests for nutrients, certain heavy metals and pH within the storm runoff water passing through the biofilter have documented a change toward neutral for pH the majority of the time and reduced or registered no change for levels of Chromium (hexavalent), Iron, Phosphates and Nitrates the majority of the time.

Nutrient, certain heavy metal and pH tests in biofilter three in 1988 were not definitive as the storm runoff water consistently "disappeared" into the ground prior to reaching the outfall. With the recent occurrence of stormwater runoff ponding in the system site tests in biofilter three have documented a change toward neutral for pH the majority of the time and reduced or registered no change for levels of Chromium (hexavalent), Iron, Phosphates and Nitrates the majority of the time.

Control Wetland: This scrub shrub wetland is an existing ecosystem that has been used as an outfall point for stormwater runoff from a 29 unit condominium development and 225 +/- feet of Town collector road. Stormwater enters the wetland from a 24-inch diameter pipe, flows across 45± feet of vegetated wetland system and discharges into a sub-channel of the Norwalk River in Wilton, Connecticut.

Tests for nutrients, certain heavy metals and pH within the storm runoff water passing through the wetland have documented a change toward neutral for pH the majority of the time and reduced or registered no change for levels of Chromium (hexavalent), Iron, Phosphates and Nitrates the majority of the time.

RESULTS AND CONCLUSIONS

The three biofilter systems and the control wetland display quite diverse results. Located in the midst of development, each is a heavily vegetated habitat niche providing visual interest and a natural buffer area adjacent to the rivers. The biofilters function with the site stormwater management systems and show visual evidence of the collection of silts, sediments and water borne "debris" carried by the stormwater runoff. Tests have shown that the biofilters function in much the same manner as the control wetland and as such are considered functioning as a natural wetland ecosystem toward runoff renovation. They buffer and help change runoff water pH levels toward neutral and generally reduce Nitrate, Phosphate, Iron and Chromium (hexavalent) levels across the system.

CHART SHOWING SUMMARY AND COMPILATION OF BIOFILTER TEST RESULTS

System	pH level		Chromium		Iron		Phosphates		Nitrates	
Test Results	pos	neg	pos	neg	pos	neg	pos	neg	pos	neg
Biofilter One (29, 25)	48%	24%	40%	16%	76%	20%	80%	16%	52%	28%
Biofilter Two (31, 26)	94%	0%	54%	15%	54%	23%	34%	27%	42%	38%
Biofilter Three (27/11, 9)	91%	0%	67%	22%	78%	22%	44%	11%	56%	44%
Control Wetland (15, 15)	60%	33%	33%	27%	47%	20%	67%	7%	47%	13%

Notes:

1. The remaining test results showed either that no change occurred in the biofilters or control wetland or the results were deemed not determineable.
2. Biofilter Three results based upon periods with flow through system.
3. Number of test in each system shown thusly (pH, Metals-Nutrients).

The visual values, habitat characteristics and water borne materials reduction represent positive environmental factors that are worthy of consideration for incorporation within development plans. The biofilter testing has documented consistent, on the whole positive, results for stormwater renovation. Incorporating stormwater runoff system biofilters within development projects represents positive environmental values.

ACKNOWLEDGMENTS

We acknowledge the efforts of the Environmental Design Associates staff in the preparation of project site plans and specifications. Credit is given to the project Architects, Robert Schwartz (Biofilter #1) and Fuller and D'Angelo (Biofilter #2,#3). Credit is also be given to the project Professional Engineers, S.E. Minor Co. (Biofilter #1) and Leonard Jackson & Associates (Biofilter #2,#3). A special thanks is given to our clients, Peter Mitchell Corp. (Biofilter #1) and Research Park Properties (Biofilter #2, #3) without whose support the biofilters would never have been built. Thanks is given to Dorothy Ferlow for assistance with the laboratory testing Finally, credit is given to Jennifer Soluri for assistance in the typing of this paper.

PLANT SPECIES IDENTIFIED IN BIOFILTERS
BIOFILTER TEST DATA

APPENDIX

BIOFILTER #1 - REPRESENTATIVE SPECIES IDENTIFIED - 1988-1989

Plant Species

American Bulrush	Scirpus americanus **
American Elm	Ulmus americana
Arrow-wood Viburnum	Viburnum dentatum **
Asters	Aster spp. **
Azalea	Rhododendron spp.
Bayberry	Myrica pensylvanica * **
Birds-Foot Trefoil	Lotus corniculatus **
Bittersweet	Celastrus orientalis **
Black-Eyed Susan	Rudbeckia hirta **
Black-haw Viburnum	Viburnum prunifolium * **
Black Locust	Robinia pseudoacacia **
Black Raspberry	Rubus occidentalis **
Blue Flag Iris	Iris versicolor **
Blue Vervain	Verbena hastata
Boneset	Eupatorium perfoliatum **
Burdock	Arctium minus **
Beggar-ticks	Bidens spp. **
Butter-and-Eggs	Linaria vulgaris
Broad-leaved Cattail	Typha latifolia * **
Chicory	Cichorium intybus
Chive Onion	Allium spp.
Cinquefoil	Potentilla simplex **
Curled Dock	Rumex crispus **
Cut Rice Grass	Leersia oryzoides
Daisy Fleabane	Erigeron annuus
Dandelion	Taraxacum officinale **
Deadly Nightshade	Solanum dulcamara
Dogbane	Apocynum spp.
Duck Weed	Spirodela polyrhiza **
Eastern Bur-reed	Sparganium americanum **
Evening Primrose	Oenothera spp. **
Fragrant Bedstraw	Galium triflorum
Giant Ragweed	Ambrosia trifida
Goldenrods	Solidago spp. **
Gray Birch	Betula populifolia **
Gray-stemmed Dogwood	Cornus racemosa **
Hayscented Fern	Dennstaedtia punctilobula
Highbush Cranberry	Viburnum trilobum * **
Japanese Barberry	Berberis vulgaris **
Jack-In-The-Pulpit	Arisaema triphyllum
Joe Pye Weed	Eupatorium spp.
Kentucky Bluegrass	Poa pratensis * **
Lanced-Leaved Coreopsis	Coreopsis lanceolata
Lurid Sedge	Carex lurida **
Mullein	Verbascum thapsus **
Norway Spruce	Picea abies **
Nut Sedge	Cyperus esculentus **
Orchard Grass	Dactylis glomerata * **
Ox-Eye Daisy	Chrysanthemum leucanthemum **
Pickerelweed	Pontederia cordata
Poison Ivy	Rhus radicans **

Biofilter #1 - Plant Species (cont)

Purple Loosestrife	Lythrum salicaria **
Pussy Willow	Salix discolor **
Quaking Aspen	Populus tremuloides **
Queen Anne's Lace	Daucus carota **
Ragweed (Common)	Ambrosia artemisiifolia **
Red Cedar	Juniperus virginiana **
Red Clover	Trifolium pratense *
Red Maple (Swamp Maple)	Acer rubrum
Red-Osier Dogwood	Cornus stolonifera * **
Red Raspberry	Rubus idaeus strigosus
Reed (Common)	Phragmites communis
Reed Canary Grass	Phalaris arundinacea
Rough Cinquefoil	Potentilla norvegica
Rye Grass	Lolium perrene **
Sensitive Fern	Onoclea sensibilis **
Silver Maple	Acer saccharinum
Smartweed	Polygonum spp. **
Soft Rush	Juncus effusus **
Spicebush	Lindera benzoin * **
Spikerush	Eleocharis acicularis
Spotted Touch-Me-Not	Impatiens capensis **
Sweetgum	Liquidamber styraciflua
Sweet Pepperbush	Clethra alnifolia * **
Tartarian Honeysuckle	Lonicera tatarica **
Thistle	Cirsium spp. **
Timothy	Phleum pratense
Tussock Sedge	Carex stricta
Umbrella Sedge	Cyperus strigosus **
Virginia Creeper	Parthenocissus quinquefoil
Water Millfoil	Myriophyllum heterophyllum
Weeping Willow	Salix babylonica (var.) * **
White Sweet Clover	Melilotus alba
White Vervain	Verbena urticifolia
Wild Grape	Vitis spp. * **
Wild Mint	Mentha arvensis
Yarrow	Achillea millefolium
Yellow Iris	Iris pseudacorus

* Originally Planted

** Present in 1986

BIOFILTER #2 - REPRESENTATIVE SPECIES IDENTIFIED - 1988-1989

Plant Species

American Bulrush	Scirpus americanus
Arrow Arum	Peltandra virginica
Asiatic Dayflower	Commelina communis
Asters	Aster spp.
Bayberry	Myrica pensylvanica *
Beggar-ticks	Bidens spp.
Black Cherry	Prunus serotina *
Blue-eye Grass	Sisyrinchium angustifolium
Blue Vervain	Verbena hastata
Boneset	Eupatorium perfoliatum
Broadleaf Arrowhead	Sagittaria latifolia
Cattail	Typha latifolia
Common St. John's Wort	Hypericum perforatum
Crown Vetch	Coronilla varia
Curled Dock	Rumex crispus
Eastern Burreed	Sparganium americanum
Evening Lychnis	Lychnis alba
False Nettle	Boehmeria cylindrica
Fringed Loosestrife	Lysimachia ciliata
Goldenrods	Solidago spp.
Gooseberry	Ribes spp. *
Green Briar	Smilax hispida
Hop Clover	Trifolium agrarium
Inkberry	Ilex glabra *
Japanese Knotweed	Polygonum spp.
Jewelweed	Impatiens spp.
Kentucky Bluegrass	Poa pratensis *
Lurid Sedge	Carex lurida
Morning-Glory	Ipomoea spp.
Mullein (Giant)	Verbascum thapsus
Nannyberry	Viburnum lentago *
Norway Maple	Acer platanoides *
Orchard Grass	Dactylis glomerata
Ox-Eye Daisy	Chrysanthemum leucanthemum
Pin Oak	Quercus palustris *
Poison Ivy	Rhus radicans
Pokeweed	Phytolacca americana
Primrose	Oenothera spp.
Purple Loosestrife	Lythrum salicaria
Pussy Willow	Salix discolor
Quaking Aspen	Populus tremuloides
Queen Anne's Lace	Daucus carota
Ragweed	Ambrosia artemisiifolia
Red Clover	Trifolium pratense *
Red Maple (Swamp Maple)	Acer rubrum *
Red Rem Honeysuckle	Lonicera maacki red rem *
Red Top	Agrostis alba *
Sensitive Fern	Onoclea sensibilis

Biofilter #2 - Plant Species (cont)

Skunk Cabbage	Symplocarpus foetidus
Smartweed	Polygonum spp.
Soft Rush	Juncus effusus
Softstem Bulrush	Scirpus validus
Spicebush	Lindera benzoin *
Spirea	Spirea spp. *
Staghorn Sumac	Rhus typhina
Timothy	Phleum pratense
Tree of Heaven	Ailanthus altissima *
Umbrella Sedge	Cyperus strigosus
Vetch	Vicia spp.
Weeping Willow	Salix babylonica (var.) *
White Pine	Pinus strobus *
White Vervain	Verbena urticifolia
Winter Honeysuckle	Lonicera fragrantissima *
Winterberry	Ilex verticillata *
Wool Grass	Scirpus cyperinus

* Originally Planted

BIOFILTER #3 - REPRESENTATIVE SPECIES IDENTIFIED - 1988-1989

Plant Species

American Sycamore	Platanus occidentalis
Asiatic Dayflower	Commelina communis
Asters	Aster spp.
Bayberry (Northern)	Myrica pensylvanica *
Black Birch	Betula lenta *
Black-Eyed Susan	Rudbeckia hirta
Black Locust	Robinia pseudoacacia
Black Raspberry	Rubus occidentalis
Boneset	Eupatorium perfoliatum
Butter-and-Eggs	Linaria vulgaris
Cottonwood	Populus deltoides
Curled Dock	Rumex crispus
False Nettle	Boehmeria spp.
Fragrant Bedstraw	Galium triflorum
Goldenrods	Solidago spp.
Gray Birch	Betula populifolia
Hayscented Fern	Dennstaedtia punctilobula
Hop Clover	Trifolium agrarium
Jewelweed	Impatiens spp.
Kentucky Bluegrass	Poa pratensis *
Ladysthumb Smartweed	Polygonum persicaria
Mullein	Verbascum thapsus
Multiflora Rose	Rosa multiflora
Milkweed (Common)	Asclepias syrica
Morning-Glory	Ipomoea spp.
Nut Sedge (Chufa)	Cyperus esculentus
Orchard Grass	Dactylis glomerata *
Pokeweed	Phytolacca americana
Purple Loosestrife	Lythrum salicaria
Pussy Willow	Salix discolor
Quaking Aspen	Populus tremuloides
Queen Anne's Lace	Daucus carota
Ragweed	Ambrosia artemisiifolia
Red Clover	Trifolium pratense *
Red Maple (Swamp Maple)	Acer rubrum *
Red Osier Dogwood	Cornus stolonifera
Red Rem Honeysuckle	Lonicera maacki red rem *
Redtop	Agrostis alba *
Reed Canary Grass	Phalaris arundinacea
Rough Cinquefoil	Potentilla norvegica
Royal Pawlonia	Pawlonia tomentosa
Rugosa Rose	Rosa rugosa
Sensitive Fern	Onoclea sensibilis
Soft Rush	Juncus effusus
Spicebush	Lindera benzoin
Staghorn Sumac	Rhus typhina
Timothy	Phleum pratense *

Biofilter #3 - Plant Species (cont)

Tree of Heaven	Ailanthus altissima
Umbrella Sedge	Cyperus strigosus
Weeping Willow	Salix babylonica L. *
White Ash	Fraxinus americana *
Wild Grape	Vitis spp.
Yellow Sweet Clover	Melilotus officinalis

* Originally Planted

BIOFILTER NO. 1

STORMWATER RUNOFF - NUTRIENTS AND HEAVY METALS

Date	Weather	Location	Chromium (hexavalent) Mg/L	Status	Iron Mg/L	Status	Phosphate Mg/L	Status	Nitrate Mg/L	Status
18 May 88	Heavy rain	Inlet 18"	0.06		0.55		4.46		0.30	
18 May 88	Heavy rain	Weir	0.08	-	0.40	+	0.83	+	0.27	+
19 May 88	Light rain	Inlet 18"	0.07		0.65		4.40		0.38	
19 May 88	Light rain	Weir	0.09	-	1.20	-	0.30	+	0.29	+
10 Jun 88	Showers	Inlet 18"	0.08		0.90		0.10		0.60	
10 Jun 88	Showers	Weir	0.06	+	0.25	+	0.20	-	0.20	+
19 Aug 88	Rain	Inlet 18"	0.11		0.30		0.67		1.30	
19 Aug 88	Rain	Weir	0.09	+	0.40	-	1.09	-	0.08	+
21 Oct 88	Start of storm	Inlet 18"	0.02		0.30		1.50		0.35	
21 Oct 88	Start of storm	Weir	0.02	0	0.00	+	0.40	+	0.60	-
1 Nov 88	Start storm	Inlet 18"	0.02		0.10		0.55		0.10	
1 Nov 88	Start storm	Weir	0.02	0	0.00	+	0.40	+	0.10	0
9 Jan 89	Moderate rain	Inlet 18"	0.00		0.00		0.40		0.30	
9 Jan 89	Moderate rain	Weir	0.00	0	0.00	0	0.30	+	0.30	0
26 Jan 89	Heavy rain	Inlet 18"	0.00		0.10		0.40		0.30	
26 Jan 89	Heavy rain	Weir	0.00	0	0.20	-	0.30	+	0.20	+
2 Feb 89	Steady rain	Inlet 18"	0.01		0.30		3.80		0.40	
2 Feb 89	Steady rain	Weir	0.01	0	0.10	+	0.50	+	0.25	+
6 Feb 89	Snow melt	Inlet 18"	0.04		0.80		3.20		0.10	
6 Feb 89	Snow melt	Weir	0.01	+	0.60	+	0.40	+	0.10	0
15 Feb 89	Light rain	Inlet 18"	0.04		1.50		3.80		0.40	
15 Feb 89	Light rain	Weir	0.04	0	0.80	+	0.30	+	0.25	+
21 Feb 89	Heavy rain	Inlet 18"	0.00		2.50		0.50		0.10	
21 Feb 89	Heavy rain	Weir	0.00	0	1.80	+	3.80	-	0.20	-
9 Mar 89	Rain	Inlet 18"	0.06		3.20		0.30		0.30	
9 Mar 89	Rain	Weir	0.02	+	1.50	+	0.30	0	0.40	-
24 Mar 89	Heavy rain	Inlet 18"	0.00		2.40		1.00		0.10	
24 Mar 89	Heavy rain	Weir	0.00	0	1.90	+	3.70	-	0.20	-
31 Mar 89	Heavy rain	Inlet 18"	0.03		2.80		0.40		0.40	
31 Mar 89	Heavy rain	Weir	0.02	+	2.50	+	0.30	+	0.30	+
12 Apr 89	Light rain	Inlet 18"	0.05		0.05		0.20		0.20	
12 Apr 89	Light rain	Weir	0.06	-	0.10	-	0.10	+	0.50	-
1 May 89	Light rain	Inlet 18"	0.07		0.25		0.50		0.20	
1 May 89	Light rain	Seeps	0.03		1.10		0.65		0.10	
1 May 89	Light rain	Weir	0.03	+	0.15	+	0.15	+	0.45	-

2 May 89	After storm	Inlet 18"	0.01		0.20		0.40		0.20	
2 May 89	After storm	Seeps	0.03		0.30		0.30		0.50	
2 May 89	After storm	Weir	0.03	0	0.30	0	0.20	+	0.50	0
5 May 89	Start storm	Inlet 18"	0.05		0.10		3.20		0.80	
5 May 89	Start storm	Seeps	0.02		0.20		0.50		1.00	+
5 May 89	Start storm	Weir	0.02	+	0.10	+	0.15	+	0.50	
10 May 89	Heavy rain	Inlet 18"	0.02		0.20		0.10		0.20	
10 May 89	Heavy rain	Seeps	0.04		0.40		0.90		0.50	
10 May 89	Heavy rain	Weir	0.03	x	0.20	+	0.20	+	0.50	x
16 May 89	Heavy rain	Inlet 18"	0.03		0.20		0.25		0.20	
16 May 89	Heavy rain	Seeps	0.04		0.90		0.75		0.60	
16 May 89	Heavy rain	Weir	0.04	x	0.70	+	0.30	+	0.20	+
25 May 89	Heavy rain	Inlet 18"	0.07		0.10		0.40		0.70	
25 May 89	Heavy rain	Seeps	0.02		0.25		0.70		2.75	
25 May 89	Heavy rain	Weir	0.04	+	0.30	-	0.20	+	1.40	+
6 Jun 89	Showers	Inlet 18"	0.02		0.70		0.40		0.75	
6 Jun 89	Showers	Seeps	0.03		0.20		0.40		2.75	
6 Jun 89	Showers	Weir	0.02	+	0.00	+	0.20	+	1.70	+
9 Jun 89	Heavy rain	Inlet 18"	0.03		0.05		0.40		0.40	
9 Jun 89	Heavy rain	Seeps	0.03		0.30		0.10		0.25	
9 Jun 89	Heavy rain	Weir	0.04	-	0.20	+	0.20	+	1.40	-
15 Jun 89	Light rain	Inlet 18"	0.05		0.00		0.40		0.80	
15 Jun 89	Light rain	Seeps	0.02		0.30		0.20		2.00	
15 Jun 89	Light rain	Weir	0.04	+	0.10	+	0.20	+	1.60	+
25 TESTS (SEEPS 9 TESTS)				10+, 4-		18+, 5-		20+, 4-		13+, 7-

Status through biofilter: positive = +, negative = -, no change = 0, not determinable = x

BIOFILTER NO. 1

pH Levels - Stormwater Runoff

Date	Weather	18" Inlet Pipe	System Center	Weir	River	Seep	Status
28 Apr 88	Periodic rain	6.30	6.70	6.20	6.80	--	-
6 May 88	Showers	6.90	6.90	6.90	7.00	--	0
18 May 88	Heavy rain	6.40	6.80	6.60	6.40	--	+
19 May 88	Light rain	6.50	6.90	6.50	6.40	--	0
24 May 88	Sunny after storm	Dry	7.00	6.60	6.60	--	x
8 Jun 88	Clearing after showers	Dry	6.80	6.40	6.60	--	x
17 Aug 88	Rain	5.80	6.50	6.50	6.20	--	+
19 Aug 88	Rain	6.80	6.80	6.80	6.40	--	0
21 Oct 88	Start of storm	6.80	6.80	6.80	6.40	--	0
1 Nov 88	Start of storm	6.60	6.50	6.40	6.20	--	-
9 Jan 89	Moderate rain	6.80	6.80	6.80	6.60	--	0
26 Jan 89	Heavy rain	6.70	6.70	6.70	6.50	--	0
2 Feb 89	Steady rain	6.20	6.40	6.70	6.50	--	+
6 Feb 89	Snow melt	6.60	6.60	6.60	6.50	--	0
15 Feb 89	Light rain	6.30	6.30	6.40	6.40	--	+
21 Feb 89	Heavy rain	6.20	6.20	6.30	6.40	--	+
9 Mar 89	Rain	6.40	6.60	6.50	6.70	--	+
24 Mar 89	Heavy rain	6.60	6.70	6.80	6.40	--	+
31 Mar 89	Heavy rain	6.10	6.20	6.50	6.40	--	+
12 Apr 89	Light rain	6.40	6.50	6.50	6.70	--	+
1 May 89	Light rain	6.40	6.40	6.10	6.20	6.80	-
2 May 89	After heavy storm	6.60	----	6.40	----	6.40	-
5 May 89	Start of Storm	6.10	6.10	5.90	6.10	6.30	-
10 May 89	Heavy rain	5.00	5.40	6.10	6.20	6.40	+
16 May 89	Heavy rain	5.50	5.60	5.80	6.00	5.80	+
25 May 89	Heavy rain	6.10	6.30	5.90	5.80	6.10	-
6 Jun 89	Showers	5.60	5.90	5.70	5.70	5.50	+
9 Jun 89	Heavy rain	5.90	5.80	5.90	5.90	5.40	+
15 Jun 89	Light rain	6.60	6.30	6.10	6.00	5.30	-

FILTER RESULTS GENERALLY POSITIVE - 29 Tests 14+, 7-

Status: positive = +, negative = -, no change = 0, not determinable = x

BIOFILTER NO. 2

STORMWATER RUNOFF - NUTRIENTS AND HEAVY METALS

Date	Weather	Location	Chromium (hexavalent) Mg/L	Status	Iron Mg/L	Status	Phosphate Mg/L	Status	Nitrate Mg/L	Status
18 May 88	Heavy rain	Inlet 24"	0.02		0.05		1.75		0.30	
18 May 88	Heavy rain	Outlet 24"	0.02	0	0.35	-	3.65	-	0.28	+
19 May 88	Light rain	Inlet 24"	0.02		0.28		0.45		0.35	
19 May 88	Light rain	Outlet 24"	0.02	0	1.25	-	0.38	+	0.20	+
10 Jun 88	Showers	Inlet 24"	0.10		0.50		0.82		0.20	
10 Jun 88	Showers	Outlet 24"	0.08	+	0.10	+	0.41	+	0.25	-
21 Oct 88	Start of storm	Inlet 24"	0.04		0.20		0.40		0.50	
21 Oct 88	Start of storm.	Outlet 24"	0.04	0	0.40	-	0.60	-	0.20	-
21 Oct 88	Mid storm	Inlet 24"	0.04		0.20		0.50		0.60	
21 Oct 88	Mid storm	Outlet 24"	0.02	+	0.20	0	0.40	+	0.20	+
1 Nov 88	Start storm	Inlet 24"	0.11		0.20		4.80		0.20	
1 Nov 88	Start storm	Outlet 24"	0.04	+	0.10	+	4.80	0	0.20	0
1 Nov 88	Mid storm	Inlet 24"	0.02		0.20		4.00		0.10	
1 Nov 88	Mid storm	Outlet 24"	0.00	+	0.20	0	4.00	0	0.10	0
9 Jan 89	Moderate rain	Inlet 24"	0.02		0.20		4.50		0.30	
9 Jan 89	Moderate rain	Outlet 24"	0.01	+	0.30	-	4.80	-	0.20	+
26 Jan 89	Heavy rain	Inlet 24"	0.02		0.30		4.00		0.40	
26 Jan 89	Heavy rain	Outlet 24"	0.01	+	0.30	0	4.00	0	0.30	+
2 Feb 89	Steady rain	Inlet 24"	0.01		0.40		0.10		0.40	
2 Feb 89	Steady rain	Outlet 24"	0.01	0	0.10	+	0.10	0	0.25	+
6 Feb 89	Snow melt	Inlet 24"	0.03		0.20		0.20		0.60	
6 Feb 89	Snow melt	Outlet 24"	0.03	0	0.20	0	0.40	-	0.10	+
15 Feb 89	Light rain	Inlet 24"	0.06		1.40		0.50		0.10	
15 Feb 89	Light rain	Outlet 24"	0.00	+	1.20	+	4.70	-	0.60	-
21 Feb 89	Heavy rain	Inlet 24"	0.10		2.30		0.20		0.30	
21 Feb 89	Heavy rain	Outlet 24"	0.00	+	1.20	+	0.20	0	0.50	-
9 Mar 89	Rain	Inlet 24"	0.06		0.70		0.20		0.35	
9 Mar 89	Rain	Outlet 24"	0.04	+	0.60	+	0.20	0	0.40	-
24 Mar 89	Heavy rain	Inlet 24"	0.02		1.30		0.30		0.20	
24 Mar 89	Heavy rain	Outlet 24"	0.01	+	1.00	+	0.30	0	0.05	+
31 Mar 89	Heavy rain	Inlet 24"	0.03		1.60		0.30		0.30	
31 Mar 89	Heavy rain	Outlet 24"	0.03	0	2.00	-	0.40	-	0.30	0
12 Apr 89	Light rain	Inlet 24"	0.04		0.10		0.10		0.20	
12 Apr 89	Light rain	Outlet 24"	0.06	-	0.00	+	2.80	-	0.30	-

1 May 89	Light rain	Inlet 24"	0.09		0.20		0.10		0.20	
1 May 89	Light rain	Inlet 18"	0.04		0.50		0.40		0.35	
1 May 89	Light rain	Outlet 24"	0.12	-	0.35	+	0.10	+	0.35	0
2 May 89	After storm	Inlet 24"	0.01		0.25		0.20		0.50	
2 May 89	After storm	Inlet 18"	0.03		2.40		0.30		0.35	
2 May 89	After storm	Outlet 24"	0.03	0	0.10	+	0.10	+	0.70	-
5 May 89	Start storm	Inlet 24"	0.04		0.50		0.10		0.35	
5 May 89	Start storm	Inlet 18"	0.03		0.50		0.20		0.40	
5 May 89	Start storm	Outlet 24"	0.05	-	0.25	+	0.10	+	0.45	-
10 May 89	Heavy rain	Inlet 24"	0.03		0.10		0.10		0.35	
10 May 89	Heavy rain	Inlet 18"	0.02		0.10		0.10		0.35	
10 May 89	Heavy rain	Outlet 24"	0.03	0	0.10	0	0.10	0	0.30	+
16 May 89	Heavy rain	Inlet 24"	0.03		0.20		0.25		0.25	
16 May 89	Heavy rain	Inlet 18"	0.00		0.10		0.20		0.25	
16 May 89	Heavy rain	Outlet 24"	0.03	x	0.20	x	0.20	+	0.45	-
25 May 89	Heavy rain	Inlet 24"	0.06		0.10		0.00		0.80	
25 May 89	Heavy rain	Inlet 18"	0.03		0.25		0.10		0.45	
25 May 89	Heavy rain	Outlet 24"	0.04	+	0.15	+	0.10	0	0.80	0
6 Jun 89	Showers	Inlet 24"	0.03		0.10		0.20		0.90	
6 Jun 89	Showers	Inlet 18"	0.03		0.80		0.20		0.35	
6 Jun 89	Showers	Outlet 24"	0.02	+	0.20	+	0.10	+	0.30	+
9 Jun 89	Heavy rain	Inlet 24"	0.01		0.05		0.10		0.35	
9 Jun 89	Heavy rain	Inlet 18"	0.01		0.10		0.10		0.25	
9 Jun 89	Heavy rain	Outlet 24"	0.02	-	0.20	-	0.10	0	0.40	-
15 Jun 89	Light rain	Inlet 24"	0.05		0.60		0.20		0.65	
15 Jun 89	Light rain	Inlet 18"	0.04		0.20		0.10		1.00	
15 Jun 89	Light rain	Outlet 24"	0.03	+	0.20	+	0.10	+	0.60	+
26 TESTS				14+, 4-		14+, 6-		9+, 7-		11+, 10-

Status through biofilter: positive = +, negative = -, no change = 0, not determinable = x

BIOFILTER NO. 2

pH Levels - Stormwater Runoff

Date	Weather	18" Inlet Pipe	24" Inlet Pipe	System Center	24" Outlet Pipe	River	Status
28 Apr 88	Periodic rain	5.80	6.60	6.30	6.30	----	+
6 May 88	Showers	6.50	6.80	6.90	6.80	7.00	+
18 May 88	Heavy rain	6.50	5.90	6.30	6.10	6.20	+
19 May 88	Light rain	6.20	6.50	6.30	6.40	6.40	+
24 May 88	Sunny after storm	6.70	6.30	6.80	7.20	6.80	+
8 Jun 88	Clearing after showers	6.00	6.00	6.20	6.60	6.60	+
19 Aug 88	Rain	6.00	6.00	6.00	6.10	6.50	+
21 Oct 88	Start of storm	----	6.30	6.50	6.40	----	+
21 Oct 88	Mid storm	6.40	6.70	6.70	6.80	----	+
1 Nov 88	Start of storm	----	6.20	----	6.40	----	+
1 Nov 88	Mid storm	5.90	6.00	6.50	6.60	----	+
9 Jan 89	Moderate rain	6.00	6.50	6.60	6.70	6.80	+
26 Jan 89	Heavy rain	6.50	6.40	6.60	6.70	6.60	+
2 Feb 89	Steady rain	5.90	5.90	6.00	6.10	6.20	+
6 Feb 89	Snow melt	7.20	6.30	6.60	6.70	6.60	x
15 Feb 89	Light rain	6.00	6.10	6.30	6.40	6.20	+
21 Feb 89	Heavy rain	6.20	6.60	6.50	6.60	6.30	+
9 Mar 89	Rain	6.30	6.30	6.60	6.50	6.70	+
24 Mar 89	Heavy rain	6.60	6.70	6.80	6.80	6.40	+
31 Mar 89	Heavy rain	5.50	5.90	6.00	6.20	5.90	+
12 Apr 89	Light rain	6.00	6.20	6.30	6.60	6.60	+
30 Apr 89	----	6.10	6.30	6.20	6.40	6.20	+
1 May 89	Light rain	5.60	5.80	5.60	5.70	6.10	x
2 May 89	After heavy storm	5.50	5.40	----	5.90	----	+
5 May 89	Start of Storm	5.40	5.20	5.40	5.40	6.10	+
10 May 89	Heavy rain	4.60	4.70	5.00	5.10	5.60	+
16 May 89	Heavy rain	4.50	4.60	5.00	4.90	5.40	+
25 May 89	Heavy rain	5.40	5.20	5.50	5.50	5.60	+
6 Jun 89	Showers	5.00	5.40	5.60	5.60	5.90	+
9 Jun 89	Heavy rain	5.20	5.20	5.30	5.40	5.90	+
15 Jun 89	Light rain	5.20	5.30	5.30	5.60	5.90	+

FILTER RESULTS GENERALLY POSITIVE - 31 Tests 29+, 0-

Status: positive = +, negative = -, no change = 0, not determinable = x

BIOFILTER NO. 3

STORMWATER RUNOFF - NUTRIENTS AND HEAVY METALS

Date	Weather	Location	Chromium (hexavalent) Mg/L	Status	Iron Mg/L	Status	Phosphate Mg/L	Status	Nitrate Mg/L	Status
1 May 89	Light rain	Inlet 24"	0.05		0.80		0.15		0.30	
1 May 89	Light rain	Outlet	0.02	+	0.55	+	0.10	+	0.15	+
2 May 89	After storm	Inlet 24"	0.06		1.30		0.10		0.25	
2 May 89	After storm	Outlet	0.03	+	0.30	+	0.15	-	0.20	+
5 May 89	Start storm	Inlet 24"	0.02		0.40		0.10		0.30	
5 May 89	Start storm	Outlet	0.05	-	0.30	+	0.05	+	0.25	+
10 May 89	Heavy rain	Inlet 24"	0.03		0.20		0.10		0.20	
10 May 89	Heavy rain	Outlet	0.03	0	0.25	-	0.10	0	0.30	-
16 May 89	Heavy rain	Inlet 24"	0.00		0.00		0.10		0.50	
16 May 89	Heavy rain	Outlet	0.03	-	0.10	-	0.10	0	0.60	-
25 May 89	Heavy rain	Inlet 24"	0.03		0.80		0.10		0.40	
25 May 89	Heavy rain	Outlet	0.02	+	0.55	+	0.10	0	0.70	-
6 Jun 89	Showers	Inlet 24"	0.03		2.00		0.10		0.60	
6 Jun 89	Showers	Outlet	0.02	+	0.30	+	0.10	0	0.40	+
9 Jun 89	Heavy rain	Inlet 24"	0.03		0.50		0.10		0.35	
9 Jun 89	Heavy rain	Outlet	0.01	+	0.20	+	0.00	+	0.90	-
15 Jun 89	Light rain	Inlet 24"	0.01		1.40		0.10		0.60	
15 Jun 89	Light rain	Outlet	0.00	+	1.00	+	0.00	+	0.20	+
9 TESTS				6+, 2-		7+, 2-		4+, 1-		5+, 4-

Status through biofilter: positive = +, negative = -, no change = 0, not determinable = x

BIOFILTER NO. 3

pH Levels - Stormwater Runoff

Date	Weather	8" Inlet Pipe	24" Inlet Pipe	Outlet	River	Status
28 Apr 88	Periodic rain	5.90	6.60	No runoff	----	x
6 May 88	Showers	6.40	6.80	No runoff	7.00	x
18 May 88	Heavy rain	4.50	3.70	No runoff	6.20	x
19 May 88	Light rain	5.60	6.30	No runoff	6.40	x
24 May 88	Sunny after storm	6.30	Dry	No runoff	6.80	x
8 Jun 88	Clearing after showers	Dry	Dry	No runoff	6.60	x
19 Aug 88	Rain	----	5.20	No runoff	6.50	x
1 Nov 88	Start of storm	6.60	6.60	No runoff	----	x
26 Jan 89	Heavy rain	6.60	6.60	No runoff	6.60	x
2 Feb 89	Steady rain	Dry	6.20	No runoff	6.20	x
6 Feb 89	Snow melt	Dry	6.00	No runoff	6.60	x
15 Feb 89	Light rain	Dry	6.40	No runoff	6.20	x
21 Feb 89	Heavy rain	6.30	6.30	No runoff	6.30	x
9 Mar 89	Rain	Dry	6.20	No runoff	6.70	x
24 Mar 89	Heavy rain	Dry	6.20	No runoff	6.40	x
31 Mar 89	Heavy rain	Dry	6.30	No runoff	5.90	x
12 Apr 89	Light rain	6.20	6.40	6.50	6.60	+
30 Apr 89	----	5.90	6.40	6.70	6.20	+
1 May 89	Light rain	5.60	5.60	6.60	6.10	+
2 May 89	After heavy storm	----	5.80	5.90	----	+
5 May 89	Start of Storm	5.20	5.30	5.50	6.10	+
10 May 89	Heavy rain	5.20	5.40	5.70	5.60	+
16 May 89	Heavy rain	4.90	4.80	5.20	5.40	+
25 May 89	Heavy rain	5.20	5.40	5.40	5.60	+
6 Jun 89	Showers	5.60	5.40	5.40	5.90	x
9 Jun 89	Heavy rain	5.00	5.60	5.90	5.90	+
15 Jun 89	Light rain	5.30	5.40	5.50	5.90	+

FILTER RESULTS GENERALLY POSITIVE - 27 Tests (11 with runoff) 10+, 0-

Status: positive = +, negative = -, no change = 0, not determinable = x

CONTROL WETLAND - BIOFILTER FEATURES

STORMWATER RUNOFF - NUTRIENTS AND HEAVY METALS

Date	Weather	Location	Chromium (hexavalent) Mg/L	Status	Iron Mg/L	Status	Phosphate Mg/L	Status	Nitrate Mg/L	Status
21 Feb 89	Heavy rain	Inlet 24"	0.02		1.00		3.70		0.00	
21 Feb 89	Heavy rain	Outlet	0.02	0	1.50	-	0.50	+	0.30	-
22 Feb 89	After storm	Inlet 24"	0.03		0.80		0.80		0.10	
22 Feb 89	After storm	Outlet	0.01	+	0.35	+	0.20	+	0.10	0
9 Mar 89	Rain	Inlet 24"	0.02		1.30		5.20		0.20	
9 Mar 89	Rain	Outlet	0.01	+	0.60	+	3.50	+	0.20	0
24 Mar 89	Heavy rain	Inlet 24"	0.02		0.70		0.80		0.20	
24 Mar 89	Heavy rain	Outlet	0.02	0	0.45	+	0.40	+	0.20	0
31 Mar 89	Heavy rain	Inlet 24"	0.01		2.40		2.70		0.50	
31 Mar 89	Heavy rain	Outlet	0.01	0	2.50	-	1.00	+	0.30	+
12 Apr 89	Light rain	Inlet 24"	0.01		1.30		3.60		0.25	
12 Apr 89	Light rain	Outlet	0.06	-	1.10	+	3.20	+	0.10	+
1 May 89	Light rain	Inlet 24"	0.07		0.55		1.10		0.25	
1 May 89	Light rain	Outlet	0.10	-	0.65	-	0.05	+	0.25	0
2 May 89	After storm	Inlet 24"	0.01		0.25		0.10		0.20	
2 May 89	After storm	Outlet	0.06	-	0.20	+	0.30	-	0.10	+
5 May 89	Start storm	Inlet 24"	0.02		0.20		0.10		0.25	
5 May 89	Start storm	Outlet	0.00	+	0.20	0	0.10	0	0.25	0
10 May 89	Heavy rain	Inlet 24"	0.01		0.10		0.10		0.30	
10 May 89	Heavy rain	Outlet	0.02	-	0.05	+	0.10	0	0.20	+
16 May 89	Heavy rain	Inlet 24"	0.04		0.20		0.10		0.20	
16 May 89	Heavy rain	Outlet	0.02	+	0.20	0	0.00	+	0.25	-
25 May 89	Heavy rain	Inlet 24"	0.06		0.20		0.20		0.50	
25 May 89	Heavy rain	Outlet	0.07	-	0.00	+	0.10	+	0.40	+
6 Jun 89	Showers	Inlet 24"	0.03		0.10		0.00		0.25	
6 Jun 89	Showers	Outlet	0.01	+	0.10	0	0.00	0	0.20	+
9 Jun 89	Heavy rain	Inlet 24"	0.04		0.10		0.70		0.40	
9 Jun 89	Heavy rain	Outlet	0.04	0	0.10	0	0.30	+	0.35	+
15 Jun 89	Light rain	Inlet 24"	0.00		0.25		0.10		1.15	
15 Jun 89	Light rain	Outlet	0.02	-	0.10	+	0.10	0	0.25	+
15 TESTS				5+, 4-		7+, 3-		10+, 1-		7+, 2-

Status through biofilter: positive = +, negative = -, no change = 0, not determinable = x

CONTROL WETLAND - BIOFILTER FEATURES

pH Levels - Stormwater Runoff

Date	Weather	24" Inlet Pipe	Outlet	Status
21 Feb 89	Heavy rain	6.40	6.40	x
22 Feb 89	After storm	6.20	6.40	+
9 Mar 89	Rain	6.40	6.50	+
24 Mar 89	Heavy rain	6.60	6.60	+
31 Mar 89	Heavy rain	6.10	6.30	+
12 Apr 89	Light rain	5.80	6.20	+
1 May 89	Light rain	5.90	6.00	+
2 May 89	After heavy storm	5.50	5.30	-
5 May 89	Start of Storm	5.70	5.50	-
10 May 89	Heavy rain	5.30	5.20	-
16 May 89	Heavy rain	5.00	5.10	+
25 May 89	Heavy rain	5.20	5.40	+
6 Jun 89	Showers	5.90	5.20	-
9 Jun 89	Heavy rain	5.30	5.40	+
15 Jun 89	Light rain	5.30	5.20	-

FILTER RESULTS GENERALLY POSITIVE - 15 Tests 9+, 5-

Status: positive = +, negative = -, no change = 0, not determinable = x

Alexandra D. Dawson, J. D.
2 West Street, Hadley, MA 01035

TO: TOWN OF EASTHAMPTON JULY 17, 1989

FINAL LEGAL RECOMMENDATIONS FOR PROTECTING AQUIFER

RECOMMENDATION I: The town should create two new zoning districts covering the aquifer recharge area and generally corresponding with Zone II and Zone III as delineated on the aquifer protection district map.

New Wording: Amendment of following portions of zoning bylaw:

A. Add to S III(a) (Establishment of Zoning Districts)
Residential Aquifer Drift Area R-40
Residential Aquifer Till Area R-80

B. Add to S. V (Use Regulations) Table 3 columns indicating the following uses are permitted (P) - all others forbidden:
one family detached dwelling
also, church, educational purpose, public park, etc., non-profit recreational facility, historical association, street, bridge, railroad, public utility (limited), essential services, agriculture, raising and keeping of livestock, noncommercial forestry, accessory buildings, accessory private garage, accessory storage of trailer, accessory signs and parking and temporary mobile homes.

C. S. VI (Area, etc. Regulations) Table 4:
Add R-40 and R-80. Dimensions for R-40 should be the same as present dimensions for R-35. Dimensions for R-80 should be the same as present dimensions for R-35 except that frontage should be increased to 240 feet.

D. S. VI (Area etc. Regulations) Table 5:
Add R-40 and R-80. Height to be the same as for present R-35. Maximum coverage to be limited to 10% for both R-40 and R-80

E. Amend S. XIII(A) (Aquifer Protection District) as follows:

--Add to definition of Hazardous Materials the list of household materials attached to this Report

--Change first sentence (5)(b)(2) to read: "Excavation of or removal of earth, sand, gravel, clay and other soils shall not be permitted." Continue second sentence as written.

--Change (5)(c)(3) to read: "storage and/or transmission of oil, gasoline, and chemicals in corrodable containers and pipelines or in underground storage tanks."

--Change (5)(d)(3) to read: "Rendering impervious, by any means, more than 10% or up to 20% of area on any single lot; except that this special permit shall be available only for lots of less than 40,000 sf. In an Open Space Residential Development permitted under s. 16 of this bylaw, the space in the entire cluster shall be considered in determining permissable lot coverage, rather than the space on individual lots."

F. Amend Zoning Map to establish R-40 and R-80 districts. Boundary of R-40 shall be boundary of Zone II area as shown on Aquifer Protection District map, namely the Stratified Drift Area. Boundary of R-80 district shall be boundary of Zone II as shown on said map, namely the Till area; except that the contact line between the drift and till areas shall be extended north (as per Dr. Ward Motts' soil maps) until it crosses Route 141, and a line shall be drawn eastward therefrom to the town boundary; and the land within the enclosed area shall be included in the R-80 district.

G. S. 16: (Open Space Residential Development)
Amend 4(B) so that the first sentence reads: "The planning board may grant a special permit for cluster development in the R-35, R-40 and R-80 Districts upon the following terms and conditions....

Amend s. 3(b)(1) by removing the "Note" now in parentheses and substitute the following sentence: "The number of dwellings which may be constructed under this bylaw is further limited by excluding from consideration of the tract 50% of all steep slopes floodplains, wetlands and isolated lands subject to flooding as defined in the regulations for the state Wetlands Protection Act."

H. Amend S. VI, Table 4 by adding a footnote keyed to R-40 and R-80 stating: "A special setback applies on both sides of Broad Brook in the aquifer protection district; see S. XIII(A)"

Amend S. XIII(A)(5) (Use regulations within the district) to add (e) Broad Brook setback:

"1. Within the aquifer district, no buildings or parking lots for over 5 cars shall be constructed within 75 feet of the annual high water line of Broad Brook;

2. Except where bridges are permitted across Broad Brook, an area of 50 feet measured from the annual high water line shall be kept in a natural vegetated condition and not altered in any way.

3. No septic system component shall be installed within 150 feet of the annual high water line of Broad Brook."

EXPLANATION OF RECOMMENDATION I:

Recommendation I creates two new zoning districts, generally corresponding with Zone II and Zone III of the aquifer protection overlay district. However, these are not overlays but totally new zoning districts. In this way, they are distinguished from R-15 and R-35 districts elsewhere in the town. In addition, the R-80 district (2 acre zoning) is extended a short distance to the north of the present aquifer protection district, to encompass an area of steep slopes along the mountain.

Important note: The zoning districts are separated by the contact line between the till and stratified drift portions of the aquifer. This line does not show on the ground although it is easily determined by soil tests. The use of this soil line is justified if you indeed have in your Clerk's office an aquifer map "at a scale of one inch to 800 feet" as stated in your Aquifer Protection District bylaw. In the absence of a map at such a scale, I would recommend instead that the zones be bounded by a monument easily determined on the ground, preferably Broad Brook (and some other way be found to protect the steep-slope area north of the district). The use of Broad Brook could be legally justified by the need for additional protection for that brook, and by the steeper area to the east of it.

The proposed rezoning does a number of things:

--it enlarges new lots in both Zone II and Zone III;
--it increases frontage on R-80 but otherwise leaves dimensions as is;
--it bans all special permits currently allowed R-15 and R-35 districts. These SPs generally involve danger of contamination of the groundwater; all would increase traffic. Note: If any SPs must be allowed, professional offices, day camps and some home occupations would be the least troublesome; you may have to allow horses for private use in the R-80 district for political reasons.
--it creates special setback/natural areas on each side of Broad Brook within the aquifer district, because of the intimate relation of the brook to the aquifer.
--it amends the aquifer district to ban all earth removal, all new underground storage tanks, and coverage of over 10% of any new lot; the special permit for coverage up to 20% of the lot is retained for the smaller existing/authorized lots. If you deem it unfair to allow the SP in 35,000 sf. lots, while banning the SP in 40,000 sf. lots, then you should use the following wording: "...rendering impervious, by any means, more than 10% or up to 20% of the area on any single lot, except that this special permit shall not be available for lots of 80,000 sf. or more."
--it allows cluster development (now confined to R-35 district) in both R-40 and R-80 districts.

The recommendation relating to computation of lots in clustering would correct an error whereby an explanatory "Note" was adopted as part of the zoning. The choice, to count 50% of wetlands and floodplains, was selected from the new Amherst farmland cluster bylaw.

RECOMMENDATION II: The town should curb the use and storage of petroleum products and hazardous chemicals within the aquifer protection district

New Wording for II(A): The Board of Health should adopt the following regulations to control underground petroleum tanks:

Note: The BOH has the legal authority to adopt the following regulation without town action. However, if town meeting approval is deemed desirable, a town meeting vote could be sought, as follows: "To direct the BOH to adopt regulations for the removal and testing of all existing underground petroleum storage tanks within theaquifer protection district."

"Board of Health Regulation:

1. Purpose: To protect the public drinking water aquifer and recharge areas from leaking underground oil and fuel tanks, the BOH adopts these regulations pursuant to Ch. 111, s. 31 of the general laws.

2. Applicability: In addition to other citywide health regulations, the following shall apply within the aquifer protection district, as identified on the official district map.

3. New Tanks: Installation of tanks for underground storage of oil, gas, other petroleum products and other chemicals is prohibited within the aquifer protection district.

4. Every owner of an underground tank subject to this regulation shall file with the BOH the size, type, age and location of each tank, and the type of materials stored, within three months of the effective date of these regulations. A tag number shall be issued for each tank. After four months from the effective date of these regulations, no underground tanks shall be filled with oil, gas, petrleum products or chemicals, or allowed to hold these products, if not so registered and assigned a tank number.

5. All tanks which were installed over fifteen years ago and tanks for which evidence of installation date is not available shall be removed within one year after the effective date of these regulations by the landowner at the landowner's expense.

6. Underground tanks remaining in the ground one year after the effective date of these regulations must be inspected annually for leaks and structural integrity by a qualified consultant hired by the landowner at the landowner's expense, with a copy of the consultant's findings sent to the BOH. If the tank is not product tight, it shall be removed by the landowner at the landowner's expense within ten days of the consultant's evaluation. Each such tank shall be removed as it attains fifteen years of age. No tank over fifteen years shall be allowed to remain in the ground, regardless of the date of inspection.

7. These regulations shall be enforced by the BOH or its agent.

8. Any landowner who does not register, inspect and remove tanks as required above, and any person who allows a tank to be filled in violation of these regulations, shall be punished by a fine of not less than one hundred nor more than five hundred dollars; each day or portion of a day to construed as a separate offense.

9. These regulations shall become effective upon publication."

New Wording for II(B): The town should adopt the following general, nonzoning bylaw to control storage of hazardous materials in the aquifer district:

Note: It is probable that the Board of Health has the legal authority to establish the following system by adopting regulations without town meeting action. However, the usual method of adopting such controls is through a non-zoning bylaw adopted under s. 21 of G.L. Ch. 40; this does not "grandfather" existing practices, as does zoning.

"S.________is hereby added to the general bylaws of the town:

Every owner or occupant of any property within the aquifer protection district who stores hazardous materials in quantities totaling more than fifty gallons liquid volume or twenty-five pounds dry weight shall register with the Board of Health the types, quantities, location and method of storage of said materials. Hazardous materials shall include all those materials named in the attached list.

Registration shall be initially submitted by sixty days after the effective date of this bylaw and annually thereafter by the end of the calendar year. The BOH may also require that an inventory of hazardous materials be maintained on the premises and reconciled with purchase, use, sales and disposal records on a monthly basis.

Hazardous materials shall be stored in product-tight storage containers on an impervious surface, and storage areas shall be enclosed by an impermeable dike with a volume at least equal to the capacity of the container(s) within it.

Notwithstanding the above, the storage of pesticides, herbicides and fertilizers shall be regulated as follows: persons storing over fifty-five gallons liquid volume or two hundred fifty pounds dry weight of pesticides and herbicides, and persons storing fertilizer containing over one hundred pounds of available nitrogen, shall register with the BOH as stated above. The other requirements shall not apply.

Persons violating this bylaw shall be punished by a fine of $300 per day, each day constituting a separate offense.

This bylaw shall not apply to storage of petroleum products in underground storage tanks.

EXPLANATION OF RECOMMENDATION II:

Recommendation II would curb storage of hazardous materials stored in the aquifer district. Different rules would apply to petroleum storage, storage of hazardous materials, and storage of pesticides and fertilizer.

1. Petroleum storage.

The proposed changes in the aquifer protection district zoning would ban all new underground tanks. There are many existing underground home heating tanks in the Zone II area, according to the IEP report. It would be best to remove them all above ground; however, this might be politically difficult. The proposed Board of Health regulations, similar to those proposed in Northampton, would require removal of all tanks over 15 years old. Newer tanks would have to be annually tested and removed when they became 15. Substitution of new underground tanks made of safer materials is not recommended because they too can leak if improperly installed. Above-ground petroleum storage over 50 gallons would be regulated by the general bylaw discussed below.

2. Hazardous materials

Hazardous chemicals on an attached list would be subject to registration with the Board of Health through adoption of a general, non-zoning bylaw. The limit for these chemicals is set at fifty gallons liquid or twenty-five pounds dry weight, as suggested by the widely copied Barnstable bylaw. The storage area is required to have a dike.

3. Pesticides and fertilizers

Pesticides, herbicides and fertilizers would also be covered under the non-zoning bylaw; but persons storing them would only have to register them with the Board of Health; and the limits are set much higher, at fifty-five gallons or two hundred fifty pounds. The limit for fertilizer registration is set at one hundred pounds available nitrogen. These limits were copied from a hard-fought bylaw of Wayland. The distinction is not scientific but political; pesticides can be very dangerous. However, the aim is to require registration by all users who store the products, including farmers; and this is a sensitive matter.

RECOMMENDATION III: The planning board should amend its regulations for subdivisions to insure that precipitation recharges the aquifer.

New Wording:

Amend s. V(C)(4) (drainage) by deleting the first sentence and substituting: "Runoff water from all impermeable surfaces shall be collected so as to divert it into recharge areas within the aquifer protection district. The use of dry wells and retention ponds with appropriate winter alternatives is acceptable. Runoff from roadways in the aquifer protection district should, however, be directed to enter the nearest drain or open stream channel, rather than being directed into the soil."

EXPLANATION OF RECOMMENDATION III:

Section V(C) of the present subdivision regulations virtually mandates that runoff be directed off the subject property into a drain or stream. This is undesirable in the aquifer district, where maximum recharge of the aquifer is important, so as to preserve water yield. The wording of the first sentence is derived from the Amherst aquifer protection bylaw. The second sentence is added to guard against aquifer contamination by road wastes. Road runoff is generally unattractive because of road salt, motor oil and other automotive chemicals.

In my opinion, the subdivision regulation should also apply, in a general way, to areas outside the aquifer district. An increasing number of planning boards are adopting a rule of "no net increase in runoff." This prevents surcharging of drainage easements and flooding of neighbors' properties, for which developers are being held legally liable. In most cases, quality of runoff is improved by draining through soils.

I would also recommend that the design storm, as set out in V(C)(1) be changed from the five-year storm to the 10-year storm, with provision that the planning board may in appropriate cases require consideration of the 25-year storm. This provision, found in Northampton subdivision regulations s. 8:19(2) is typical of modern regs.

RECOMMENDATION IV: Some initiatives for town policy

1. All development in the aquifer district should be sewered. Watertight pipes, as recommended by your engineering consultant, should be used in all new development and in replacement of existing pipes as they age.

Explanation: A special permit is required for a septic system in the aquifer district. Rather than delete that, we recommend a policy of requiring sewering. Even though this diminishes recharge of the aquifer, sewering is desirable in order to curb pollution of groundwater. Sewer pipes are designed with varying degrees of tightness. Your consultant can pick a design which balances safety against cost.

2. The selectboard and conservation commission should negotiate with Northeast Utilities regarding amount and type of herbicides it will use on the utility ROW running through Zone II. Amount and type must appear in the Yearly Operation Plan and 5-year Vegetation Management Plan filed with the state under Food & Agriculture regulations.

Explanation: New state regulations found in 333 Code of Mass. Regulations s. 11.00 require utilities to develop "YOPs" and "VMPs" for public comment. Although the regulations ban use of herbicides only for the first 400 feet around a public well, protection in the recharge area may be negotiated.

3. The town DPW should erect signs on roads passing through the "100-day contaminant zone" identified by Dr. Ward Motts, to the effect of "Danger: Public Well Area". The selectboard should try to negotiate agreements with oil companies and other carriers of hazardous materials (including carriers servicing Southampton Sanitary Engineering) that they will use other routes, whenever feasible.

Explanation: To ban the use of a town way by a certain kind of carrier would be difficult and require state DPW approval. Informal negotiation may be possible. The signs must help impose liability for careless spills. They will also help educate the public.

4. The town should remove the underground petroleum storage tanks installed at its wellheads.

Explanation: The IEP report shows tanks buried at wellheads, to supply water pumps. Although we have not inspected them, we think that removal of tanks in such a location would be a safety precaution and a good example.

5. Use of road salt and lawn chemicals is best controlled by installation of a monitoring well at appropriate points (heavily traveled road, densely developed residential area) and watching the results closely. If salt levels rise, the town DPW can be informed. If lawn chemicals cause a problem, further action can be considered at that time.

(REC. IV: CONT.)

6. Easthampton should insure that it has at least one center which accepts used motor oil even if the person bringing it in cannot produce proof that it was bought there. The town might give favorable publicity and even some funds to a facility agreeing to do this; or it could start a public center at the town garage. This is the best way to reduce spills into the ground, drains, or streams, of crankcase wastes generated by people who change their own motor oil.

7. No zoning or other changes are recommended in the 100-day contaminant travel zone of the Lovefield well, at least until the Zone II and Zone III areas are delineated by a study.

RECOMMENDATION V: Actions for Holyoke and Southampton

The town should recommend to the inter-community "BAPAC" the following procedures, which will generally conform with PVPC recommendations:

1. Similar one- and two-acre zoning in Zones II and III of their portion of the aquifer.

2. Similar Board of Health registration of pesticides, fertilizers, hazardous materials, and above-ground petroleum tanks

3. Similar removal/testing of all underground petroleum storage tanks

4. Similar encouragement of cluster development in Zone II and Zone III, even if these are not sewered.

5. A general, non-zoning bylaw requiring that existing commercial and industrial uses (such as landscaping firms, gas stations, metal-working business, body shop) do all their work and store all vehicles and materials under cover on impervious surfaces, with collection and proper disposal of any runoff.

6. Special provisions for Southampton Sanitary Engineering on County Road. Ideally, the town should work for removal of this hazardous-waste storage and transportation facility to another site off the aquifer, since no matter how safe the onsite procedures are, the risk of contamination through accidents cannot be eliminated. Accidents to vehicles coming and going from the facility are especially likely. However, since a DEQE license for the facility seems virtually certain, Southampton should require adequate monitoring wells at the very least.

Appendix

HAZARDOUS SUBSTANCES IN HOUSEHOLD PRODUCTS

CHEMICAL TYPE	HOUSEHOLD PRODUCTS	POTENTIAL HAZARDS
Asbestos (silicates)	asbestos cloth; brake and clutch linings; plastic filler; insulation and fire-proofing materials; pipes; roofing; (most of these no longer contain asbestos)	highly carcinogenic, microscopic particles may cause lung diseases and lung cancer; contact dermatitis
Chlorinated aliphatic hydrocarbons--(halogenated hydrocarbons, chlorinated paraffins) *carbon tetrachloride* (banned), *chloroform* (banned), trichloroethylene (TCE), trifluoroethane, perchloroethylene, trichloroethane (methyl chloroform), methylene chloride (dichloromethane), dichloropropane (aliphatic hydrocarbons that have some hydrogens replaced by chlorines are less flammable and better solvents than hydrocarbons, but decompose more slowly in the environment)	spot removers, degreasers; dry cleaners; paint & varnish removers; aerosols; metal cleaners; flame retardants; rust preventives; automotive cleaners; laundry-stain remover; drain cleaners; cesspool cleaners; refrigerants; waterproofing agents	slow decomposition; trichloroethylene & perchloroethylene are suspected carcinogens; trifluoroethane is suspected of damaging the earth's ozone layer; liver and kidney damage
Chlorinated aromatic hydrocarbons--chlorobenzene, dichlorobenzene, *polychlorinated biphenyls* (PCBs), chlorinated naphthalenes, chlorinated pesticides (DDT, *kepone*, etc.)	chemical deodorizers; pesticides; radiator cleaners; engine conditioners; leather dyes; wood preservatives; air-filter adhesives; capacitors & transformers (PCB); toilet cleaners	flammable; toxic, PCBs and DDT are banned; accumulate in the food chain
Chlorofluorocarbons--fluorocarbons, fluorinated hydrocarbons, halogenated hydrocarbons	aerosol propellants (banned); illegal drug (inhalant)	very slow decomposition rate means they reach the ozone layer and break it down; banned; toxic in high doses
Cutting Oils	welding and metal work	human carcinogen due to presence of a variety of nitrosamines; may cause dermatitis

HAZARDOUS SUBSTANCES IN HOUSEHOLD PRODUCTS

CHEMICAL TYPE	HOUSEHOLD PRODUCTS	POTENTIAL HAZARDS
Esters--methyl acetate, ethyl acetate, butyl acetate	solvents used in lacquers, varnishes, and paints	toxicity varies with specific chemical; causes eye, nose & throat irritation and anesthesia (dopy, drugged behavi
Ethers--ethyl ether, isopropyl ether, glycol ether	anesthetics; driveway degreasers	highly flammable; potentially explosive
Explosives--ammonium nitrate, NAFO, dynamite, mercury fulminate, nitroglycerin, 2,4,6-trinitrotoluene (TNT), watergel explosives	fireworks; blasting caps, detonators; ammunition	explosive; causes dermatitis, "dynamite headache;" can caus anemia and hepatitis
Gases--acetylene, ammonia, carbon monoxide, chlorine, ethyl chloride, hydrogen, hydrogen sulfide, methyl chloride, nitrogen dioxide, oxygen	welding gases; laboratory gases; local anesthetic aerosol cans; medical oxygen cylinders; refrigerants	asphyxiation; pulmonary edem skin and eye irritation
Glycols--methyl cellosolve, ethylene glycol, diethylene glycol, carbitol	solvents for resins, lacquers, inks, paints, varnishes, and dyes; antifreeze; lubricants; cosmetics; lacquers	poison by skin absorption, ingestion, and sometimes by inhalation; eye irritant; narcosis; kidney damage; anemia; 3 ounces of ethylene glycol can be fatal to adult
Ketones--acetone, methylethyl ketone, hexane, MIBK, MBK	nail-polish remover, paint, plastic, and resin solvent; general solvents; engine and radiator flushes	flammable, may cause respiratory ailments; toxic, toxicity varies with specific ketone
Lead	lead-based paints; rustproofers; printing ink; batteries; pesticides; some solders	damage to digestive, genito-urinary, neuromuscular, and central nervous system; anemi palsy; retardation and brain damage; lead paint illegal

HAZARDOUS SUBSTANCES IN HOUSEHOLD PRODUCTS

CHEMICAL TYPE	HOUSEHOLD PRODUCTS	POTENTIAL HAZARDS
Petroleum distillates-- petroleum ether; gasoline (petrol), white spirits, mineral spirits (Stoddard solvent), kerosene, fuel oil, lubricating oils, petroleum naphtha, lamp oil	fuels; anesthetics; household cleaners; hobby products; aerosol containers; cesspool cleaners; radiator flushes; metal polishes; auto additives; driveway degreasers; asphalt and roofing tar; paint thinners	highly flammable; associated with skin and lung cancer; irritant to skin, eyes, nose, throat, lungs; entry into lungs may cause fatal pulmonary edema
Sodium cyanide	pesticides	interferes with enzymes which supply oxygen to cells; may be fatal; irritates eyes and respiratory tract
Sodium hypochlorite	swimming-pool chlorine; laundry bleach	irritates skin, eyes, respiratory tract; may cause pulmonary edema and skin burns; may cause vomiting and coma if ingested, contact with other chemicals may cause chlorine fumes
Turpentine	dissolves waxes & oils; used in paint products; disinfectants; polishes; perfumes	skin, eye, throat irritation; central nervous system depressant; kidney damage

Sources: Benson, Nitsa, "Solvents in Consumer Products," from Solvents: Chemical Hazards in the Home.

Corbett, T.H., Cancer and Chemicals (Nelson-Hall, Chicago, Illinois), 1977.

McCann, M., Artist Beware (Watson-Guptill Publications, New York, New York), 1979.

Plunkett, E.R., Handbook of Industrial Toxicology (Chemical Publishing Co., Inc., New York, New York), 1976.

Town of Barnstable, Massachusetts, Board of Health.

Zamm, A.V. and R. Gannon, Why Your House May Endanger Your Health (Simon and Schuster, New York, New York), 1980.

*: Known carcinogens are marked with italics. Other substances may be added to the list of carcinogens in the future, pending the results of ongoi[illegible] tudies.

HAZARDS OF HOUSEHOLD PESTICIDES

PESTICIDE CATEGORIES	PESTICIDE NAMES	POTENTIAL HAZARDS
Urea, Uracil, and Triazine-based (herbicides)	Monvran*, Diuron, Linuron, Bromacil, Terbacil, Altrazine, Ametryn	low toxicity, but will irritate skin, eyes, throat

*These substances should not be used by the homeowner. They are banned or restricted-use pesticides.

Source: Benson, Nitsa. "Types of Pesticides Available," from Pesticides: Chemical Hazards in the Home.

ARTICLE 22: To see if the Town will vote to amend Section V, Use Regulations of the Easthampton Zoning Bylaw to control the removal of clay materials throughout town.

Zoning Amendment

Clay Excavation

On Use Table: Wholesale, Transportation and Industrial

Change:

1. Removal of sand, gravel, quarry or other raw material

to

1. Removal of sand, gravel, quarry, clay, or other raw material **provided that the removal of such material will not increase the threat of contamination to the groundwater as determined by a professional geologist, hydrogeologist, soil scientist or engineer trained or experienced in hydrogeology.**

ARTICLE 23: To see if the Town will vote to change and describe the boundaries of the Aquifer Protection District by revising the map "Aquifer Protection District of Easthampton".

Zoning Amendment

Aquifer Protection District

Description (Given for Town Meeting Information, not to be included in bylaw) -

The proposed overlay as shown on a map, "Aquifer Protection District of Easthampton" follows the existing boundary line from the intersection of Park Street and West Park Circle along Park and Line Streets, along the southern town border with Southampton and Holyoke, along the eastern border to the existing point where it turns west until it intersects with East Street. The boundary then follows Vadnais Street, Summit Street, and a straight line projection of Summit until it intersects with Broad Brook. The boundary then follows Broad Brook North, then follows a line from the northern end of the Brook to a point 400 feet north of the Nonotuck wellhead. From that point, the boundary follows a straight line southwesterly to the existing intersection with White Brook then along the existing boundary to the point of beginning.

[The revised map of the "Aquifer Protection District" is available for review at the Town Clerk's office.]

ARTICLE 24: To see if the Town will vote to amend Section XIII(A), Aquifer Protection District, of the Easthampton Zoning Bylaw.

In Section XIII(A), make the following changes:

1. Change definition of "Hazardous Material"

   "A substance or material which has been determined by the ~~secretary of transportation~~ **Department of Environmental Protection** to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce. Hazardous materials have been designated by the ~~U.S. Department of Transportation under 49CFR parts 171.8 and 173~~ **Department of Environmental Protection under Chapter 21C and 21E M.G.L and 310 CMR 30.130-136.**

2. Change (5)(b)(2) to read: "Excavation of or removal of earth, sand, gravel, **clay** and other soils shall not **be permitted.** ~~extend closer than ten (10) feet above high ground water table.~~ This section shall not apply to such ~~uses~~ **limited excavations** incidental to permitted uses including, but not limited to, providing for installation or maintenance of structural foundations, utility conduits or on site sewage disposal."

3. Add (5)(b)(5) to read: **"With the exception of bridges, the area within 75 feet of Broad Brook shall be kept in a natural vegetated condition and not altered in any way."**

4. Change (5)(c)(3) to read: "Storage and/or transmission of oil, gasoline, and chemicals in corrodible containers and pipelines, or **in underground storage tanks of any type.**"

5. Change (5)(c)(7) to read: "Rendering impervious by any means, more than twenty (20) percent of the area of any single lot, **or more than ten (10) percent of the area of lots of 35,000 square feet or more. In an Open Space Residential Development permitted under Section XVI of this bylaw, the space in the entire cluster minus the area of the roadways shall be considered in determining permissible lot coverage, rather than the space on individual lots. The permissible coverage shall be evenly divided among the individual lots on a pro-rated basis."**

6. Add (5)(c)(9) to read: **"Septic system components within 150 feet of Broad Brook."**

7. Change (6)(d)(4) to read: "Will not, during construction or site work or thereafter, have an adverse environmental impact on any watershed or watercourse in the district. A commercial forestry operation shall present a plan for cutting which provides safe temporary equipment storage, and follows the Massachusetts Forest Cutting Practices Act 304 CMR 11.00."

8. Add (6)(d)(6) to read: "Has, where required, provided the mechanism to assure on-site quality recharge. Assurance shall be given by a professional engineer."

9. Add (6)(d)(7) to read: "Will not promote the intensive use of pesticides. Golf courses must present an application schedule and list of pesticides to be used which will not contaminate the aquifer."

ARTICLE 25: To see if the Town will vote to amend the Easthampton Zoning Bylaw and the Zoning Map of the Town of Easthampton by adding two new zoning districts, R-40 Residential Aquifer Drift Area and R-80 Residential Aquifer Till Area, and to revise the use regulations accordingly.

In Section III, Establishment of Zoning Districts, make the following changes:

1. Add to (a):

Residential - Aquifer Drift Area	R-40
Residential - Aquifer Till Area	R-80

2. Change (b) to read: "Zoning Map. The location and boundaries of the zoning districts are hereby established as shown on a map titled "Zoning Map of the Town of Easthampton, Massachusetts," **dated May** 29, 1990 which accompanies and is hereby declared to be a part of this bylaw. The authenticity of the zoning map shall be identified by the signature of the town clerk, and the imprinted seal of the town under the following words: "This is to certify that this is the zoning map of the Town of Easthampton, Massachusetts, referred to in the zoning bylaw of the Town of Easthampton, Massachusetts, which was approved by the town meeting on **May 29, 1990.**"

[Map available for review]

In Section V, Use Regulations, make the following changes to Table 3. Use Regulations

Table 3. Use Regulations

	Principal Uses	R-40	R-80
RESIDENTIAL			
1.	One-family detached dwelling	P	P
2.	Multifamily dwelling	-	-
3.	Conversion of existing one-family dwellings to two-,three-, and four-family	-	-
COMMUNITY FACILITIES			
1.	Church or other religious purpose	P	P
2.	Educational purpose which is on land owned or leased by the commonwealth or any of its agencies, subdivisions, or bodies political; or by a non-profit educational corporation	P	P
3.	Public park, conservation area and preserved open spaces including areas for passive recreation, but not including active recreational facilities.	P	P
4.	Nonprofit recreational facility, not including a membership club	P	P
5.	Nonprofit country, hunting, fishing, tennis or golf club	S	S
6.	Day camp or other similar camping area	S	S
7.	Town building except highway equipment garage and electric utility garage	P	P
8.	Town cemetery, including any crematory therein	-	-
9.	Historical association or society	P	P
10.	Public libraries and museums	S	S
11.	Nursing, rest, or convalescent home	S	S

		R-40	R-80
12.	Hospital, sanitarium, or philanthropic institutions	S	S
13.	Street, bridge, railroad	P	P
14.	Town highway equipment and electric utility garage	-	-
15.	Public utility except power plant, water filter plant, sewage treatment plant, and refuse facility	P	P
16.	Essential services	P	P
AGRICULTURAL			
1.	Agriculture, horticulture, and floriculture except for a greenhouse or stand for retail sale		
	a. On parcels of 5 acres or under	P	P
	b. On parcels of over 5 acres	P	P
2.	Year-round greenhouse or stand for wholesale and retail sale of agricultural or farm products		
	a. Retail products	S	S
	b. Wholesale products	P	P
3.	Temporary (not to exceed erection or use for a period exceeding 3 months in any one year) greenhouse or stand for retail sale of agricultural or farm products raised primarily on the same premises	P	P
4.	Raising and keeping of livestock, horses, and poultry, not including the raising or swine or fur animals for commercial use	P	P
5.	Raising of fur animals and/or swine	-	-
6.	Commercial stables, kennels, or veterinary hospital in which all animals, fowl or other form of life are completely enclosed in pens or other structures	S	S

		R-40	R-80
7.	Noncommercial forestry and growing of all vegetation	P	P
8.	Commercial forestry	S	S

RETAIL AND SERVICE

		R-40	R-80
1.	Retail establishment selling principally convenience goods including but not limited to food, drugs,and proprietary goods	-	-
2.	Retail establishment selling general merchandise, including, but not limited to dry goods, apparel and accessories, furniture and home equipment, small wares, and hardware, and including discount and limited price variety stores	-	-
3.	Eating and drinking places not including drive-in establishments	-	-
4.	Drive-in eating establishments	-	-
5.	Sales by vending machines as a principal use	-	-
6.	Establishment selling new and/or used automobiles and trucks, new automobile tiers and other accessories, aircraft, boats, motorcycles and household trailers	-	-
7.	Motel	-	-
8.	Lodging house	-	-
9.	Personal and consumer service establishment	-	-
10.	Funeral establishment	-	-
11.	Membership club	S	S
12.	Professional and business offices and services	-	-

		R-40	R-80
13.	Automotive repair, automobile service station or garage (not including a junkyard or open storage of abandoned automobiles or other vehicles.	-	-
14.	Motor vehicle, machinery or other junkyard, provided it shall be screened from outside view by an enclosed solid fence or wall and gate at least 10 feet in height or by natural or topographic features	-	-
15.	Miscellaneous business repair services	-	-
16	Amusement and recreation service, outdoor	-	-
17.	Amusement and recreation service, indoor	-	-
18.	Communications, radio and television tower or station	S	-
19.	Antique or gift shop	S	S
20.	Reserved		
21.	Planned business development (see Section XI(C))	-	-
22.	Construction of drainage facilities other than essential services or damming up or relocating any watercourse, water body or wetlands	S	S

WHOLESALE, TRANSPORTATION AND INDUSTRIAL

		R-40	R-80
1.	Removal of sand, gravel, quarry, clay, or other raw material provided that the removal of such material will not increase the threat of contamination to the groundwater as determined by a professional geologist, hydro-geologist, soil scientist or engineer trained or experienced in hydrogeology.	-	-

2.	Process and treating of raw materials including operations appurtenant to the taking, such as grading, drying, sorting, crushing, grinding, and milling operations	-	-
3.	Construction trailers (temporary) while construction is in progress	S	S
4.	Transportation service facilities	-	-
5.	Open storage of raw materials, finished goods, or construction equipment and structures for storing such equipment provided it shall be screened from outside view by an enclosed solid fence and gate at least 10 feet in height, or a solid wall of evergreens when planted not more than 18 inches apart and at least 3 feet in height, and a solid gate at least 10 feet in height and not more than 20 feet in width.	-	-
6.	Research offices or establishments devoted to research and development activities	-	-
7.	Planned industrial development (see Section XI(d)	-	-
8.	Manufacturing	-	-
9.	Radioactive waste disposal. No land or structures within any use district in the Town of Easthampton may be used for the collection, treatment, storage, burial, incineration, or disposal or radioactive waste, including, but not limited to wastes classified as low-level radioactive waste, or for the garaging or temporary storage of vehicles used in the transportation of waste.		

		R-40	R-80
	Accessory Uses		
1.	Home occupation (see Section XI(e))	S	S
2.	Private day nursery or kindergarten, provided it shall not occupy more than 40 percent of the gross floor area of the structure; and there shall be a minimum of 100 square feet of outside play area for each enrolled child	S	S
3.	Accessory building such as a private garage, playhouse, greenhouse, tool shed, private swiming pool, or similar accessory structures, subject to provisions of Section VI	P	P
4.	Accessory private garage for not more than 3 noncommercial motor vehicles, and, except on a farm, not more than one-half ton-rate or less in size commercial motor vehicle. Subject to provisions of Section VI	P	P
5.	Accessory storage of a trailer, unregistered automobile or boat provided: it shall either be stored within a principal or accessory building or not less than 25 feet from any front line and not within the side yards; and it shall not be used for dwelling or sleeping purposes. Maximum number - two trailers, autos, or boats.	P	P
6.	Accessory repair and storage facilities in any retail sales or consumer establishment provided: it shall not occupy more than 25 percent of the gross floor area	-	-
7.	Keeping of a small flock (25 maximum) of poultry and saddle or riding horses and other farm animals, for use of occupants only	P	P

		R-40	R-80
8.	Accessory industrial and commercial uses to serve principal industrial and commercial uses respectively	-	-
9.	Accessory signs subject to the provisions of Section VII	P	P
10.	Accessory off-street parking and loading spaces as required in Section VIII	P	P
11.	Accessory uses which are necessary in connection with scientific research or scientific development or related production provided that the board of appeals finds that the proposed accessory use doe not substantially derogate from the public good.	S	S
12.	Removal of sand, gravel, quarry, clay, or other raw material provided that the removal of such material will not increase the threat of contamination to the groundwater as determined by a professional geologist, hydrogeologist, soil scientist or engineer trained or experienced in hydrogeology.	-	-
TEMPORARY			
1.	Temporary mobile homes to be placed on the same lot as a residence which has been destroyed by fire or other natural holocaust. Such temporary living quarters may remain on the lot for 12 months while the residence is being rebuilt. Any such mobile home shall be subject to the provisions of the state sanitary code.	P	P

In Section VI, Area, Height and Bulk Regulations, make the following changes:

1. Add to Table 4. Area Regulations to read:

District	Use	Minimum required lots: Area sq.ft.	Width ft.	Frontage ft.	Yards: Front ft.	Side ft.	Rear ft.
R-40	One-family detached year-round dwelling or other permitted structure or principal use	40,000		120	50	25	50
R-80	One-family detached year-round dwelling or other permitted structure or principal use	80,000		240	50	25	50

2. Add footnote 4 to read:

4 A special setback applies on both sides of Broad Brook in the Aquifer Protection District; see Section XIII(A)

3. Add to Table 5, Height and Bulk Regulations, to read:

District	Maximum permitted height, ft.	Maximum permitted height, stories	Maximum building coverage of lot (covered area as percent of total lot area)
R-40	35	2½	10
R-80	35	2½	10

4. In Section XVI, Open Space Residential Development, chasnge paragraph B to read:

"B. The Planning Board may grant a Special Permit for cluster development in the R-35, **R-40, and R-80** Districts upon the following terms and conditions:"