Aquifer Land Acquisition Study

Town of Easthampton, Massachusetts
September 1987

Volume I

DRAFT

Prepared For:

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Board of Public Works
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1.0 INTRODUCTION

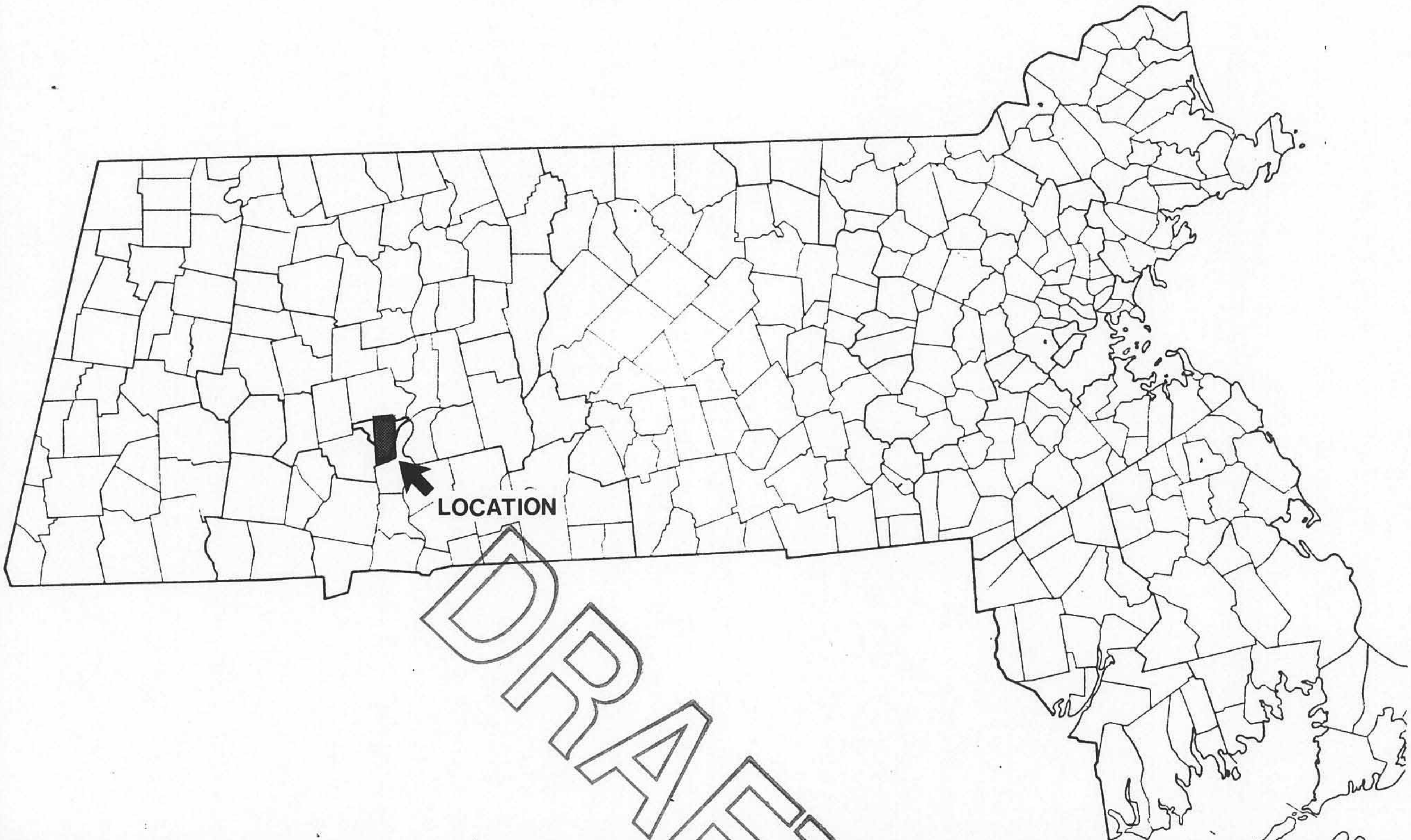
The Town of Easthampton in located in western Massachusetts, just west of Route 91 and north of the Massachusetts Turnpike. It is located in Hampshire County in the vicinity of Holyoke, Northampton, and Hadley, as shown in Figure 1.

This study was funded under the Chapter 286, Aquifer Land Acquisition (ALA) Program. The Town of Easthampton requested that 50,000 dollars of the 500,000 dollars be used to further define the Zone 2 and 3 areas of the Hendrick Street and Nonotuck Park Well fields, particularly the northern and southern extent of these Zones. Also, this study was intended to address the impact of potential contamination sources on the aquifer. The remainder of the money is to be spent to acquire strategic properties for the protection of the Easthampton Aquifer.

The ALA application was submitted jointly by the Towns of Easthampton and Southampton. Wagner Associates is conducting a similar Chapter 286, ALA Hydrogeologic Study in Southampton.

The Easthampton Aquifer provides the Town with 100 percent of its water supply. The aquifer system, of which the Easthampton Aquifer is a part, extends regionally from Northampton to Southwick. Since aquifer systems seldom are confined within Town boundaries, coordination and cooperation, such as that between Northampton and Southampton, will aid in aquifer protection. Increasing development pressures make it imperative that steps be taken to protect Easthampton's ground-water supply.

Easthampton has already adopted an aquifer protection zoning by-law. This by-law protects the area south of Plain Street by limiting the use of salt, herbicide, hazardous chemicals, and subsurface waste disposal. More precise definition of the recharge areas of the Town's well fields and extension of the aquifer protection measures to include the entire aquifer recharge area will safeguard the future of this aquifer and its use as an abundant supply of potable water.



SCALE 1"=16miles

EASTHAMPTON, MASS.

AQUIFER LAND ACQUISITION STUDY

STUDY AREA LOCATION

FIGURE

IEP inc.

2.0 SCOPE

The scope of services provided as part of this study include the following.

1) Review, compilation, and evaluation of all available existing data;

   This review included the compilation of all existing well logs, pump tests, and water table records as well as any state and federal publications covering the hydrogeology of this area. All available pumping test information was evaluated.

2) Preparation of Initial Maps;

   The hydrology and geology of Easthampton were quantified using a series of maps including: 1) a surficial geologic map, 2) a water table topography map, 3) a potentiometric surface map, and 4) a clay isopach map.

3) Geophysical and Test Well Exploration;

   Seven electrical resistivity soundings and two monitoring well clusters of two wells each were installed in the central portion of the study area.

4) Computer Modeling and Zone Delineation;

   The McDonald-Harbough 3-Dimensional Ground-water Flow Model was used to delineate the primary recharge areas for the Hendrick Street and Nonotuck Well fields. This information was used along with other pertinent hydrogeologic information to identify Zones 1, 2, and 3 for each well field.

5) Land Use Survey;

   Land usage within Zones 1, 2, and 3 was identified and potential sources of contamination evaluated.

3.0 DATA REVIEW AND EVALUATION

All existing available hydrogeologic information was collected and reviewed. The information obtained at each subsurface data location was summarized in Table 1, Subsurface Data Points and each data point is located on Plate 1, Subsurface Data Points Map. The data points are listed in the table by year. For example, the symbol 1-87 indicates the first boring drilled in 1987. Listed below is a summary of the information which was reviewed and compiled as part of this phase of work. The information below is listed by well field and then any additional hydrogeologic sources of information follow.

Lovefield Street (Maloney Property) Well Data:

1956 - In March, 1956, data on test well drilling, water quality testing and the results of a pump test were presented in a report prepared by Tighe and Bond Inc. of Holyoke, Massachusetts. The work was performed at the Lovefield Street Well station (Maloney Property). Fourteen test wells, both two-inch and two-and-one-half-inch diameter, were drilled. The pump test was performed for seven days on an eight-inch diameter well.

1975 - A report was submitted to the Massachusetts Department of Environmental Quality Engineering (DEQE) by Tighe and Bond requesting that an eight-inch diameter pumping well at the Lovefield Street site be allowed as a municipal water supply for the Town of Easthampton with a maximum capacity of 1.5 million gallons per day (MGD). The report includes test well logs, pumping test data, and water quality data.

Nonotuck Park Well Data:

1959 - An eight-inch diameter well was installed in December 1959. The depth of the well is 168 feet. A pump test was performed on the well in December 1959. In January 1960, the DEQE approved this well as a public water supply for the Town of Easthampton.

Twelve test wells were drilled in the vicinity of Nonotuck Park by R. E. Chapman, Inc. in October 1959. Screens were left in place for five of these test wells.

1962 - An eighteen-inch diameter well was installed in May 1962. Two pump tests were performed on this well, one in June and one in August 1962. IEP, Inc. was able to obtain the data from both of these pumping tests. The data from the pump test is included in Appendix A.

1982 - Nonotuck Park Well No. 6 (eighteen-inch diameter) was cleaned by R. E. Chapman Co. when the drawdown in the well increased dramatically over a short period of time.

TABLE 1

Town of Easthampton
Subsurface Data Points Table

Well #	Date Drilled	Driller	Type Well	Diam. (inches)	Depth (feet)	Soil Logs		Well Yield (gpm)	Water Level (feet)	Remarks
Easthampton Test Well Installation										
10-56	02/56	Chapman	T.W.	2	156	Gravel	0-8	100	3.2 A.G.	Well @ 136' Refusal (not ledge) 156'
						Clay	8-65			
						Sand + Gravel	65-156			
11-56	02/56	Chapman	""	"	138	Gravel	0-8			
						Clay	8-40			
						f. Sand & Silt	40-135			
						Gravel + Bedrock	135-138			
12-56	"	"	" ""	"	128	Sand + Gravel	0- 8	42	5	Pipe @ 116'
						Clay	8-100			
						f. Sand	100-120			
						Gravel	120-128			
13-56	"	"	" ""	"	185	Clay	0-3	73	6.5' A.G.	Well flows @ 20+ gpm @ ground level
						Gravel	3-16			
						Sand + Clay	16-110			
						Sand Gravel	110-185			
14-56	"	"	" ""	2.5	119	Clay	0-108			
						Silty sand, Clay	108-119			
15-56	"	"	" ""	8	208	Sand	0-5	825	2+' A.G.	Well set 100' pump test performed
						Clay	5-130			
						f. Sand	130-205			
						Clay	205-208			
8" Production Well - Hendrick Street										
1-53	12/53	"	" W.S.	8	121	Clay	0-9	800	overflowing Well @ 101.5'	
						f-c Sand + Gravel	9-110			
						Clay + Sand	110-118			
						Bedrock	118-121			

Note - Water levels measured from top of casing
Abbreviations: T.S. - Test Well; W.S. - Water Supply Well; E.R. - Electrical Resistivity Line; S.L. - Seismic Line; NIA - no information available

Town of Easthampton
Subsurface Data Points Table

Well #	Date Drilled	Driller	Type Well	Diam. (inches)	Depth (feet)	Soil Logs		Well Yield (gpm)	Water Level (feet)	Remarks
Production Well - Hendrick Street, The Pines										
1-57	05/57	" "	W.S.	10	98	Fill f. Silty Sand, Clay c. Sand f. Silty Sand f. Sand Till Bedrock	0-5 5-70 70-75 75-94 94-96 96-98 98	725	6.5′	Well set @ 69.5′
Easthampton Test Well Installation										
1-59	12/59	" "	W.S.	8	168	Clay Gravel f. Sand + Clay	0-106 106-165 165-168	670	8.17	Well set @ 149′
7B-59	10/59	" "	T.W.	2	136	f. Sand Clay Gravel	0-16 16-105 105-136	133	70	3.08 Well set @ 125′
1-56	02/56	" "	T.W.	2.0	120	Gravel Till Clay f. Sand Bedrock	0-13 13-74 74-120 120′	—	10	
2-56	02/56	" "	T.W.	2	109	f. Sand Clay f. Silt + Clay Bedrock	0-9 11-75 75-109 109	—	—	
3-56	02/56	" "	T.W.	2	60	Clay Gravel f. Silt + Clay Gravel + Bedrock	0-3 3-12 12-57 57-60	—	—	

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Town of Easthampton
Subsurface Data Points Table

Well #	Date Drilled	Driller	Type Well	Diam. (inches)	Depth (feet)	Soil Logs		Well Yield (gpm)	Water Level (feet)	Remarks
4-56	02/56	" "	T.W.	2	140	Sand	0-12	—	—	
						Gravel	12-22			
						f. Silt + Clay	22-138			
						Gravel + Bedrock	138-140			
5-56	02/56	" "	T.W.	2	175	Gravel	0-6	80	3.5	Top of pipe 6" A.G. Pipe in @ 157"
						Clay	6-30			
						f-m Sand	30-150			
6-56	02/56	" "	T.W.	2	126	Gravel	0-15	—	—	
						f. Silt, Clay	15-126			
						Bedrock	126			
7-56	02/56	" "	T.W.	2	68	f. Silt + Clay	0-50	20	15	Refusal not on ledge
						f. Sand	50-68			
						Refusal	68			
8-56	02/56	" "	T.W.	2	98	Clay	0-4	60	13.33	Pipe in @ 84′
						f. Silt	4-80			
						Sand	80-98			
9-56	02/56	" "	T.W.	2	114	Clay	0-4	75	12	Pipe in @ 105′
						Gravel	4-13			
						Clay	13-35			
						f. Sand	35-104			
						Gravel	104-118			
8B-59	10/59	" "	T.W.	2.5	196	Clay	0-49	75	3 A.G.	Well left in 139′
						c. Sand + Gravel	49-62			
						f. Sand	62-78			
						f. - m. Gravel	78-94			
						f. - m. Sand	94-135			
						Sand + Gravel	135-146			
						Refusal	146			

Note - Water levels measured from top of casing

Abbreviations: T.S. - Test Well; W.S. - Water Supply Well; E.R. - Electrical Resistivity Line; S.L. - Seismic Line; NIA - no information available

Town of Easthampton
Subsurface Data Points Table

Well #	Date Drilled	Driller	Type Well	Diam. (inches)	Depth (feet)	Soil Logs		Well Yield (gpm)	Water Level (feet)	Remarks
9B-59	11/59	" "	T.W.	2.5	173	Clay ——— f.-c. Sand/Gravel – Refusal ———	0-70 70-173 173	70	0.0 A.G.	Well set @ 153′
10B-59	11/59	" "	T.W.	2.5	163	Clay ——— Sand + Gravel ———	0-90 90-163	73	2.5	Well set @ 46′ 10"
11B-59	11/59	" "	T.W.	2.5	115	Clay ——— f. Gravel ———	0-104 104-115			Well for observation only @ 106′
Production Well										
1-62	5/62	" "	W.S.	18	165	Clay ——— Sand + Gravel ———	0-97 97-165	—	10.67	Well set @ 148′
White Brook, Middle School										
1-72	9/72	" "	T.B.	2	51	Clayey Silt ——— Sandy Silt ——— Shale ———	0-41 41-46 46-51	—	Net @ 16′	No well Installed
2-72	9/72	" "	T.B.	2	49	Clayey Silt ——— Shale ———	0-44 44-49	—	Net @ 16′	No Well Installed
Fish & Wildlife Test Borings										
25-80	3/81	Sullivan	T.W.	2.5	73	Sand ——— Clay ——— Sand, some Clay — Clay, Till ——— Refusal ———	0-10 10-60 60-65 65-73 73	—	—	
26-80	3/81	" "	T.W.	2.5	70	Sand ——— Clay ——— Refusal ———	0-10 10-70 70	—	—	

Note - Water levels measured from top of casing
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Town of Easthampton
Subsurface Data Points Table

Well #	Date Drilled	Driller	Type Well	Diam. (inches)	Depth (feet)	Soil Logs		Well Yield (gpm)	Water Level (feet)	Remarks
27-80	3/81	" "	T.W.	2.5	163	Sand Clay Silty Sand Refusal	0-10 10-120 120-163 163	—	—	
28-80	3/81	" "	T.W.	2.5	107	Sand Refusal	0-107 107	45	7.5 A.G.	Well Potential 150-250 gpm
29-80	3/81	" "	T.W.	2.5	187	f. Sand, Silt/Clay Refusal	0-187 187	—	—	
Town Test Wells										
1-86	12/86	Chapman	T.W.	2.5	191	Sand + Gravel Silt + Clay Silty Sand + Clay f. Sand f.-c. Sand + Gravel v. fine-m. Sand, Silt	0-9 9-30 30-60 60-95 95-154 154-191	—	36.4	
2-86	12/86	" "	T.W.	2.5	166	Sand + Gravel Clay Clay, Sand + Gravel Silty Sand Sand + Gravel Refusal	0-13 13-66 66-86 86-105 105-166 166	10	31.70	Well set @ 146′
3-86	12/86	" "	T.W.	2.5	114	Sand + Gravel Clay Silty Sand + Clay Sand + Gravel Refusal	0-6 6-78 78-94 94-114 144	30	22.2	Well set @ 110′
4-86	12/86	" "	T.W.	2.5	112	Sand + Gravel Clay Silty Sand + Clay Sand + Gravel	0-6 6-78 78-94 94-112	—	25.51	Well set @ 112′ No refusal

Note - Water levels measured from top of casing

Abbreviations: T.S. - Test Well; W.S. - Water Supply Well; E.R. - Electrical Resistivity Line; S.L. - Seismic Line; NIA - no information available

Town of Easthampton
Subsurface Data Points Table

Well #	Date Drilled	Driller	Type Well	Diam. (inches)	Depth (feet)	Soil Logs		Well Yield (gpm)	Water Level (feet)	Remarks
5-86	12/86	" "	T.W.	2.5	155	Sand + Gravel ———	0-13	10	31.47	Well set @ 155′
						Clay ———	13-86			
						Sand, Gravel + Clay —	86-105			
						Sand + Gravel ———	105-155			
USGS										
106	8/52	" "	T.W.	6.0	—	———		—	48	
114	9/49	Becker	T.W.	6	83	———		12.5	17	Well set @ 26′
2	8/44	" "	Ind.	—	400	———		600	—	Bedrock well
1	NIA									
3-10	NIA									
11-69	NIA									
6	NIA									
141	NIA									
142	NIA									
200	NIA									
202	NIA									
203	NIA									

DRAFT

Note - Water levels measured from top of casing
Abbreviations: T.S. - Test Well; W.S. - Water Supply Well; E.R. - Electrical Resistivity Line; S.L. - Seismic Line; NIA - no information available

Town of Easthampton
Subsurface Data Points Table

Well #	Date Drilled	Driller	Type Well	Diam. (inches)	Depth (feet)	Soil Logs	Well Yield (gpm)	Water Level (feet)	Remarks
IEP Test Wells									
1-87	2-87	Guild	T.W. (Two-well Cluster)	2	182 50	f Sand — 0-1 f-c Sand — 1-5 f-m Sand — 5-9 f Sand + silt — 9-47 f Sand + silt, tr clay 47-69 f-m Sand, tr silt — 69-117 f-c Sand, s silt — 117-169 Silt, tr vf sand — 169-182			No mud used; 4" casing to 180′; 4" casing to 19′ in shallow boring
2-87	2-87	"	"	"	59 15	f Sand + silt — 0-6 Silt, tr vf sand — 6-50 f-c Sand + silt — 50-55 Boulder (?) — 55-59			Laminae from 0-50′ Mud used in deep boring; Casing to 9′ in shallow boring
Electrical Resistivity Surveys									
ER-1	1-87	Kick	E.R.		NA				
ER-2	2-87	"	"		"				
ER-3	2-87	"	"		"				
ER-4	2-87	"	"		"				
ER-5	2-87	"	"		"				
ER-6	2-87	"	"		"				
ER-7	2-87	"	"		"				
Seismic Surveys									
S-1	6-81	Berndt	S		NA				
S-2	6-81	"	"		"				
S-4	6-81	"	"		"				
S-5	6-81	"	"		"				

Note - Water levels measured from top of casing

Abbreviations: T.S. - Test Well; W.S. - Water Supply Well; E.R. - Electrical Resistivity Line; S.L. - Seismic Line; NIA - no information available

1986 - Nonotuck Park Well No. 6 was again cleaned by R. E. Chapman Co., increasing its capacity by approximately forty percent. The Water Department has a summary of well drawdowns for Well No. 6 for June through September 1986.

Hendrick Street Well Data:

1953 - In December 1953, an eight-inch well was installed and a pump test was performed by R. E. Chapman Co. The data for this pump test are included in Appendix B.

1956 - In May 1956, R. E. Chapman Co. performed test well drilling in the vicinity of the Hendrick Street Well field. IEP, Inc. has incomplete well logs for this well drilling, but it appears that at least thirteen wells were drilled.

1957 - The Pines - In April 1957, five test wells were drilled by R. E. Chapman in the vicinity of the now existing pumping well called The Pines (near the Hendrick Street Well field). In May 1957, a pump test was performed on a ten-inch test well installed at this site. Data from the pump test are included in Appendix C.

R. E. Chapman Co. cleaned fifty wells in the Hendrick Street Well field. Improvements in well yields were reported by R. E. Chapman.

1959 - During May, June, and July 1959, thirty new wells were installed by R. E. Chapman in the Hendrick Street Well field. IEP, Inc. obtained complete logs of these test wells, including a description of well construction and well yields.

1961 - Ten new wells were installed at the Hendrick Street Well field. A ten-inch gravel pack well was rehabilitated by R. E. Chapman.

1962 through 1965 - Ten wells were replaced each year in the tubular well field.

1964 and 1965 - The Holyoke Water Power Company of Holyoke, Massachusetts performed a series of flow measurements at the Hendrick Street Well field. These data are presented graphically on computation sheets.

1966 and 1967 - Ten new (additional) wells were installed both years in the tubular well field.

1968 - Most of the wells at the Hendrick Street Well field were cleaned. Static water table measurements before and after cleaning were recorded as well as the yield from the well after cleaning.

Well number B-1 was monitored twice daily from July to September 1968. The pumping rate and drawdown were monitored as well as the pump that was running at the time.

1986 - Information showed that cleaning of The Pines Well No. 5 resulted in a much greater yield from the well.

R. E. Chapman installed six test wells near the Nonotuck Park Well and conducted a small-scale pump test in one of the wells. Information on these borings and the pump test are included in Appendix D.

1986- The tubular well field at Hendrick Street was developed by R. E. Chapman. Data on yields from the individual wells are included in Appendix E.

Tighe and Bond Reports:

1946 - Report on future expansion of the Town's water system.

1953 - Report on Town's water supply and distribution.

1955 - Report on pumping test performed at Hendrick Street Well field (eight-inch test well).

1956 - Report and cost estimate for installing eight-inch test well at Hendrick Street Well field.

1957 - Report on developing an additional water supply for the Town. The report includes tests performed on the Hendrick Street Well field.

1959 - Report on the capacity of Hendrick Street Well field.

1960 - Letter explaining the head-capacity curve for two pumps at the Hendrick Street Well field.

1962 - Report on construction record, well log, and pump test log of an eighteen-inch well installed at Nonotuck Park.

1966 - Report on water supply, distribution, and pumping rates for all of the wells in the Town. The report also includes suggestions for increasing storage capacity in the Town.

1970 - Proposal for an engineering study of the Town's water supply system. The proposal includes a summary of when each system was installed in the Town and their yields.

1974 - Letter to the Town suggesting that a well similar to the one at Nonotuck Park be installed at the Lovefield Street site (Maloney property). Another letter was sent to the Town that compared the peak day, peak week, and peak month of pumping with the annual average water consumption for the years 1960-1973.

Water Quality Data:

A complete tabulation of water quality for all of the wells in the Town was kept from 1950 to 1982. Several more recent reports on water quality are also available.

Miscellaneous Reports:

There are several miscellaneous reports on the Town wells dating from 1978 to 1986. These reports include statistics supplied to the DEQE each year regarding the Town wells and distribution system, and water quality data from various years.

United States Geological Survey Reports:

Several reports are available from the United States Geological Survey (USGS) on the surficial geology and hydrology of the study area. The reports on hydrology include studies of streamflow and water quality in the Connecticut River Lowlands (Wandle and Caswell, 1977; Brackley and Thomas, 1978) and ground-water availability in the Connecticut River Basin (Frimpter, 1980; Walker and Caswell, 1977).

Several studies have been performed by the USGS on the distribution of unconsolidated deposits in the study area (Langer, 1979; Stone and others, 1979; Larsen, 1972). Studies have also been performed on the configuration of the bedrock surface in the Mt. Tom quadrangle (Londquist, and Larsen, 1976; Londquist, 1973).

Smith College Reports:

Three reports on the geology and aquifer characteristics of Easthampton were prepared by Smith College students under the direction of Professor Robert Newton. Berndt and others (1981) discuss the geology and aquifer characteristics of the Easthampton area. Included in the report are maps and figures showing the boundaries of the aquifer, the surficial geology in the Town, the potentiometric surface of the aquifer, and cross-sections through the aquifer area.

A study on ground-water contamination in the shallow water table aquifer near the Maloney Street Well was performed by Abrahams (1984). Fly ash and a white, clay-like substance composed of sodium hydroxide and calcite were disposed of in surface impoundments at the Warner Brothers Factory off Ferry Street approximately 1200 feet south of the Maloney Street Well. Abrahams (1984) concluded that the contaminated ground water is discharged to a tributary of the Manhan River before reaching the Maloney Street Well.

The geophysical properties of the aquifer near the Maloney Street Well were studied by Aubuchon and Gil (1986). Both seismic and electrical resistivity techniques were used to analyze the geology of Maloney Street Well area and the distribution of ground-water contamination in the area.

University of Massachusetts Reports:

The water quality, hydrogeology, and Pleistocene geology of the Hannum Brook Aquifer were studied by Walsh and Sackrey (1984). Surface water quality samples were collected to determine the migration of leachate near the Easthampton and Northampton landfills.

The hydrogeology of Rock Valley, immediately south of the Easthampton aquifer, was studied by Motts (1985) for the Town of West Holyoke. The surficial deposits were mapped, the aquifer parameters were determined, and a finite-difference computer simulation of the aquifer was performed in this study.

4.0 FIELD STUDIES

4.1 Geologic Reconnaissance

On November 11, 1986, Ms. Sarah Walen and Dr. James Hall of IEP, Inc., performed a geologic reconnaissance of the study area. The reconnaissance was performed to confirm and clarify some of the contacts on Larsen's (1972) map of surficial deposits. Subsequent geologic reconnaissance was performed by Mr. Michael Hudson and Mr. Gene McLinn of IEP, Inc. during February through April 1987.

4.2 Well Installation

During the last two weeks of January and the first week of February 1987, Guild Drilling Co. of East Providence, RI (Guild) installed two well clusters (PS-1 and PS-2) in Easthampton under the supervision of IEP, Inc. geologists. Clusters PS-1 and PS-2 are referred to as 1-87 and 2-87, respectively, in Table 1 and the Subsurface Data Points Map (Plate 1).

The test borings were installed using the drive-and-wash and rotary-wash methods. The wells were constructed of 2-inch inside diameter (ID) solid PVC riser pipe with 2-inch ID 0.020-inch factory-slotted screen. All the wells were finished flush to the ground and protected with a cast-iron road box. The annulus between the PVC well and the wall of the boring was filled with Ottawa sand and grouted to prevent flow of surface water through the annulus. The remaining annulus between the well and the boring wall was backfilled with sediments from each boring. Sediment samples were collected with a split-spoon sampler and a 140-pound hammer with a 30-inch drop. Samples were collected at lithologic changes as detected by the driller. Logs from the borings installed by Guild for this study are included in Appendix F.

Each cluster consisted of two observation wells, one screened in the glaciolacustrine deposits (Layer 1) and one screened in the glaciodeltaic deposits (Layer 2). Cluster PS-1 is located on Plain Street approximately 4000 feet west-southwest of the Hendrick Street Well field. The deep boring of the cluster (PS-1D) was installed to refusal at 182 feet below grade. Nineteen feet of 5-inch ID casing was used during well installation, and the remainder of the boring (160 ft) was installed with 4-inch ID casing. A 10-foot length of screen was installed at the base of the well with 172 feet of solid PVC riser pipe.

The shallow boring (PS-1S) was installed to a depth of 50 feet, with the lower 10 feet of the well screened and the upper 40 feet composed of solid PVC riser pipe. Fourteen feet of 4-inch ID casing was used during the well installation, and no drilling mud was required to keep the hole open.

Cluster PS-2 is located approximately 800 feet east of Strong Street. The deep boring (PS-2D) was installed to refusal at 59 feet below grade. Ten feet of screen was installed at the base of the well with 49 feet of solid PVC riser pipe. No casing was used, but drilling mud was used to keep the hole open during installation of the well.

The shallow boring (PS-2S) was installed to a depth of 15 feet, with the bottom 5 feet of the well screened and the remainder of the well solid riser. Four inch ID casing was installed to a depth of 9 feet, and the remainder of the well was drilled as an open hole.

4.3 Electrical Resistivity Soundings

Electrical resistivity soundings were performed for this study by John F. Kick, Ph.D. of Dunstable, Massachusetts (Kick). The full text of Kick's report is included in Appendix G. Geophysical field work was performed by Kick from the last week in January to the first week in February 1987. The soundings were used to determine the depth to ground water, the depth to bedrock, and the thickness of the aquifer's confining layer. The soundings were performed using the Schlumberger electrode configuration. Several of the soundings were performed very close to the test wells that Guild installed as part of this study in order to establish geologic control for the geophysical model calibration. Soundings ER-1 through ER-7 are located as shown in Plate 1. The soundings were performed mainly in the central third of the study area to refine the estimates of the thickness of the confining layer in the transition zone between the confined and unconfined aquifers.

5.0 GEOLOGY

5.1 Introduction

Understanding the geology of the study area, particularly the Mount Tom area west of the Holyoke Basalt ridge, is essential to accurately interpret the hydrogeology of the Nonotuck and Hendrick Street Well sites due to surficial and bedrock geology control of the occurrence and movement of ground water. Many of the boundary conditions used in the computer simulation of the aquifer system supplying the Nonotuck and Hendrick Street Wells are defined by actual changes in the geologic environment.

Both the surficial and bedrock geology of the Mount Tom area have been well studied. In 1898, the geology of the Mount Tom area as mapped and interpreted by Benjamin Kendall Emerson, was described in both the Holyoke Folio of the Geologic Atlas of the United States and as Monograph 29 under "The Geology of Old Hampshire County" published by the U.S. Geological Survey. A detailed interpretation of the surficial geology and a comprehensive review of the bedrock geology of the Mount Tom quadrangle are contained in the "Surficial Geology of the Mount Tom quadrangle, Massachusetts" (Larsen, F.D., U.S. Geological Survey, Open File Report No. 72-219, 1972). A study of the history of deglaciation and glacial readvance in the southern area of the Connecticut Valley in Massachusetts, including the Easthampton area, is described in an article entitled, "Deglaciation of the Southern Portion of the Connecticut Valley of Massachusetts" (Larsen, F.D. and Hartschorn, J.H. from "Late Wisconsinan Glaciation of New England" by Larson, G.J. and Stone, B.D.). Several smaller studies performed by students at Smith College and at the University of Massachusetts have added valuable insight into the geologic interpretation of the Mount Tom and Easthampton quadrangles. These studies are referenced in Section 3.0, Data Review and Evaluation.

Geologic logs from previous and on-going engineering and hydrogeologic studies performed in Easthampton have provided information about the geology of the study area. Additional subsurface exploration performed for this study has consisted of boring and monitoring well installation, and geophysical exploration in areas where geologic and hydrogeologic information was lacking. All of these data have been integrated in this geologic summary.

Discussion about the geology of the study area in this report will center around the surficial and bedrock geology of the Mount Tom and Easthampton quadrangles west of the Holyoke Basalt ridge. Emphasis will be placed on the surficial deposits which form the aquifer system studied.

5.2 Surficial Geology

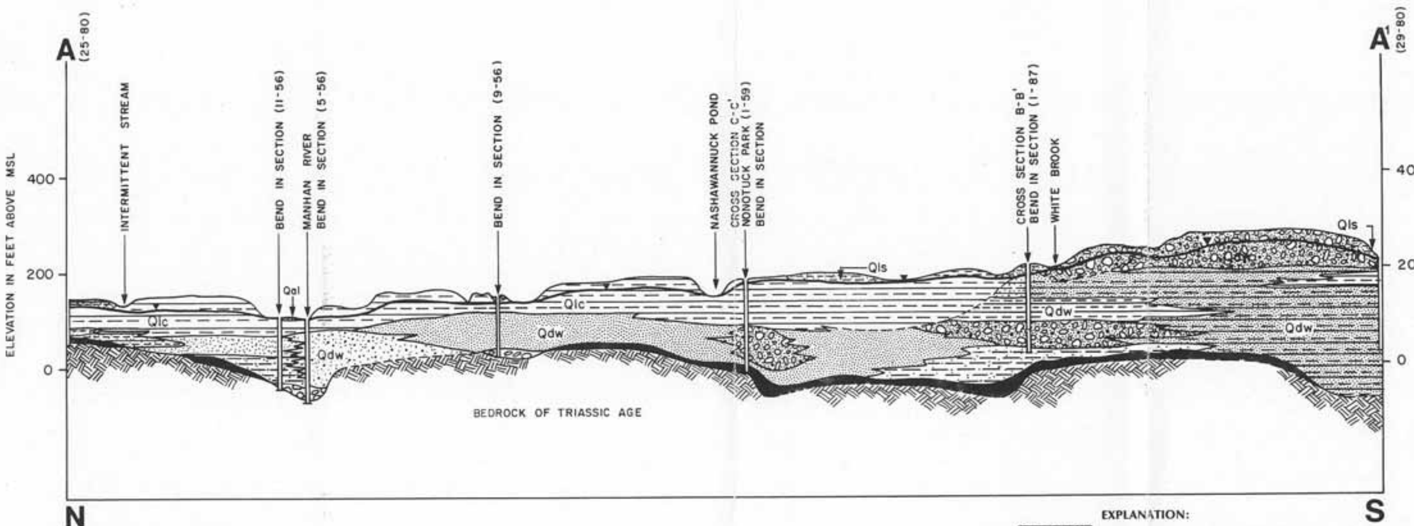
Surficial deposits in the study area have been strongly influenced by glaciation. Glacial deposits in the study area consist of till, ice-contact stratified drift, outwash deposits, glacial lake sediments and eolian (wind deposited) deposits. Comparatively small areas of generally thin deposits have been formed by more recent, post-glacial processes [consisting of man-made filling, fluvial deposition (alluvium), talus (bedrock wasting from weathering processes), wetland accumulation, stream terrace and wind deposition (eolian)].

Surficial deposits characteristic of the study area are shown on Plate 2 (after Larsen, F.D., 1972). Deposits are distinguished by depositional environment and, where possible, are grouped as land forms that constitute morphologic sequences presumed to have been contemporaneously deposited by meltwater as the continental ice sheet retreated. A north-south projected profile of glacial lake features in the Mount Tom quadrangle (after Larsen, 1972) show the relationship between some contemporaneously deposited sediments seen as landforms (see Figure 2). Also located on Plate 2 are three transects labeled A-A′, B-B′ and C-C′ along which geologic cross sections have been constructed to represent a three dimensional interpretation of the geology in the study area. Geologic cross sections A-A′, B-B′, and C-C′ are shown on Figures 3, 4, and 5, respectively.

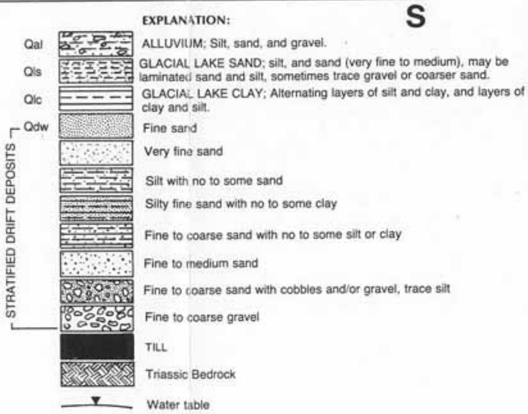
Movement or advance of the last continental ice sheet was to the south in the study area as indicated by drumlins, striations, and indicator stones (Larsen, 1972). West of the Holyoke Basalt ridge Larsen has observed two tills (Qt on Plate 2) deposited by that ice sheet; (1) a reddish-brown sandy till and (2) a grayish-brown till, both of which occur in the Easthampton quadrangle and in the north-central areas of the Mount Tom quadrangle.

Glacial retreat northward was characterized by an active ice lobe occupying the Connecticut Valley that readvanced several times. The readvance is evidenced outside the study area by till overlying deformed stratified drift or lacustrine deposits.

A series of proglacial lakes formed as the ice retreated. East of the Holyoke ridge, glacial Lake Hitchcock formed. West of the basalt ridge, Lake Westfield (graded to Harts Pond gap south of the study area) formed and was rapidly filled with river and meltwater sediments. Continued retreat of the ice margin to a position in the northern part of the Mt. Tom quadrangle diverted the lake drainage from Harts Pond gap to the Westfield gap, thus marking the end of Lake Westfield. At the time of the diversion, glacial Lake Manhan was formed between the ice front and the Timberswamp spillway located



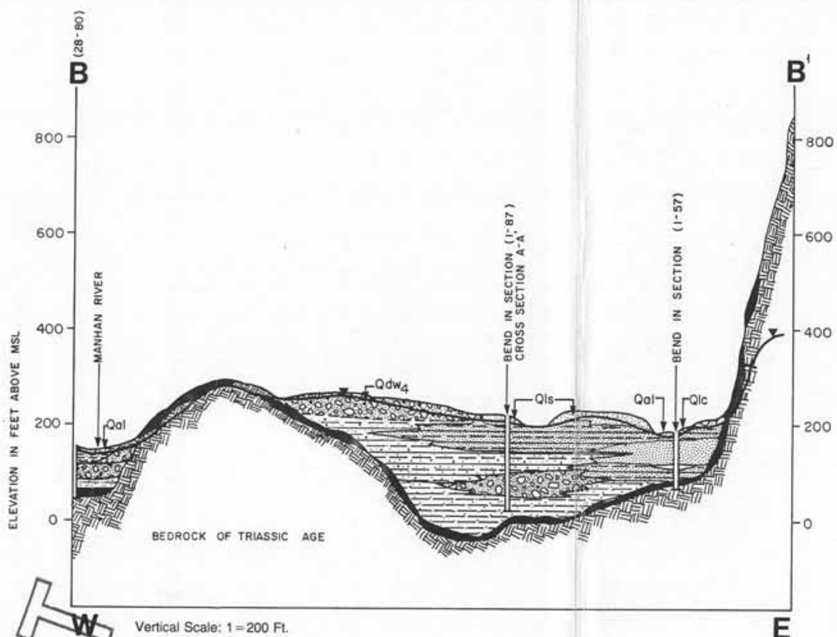
Vertical Scale: 1 = 200 Ft.
Horizontal Scale: 1 = 2083 Ft.
Vertical Exaggeration: 10.4X
Line of Cross Section Shown on Plate 1



EASTHAMPTON AQUIFER LAND ACQUISITION STUDY

JOB NO. EHO-1
AUGUST 1987

GEOLOGIC CROSS SECTION A-A[1]



Vertical Scale: 1 = 200 Ft.
Horizontal Scale: 1 = 2083 Ft.
Vertical Exaggeration: 10.4X
Line of Cross Section Shown on Plate 1

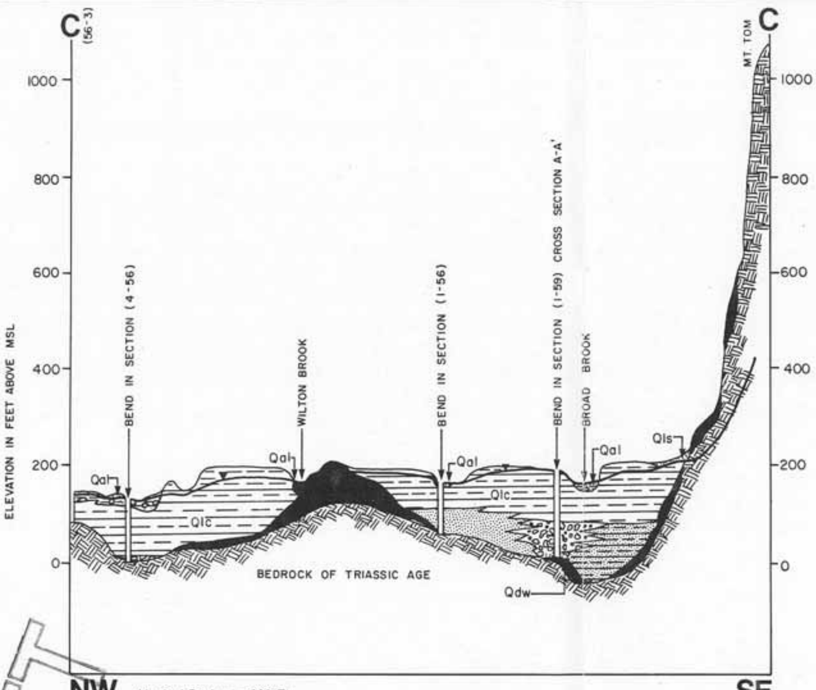
EXPLANATION:

- Qal — ALLUVIUM; Silt, sand, and gravel.
- Qls — GLACIAL LAKE SAND; silt, and sand (very fine to medium), may be laminated sand and silt, sometimes trace gravel or coarser sand.
- Qlc — GLACIAL LAKE CLAY; Alternating layers of silt and clay, and layers of clay and silt.
- Qdw — STRATIFIED DRIFT DEPOSITS:
  - Fine sand
  - Silt with no to some sand
  - Silty fine sand with no to some clay
  - Fine to coarse sand with no to some silt or clay
  - Fine to coarse sand with cobbles and/or gravel, trace silt
- TILL
- Triassic Bedrock
- Water table

EASTHAMPTON AQUIFER LAND ACQUISITION STUDY

JOB NO. EHO-1
AUGUST 1987

GEOLOGIC CROSS SECTION B-B[1]



Vertical Scale: 1 = 200 Ft.
Horizontal Scale: 1 = 2083 Ft.
Vertical Exaggeration: 10.4X
Line of Cross Section Shown on Plate 1

EXPLANATION:

Qal	ALLUVIUM; Silt, sand, and gravel.
Qls	GLACIAL LAKE SAND; silt, and sand (very fine to medium), may be laminated sand and silt, sometimes trace gravel or coarser sand.
Qlc	GLACIAL LAKE CLAY; Alternating layers of silt and clay, and layers of clay and silt.
Qdw (STRATIFIED DRIFT DEPOSITS)	Fine sand
	Silty fine sand with no to some clay
	Fine to coarse gravel
	TILL
	Triassic Bedrock
	Water table

EASTHAMPTON AQUIFER LAND ACQUISITION STUDY

JOB NO. EHO-1
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GEOLOGIC CROSS SECTION C-C[1]

in the west-central section of the Mt. Tom quadrangle. Progressive northward retreat of the ice margin from the Holyoke Narrows (northeast of the study area) caused the level of Lake Manhan to drop to that of Lake Hitchcock.

Identifying stratified drift deposits as parts of morphosequences graded to this sequence of lake levels has been used by Larsen to show that the retreating ice margin was lobate. West of the Holyoke ridge there is evidence of four stillstands or stages which resulted in the deposition of outwash deltas in proglacial lakes in the study area. These outwash deltas and other associated land forms are distinguished on Plate 2 from oldest to youngest as Qdw_2, Qdw_3, and Qdw_4. A table associating major landforms consisting of outwash deltaic deposits with glacial lake stages (morphosequences) follows. Figure 2 shows a graphic representation of these morphosequences.

TABLE 2

Deltaic Deposits Associated with Glacial Lake Stages in the Easthampton Area

STAGE	LAKE	DEPOSIT	DRAINAGE GAP
II	Manhan I	Barnes Delta (Qdw_2)	Harts Pond
III	Manhan II	Pomeroy Street Delta (Qdw_3)	Westfield
IV	Manhan III	White Brook Delta (Qdw_4)	Timberswamp/ Westfield

Lake Hitchcock-associated deposits formed after the drainage of Lake Manhan III are observed in the north-central area of the Mount Tom quadrangle, and in large areas of the Easthampton quadrangle. Drainage of glacial Lake Hitchcock, which transpired 10,700 years ago (Flint, 1956), caused a sudden drop in the base level of streams that graded to the lake, thus accelerating downcutting by streams. Evidence of such downcutting is seen outside the study area in the form of stream terraces.

All of the glacial sediments observed in the study area were deposited during and since the last major glaciation in the late Wisconsinan stage (which started roughly 75,000 years ago) of the Pleistocene epoch. The Pleistocene is the earlier of two epochs in the Quaternary which started roughly 2 to 3 million years before present. More recent post-glacial deposition occurred during the Holocene epoch, which started roughly 8,000 years ago, the later of the two epochs in the Quaternary. Each deposit is described below in order of deposition from oldest to youngest. Table 3 lists the deposits for ease of reference.

TABLE 3

Glacial and Post-Glacial Deposits
(Listed By Convention from Youngest to Oldest)

Deposit	Geologic Time
Alluvium Talus Peat Stream-terrace Eolian	Holocene
Lacustrine sediments Outwash deposits Ice-contact deposits Till	Late Wisconsin

5.2.1 Glacial Till (Qt)

Generally, till consists of poorly sorted, unstratified clay through boulder sized sediment deposited from or beneath glacial ice. Very little till was actually observed in borings performed for this study. Areas underlain by till were more frequently identified during the geologic reconnaissance through topographic interpretation. Thin and discontinuous deposits of till have been identified by Larsen on the Holyoke Basalt ridge. Thin deposits of till, punctuated by occasional exposures of the Sugarloaf Formation, cover the Whiteloaf Mountain high which extends from the north central region of the Mount Tom quadrangle southward. Other smaller areas underlain by till extend along Strong Street northward to Rubber Thread Pond, and along and east of Florence Road, west of Route 10.

Larsen contends that 50 percent of the Mount Tom quadrangle is underlain by three tills, two of which are represented in the study area (west of the Holyoke Basalt ridge). All of the tills are thought to be associated with the last major glaciation, are of equivalent age, and are interpreted as being deposited contemporaneously with the "upper" till.

The two tills that Larsen identified in the field area are a reddish-brown till and a grayish-brown till. The reddish-brown till is sand-rich and is derived mainly from the Sugarloaf Formation. The matrix ranges from 68.5 to 73.5 percent sand, 13.6 to 27.4 percent silt, and 2.6 to 15.2 percent clay by weight. He suggests that the best exposure of this till is on the east side of Route 10, six tenths of a mile north of Swanson Corners. The greyish-brown till is loose and sandy, and contains many clasts with silt caps. The matrix may consist of 57.6 to 70.0 percent sand, 20.5 to 32.6 percent silt, and 2.6 to 21.9 percent clay. This till occurs in the north-central area of the Mount Tom quadrangle.

5.2.2 Ice-Contact Stratified Drift (Qic)

Ice-contact stratified drift may consist of silt through cobble-sized sediment deposited by meltwater streams in, on, or adjacent to glacial ice. Features used to identify ice-contact deposits are the presence of 1) flowtill interbedded with stratified drift, 2) collapsed sedimentary structures resulting from melting ice below or adjacent to stratified sediments, 3) rapid changes in grain size, 4) large boulders contained in finer-grained sediments, and 5) sedimentary layers containing angular clasts. If some of these features are present, ice-contact deposits can also be recognized by several landforms: ice-channel fillings, kames, and kame terraces.

Kame terraces and ice channel fillings are the only ice-contact landforms represented in the study area. Kame terraces are flat-topped landforms composed of stratified drift that was deposited between the glacial ice and a wall of till or bedrock. Terraces are commonly elongate along a valley wall with a surface which slopes in the direction of meltwater flow at the time of formation. When the ice melted, the stratified drift, previously supported by the ice, collapsed forming a characteristic ice-contact slope toward the center of the valley.

Several examples of kame terraces located in the study area. On the east side of Broad Brook valley, roughly one (1) mile southwest of Mount Tom, kame terraces are labeled as part of the Qdw_3 or the Pomeroy Street delta sequence associated with Stage III of glacial Lake Manhan. Although somewhat irregular, the top of these terraces ranges between 270 and 285 feet above mean sea level (AMSL). A second set of kame terraces located between 1.4 and 2 miles southwest of Mount Tom level off at between 290 and just over 305 feet AMSL. These terraces are labeled Qdw_2 and are graded to the Barnes delta sequence associated with Stage II of glacial Lake Manahan. Sediments characteristic of both of these kame terraces consist of fine to medium sand of probable glaciolacustrine origin, variable amounts of cobbles, and pebble gravel with a matrix of medium to coarse sand.

Ice channel fillings are seen as narrow, elongate ridges that are comprised of melt-water deposited ice contact stratified drift. Ice channel deposits are classified as eskers which consist of melt-water sediments deposited in subglacial and englacial stream tunnels, and as crevasse fillings which consist of melt-water sediments deposited in open channels which surrounded blocks of stagnant glacial ice. One example of an ice channel filling is observed in the study area. It is located in the Easthampton quadrangle, 600 feet south of the Northampton town line and 1000 feet west of Florence Road. It is not known whether the ice channel deposit is an esker or a crevasse filling.

5.2.3 Outwash (Qdw)

Outwash consists of well washed, moderately to moderately well sorted sand and gravel and is deposited by high energy melt-water streams in a proglacial fluvial environment. Coarser sediments are deposited near the glacier and progressively finer sediments are deposited with distance from the glacier as the high energy of the melt-water streams drops off.

Landforms characteristic of outwash deposits evidenced in the study area are: heads of outwash which represent the terminus of the glacial ice during temporary stillstands and are formed during glacial retreat, associated outwash plains, and kettles (depressions) formed by melting stagnant ice buried by glaciofluvial sediments. Heads of outwash are frequently identified by an ice-contact slope that drops from the outwash surface towards the direction of ice movement. If, as is the case in the Easthampton area, a glacial lake is formed during the glacial retreat, outwash deposits are not deposited until the deltaic sediments reached the lake level, or new drainage outlets are uncovered.

In the Mount Tom quadrangle, outwash deposits consist largely of the topset beds of the deltas built into glacial Lake Manhan I (head of the Barnes delta). These are represented as Qdw_2 on Plate 2 along and 3 tenths of a mile south of Pomeroy Street). The second stage of Lake Manhan, Manhan II, head of the Pomeroy Street delta, is represented as Qdw_3 on Plate 2 parallel to and just northeast of Phelps Street. The third stage of Lake Manhan, Manhan III, head of the White Brook delta, is represented as Qdw_4 on Plate 2 just northeast of Strong street. Examples of kettles are the Hampton Ponds located at the southern extent of the study area.

5.2.4 Glacial Lake Sediments (Qlc and Qls)

Lacustrine sediments, deposited in the lakes that occupied the Easthampton area, range in grain size from pebble gravel to clay, and occur in small areas up to an elevation of 270 feet AMSL and more extensively below an elevation of 200 feet AMSL in stream valleys. Coarser lacustrine deposits consisting of sand and gravel are associated with shoreline and deltaic deposits. Shoreline or beach deposits of Lake Hitchcock, shown as Qb on the surficial map, were deposited in shallow water as a result of wave erosion of ice-contact deposits. An example of beach deposits associated with Lake Hitchcock is seen below the 250 foot elevation contour extending southward from the intersection of Hendrick Street and Route 141.

Delta foreset deposits consisting of pebble gravel to coarse sand are associated with the outwash deltas correlated with the glacial lake stages referenced in Table 2 (units Qdw_2, Qdw_3 and Qdw_4 on Plate 2). No exposures of foreset beds were observed in the study area, however Larsen notes the best exposure is in a gravel pit 1.65 miles southwest of Southampton village.

Fine-grained lake bottom sediments deposited in glacial Lake Hitchcock are most prevalent in the northern half of the study area extending northward from Plain Street towards Northampton and the Connecticut River (units Qls and Qlc). The finer deposits area characterized by thin beds of silt or fine sand alternating with variable thicknesses of clay. A likely explanation for how these units were formed is that the finer clays and silt were deposited during the winter when the lake was frozen over, and the coarser fine sand and silt layers were deposited during the melt season distributed by higher energy streams feeding the lake. The couplet or rhythmite composed of the two layers is called a varve. Larsen has distinguished lacustrine clay (Qlc) from lacustrine sand and silt (Qls) in the following manner: lacustrine clay is made up of clay-silt varves where clay layers constitute greater than 10 percent of the varve thickness and lacustrine sand and silt where are made up of deposits where the clay composes less than 10 percent of the varve thickness.

Varves dominating the northern part of the study area form the major confining layer influencing the Nonotuck Park well site. Thicknesses of varved clays observed in boring logs at the site range between 61 and 100 feet. Varves deposited in various stages of glacial Lake Manhan are observed along the western side of Whiteloaf Mountain in the Manhan River valley in the western edge of the study area.

5.2.5 Eolian Deposits

Eolian Mantle

An eolian mantle, or a blanket of wind blown sand, was deposited during deglaciation and before the Easthampton area was revegetated following glaciation. The source of mantle deposits was outwash to the west and northwest. Although present over most of the higher, older deposits, the eolian mantle is missing on the postglacial stream terrace deposits and on modern flood plains. The mantle is not shown on the Surficial Geology map (Plate 2) of the study area.

The eolian mantle is composed of poorly sorted to very poorly sorted fine and very fine sand with less amounts of medium, coarse and very coarse sand and silt. The mantle has no sedimentary structures, however weathering zones which have developed since sediments were deposited are evident. Thicknesses of up to 5 feet of mantle deposits have been observed in the study area. The contact between the mantle and underlying deposits is either sharp or gradational.

Sand Dunes (Qds)

Sand dunes which are shown on the Surficial map as Qds, were also formed by wind transport and deposition following glaciation. Dune sands area better sorted than eolian mantle sand, and are comprised largely of medium and fine sand. Examples of sand dunes in the study area are seen on outwash delta Qdw_3 between Phelps and Pomeroy Streets, and south of Pomeroy Street between County Road North and Broad Brook.

5.2.6 Stream Terrace Deposits (Qst)

Stream terrace deposits which were formed during late glacial and post glacial periods, are observed as nonpaired terraces along parts of all of the major rivers and tributaries in and proximal to the study area. Within the study area, terrace deposits associated with post-late Hitchcock are observed along the Manhan River on either side of the Conrail railroad track and west of the Manhan.

Terrace deposits range in thickness between 2 and 10 feet. Sediments comprising the terraces are moderately well, to moderately sorted loose, coarse sand with components of fine sand to pebble gravel.

5.2.7 Swamp Deposits (Qs)

Swamp deposits are observed throughout the study area occupying depressions that were produced by glacial activity. Glacial depressions are characterized by rock-scoured basins and are observed along the basalt ridge, and kettles that were formed by melting ice blocks in stratified drift.

The depressions were filled slowly with the accumulation of sediments and by organic debris generated by vegetation over time. Swamp deposits, estimated to range between 5 and 15 feet in thickness, are comprised of dark-brown peat, black organic muck, and dark gray sand, silt and clay.

5.2.8 Talus

Talus consists of slide blocks of bedrock (Holyoke Basalt), that have originated as a result of frost wedging of steep, west-facing cliffs of bedrock along the Mount Tom Range. Talus deposits are thin, and occur frequently over bedrock or till. Talus is not shown on the Surficial Geology map.

5.2.9 Alluvium Deposits (Qal)

Alluvium, represented as Qal on the Surficial Geology map, is observed on the flood plains of all stream and rivers in the study area. Broad, well developed plains of alluvium up to 20 feet above existing streams are evident along the Connecticut and Westfield Rivers. Alluvium observed along the Manhan River does not occur in broad plains, and is characterized by irregular topography consisting of scarps and former channels.

Alluvium is composed of moderately to poorly sorted fine sand and silt containing minor amounts of coarse sand and pebble gravel. In general, alluvium observed is finer grained than the stream-terrace deposits.

5.3 Bedrock Geology (TRu)

The study area is underlain by sedimentary and igneous rocks of the Newark Series of upper Triassic age. These deposits are flanked to the west, outside the study area, by crystalline rock of probable Carboniferous age. The Triassic sedimentary rocks which comprise the Sugarloaf Formation, are composed of conglomerate through arkosic sandstone, to siltstone and silty shale, all of which are of continental origin. Triassic igneous rocks in the study area, the Holyoke Basalt, are composed largely of tholeiitic basalts with minor amounts of volcanic agglomerate, breccia and tuff. The Holyoke Basalt is observed in the northeast corner of the Mount Tom quadrangle. The Triassic bedrock described is located in the northwest section of a large graben, the Hartford Basin, which is tilted between 20 and 25 degrees to the east-southeast.

The Carboniferous crystalline bedrock west of the study area consists of the Williamsburg Granodiorite which is characterized by a gray, fine to medium grained biotite granite with some muscovite. Exposures of the Williamsburg Granodiorite are seen in the northwest corner of the Mt. Tom quadrangle on the southeast slope of Pomeroy Mountain, an area which comprises part of the New England Upland section of the New England physiographic province. Outcrops observed west of the study are are well jointed.

The contact between the crystalline Carboniferous bedrock (Williamsburg Granodiorite) to the west and the Triassic rocks (Sugarloaf Arkose) to the east is a fault contact (perhaps the western border fault of the Hartford Basin described above) which extends along the foot of Pomeroy Mountain parallel to Red Brook. Triassic rocks dip gently westward into the eastward dipping fault.

Although not well exposed due to low resistance to weathering and to a thick cover of glacial drift west of the Holyoke Basalt ridge, the Sugarloaf Formation is the dominant formation underlying the study area. Some exposures are observed along Whiteloaf Mountain, Red Brook, and the Manhan River just west of the Holyoke Basalt.

Lithologies characteristic of the Sugarloaf Formation include a light to dark reddish-brown arkosic conglomerate, arkose, arkosic siltstone, and arkosic Shale. It is most commonly observed in the field as a reddish-brown, medium to coarse grained arkose with or without pebbles. Bedding plans, joints, and faults through which ground water has infiltrated, are observed to varying degrees in the lithologies exposed. Where ground-water infiltration has occurred, particularly along the Carboniferous/Triassic contact west of the study area, color changes in the lithologies from red-brown to greenish gray are evident.

The Triassic igneous unit, the Holyoke Basalt, is observed in continuous outcrop trending north 18° east from the center of the southeastern extreme of the Mount Tom quadrangle. The ridge of comparatively resistant basalt forms the west-facing cliffs on Mount Tom which border the eastern edge of the study area. The dip slope of the Holyoke Basalt forms the eastern slope of the Mount Tom Range.

The primary lithology characteristic of the Holyoke Basalt is a medium to dark-gray, very fine to fine-grained basalt which is dense and homogeneous in texture. Occasional textural variation is seen in coarse basalt pegmatite lenses (as seen on the crest of the Mount Tom Range).

Two structural features are observed frequently in the Holyoke Basalt. Sub-vertical to vertical columnar jointing which produces polygonal and triangular blocks of basalt is seen along the west-facing cliff of the Mount Tom Range. Sub-horizontal jointing (similar to sheeting) which generally dips in the direction of the basalt contact with the Sugarloaf Formation, is observed in most outcrops of basalt. A third, less obvious structural feature observed in the basalt is a series of tensional faults which have offset the Holyoke Basalt to varying degrees, as is evidenced by the irregular outcrop pattern of the basalt.

6.0 SURFACE WATER HYDROLOGY

6.1 Drainage Basin Overview

The chief surface water bodies draining the study area are Broad Brook, White Brook, and the Manhan River. Broad Brook is the major surface water feature draining the southern portion of the study area. The headwaters of Broad Brook are in the wetland on the southern slope of Mt. Tom (elevation 540 feet AMSL). Broad Brook drains the entire southern portion of the study area until it discharges to Nashawannuck Pond. Most of the runoff from the western slope of the Mt. Tom Range and the western slope of Whiteloaf Mountain flows to Broad Brook.

White Brook is a smaller stream whose confluence with Broad Brook is at Nashawannuck Pond (elevation 150 feet AMSL), a surface-water impoundment west of downtown Easthampton. White Brook drains a portion of the runoff that falls on the southern slope of Whiteloaf Mountain.

Wilton Brook is an intermittent stream that discharges to Rubber Thread Pond (elevation 150 feet AMSL). Nashawannuck Pond and Rubber Thread Pond drain to Lower Millpond (elevation 129 feet AMSL) at Holyoke Road. Lower Millpond discharges to the Manhan River (elevation 105 feet AMSL) at Lovefield Street.

White Brook, Wilton Brook, and Broad Brook are all grouped into the Broad Brook sub-watershed for this study, because Wilton and White Brooks flow predominantly on the confining layer of the Easthampton aquifer system. Flow divides among the sub-sub-watersheds are not expected to affect the flow of ground water, and consequently this simplification does not decrease the accuracy of this study.

The Manhan River flows into the study area at Main Street in Easthampton is the major surface water feature in the northern portion of the study area. The Manhan River drains to the Oxbow. The Oxbow (elevation greater than 100 feet) is the local base level for the study area. The Oxbow is a meander cutoff that is hydraulically connected to the Connecticut River.

6.2 Surface Watershed Boundaries

The boundaries of the study area are coincident with the surface water divides for the Broad Brook drainage basin. The local topographic high between Pequot Pond and Broad Brook in Southampton is a surface water divide that was used as the southern watershed boundary for the study area. The Mt. Tom Range forms the eastern boundary of the study area. The southwestern boundary of the study area is defined by Whiteloaf Mountain. The rest of the western boundary consists of the topographic high that extends north-northeast from the base of

Whiteloaf Mountain to the intersection of the Manhan River and Main Street in downtown Easthampton. The western boundary then extends to the top of the hill near Wilson and Florence Roads in Northampton. The northern boundary of the study area extends from the hill at the intersection of Wilson and Florence Roads east to the Oxbow. The Oxbow completes the northern boundary of the study area.

7.0 GROUND-WATER HYDROLOGY

7.1 Ground-Water Basin Overview

The boundaries of the study area are defined by the surface watershed boundaries as described in Section 6.2, Surface Watershed Boundaries. The ground-water flow divides are assumed to be coincident with the surface water divides. The ground-water flow directions are approximately coincident with the surface water flow directions in the study area.

The major aquifer in the study area consists of the glaciodeltaic deposits which are thought to be contiguous across the length of the ground-water basin, based on field work and data review performed for the study. A wedge of fine-grained glaciolacustrine deposits overlies the aquifer in the central and northern portions of the study area. The unconsolidated deposits are fully described in Section 5.2, Surficial Geology.

7.2 Ground-Water Flow Directions and Hydraulic Gradient

Ground-water flow in the study area is predominantly from south-southwest to north-northeast. Ground-water flow near the eastern and western boundaries of the study area is at an oblique angle to the regional flow direction before entering the central portion of the ground-water basin and veering to the north. Ground-water flow in the unconfined, southern portion of the aquifer is predominantly horizontal. Plate 3, the Water Table Topography Map, shows the simulated water table for the unconfined aquifer in the study area. As the aquifer becomes confined near the central portion of the study area, the vertical component of ground-water flow increases. The potentiometric Surface Map (Plate 4), generated during the modeling portion of this study, illustrates the head elevations for the confined aquifer. Artesian head at the pumping stations at Nonotuck Park, Hendrick Street, and Lovefield Street is between 5 and 10 feet above ground surface. The unconfined, southern portion of the study area is the major recharge zone for the confined aquifer in the central and northern portions of the study area.

The hydraulic gradient across the study area is 0.0042, from the 240 foot contour on Broad Brook to the 110 foot piezometric contour near the Manhan River. The surface water gradient across the same transect is 0.0043.

7.3 Ground-Water Supply

The study area uses ground water for essentially all of its water supply. Three pumping stations supply Easthampton with water: the Hendrick Street Well field; the Nonotuck Park Well; and the Lovefield Street Well field. Information in this portion of the report is derived from the Easthampton

Water Department data for 1985. All of the wells are screened in the confined portion of the aquifer, and all were developed by pumping. The Lovefield Street and Hendrick Street wells were cleaned during February 1986 by R. E. Chapman Co. The total estimated safe yield from the existing pumping stations is 6.1 MGD.

The Hendrick Street pumping station is supplied by a tubular well field composed of 106 two and one half inch diameter gravel-packed wells screened in the lower aquifer (yield = 2.9 MGD), two eight-inch diameter gravel-packed wells (in reserve), and a ten-inch diameter gravel-packed well (safe yield = 0.9 MGD). The estimated safe yield from this source is 3.8 MGD.

The Nonotuck Park well is an eighteen-inch diameter gravel-packed well. The safe yield from this well is estimated at 1.0 MGD. The well has very low efficiency because the screen is reported to be plugged with sand.

The Lovefield Street pumping station has one eighteen-inch diameter gravel-packed well. The safe yield from this well is estimated to be 1.5 MGD.

Water from the well fields is stored in a 1.7 million gallon reservoir on the western slopes of the Mt. Tom Range. The elevation of the surface of the full reservoir is 390 feet AMSL.

7.4 Aquifer Characteristics

In general, primary and secondary porosity characteristic of the geologic unit (s) will provide a major control over how ground water will behave in the environment. Geologic factors that define the porosity and permeability of geologic units are: grain size distribution, grain shape, how the grains are packed together, and the existence and characteristics of secondary features such as joints, fractures and faults. Porosity, expressed as a percentage, is a measure of the volume of pore space in a unit of geologic material compared to the total volume of that unit. Porosity thus represents potential ground-water storage space. Permeability, expressed in gallon per day per foot squared, is a term which describes the ease with which ground water will move through interconnected pore space is a geologic unit.

For example, sand and sand and gravel have moderate porosities and moderate to high permeabilities. Thus, moderate volumes of ground water can be stored in such deposits, and those volumes of water can move through the deposits with moderate to high ease. In contrast, although clay and clay and silt have relatively high porosities, permeability values, characteristics of both are extremely low. As a consequence, such deposits act as barriers or retardants through which ground water moves very slowly.

As a rule, undisturbed bedrock is characterized by variable but very low porosities and permeabilities. However, secondary structural features such as joints, fractures, and faults may create higher secondary porosity and permeability into which or through which ground water may flow. The jointing and faulting observed in both the Triassic sedimentary and igneous bedrock exemplifies secondary porosity and permeability.

The geomorphology of the geologic units, combined with the type and density of vegetation growing on the units will influence their recharge characteristics. In general, gentle slopes and more permeable, moderately vegetated geologic units will maximize the amount of recharge to the ground water.

As previously noted, three geologic cross sections (Figures 3, 4, and 5) have been constructed along transects A-A′, B-B′, and C-C′ in the study area. Cross section A-A′ (Figure 3) which is oriented roughly north-south through the Nonotuck Park well site bisecting most of the study area, shows a geologic interpretation of the relationship between the geologic units supplying ground water to the well. Clearly depicted in the cross section is the massive clay unit which is responsible for the artesian characteristics aquifer supplying the Nonotuck well and the bedrock horizon which represents the lower confining layer of that aquifer. Also clearly shown is the absence of the clay unit in the southern end of the study area, however the unit does extend continuously northward across the remainder of the study area.

Cross sections B-B′ and C-C′ were constructed across the length of the study area in order to further describe the dimension of the aquifer system in the study area, and to establish the eastern and western boundaries of the aquifer utilized in the computer model. Cross section B-B′ represents the aquifer configuration in the vicinity of the Hendrick Street well site (as seen near the bend in section at 1-57).

Data from pump tests conducted at the Nonotuck Park and Hendrick Street Well fields by R.E. Chapman Co. of Oakdale, Massachusetts were analyzed to determine the characteristics of the Easthampton aquifer. The 12-day pump test at the eighteen-inch diameter Nonotuck Park well was performed in July 1962; the 24-hour pump test in the eight-inch diameter well at Hendrick Street was performed in May 1957; the 24-hour pump test for the ten-inch diameter well at Hendrick Street was performed on December 1953. No analysis was performed on pumping test data from the Lovefield Street well.

All available aquifer test data were analyzed using straight-line techniques (for example, Cooper and Jacob, 1946) including time-drawdown, distance-drawdown, and time-recovery. Curve matching techniques were also used to calculate the transmissivity and storativity values in the vicinity of each pumping well.

The aquifer test information was input into a Pump Test Analysis Program written by Hall Ground-Water Consultants, Inc., located in St. Albert, Alberta, Canada. This program outputs the semi-log plots for all the straight line analytical methods as well as the log-log plots for use with curve matching techniques. The calculation of transmissivity and storativity using the straight line methods was also performed with the Pump Test Analysis Program. Curve matching and calculation of transmissivity and storativity using the log-log plots were performed manually. Transmissivity and storativity data are summarized in Table 4.

TABLE 4. RESULTS OF ANALYSIS OF PUMP TESTS PERFORMED AT NONOTUCK PARK AND HENDRICKS STREET WELLS

OW #	T ($ft^2/d \times 10^3$)	S	Q (gpm)	Method	Comments
Hendricks Street 8-Inch Well					
W2-A	15	0.00068	800	Theis	Tubular well field running at 0.9 MGD during test
	102	0.0076	"	CJ SLA	Early time
	156	0.0023	"	CJ SLA	Late time
	142	0.0041	"	CJ SLA	All times
W2	1.6	0.04	"	Theis	
	119	0.0037	"	CJ SLA	Late time
	68	0.039	"	CJ SLA	Early time
	86	NP	"	CJ SLA	RA
W4	87	NP	"	CJ SLA	RA
	53	0.0053	"	CJ SLA	
	137	NP	"	CJ SLA	
NA	57	0.00005	"	CJ SLA	Distance-drawdown
	16	0.17	"	CJ SLA	Distance-drawdown
Hendricks Street 10-Inch Well					
OB4	1.1	0.114	725	Theis	
	35	0.0026	"	CJ SLA	
	38	NP	"	CJ SLA	RA
OB5	1.3	0.022	"	Theis	
	57	NP	"	CJ SLA	
	52	NP	"	CJ SLA	RA
	23	NP	"	CJ SLA	RA
Nonotuck Park 18-Inch Well					
7B	41	0.00028	681	Theis	
	25	0.00035	"	CJ SLA	
	22	NP	"	CJ SLA	RA
8B	39	0.0017	"	Theis	
	34	0.70	"	CJ SLA	
	21	NP	"	CJ SLA	RA

Abbreviations: NA-Not Applicable; CJ SLA-Cooper-Jacob Straight-Line Approximation; RA-Recovery Analysis; OW-Observation Well; T-Transmissivity; S-Storativity; Q-Discharge; NP-Not Performed

TABLE 2. RESULTS OF ANALYSIS FROM PUMP TESTS PERFORMED AT NONOTUCK PARK AND HENDRICKS STREET WELLS (Cont.)

OW #	T ($ft^2/d \times 10^3$)	S	Q (gpm)	Method	Comments
Nonotuck Park 18-Inch Well					
9B	25	0.0024	681	Theis	
	31	0.0015	"	CJ SLA	
	22	NP	"	CJ SLA	RA
10B	14	NP	"	Theis	
	17	0.52	"	CJ SLA	
	52	NP	"	CJ SLA	RA; Late time
	20	NP	"	CJ SLA	RA; Early time
NA	44	0.000001	"	CJ SLA	Distance-drawdown
9B	19	0.0061	1080	Theis	
	24	0.0059	"	CJ SLA	
	27	NP	"	CJ SLA	RA
10B	22	0.57	"	Theis	
	17	0.52	"	CJ SLA	
	52	NP	"	CJ SLA	RA; Late time
	20	NP	"	CJ SLA	RA; Early time
11B	17	0.0064	"	Theis	
	21	0.0043	"	CJ SLA	
	27	NP	"	CJ SLA	RA
13B	20	0.15	"	Theis	

Abbreviations: NA-Not Applicable; CJ SLA-Cooper-Jacob Straight-Line Approximation; RA-Recovery Analysis; OW-Observation Well; T-Transmissivity; S-Storativity; Q-Discharge; NP-Not Performed

8.0 GROUND-WATER FLOW MODELING

8.1 Purpose

The purpose of the modeling portion of the study is to define the primary and secondary recharge areas for the Nonotuck Park and Hendrick Street Well fields according to the criteria outlined in MGL c. 286. This Subsection follows the quality control/quality assurance procedures outlined in van der Heijde (1986).

8.2 Conceptual Model

Easthampton's aquifer is a Pleistocene glaciodeltaic complex that consists of medium to coarse-grained sands and gravels. The aquifer is bounded to the east and west by the walls of a bedrock valley. The eastern boundary of the valley is the Mount Tom Range. The western boundary is Whiteloaf Mountain and the ridge that extends from the northern edge of the mountain to the Manhan River. The northern boundary of the aquifer consists of the Oxbow and associated Connecticut River floodplain deposits. The southern boundary of the model area is defined by a surface water (ground-water) divide between Broad Brook and Pequot Lake.

The northern portion of the aquifer is confined beneath a wedge of glaciolacustrine deposits consisting of sands, silts, and clays (Larsen, 1972; Langer, 1979). The southern edge of these fine-grained deposits roughly parallels Plain Street in Easthampton. The deposits thicken to the north until they are truncated by Connecticut River fluvial deposits near the northern boundary of the study area. The glaciolacustrine deposits thicken to a maximum depth of approximately 100 feet near the northern boundary. The southern, unconfined portion of the aquifer consists of coarse-grained deltaic deposits. The maximum thickness of the deltaic deposits is approximately 140 feet along the axis of the bedrock valley (Londquist, 1973; Londquist and Larsen, 1976).

The glaciolacustrine deposits are underlain by a layer of glacial till of variable thickness. The till is underlain by the Triassic Sugarloaf Formation, which is predominantly arkosic sandstone to conglomerate, with some siltstone and silty shale. A detailed discussion of the surficial deposits is included in Section 5.2, Surficial Geology.

The axis of the bedrock valley approximately reflects the topographic expression of the existing surface valley. The unconsolidated deposits pinch out as they approach the walls of the bedrock valley to the east and west.

Ground-water flow in the valley is from south to north, as evidenced by potentiometric head levels in the lower aquifer and the elevation of surface water features from topographic maps of the area. Artesian conditions exist at the the Nonotuck Park, Hendrick Street, and the Lovefield Street Well fields. Artesian conditions at the Hendrick Street Wells have existed for 100 years without substantial head losses, despite continuous pumping of more than 0.9 MGD.

Broad Brook is a major surface water feature that drains the model area. Broad Brook flows from the southern edge of the model to its confluence with the Manhan River in the north-central portion of the model area. The Manhan River flows from west to east across the northern portion of the model area and drains to the Oxbow. The Oxbow is a lake that is thought to be hydraulically connected to the Connecticut River.

How much?

Recharge is supplied to the model area through infiltration of precipitation falling on the valley. Additional water is supplied to the study area from ground-water flow through the till layer and fractured bedrock.

What about stream/pond recharge?

8.3 Data Collection

Subsurface data (including depth to bedrock, clay thickness (Plate 5, Clay Isopach Map) and lithology) were gathered from well logs, electrical resistivity surveys, and seismic surveys. Stratigraphic logs were collected from borings installed for this study, from logs for the various well fields, and the USGS in Boston, as well as several engineering studies performed for the Town. The stratigraphic and hydrologic control for the northern portion of the aquifer is more complete than that for the southern portion. Data sources in this study are detailed in Section 3.0, Data Review and Evaluation. Table 1 and Table 4 summarize the lithology and aquifer parameters used in modeling the study area.

Surficial geology was determined through field mapping and correlated with well log data, as well as previous investigations of the study area (Larsen, 1972; Larsen and Hartschorn, 1982; Motts, 1985). The areal distribution of surficial deposits is well-defined, but the three-dimensional interpretation is limited by the small number of subsurface data points, especially near the model boundaries and in the southern half of the model area.

Potentiometric head was measured in borings that extend into the confined layer in the northern portion of the aquifer. Water table data was used for the unconfined portion of the Easthampton aquifer. Water table elevations in the upper layer were determined from the elevations of surface water bodies shown on the USGS topographic maps and the depth to water in shallow borings installed for this study.

Horizontal hydraulic conductivity (K_h) values for the lake deposits and deltaic deposits were estimated from analysis of the transmissivity data. Vertical hydraulic conductivity (K_v) could not be calculated from the pump test data, because none of the pump tests were of sufficient duration to allow the aquifer to begin to behave as an unconfined system or for Broad Brook to begin to behave as a recharge boundary. The K_h of the glaciodeltaic deposits was well-established from analysis of the pump test data. The contrast between K_h and K_v of the lake deposits was less well-defined because of the lack of useful field data. The K_v of the lake deposits was estimated from studies performed on surface water/ground-water interaction by Winter (1976) and McBride and Pfannkuch (1974).

All aquifer analysis plots are located in Appendices A, B, and C. A discussion of the transmissivity and storativity values calculated using these methods is located in Section 8.5, Initial Conditions and Boundary Conditions.

The hydraulic properties of the till and fractured bedrock were assumed to be similar to the hydraulic properties of the fine-grained glaciolacustrine deposits. No data were available on the properties of these two units, but they are suspected to have low transmissivities. Even though these units have low transmissivities, it is likely that both of these units contribute a significant volume of water to the Easthampton ground-water flow system because of their large areal extent. The exact value of hydraulic properties of these units is not felt to be critical in the model, because the hydraulic conductivity of the glaciodeltaic unit dominates the simulations. Inflow from the till and bedrock was represented by increased recharge along the till/stratified drift and till/glaciolacustrine deposits boundary.

The value for recharge was determined from meteorological data gathered from 1951 to 1980 by NOAA (National Climatic Center, 1982). The quantity of recharge entering particular portions of the model was estimated based on the horizontal hydraulic conductivities of the material on which the recharge fell.

8.4 Model Description

The USGS modular three-dimensional finite-difference ground-water flow model, MODFLOW, (McDonald & Harbaugh, 1983) was used to simulate the Easthampton aquifer. The differential equation describing three-dimensional ground-water flow is

$$\partial/\partial x\,(K_{xx}\,\partial h/\partial x) + \partial/\partial y\,(K_{yy}\,\partial h/\partial y) + \partial/\partial z\,(K_{zz}\,\partial h/\partial z) - W = S_s\,\partial h/\partial t \quad (1)$$

where x, y, and z = Distances along the main axes of hydraulic conductivity, K_{xx}, K_{yy}, and K_{zz};
h = Potentiometric head;
S_s = Specific capacity of the aquifer;
t = Time; and
W = Volumetric flux per unit time.

The values for hydraulic conductivity and specific storage are functions of space; head and volumetric storage are functions of space and time. Therefore, Equation 1 can be used to describe ground-water flow under heterogeneous, anisotropic conditions (McDonald & Harbaugh, 1983).

MODFLOW was chosen to simulate the Easthampton aquifer because it was designed to model three-dimensional flow and is used extensively by the USGS and throughout the hydrogeologic consulting industry. The chief simplifying assumption made about the model in applying the model to the Easthampton aquifer study was that two layers are adequate to describe the behavior of the system. This assumption was made because there are essentially two major unconsolidated units in the bedrock valley, the lacustrine deposits and the deltaic deposits.

MODFLOW modules used in the simulation of the Easthampton aquifer included: MODRIV1, MODWEL1, MODRCH1, MODBAS1, MODMAIN, MODSIP1, and MODUTL1. The Strongly Implicit Procedure was used for the solution algorithm in the simulations (Weinstein and others, 1968). The closure criterion used in the simulations was 0.01 feet, and the acceleration parameter was 1.00.

8.5 Initial Conditions and Boundary Conditions

The block-centered, finite-difference grid used in this simulation had variable spacing, with 39 rows, 23 columns and 2 layers. The minimum node spacing was 260 feet, and the maximum spacing was 2080 feet. The eastern and western boundaries of the grid correspond to the contact between the till unit and other unconsolidated deposits in the valley.

Ten time steps were used during the transient simulations. Only one stress period was applied for all the simulations in this study.

The aquifer was simulated as a two-layer system, with the upper layer consisting of the glaciolacustrine deposits (see Plate 5, Clay Isopach Map) in the northern portion of the aquifer and the upper portion of the till, bedrock, and glaciodeltaic deposits in the southern portion of the model area.

The lower layer consisted of the coarse-grained sand and gravel deposits, till, and bedrock present at depth in the northern and southern portions of the aquifer. The top of the upper layer was set equal to the elevation of the water table. The bottom of the upper layer and the top of the lower layer were set at a uniform elevation of 60 feet AMSL throughout the model area. This elevation corresponds to the known elevation of the deepest portion of the confining layer. The bottom of the lower layer was set uniformly equal to -60 feet AMSL. The deepest portion of the sand and gravel layer is at -60 feet AMSL.

In the early phases of this investigation, the base of the clay layer was set as the bottom of Layer 1 and the top of Layer 2, and the elevation of the bedrock surface was used as the bottom of Layer 2. However, the wide variation in bottom elevations throughout the model area resulted in substantial numbers of nodes going dry during the steady-state runs. An attempt was made to smooth the bottom of the aquifer by making the largest elevation change between adjacent nodes less than 15 ft. This still resulted in approximately 15 percent of the nodes in Layer 1 going dry. Consequently, the bottoms of the layers were rediscretized as discussed in the above paragraph. Flattening the bottoms of the layers alleviated the problem.

The southern boundary of the aquifer model is composed of no-flow nodes. This corresponds to the surface water divide between Pequot Pond and Broad Brook. The boundary nodes along the northern edge of the model in Layer 1 are constant head nodes. These nodes correspond to the wetland area associated with the Oxbow. This boundary represents the outflow portion of the model system.

The eastern and western edges of the aquifer system were set at the till/stratified drift or till/lacustrine deposits contacts. The water-table gradient becomes very steep outside of the till contacts. An attempt was made to simulate the aquifer in the till areas, but was aborted because of the difficulty in simulating the steep hydraulic gradient.

There is no record of the distribution of head levels in the Easthampton aquifer prior to installation of the Hendrick Street Well field in the early 1900's. At that time the head in the deep aquifer was approximately 10 to 15 feet above the ground surface. The head in the same well after roughly 100 years of continuous pumping of 1 MGD is approximately 5 feet above the ground surface. Because of the lack of decline in head with such a large period of continuous water withdrawal, it is assumed that the existing head distribution in the upper and lower portions of the aquifer can be used as the initial or static head conditions in the steady-state aquifer simulation.

Values for vertical and horizontal hydraulic conductivity (K_v and K_h) were assigned to the model on the basis of pump test data from tests at the Nonotuck Park and Hendrick Street Well fields. The range in K_h for the sand and gravel deposits was from 1100 ft/day in the proximal deltaic deposits in the southern portion of the model area to 210 ft/day in the distal deltaic deposits in the northern portion. The decrease in K_h is probably due to a decrease in sorting of the distal deltaic deposits compared to the proximal deposits. The hydraulic conductivity contrast (HCC) between K_v and K_h was expressed as a ratio, Kv/Kh. HCC for the coarse-grained sand and gravel deposits was set from 0.2 to 0.01. The variation in HCC corresponded to changes in the abundance of fine-grained materials. The HCC for the glaciolacustrine deposits was estimated to be from 0.005 to 0.001. The strong anisotropy was suspected to be due to the presence of sand stringers and rhythmites in the silty sand matrix of the glaciolacustrine deposits. The complex glacial depositional environment resulted in a high degree of vertical and horizontal heterogeneity of aquifer properties in the Easthampton aquifer.

The specific storage of the upper layer was set at 0.010 to 0.0010, and the storativity of the lower layer varied from 0.00010 near Nonotuck Park to 0.0010 near Hendrick Street. These values are lower than the average values calculated from the pump tests, but both are within the range of calculated values. The low storativity values were caused by compaction of the unconsolidated deposits during a late-Wisconsinan glacial readvance (Larsen and Hartschorn, 1980).

Initial head values for Layer 1 and Layer 2 were taken from the USGS topographic maps for the Mount Tom and Easthampton quadrangles and field measurements. The 10-year steady-state solution was compared to the 50-year steady-state solution to assess the stability of the simulation. The two models showed no difference; therefore, the simulation is stable.

The head values for Layer 1 and Layer 2 from the 10-year steady-state solution (10YRSS.DAT) were used as input heads for the various transient simulations.

Layer 1 of the simulation was simulated as an unconfined layer (MODFLOW type LAYCON = 1) because a portion of Layer 1 was unconfined (the sand and gravel deposits in the southern end of the model area) and a portion of the Layer 1 was semi-confined (the lacustrine deposits in the northern half of the model area). Layer 2 of the simulation was modeled as a confined layer (MODFLOW type LAYCON=0).

Nodes along the Manhan River and Broad Brook were set as constant-head nodes in the northern and southern thirds of the model during the steady-state model simulations. The constant head nodes stabilized the model solution at either end of the model. River nodes within 2000 feet of the pumping wells were simulated with the Rivers package. This was done to allow calibration of the model to the river elevations close to the pumping wells.

The courses of the Manhan River and Broad Brook within the model area were simulated with the Rivers package during the transient simulations. This was done so that the constant head nodes would not distort the simulations under pumping conditions. The K_v of the riverbed was assigned the same value as the K_v of the formation over which the river was flowing.

Water enters the aquifer system from the sides of the valley. The eastern and western boundaries of the model correspond to the contact between till or bedrock and glaciodeltaic or glaciolacustrine deposits. Early attempts at simulation of the water table along the sides of the mountains were unsuccessful because the large head changes between adjacent nodes caused large round-off errors. The errors resulted in large numbers of nodes along the boundary going dry immediately. Consequently, water entering the aquifer from the sides of the valley was represented in this simulation by increased recharge in the boundary nodes.

Additional recharge into the lower portion of the aquifer from infiltration through the fractured bedrock was simulated through recharge nodes in layer 2. Approximately 0.00001 ft/yr of recharge was added to the modeled system along the eastern boundary of the model area.

Recharge also enters the top layer of the aquifer system through infiltration of precipitation. The average precipitation falling on the valley was approximately 37 inches per year (National Climatic Center, 1981). Approximately 30 percent of the total precipitation, or 1.0 ft/yr, was estimated to infiltrate into the ground-water flow system in the sand and gravel portions of the aquifer. The amount of recharge entering the various sectors of the modeled area was adjusted depending on the lithology of the sectors. In areas of low K_v, the recharge value was set as low as 0.001 ft/yr.

8.6 Model Calibration

The steady-state simulation was calibrated to the observed head distributions in the confined and unconfined aquifers derived from the observation wells, boring logs, and topographic map. The first concern in simulating the aquifer was the replication of the observed water table and stream elevations. The configuration of the simulated stream and water table was a close approximation of the observed stream and water table.

The model was also calibrated to the observed head distribution in the lower aquifer. The calibration goal was to simulate the artesian conditions observed in the northern part of the aquifer as closely as possible. The observed artesian head at Nonotuck Park was approximately 10 feet and the simulated artesian head was 1.0 foot. The calibration goal at Hendrick Street was approximately 5 feet of artesian head and the simulated artesian head was -2.6 feet. The head in the lower layer ranged from approximately 250 feet in the southern portion of the aquifer to approximately 130 feet in the northern portion.

The conceptual model of the Easthampton aquifer assumes recharge enters the southern portion of the system through infiltration of precipitation and flows north beneath the confining layer until the water outflows to the Oxbow at the northern boundary of the aquifer system. In the simulated ground-water flow model, recharge enters the southern portion of Layer 1 and the vertical component of flow directs the recharge down into the Layer 2. The central and northern portions of the simulated system show Layer 2 as a confined aquifer, with vertical head gradients between Layer 1 and Layer 2 of up to 10 feet near the center of the aquifer. The simulated steady-state ground-water flow system replicates the conceptual model.

Transient simulations were conducted to simulate the results of pump tests that were conducted at the Hendrick Street and Nonotuck Park Well fields. The Nonotuck Park pump test was conducted during June 1962, and the Hendrick Street pump test was conducted during May 1957.

The calibration goal for the twelve-day pump test at Nonotuck Park was 4.5 feet of drawdown in the confined aquifer 250 feet from the pumping well and 0.5 feet of drawdown 500 feet from the pumping well. No drawdown was observed in the simulated upper layer. No observation wells were installed in the confining layer for the pump test. The simulated drawdown in the lower layer was 4.1 feet at 260 feet from the pumping well and the drawdown at 520 feet was 4.0 feet. Part of the reason for the discrepancy between the observed and simulated drawdowns was that the head value in the simulation was averaged over the entire area of the 260 feet by 260 feet cell, while the field measurements were taken at a single point. The large drawdown during the pump test was due to the low storativity and high transmissivity of Layer 2.

The calibration goal for the Hendrick Street 25.5-hour pump test in the ten-inch diameter well was 1.5 feet of drawdown 260 feet from the pumping well. The simulated drawdown for the pump test was 1.4 feet 260 feet from the pumping well. No observation wells were located in the confining layer at Hendrick Street, and no drawdown was observed in the upper layer during the simulations.

The mass balance errors for the steady-state simulation was 0.00 percent of total water volume and flow rate. The mass balance errors for all the simulated pump tests were less than 3 percent for volume and rate. The mass balance errors were probably due to round-off errors during the iterative computation of the solution and are not large enough to be considered significant in this study.

8.7 Sensitivity Analysis

The effects of varying the grid discretization were not evaluated due to budgetary constraints. Also, no additional columns, rows, or layers could be added to this simulation because the dimension of the X-array was at the maximum value.

The time domain discretization for the transient runs was not evaluated quantitatively. Halving the length of the time steps in the transient simulations did not result in any predictable increase or decrease in the mass balance error.

A qualitative sensitivity analysis was performed during the calibration of the Easthampton ground-water flow model. The model was sensitive to essentially the same parameters during the transient and steady-state simulations.

The model was quite sensitive to storativity during the transient simulations, especially in the confined portion of the aquifer. When storativity values of greater than 0.0010 were used, little drawdown was observed 260 feet from the pumping well; when the storativity was set to 0.00010, 1.4 feet of drawdown was observed.

The simulations were relatively insensitive to changes in K_h. Varying the value of K_h by a factor of 2 resulted in only a 20 percent decrease in observed drawdown around the Hendrick Street and Nonotuck Park Well fields.

The model was sensitive to changes in K_v, especially near Nonotuck Park. A minimum K_v of 0.00005 ft/day was used in Layer 1 north of Plain Street. Using K_v values of less than 0.00005 ft/day did not increase the artesian head or the drawdown around the pumping wells during the simulated pump test, but using K_v of greater than 0.00005 ft/day resulted in the lower layer becoming unconfined in the northern portion of the simulation.

The presence or absence of the river during the transient simulations did not appreciably affect the head distributions in Layer 1 or 2. This is probably due to the confined nature of the aquifer in the vicinity of the pumping wells.

The steady-state simulation was quite insensitive to the initial head values. The only difficulties arose when the initial heads were lower than or equal to the elevation of the aquifer bottom, in which case the nodes immediately went dry. These problems arose due to initial head input errors.

The steady-state simulation was quite sensitive to the presence of recharge in Layer 2. The head values in Layer 2 were approximately the same regardless of whether the recharge rate in Layer 2 was 0.00001 ft/yr or 0.01 ft/yr.

The simulated pumping tests were quite insensitive to recharge, the presence or absence of constant-head nodes 1000 feet from the pumping wells, and the presence or absence of River nodes adjacent to the pumping wells in the central portion of the model. A 20 percent increase in recharge over the entire aquifer area resulted in ground-water mounding (approximately 300 feet of excess head) near the eastern and western edges of the northern portion of the model, while the southern portions of the system were relatively unaffected during the steady-state simulations. Increasing the recharge by 20 percent only in the southern portion of the aquifer resulted in a slight increase in head in Layers 1 and 2, with a net decrease in artesian head of 3 feet at Nonotuck Park and 0.5 feet at Hendrick Street. The steady-state simulation was quite sensitive to the presence or absence of constant head nodes along the course of Broad Brook and the Manhan River.

8.8 Data Preprocessing and Postprocessing

A Pre- and Postprocessor was used to input data to and print the output data from MODFLOW. Hard copies of the input and output files are located in Appendices H and I, respectively. The software was written by Hall Groundwater Consultants, Ltd., of St. Albert, Alberta, Canada. A BASIC program, MODGGCON, was written by IEP, Inc. personnel to convert the output file from MODFLOW to x-, y-, and z-values. The z-values for Layers 1 and 2 were contoured on an x-y grid and printed with the Golden Graphics System by Golden Software, Inc., of Golden, Colorado.

A BASIC program, DIFFER, was written by IEP, Inc. personnel to subtract the head values between simulations that were run under pumping and nonpumping conditions. The resulting data file showed the drawdown caused by the pumping wells and was written to the output file as x-, y-, and z-values.

8.9 Model Results and Discussion

A 10-year steady-state simulation was performed with the wells pumping continuously at their safe yield in order to estimate the impact of prolonged pumping on head levels in the aquifer (Plate 6). The drawdown in Layer 2 was greater than the drawdown in Layer 1 over the entire model area, so the drawdown in Layer 2 was used to outline the effects of prolonged pumping. The maximum drawdown observed was in a zone extending approximately 1 mile north and south of the pumping wells at Hendrick Street and Nonotuck Park, with the drawdown decreasing at the rate of approximately one feet per 0.5 mile north and south of the pumping wells. The maximum drawdown observed was 10.3 feet at Nonotuck Park. The simulated long-term drawdown for the Hendrick Street Well field was 9.6 feet. The long-term drawdown at the northern end of the model area was 1.9 feet. No drawdown was detected at the southern end of the model area in Layers 1 or 2.

The zones of contribution outlined from computer modeling of the Easthampton aquifer are a numerical approximation of the actual physical system. MODFLOW represents the state-of-the-art for commercially available computer modeling technology. Very little information was available in portions of the modeled area; for example, little data was available on aquifer parameters along the edges and in the southern half of the study area, as well as the flow characteristics of the rivers in the study area. Consequently, assumptions were made about the properties of the aquifer and the hydrologic system in those areas. The quality of the Zone delineation according to 310 CMR 24.06 is dependent on the accuracy of those assumptions. The assumptions were tested during calibration of the flow model. Based on the transient and steady state calibration runs and subject to the limitations described in this Report, it is the opinion of IEP, Inc. that the simulated system accurately reflects the physical reality of the Easthampton aquifer.

According to 310 CMR 24.06, the areas of aquifer resource protection are as follows:

> **Zone 1:** the 400 foot radius or other designated area surrounding a water supply well, must be in compliance with DEQE Drinking Water Regulation (310 CMR 22.00).
>
> **Zone 2:** that area of an aquifer which contributes water to a well under the most severe recharge and pumping conditions that can be realistically anticipated. It is bounded by the ground-water divides which result from pumping the well and by the contact of the edge of the aquifer with less permeable materials such as till and bedrock. At some locations, streams and lakes may form recharge boundaries.

Zone 3: that land area beyond the area of Zone 2 from which surface water and ground water drain into Zone 2. The surface drainage area as determined by topography is commonly coincident with the ground-water drainage area and will be used to delineate Zone 3. In some locations, where surface and ground-water drainage are not coincident, Zone 3 shall consist of both the surface drainage and the ground-water drainage areas.

Severe recharge and pumping conditions were defined as pumping at the safe yield of the wells for 180 days with no recharge. This simulated drought condition is analogous to the growing season in Massachusetts, from late spring to early fall. During this period evapotranspiration is greater than or equal to precipitation except during extreme rainfall events, such as hurricanes (Frimpter, 1982).

Zone 2 for the study area was delineated using MODFLOW, the USGS three-dimensional ground-water flow model. Zone 2 is defined by the drawdown contours around the pumping wells during severe recharge and pumping conditions. The drawdown was defined by performing two simulations: 1) the control simulation, during which the wells were not pumped, and 2) the pumping simulation, during which the pumping wells were operated continuously at their safe yield. Both of these simulations were run for 180 days with no recharge. Aside from the pumping wells, all other parameters were identical for the simulations. The drawdown due to pumping is calculated by subtracting the head values from the pumping simulation from the head values for the control simulation.

Because the Easthampton aquifer was simulated as a two-layer system, the head distributions in Layers 1 and 2 were compared for the control and pumping conditions. Drawdown in Layer 2 was greater than that in Layer 1.

The maximum drawdown detected in Layer 2 during the 180-day drought simulation was near the Hendrick Street Well field, 18.5 feet. The minimum drawdown was at the northern end of the study area, 1.9 feet. The drawdown near Nonotuck Park was 15.8 feet, and the drawdown at the southern limit of the study area was 3.3 feet. The zones of influence for the Nonotuck Park Well and Hendrick Street Well field overlap extensively in the central portion of the study area.

IEP, Inc. proposes that Zone 2 for the Easthampton aquifer be considered that portion of the recharge area which contributes flow downward into Layer 2 from Layer 1 under drought conditions. This was determined by subtracting the head values under drought pumping conditions in Layer 1 from Layer 2. The area where the head in Layer 1 becomes equal to the head in Layer 2 is approximately coincident with Pomeroy Street in Easthampton.

Analysis of the Surficial Geology Map (Plate 2) suggests that the northern boundary of the recharge area is approximately concurrent with the southern edge of the 10-ft clay isopach, which is nearly parallel with Plain Street. Field measurements performed at piezometer cluster 1-87 indicate approximately 1.7 feet of artesian head at Plain Street in the central portion of the model area (Plate 1). Consequently, a conservative value for the northern boundary of Zone 2 is the contact between glaciodeltaic deposits and the glaciolacustrine deposits. Zone 2 extends south to the surface water divide between Pequot Pond and Broad Brook, as shown on Plate 2. Zone 3 consists of the till and bedrock portions of the ground-water basin which contribute runoff to Zone 2 in the unconfined portion of the aquifer, as shown on Plate 7.

The output from MODFLOW includes a mass balance summary that summarizes both the rates and volumes of water moving through the simulated system. The mass balance discrepancy in the transient simulations was probably due to round-off error during the computation of the various solution vector, and the errors are not large enough to be considered significant for the purposes of this study.

Vertical leakage from Layer 1 into Layer 2 was not determined from the simulations in this study because of the lack of adequate field data. Also, the vertical discretization of the study area was not such that the problem of flow from the confining layer into the unconfined layer could be effectively addressed from the simulations.

8.10 Model Records

The output runs from all the simulations are included in Disks 1 and 2. Disk 1 contains:

EHOALS.L1 and EHOALS.L2 (the input data files for the preprocessor for steady-state simulations)

EHOALT.L1 and EHOALT.L2 (the input data files for the preprocessor for transient simulations

Disk 2 contains U1SS, U1TR, U3SS, U3TR, U4HS, U4NP, U4DRT, U8SS, U8TR, U11SS, U11TR, U12, (the input files for the simulations)

Disk 3 contains: 10YRSS.DAT, 10YRSSP.DAT, DRTN.DAT, and, DRTP.DAT

Disk 4 contains: HSN.DAT, HSP.DAT, NPN.DAT, and NPP.DAT (the output from the transient calibration runs)

Disk 5 contains the executable version of MODFLOW used for this simulations

Disk 6 and 7 contains copies of the Pre- and Postprocessor programs.

9.0 LAND USE

9.1 Introduction

The purpose of this land use survey was to identify potential sources of contamination within the primary and secondary recharge areas the Town's existing well fields. The survey was concentrated within the Broad Brook Watershed. Information was gathered from the Pioneer Valley Planning Commission, the Department of Environmental Quality Engineering, the Town Engineer's Office, the Town Fire Department, and by conducting a field windshield survey.

9.2 Background Information

In 1983, the Pioneer Valley Planning Commission (Commission) filed a Chapter 286 Aquifer Land Acquisition Application (ALA) for the Towns of Easthampton and Southampton. A map entitled "Land Use in the Easthampton, Southampton and Holyoke Area" was prepared by the Commission for that application. The map indicated the major land uses in the Broad Brook Watershed, and was prepared using data from Massachusetts Map Down. For this study, IEP, Inc. revised the map to include the current layout of sewer lines, newly developed areas, hazardous waste generators, and other potential problem areas. The Commission's map was compiled using Soil Conservation Service (SCS) soils maps, which are based upon United States Geological Survey (USGS) topographical maps dated from the early 1970's. IEP, Inc. has updated the map to include the developments that have occurred since that time.

9.3 Existing Land Uses

There are four major land use types in the watershed area These are: Recreation/Forest/Wetland, Agriculture/Open Space, Residential Sewered and Unsewered, and Commercial/Industrial and are shown on Plate 8. Each use can effect the aquifer in a different way.

The Town of Easthampton has seen considerable development since the original land use map was prepared. Within the primary recharge area to the Town's well fields, development in the Pomeroy Street area has been particularly heavy. Sewer lines were extended to include approximately half of this development, and an eight-inch high pressure line was extended across the fields east of Line Street to include the Plain Street area development.

As reported by the Easthampton Fire Chief and Deputy Fire Chief, there are many more private fuel oil tanks in the Town now than were listed by the Commission in 1983. The Town began keeping records of underground storage tanks in approximately 1970. Table 5 is a list of all known underground

Underground Storage Tanks Located in Zone II
Table 5

Location	Age (years)	Volume (gallons)	Contents
9 Brewster Ave.	8	500	fuel oil
7 Chapman Ave.	-	3000	fuel oil
6 High Street	-	1000	fuel oil
8 High Street	-	1000	fuel oil
14 High Street	-	1000	fuel oil
Main Street	5	2000	fuel oil
Main Street (Lamoureaux)	-	1000	fuel oil
Main Street (Exper. Tool)	5	1000	fuel oil
Main St. (Easthampton Savings)	17	5000	fuel oil
43 Main Street	-	1000	fuel oil
19 Main Street	13	1000	fuel oil
135 Main Street	5	1000	fuel oil
194 Main Street	6	1000	fuel oil
209 Main Street	-	1000	fuel oil
Lot #22, Overlook Drive	8	1000	fuel oil
239 Main Street	8	500	fuel oil
36 Overlook Drive	8	1000	fuel oil
282 Main Street	8	550	fuel oil
285 Main Street	8	550	fuel oil
305 Main Street	8	550	fuel oil
377 Main Street	-	1000	fuel oil
380 Main Street	-	500	fuel oil
412 Main Street	4	2000	fuel oil
34 Sandra Road	-	1000	fuel oil
5 School Street	-	1000	fuel oil
9 School Street	-	10000	fuel oil
4 Sheldon Avenue	-	1000	fuel oil
6 South Street	-	1000	fuel oil
16 South Street	-	1000	fuel oil
74 South Street	-	1000	fuel oil
8 Sterling Drive	-	1000	fuel oil
58 Strong Street	-	1000	fuel oil
17 Summit Avenue	-	1000	fuel oil
18 Summit Avenue	-	1000	fuel oil
79 Torrey Street	-	1000	fuel oil
79 Union Street	-	550 (3 tanks)	fuel oil
61 Union Street	-	1000 (2 tanks)	fuel oil

Underground Storage Tanks Located in Zone II
Table 5 Cont.

39 West Street	–	1000	fuel oil
87 West Street	–	500	fuel oil
127 West Street	–	500	fuel oil
6 West Park Drive	–	1000	fuel oil
52 Westview Terrace	–	2000 (3 tanks)	fuel oil
54 Westview Terrace	–	2000 (3 tanks)	fuel oil
14 Westview Terrace	–	1000	fuel oil
39 Westview Terrace	–	1000	fuel oil
40 Westview Terrace	–	1000	fuel oil
5 Ranch Avenue	–	1000	fuel oil
4 Park Street	–	10000	fuel oil
81 Park Street	–	550	fuel oil
117 Park Street	–	500	fuel oil
156 Park Street	–	1000	fuel oil
160 Park Street	–	1000	fuel oil
180 Park Street	–	550	fuel oil
82 Park Hill Road	–	2000	fuel oil
108 Park Hill Road	–	500	fuel oil
19 Parsons Street	–	6000 (2 tanks)	fuel oil
133 Parsons Street	–	1000	fuel oil
26 Payson Avenue	–	2000	fuel oil
3 Payson Avenue	–	550	fuel oil
11 Payson Avenue	–	550	fuel oil
35 Payson Avenue	–	1000	fuel oil
50 Payson Avenue	–	4000	fuel oil
32 Pipin Avenue	–	1000	fuel oil
20 Pine Street	–	500	fuel oil
78 Plain Street	–	1000	fuel oil
92 Plain Street	–	1000	fuel oil
82 Golden Drive	–	550	fuel oil
219 Hendrick Street	–	1000	fuel oil
225 Hendrick Street	–	1000 (2 tanks)	fuel oil
1 Kania Street	–	550	fuel oil
11 Kania Street	–	1000	fuel oil
28 Kania Street	–	1000	fuel oil
22 Overlook Drive	–	1000	fuel oil
36 Overlook Drive	–	1000	fuel oil

Underground Storage Tanks Located in Zone II
Table 5 Cont.

15 Picard Circle	–	550	fuel oil
78 Plain Street	–	1000	fuel oil
92 Plain Street	–	1000	fuel oil
93 Plain Street	–	550	fuel oil
113 Plain Street	–	1000	fuel oil
34 Sandra Road	–	1000	fuel oil
58 Strong Street	–	1000	fuel oil
8 Sterling Drive	–	1000	fuel oil
84 Union Street	–	550 (2 tanks)	gasoline
84 Union Street	–	1000	fuel oil
Railroad Street (Telephone Building)	–	1000	fuel oil
Liberty Street (Pump Station)	–	1500	fuel oil
Lovefield Street (Pump Station)	–	1500	fuel oil
Daley Field	–	1000	fuel oil

storage tanks. The private owners of these tanks are not required to have the tanks tested on a regular basis. The commercial and industrial users of underground tanks must have their tanks tested on a regular basis according to Federal and State laws. The Fire Department officials stated that all of the industries in Town are in compliance with the Fire Department. The Fire Department does not have on record any violations of the underground tank regulations or releases at gasoline stations within the watershed boundary.

Listed below in Table 6 are the companies in Easthampton and Southampton that were on the Hazardous Waste Generators List at the DEQE in Springfield. These companies may be small or large quantity generators.

Easthampton Hazardous Waste Generators List
Table 6

Company	Activity Type
DOS Concrete Service Inc. Wemelco Way	
Easthampton Dye Works Inc. 1 Cottage Street	2
Ed's Autobody Mechanic Street	Non-Reg. 2
Everett Street Motors 158 Everett Street	2
Farm Petroleum Co. Lot 15, O'Neill Street	
W. R. Grace & Co. Construction Wemelco Way	2
Hampshire Experimental Tool Co. 396 Main Street	
Industrial Prop. of Easthampton, Inc. 1 Ferry Street	
Kellogg Brush Manufacturing Co. 122 Pleasant Street	2
Magnat Corporation 52 O'Neill Street	2
National Felt Co. 122 Pleasant Street	
The October Co., Inc. O'Neill Street	2
Paragon Rubber Corp./Rhodes Rubber Corp. Spring Action Electric Pleasant Street	

Easthampton Hazardous Waste Generators List
Table 6 (Continued)

Paramount Auto Body 51 Holyoke Street	2
Peter Rapid Cleaners 38 Union Street	1
The Phillip Manufacturing Co. 19 Ward Avenue	Non-Reg 1
Stanley Home Products, Inc. 116-118 Pleasant Street	2
Stevens Elastomeric & Platic PDTS 1 Cottage Street - Inactive 26 Payson Street - Inactive	1
Stevens J. P. & Co., Inc. 412 Main Street (Rte. 10)	1
Stonington Corporation 45 Ferry Street	2
Tighe & Bond 50 Payson Avenue	2
Tubed Products, Inc. 44 O'Neill Street	1
Zonolite Division of Grace Co. Wemelco Way	

Southampton Hazardous Waste Generators List

Company	Activity Type
Southampton Sanitary Engineers County Road	1
Southampton Sanitary Landfill Moose Brook Road	1

REFERENCES CITED

Brackley, R., and M. Thomas, 1978. Mean annual runoff and major drainage basins in the Connecticut Valley urban area, Central New England. United States Geological Survey Miscellaneous Investigations Map 1-1074-G, 2 sheets, 1:25000.

Cooper, H., and C. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well field history. Transactions of the American Geophysical Union, V. 27, pp. 526-534.

Frimpter, M., 1980. Ground-water availability in the north part of the Connecticut Valley urban area, Central New England. United States Geological Survey Miscellaneous Investigations Series Map 1-1074-I, 1:25000.

Langer. W., 1979. Map showing distribution and thickness of the principal fine-grained deposits, Connecticut Valley, urban area, Central New England. United States Geological Survey Miscellaneous Field Studies Map MF-504A, 1:25000, 2 sheets.

Larsen, F., 1972. Surficial geologic map of the Mount Tom quadrangle, Massachusetts, United States Geological Survey Open-File Report 72-104: United States Government Printing Office, Washington, D.C., 350 pp.

Larsen, F., and J. Hartschorn, 1982. Deglaciation of the southern portion of the Connecticut Valley of Massachusetts, in Larson, G., and B. Stone (eds.), Late Wisconsinan glaciation of New England: Kendall-Hunt Publishing Co., Dubuque, Iowa, pp. 115-129.

Londquist, J., 1973. Contour map of the bedrock surface, Mount Tom quadrangle, Massachusetts. United States Geological Survey Miscellaneous Field Studies Map MF-504C, 1:25000.

Londquist, J., and F. Larsen, 1976. Map showing depth to bedrock, Mount Tom quadrangle, Massachusetts. United States Geological Survey Miscellaneous Field Studies Map, MF-504C, 1:25000.

McBride, M., and H. Pfannkuch, 1975. The distribution of seepage within lakebeds. Journal of Research of the United States Geological Survey, V. 3, No. 5, pp. 505-512.

McDonald, M., and A. Harbaugh, 1984. A modular three-dimensional finite-difference ground-water flow model: United States Geological Survey, Reston, VA, 528 pp.

Motts, W., 1985. Hydrogeology of West Holyoke and adjacent areas. Consultant's report for the Town of West Holyoke, 158 pp.

National Climatic Center, 1982. Monthly normals of temperature, precipitation, and heating and cooling degree days, 1951-1980, Massachusetts. Climatography of the United States, No. 81 (by State): National Oceanic and Atmospheric Administration, Reston, VA, 11 pp.

Stone, J., E. London, and W. Langer, 1979. Map showing textures of unconsolidated materials, Connecticut Valley urban area, Central New England. United States Geological Survey Miscellaneous Investigations Series Map 1-1074-B, 1:25000, 3 sheets.

van der Heijde, P., 1986. Quality assurance in computer simulations of ground- water contamination: Holcomb Research Institute, Butler University, Indianapolis, IN, 26 pp.

Walker, E., and W. Caswell, 1977. Map showing availability of ground water in the Connecticut River lowlands, Massachusetts. United States Geological Survey Hydrologic Investigations Atlas HA-563, 1:48000, 2 sheets.

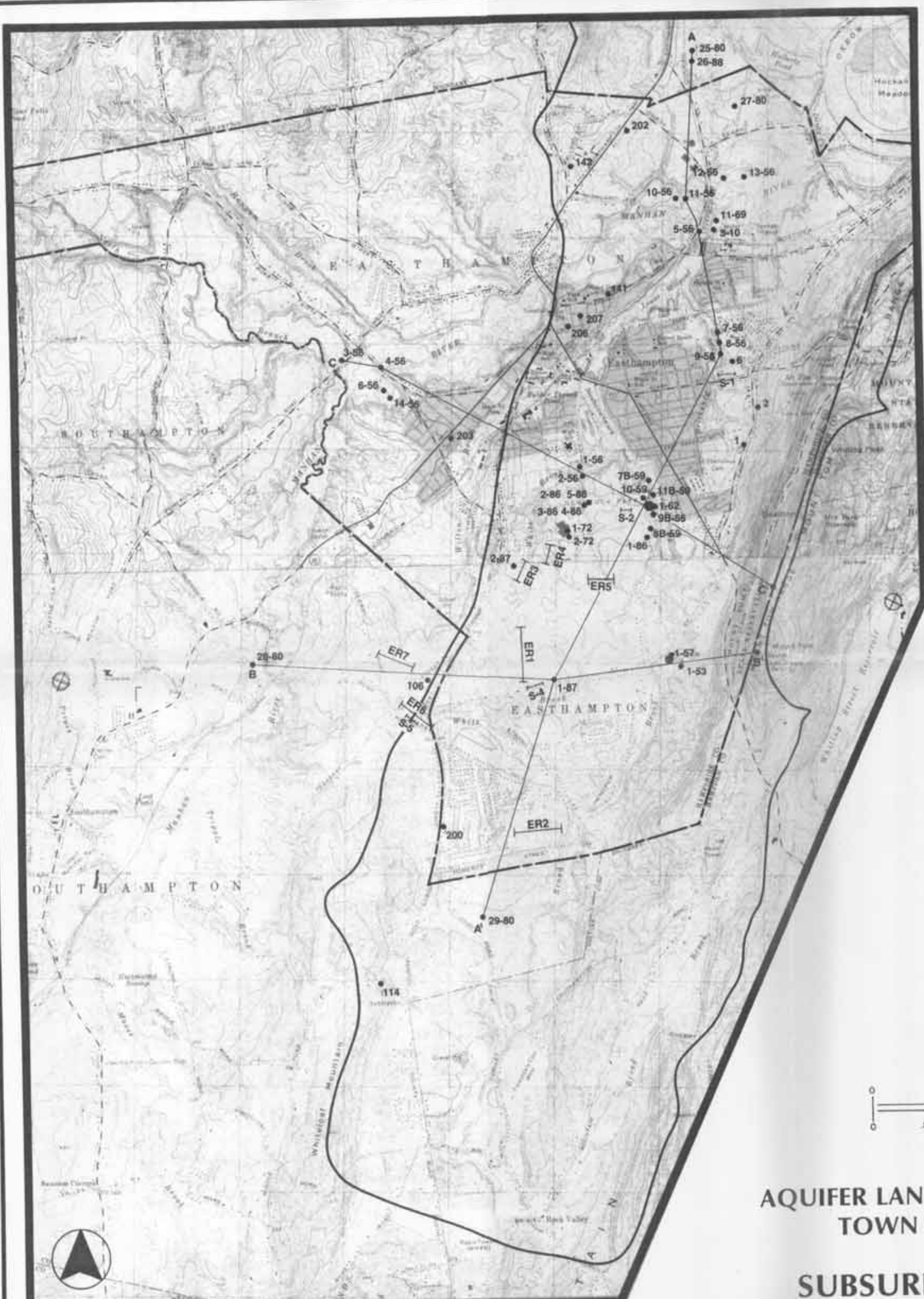
Walsh, D., and Sackrey, J., 1984. Preliminary investigation of the hydrogeology and surface water chemistry of the Hannum Aquifer in the vicinity of the Easthampton and Northampton landfills, Massachusetts. Unpublished Master's thesis, University of Massachusetts-Amherst, 36 pp.

Wandle, S., and W. Caswell, 1977. Streamflow and water quality in the Connecticut River lowlands, Massachusetts. United States Geological Survey Hydrologic Investigations Atlas HA-562, 2 sheets.

Weinsten, H., H. Stone, and T. Kwan, 1969. Iterative procedure for solution of systems of parabolic and elliptic equations in three dimensions: Industrial Engineering Chemistry Fundamentals, v. 8, no. 2, pp. 281-287.

Winter, T., 1983. Numerical simulation analysis of the interaction of lakes and ground water, United States Geological Survey Professional Paper 1001: United States Government Printing Office, Washington, D.C., 45 pp.

PLATE 1



EXPLANATION:

- Line Of Geologic Cross Section (A — A')
- Seismic Line (S-1)
- Electrical Resistivity Sounding (ER-1)
- Subsurface Data Point (26-80) (Exploratory Test Wells, Auger Holes, Road Borings, and Bedrock Wells, Described In Data Points Table)
- Pumping Station
- Study Area Boundary (Includes Broad Brook And White Brook Sub-Watersheds And A Portion Of The Manhan River Watershed)
- Town Boundary

REFERENCES:

Berndt, M., J. Davis, A. Hartnell, J. Sandeen, and H. Stevens. 1981. Groundwater Geology Of The Easthampton Area. Smith College. Unpublished Report.

R.E. Chapman Co., Oakdale, MA.

IEP, Inc., Northborough, MA.

Kick, J., 1987. Electrical Resistivity Survey, Easthampton, MA. Report For IEP, Inc.

Petersen, R. and A. Maevsky. 1962. Massachusetts Basic Data Report No. 6, Ground Water Series, Western Massachusetts Area. Reston, VA: USGS. Table 1.

F.G. Sullivan Drilling Co., Lancaster, MA.

BASE MAPS:

USGS. 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.
USGS. 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.

MILES: 0 .5 1 2
KILOMETERS: 0 .5 1 2 3

AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

DRAFT

SUBSURFACE DATA POINTS

iEP inc.

PLATE 2

EXPLANATION:

- Town Boundary
- Pumping Station
- Study Area Boundary
- A — A' Line of Geologic Cross Section

HOLOCENE

Qal	Alluvium Recent stream deposits: silt, sand, and gravel
Qs	Swamp Deposits Peat, organic muck, silt, sand, and clay
Qds	Dune Sand Well sorted, medium to fine sand
Qaf	Artificial Fill

PLEISTOCENE

Bottom Deposits Of Lakes Hitchcock And Manhan

Qb	Beach Deposits Well sorted sand and gravel
Qls	Lake Sand Deposits Laminated sand and silt includes proximal and distal bottomset beds of delta
Qlc	Lake Clay Deposits Alternating thin silt layers and clay layers
Qst	Terrace Deposits Silt, sand, and gravel

WISCONSIN

Glacial Stream and Lake Deposits West Of Holyoke Basalt Ridge

Stratified Drift

Qdw_4	Deltaic, Lacustrine, and Ice-contact Deposits; Fine to coarse sand and pebbles
Qdw_3	Deltaic, Lacustrine, and Ice-contact Deposits; Clay, silt, sand, pebbles, and cobbles
Qdw_2	Deltaic, Lacustrine, and Ice-contact Deposits; Medium to coarse sand, pebbles, and cobbles; includes minor amounts of clay, silt, and flowtill
Qic	Undivided and Unassigned Ice-contact Deposits Silt, sand, and gravel; displays collapse bedding
Qt	**Till** Compact to loose, nonsorted to poorly sorted, nonstratified mixture of clay, silt, sand, pebbles, cobbles and boulders

Tru	**Bedrock** Undifferentiated Triassic Sedimentary and igneous rocks. Sedimentary rocks consist of arkosic siltstone, sandstone, and conglomerates. Igneous rocks consist of basalt, tuff, agglomerate, and volcanic, and volcanic sandstone.

NOTES:

Eolian Mantle

A layer of windblown sand or silt, mixed with the underlying glacial deposits, is present over much of the area but has not been mapped. The mantle is best developed overlying higher, older deposits, and is generally missing over lower, younger deposits.

REFERENCES:

Larsen, F.D., 1972. Surficial Geology Of The Mount Tom Quadrangle, Massachusetts. U.S. Geological Survey Open File Report 72-219.

Larsen, F.D., Post 1972. Additional unpublished surficial mapping of the Easthampton Quadrangle.

Reconnaissance surficial geologic mapping was performed in the study area in both the Mount Tom and Easthampton quadrangles by IEP, inc. surficial geologists.

BASE MAPS:

USGS, 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.
USGS, 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.

MILES

0 .5 1 2

0 .5 1 2 3

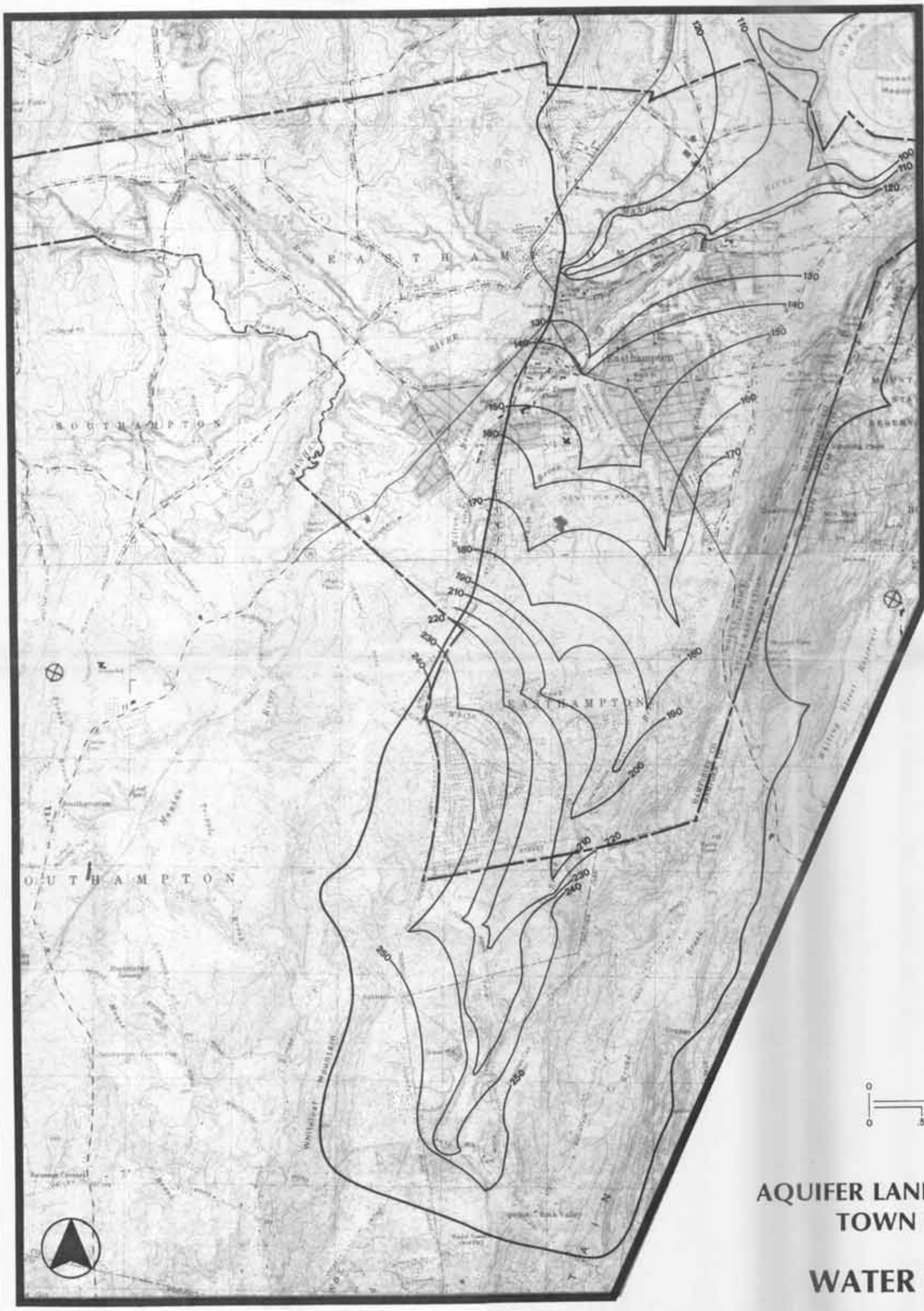
KILOMETERS

AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

SURFICIAL GEOLOGY

DRAFT

PLATE 3



EXPLANATION:

- — – Town Boundary
- —130— Equipotential Line
- —— Study Area Boundary
- Limit of Finite Difference Grid

NOTES:

1) Elevations given in feet above mean sea level

2) Potentiometric surface contours based on:
   a) Interpretation of the topographic map,
   b) Field observations, and
   c) 10-year steady-state ground-water flow simulation

3) Study area includes Broad Brook and White Brook Sub-Watershed and a portion of the Manhan River Watershed.

BASE MAPS:

USGS, 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000
USGS, 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000

Contour Interval = 10 Feet

MILES: 0 .5 1 2
KILOMETERS: 0 .5 1 2 3

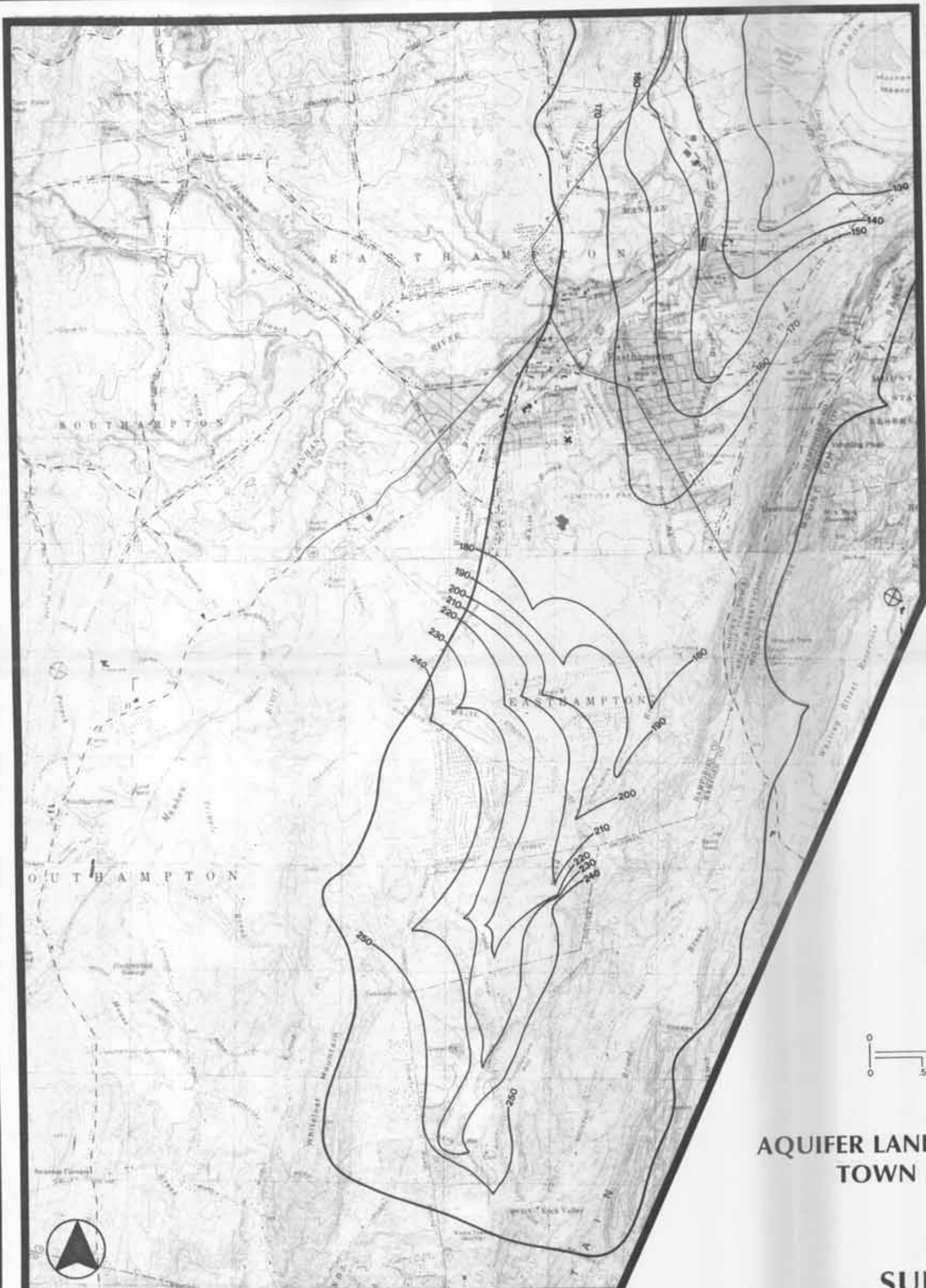
AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

DRAFT

WATER TABLE ELEVATIONS

iEP inc.

PLATE 4



EXPLANATION:

— —	Town Boundary
—130—	Equipotential Line
——	Boundary of Study Area
	Limit of Finite Difference Grid

NOTES:

1) Elevations given in feet above mean sea level.

2) Potentiometric surface contours based on:
   a) Interpretation of the topographic map,
   b) Field observations, and
   c) 10-year steady-state ground-water flow simulation

3) Study area includes Broad Brook and White Brook Sub-Watershed and a portion of the Manhan River Watershed

BASE MAPS:

USGS. 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000
USGS. 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000

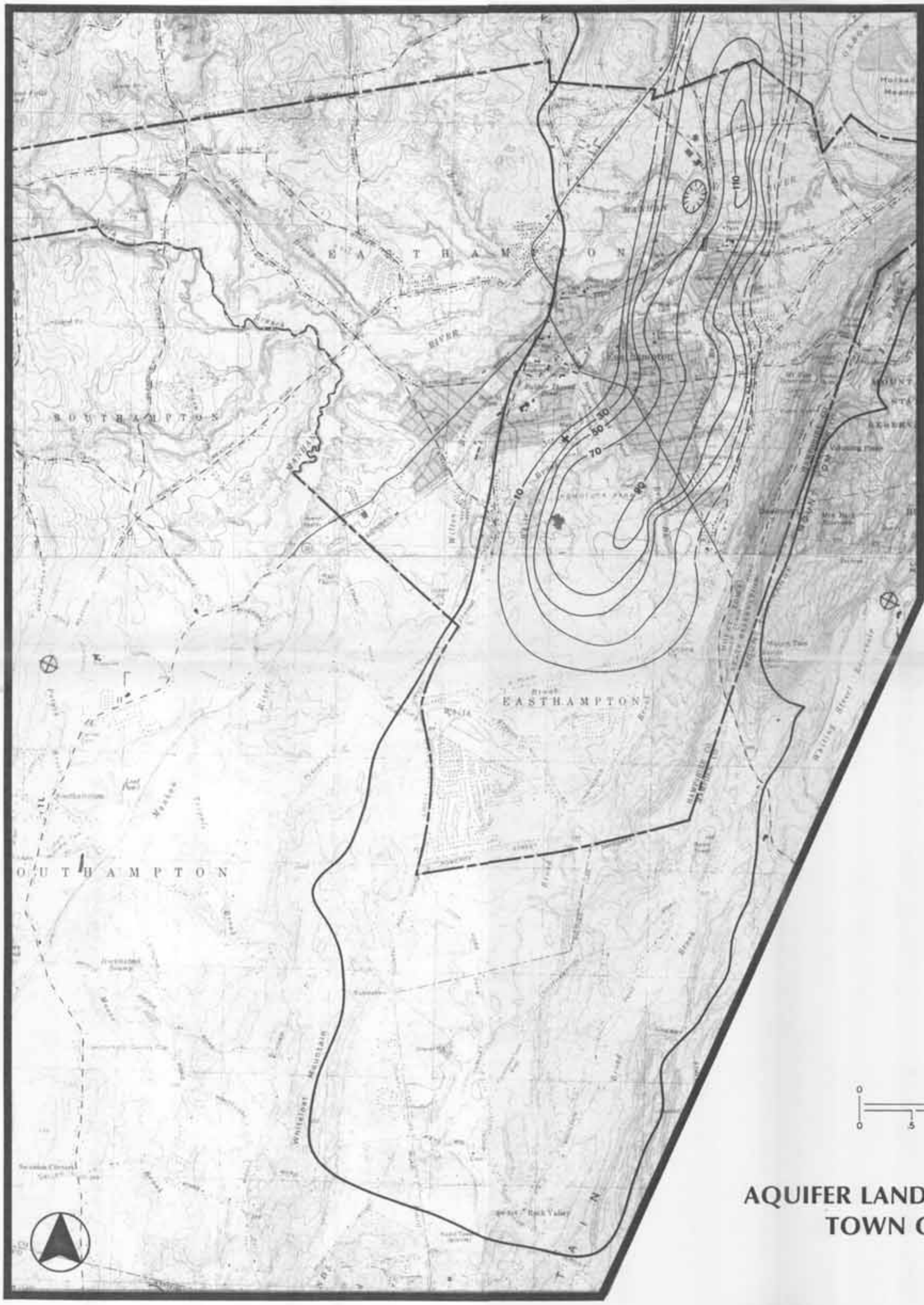
Contour Interval = 10 Feet

MILES: 0 .5 1 2
KILOMETERS: 0 .5 1 2 3

AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

POTENTIOMETRIC SURFACE ELEVATIONS

DRAFT



iEP inc.

PLATE 5

EXPLANATION:

- Town Boundary
- Study Area Boundary
- —70— Isopach Lines (dashed where inferred)

NOTES:

1. Isopach lines correspond to the thickness of glaciolacustrine deposits based on well logs, surficial deposit mapping, and electrical resistivity soundings for the study area

REFERENCES:

Subsurface Data Points Table I
Larsen, F., 1972. Surficial Geology of the Mount Tom Quadrangle USGS Open-File Report No. 72-219. Reston, VA: USGS. 272 pp.

BASE MAPS:

USGS. 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000
USGS. 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000

Contour Interval = 20 Ft

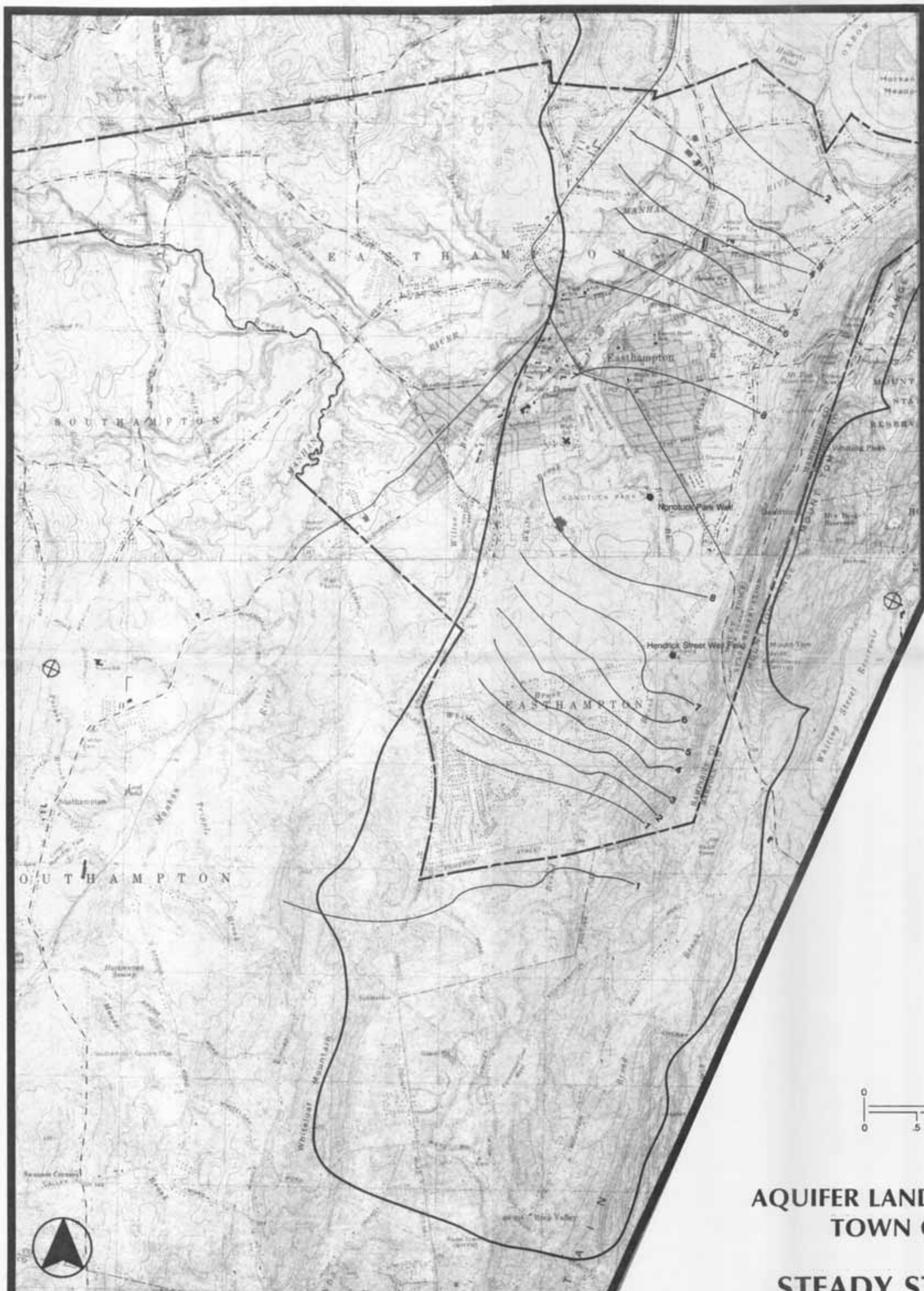
MILES: 0, .5, 1, 2
KILOMETERS: 0, .5, 1, 2, 3

AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

DRAFT

CLAY ISOPACH

PLATE 6



EXPLANATION:

- Town Boundary
- Pumping Station
- Surface Watershed Boundaries
- Limit of Finite Difference Grid
- Isodrawdown Contours

NOTES:

1. Drawdowns are referenced to Plate 4 (Potentiometric Surface Elevations)

2. Isodrawdown lines are derived from a computer simulation of 10-year steady state, normal recharge conditions with continuous pumping at the safe yield of the wells.

3. The pumping rates used in this simulation are based on information from the Easthampton Board of Public Works. The pumping rates used are as follows:
Nonotuck Park 18-inch Well - 0.90 million gallons per day (MGD)
Hendricks Street Wellfield - 3.70 MGD
The Lovefield Street well was not simulated because it was not suspected of affecting the cones of drawdown around the other two pumping wells.

BASE MAPS:

USGS, 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.
USGS, 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.

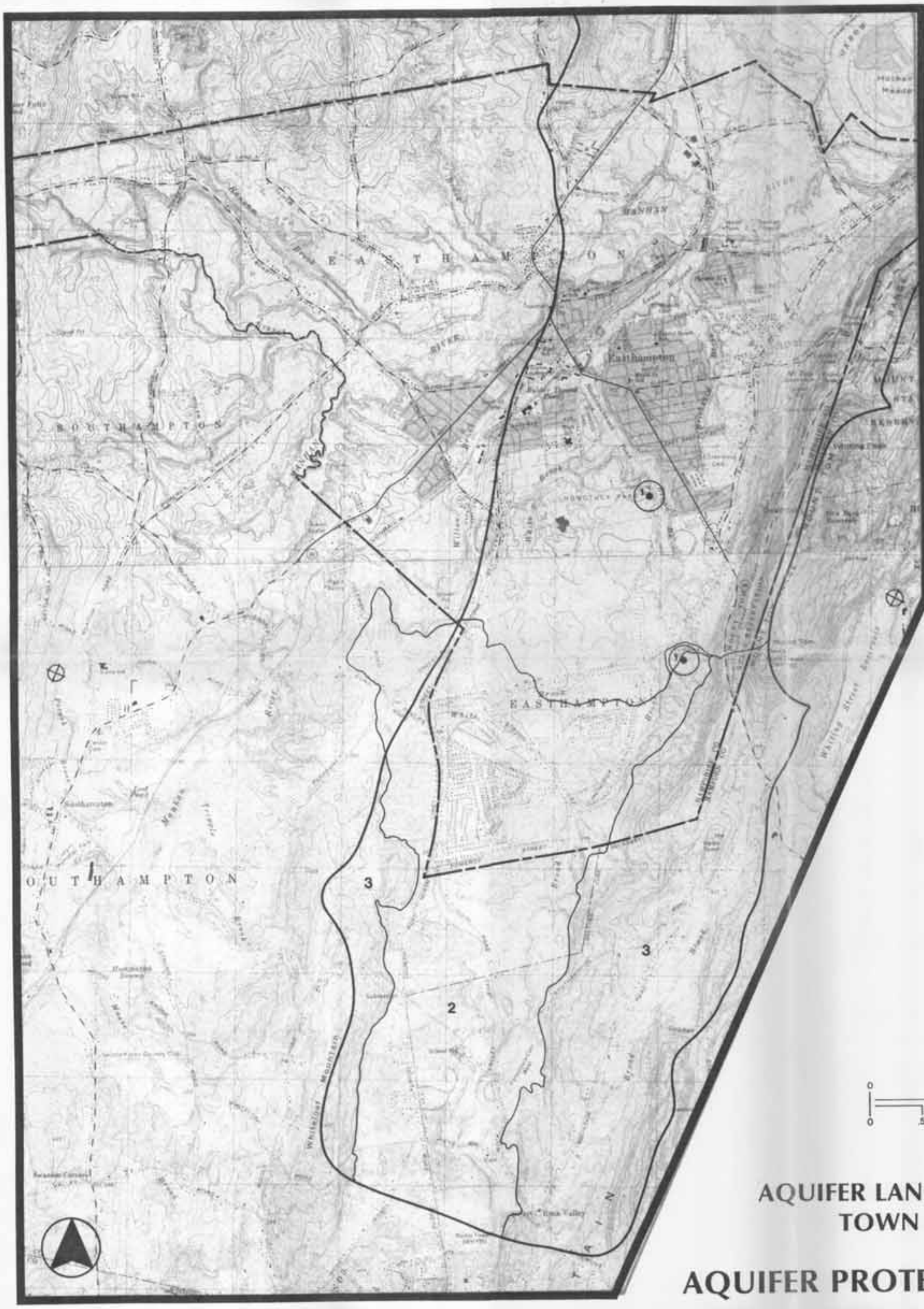
AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

DRAFT

STEADY STATE DRAWDOWN

iEP inc.

PLATE 7



EXPLANATION:

Town Boundary

Study Area Boundary

Pumping Station

(1) Zone 1:
the 400-foot radius or other designated area surrounding a water supply well as required by DEQE for the protection of the supply

(2) Zone 2:
the area of an aquifer which contributes water to a well under the most severe recharge and pumping conditions that can be realistically anticipated (i.e., pumping at the well's safe yield for 180 days with no natural recharge). It is bounded by the ground-water divides which result from pumping the well and by the contact of the edge of the aquifer with less permeable materials such as till and bedrock. The limit of the cone of depression (0.1 foot drawdown) was determined using a three-dimensional numerical ground-water flow model and then extended upgradient to the edge of the sand-and-gravel aquifer.

(3) Zone 3:
the land area beyond the area of Zone 2 from which surface and ground water drain into Zone 2. The surface drainage area as determined by topography and the ground-water drainage area as defined by the numerical ground-water flow modeling were used to delineate Zone 3.

BASE MAPS:

USGS, 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000
USGS, 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000

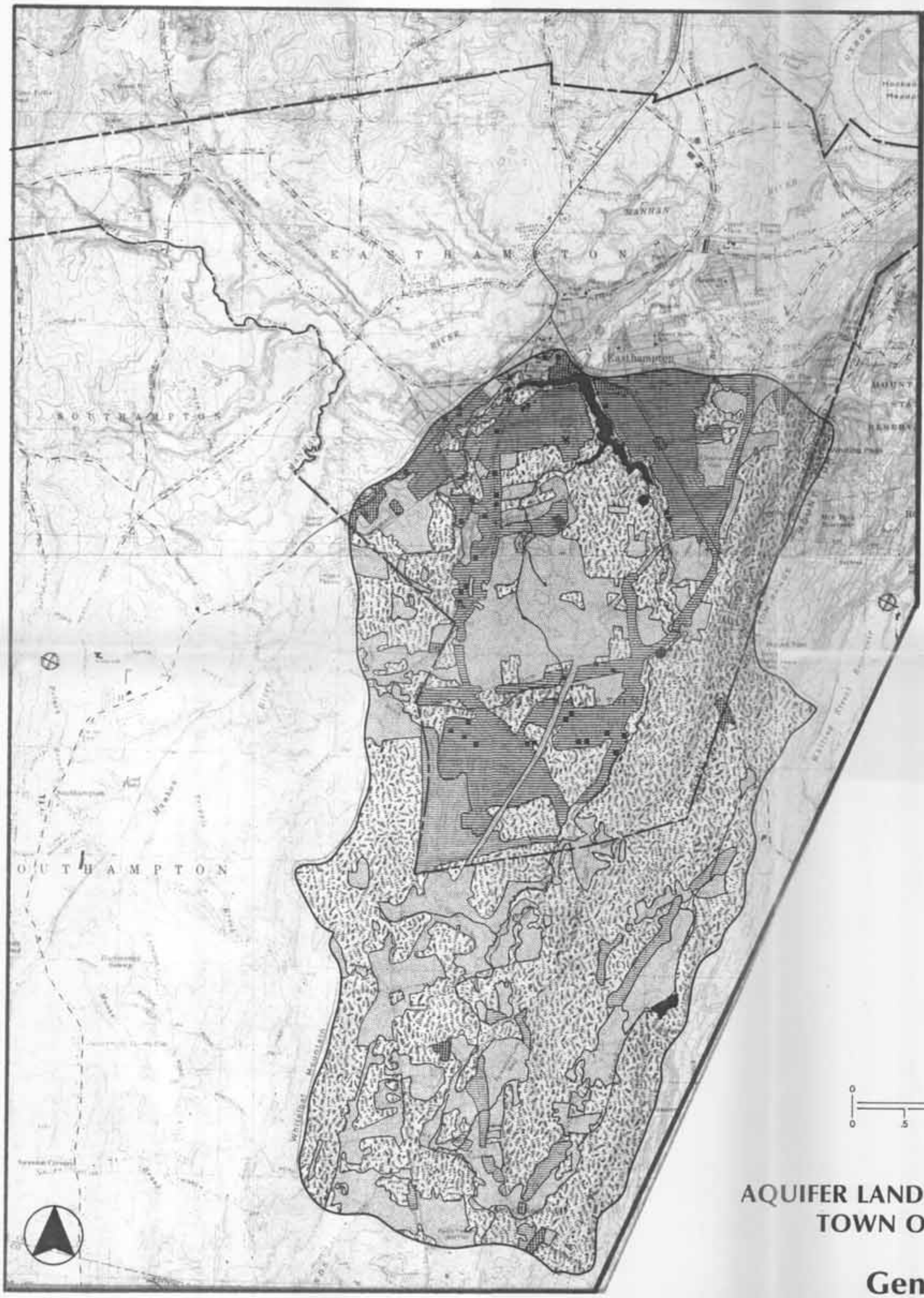
MILES
0 .5 1 2
0 .5 1 2 3
KILOMETERS

AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

DRAFT

AQUIFER PROTECTION DISTRICTS

PLATE 8



EXPLANATION:

- Residential, Unsewered
- Industrial, Commercial, Transportation
- Residential, Sewered
- Agricultural and Open Space
- Recreational, Forest, Wetland
- Nashawannuck Pond Watershed Boundary
- Pumping Station

REFERENCES:

MacConnell, William P., 1973.

Massachusett Map Down: Land-use and Vegetative Cover Mapping Classification Manual For Use with Massachusetts Map Down Maps. Planning, and Resource Development Series No. 25 Publication No. 97. Amherst, MA: Cooperative Extension Service University of Massachusetts.

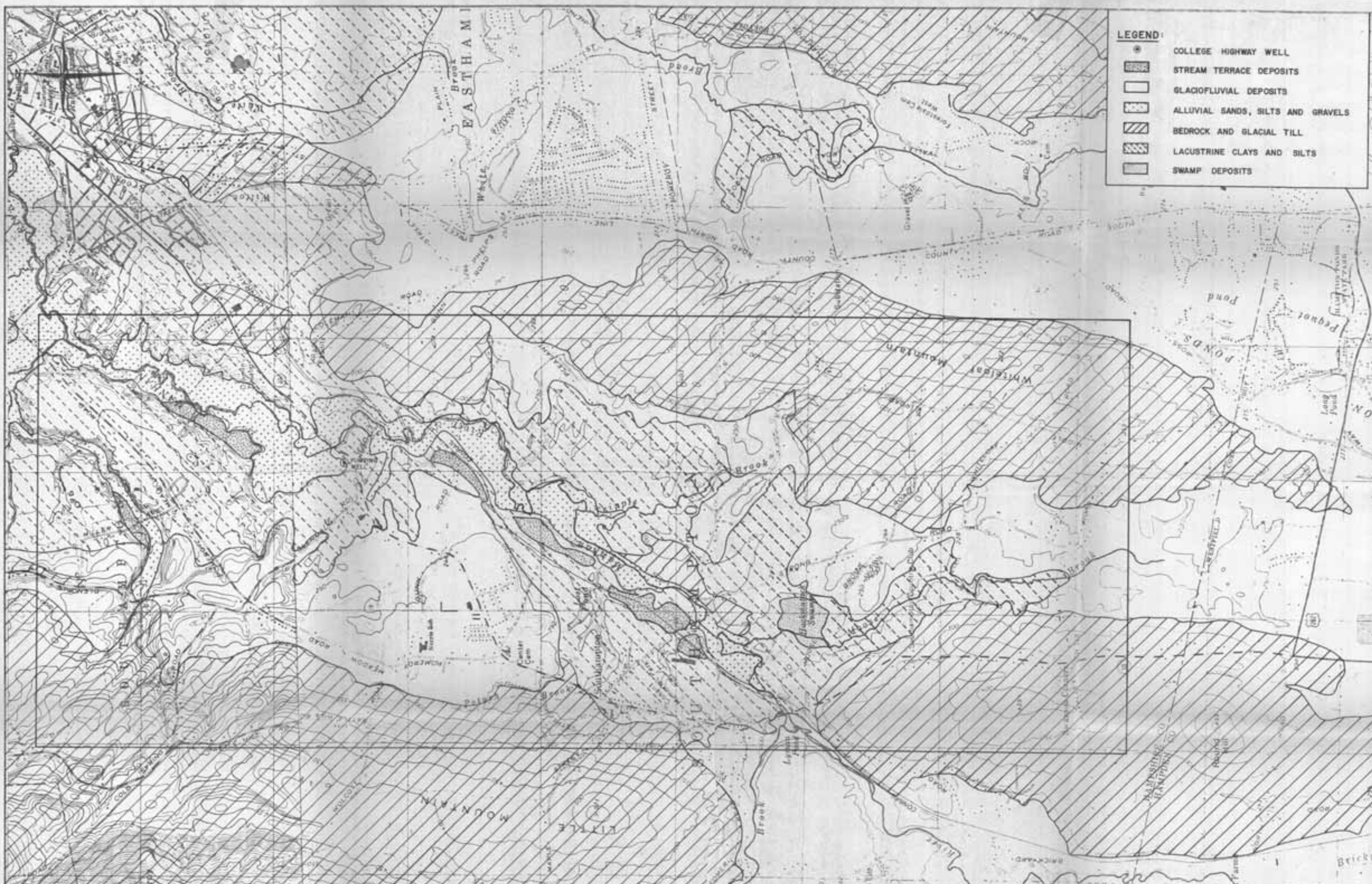
BASE MAPS:

USGS. 1979. Mount Tom Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.
USGS. 1979. Easthampton Quadrangle 7.5-Minute Topographic Map. Reston, VA: USGS. 1:25000.

MILES: 0 .5 1 2
KILOMETERS: 0 .5 1 2 3

AQUIFER LAND ACQUISITION STUDY
TOWN OF EASTHAMPTON 1987

Generalized Land Use



WEHRAN ENGINEERING
CONSULTING ENGINEERS

Drawn by: GB
Checked by: AD
Date: 1/24/81

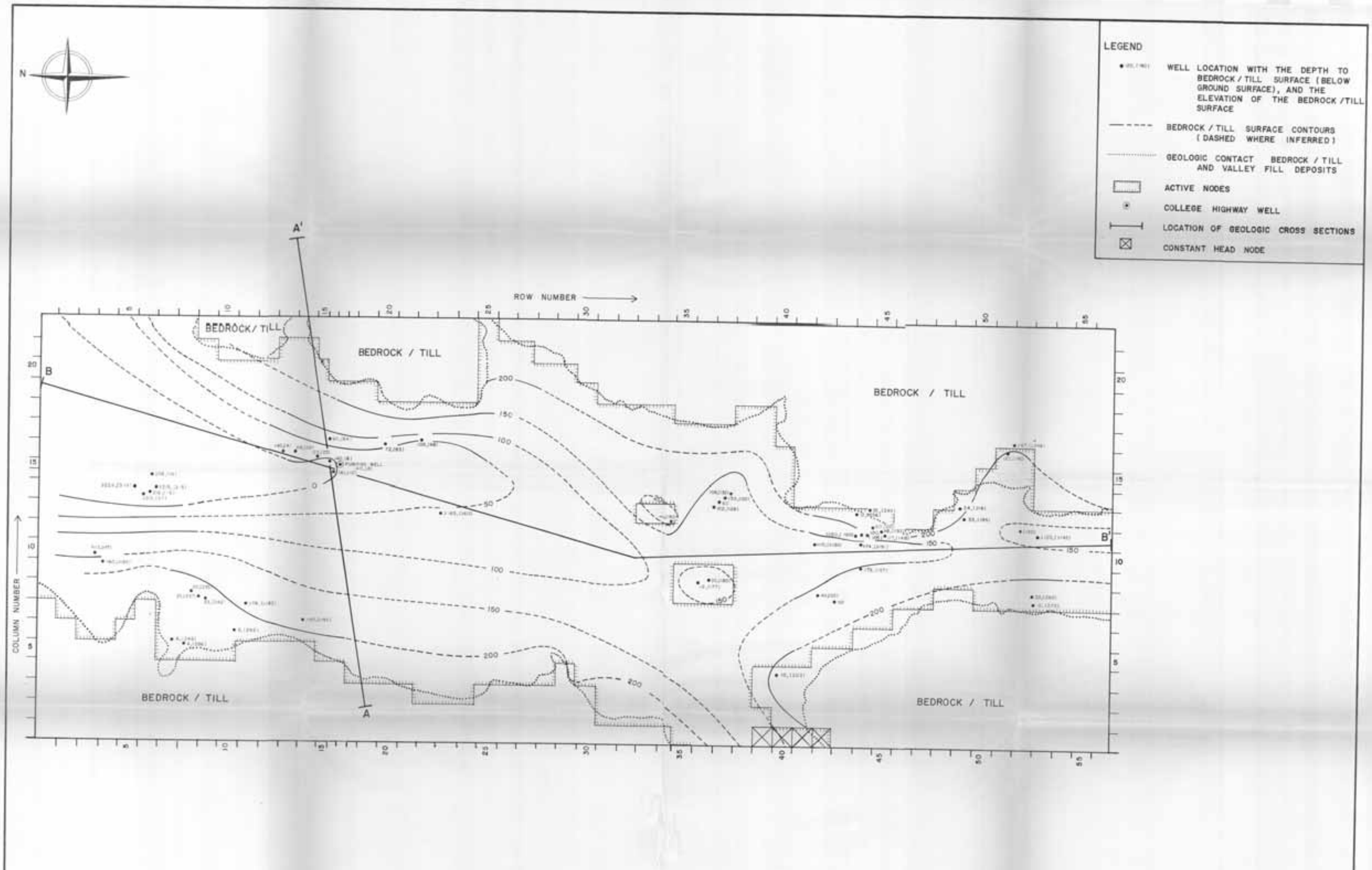
Scales
1" = 1,000'

ADAPTED FROM F. LARSH, 1972

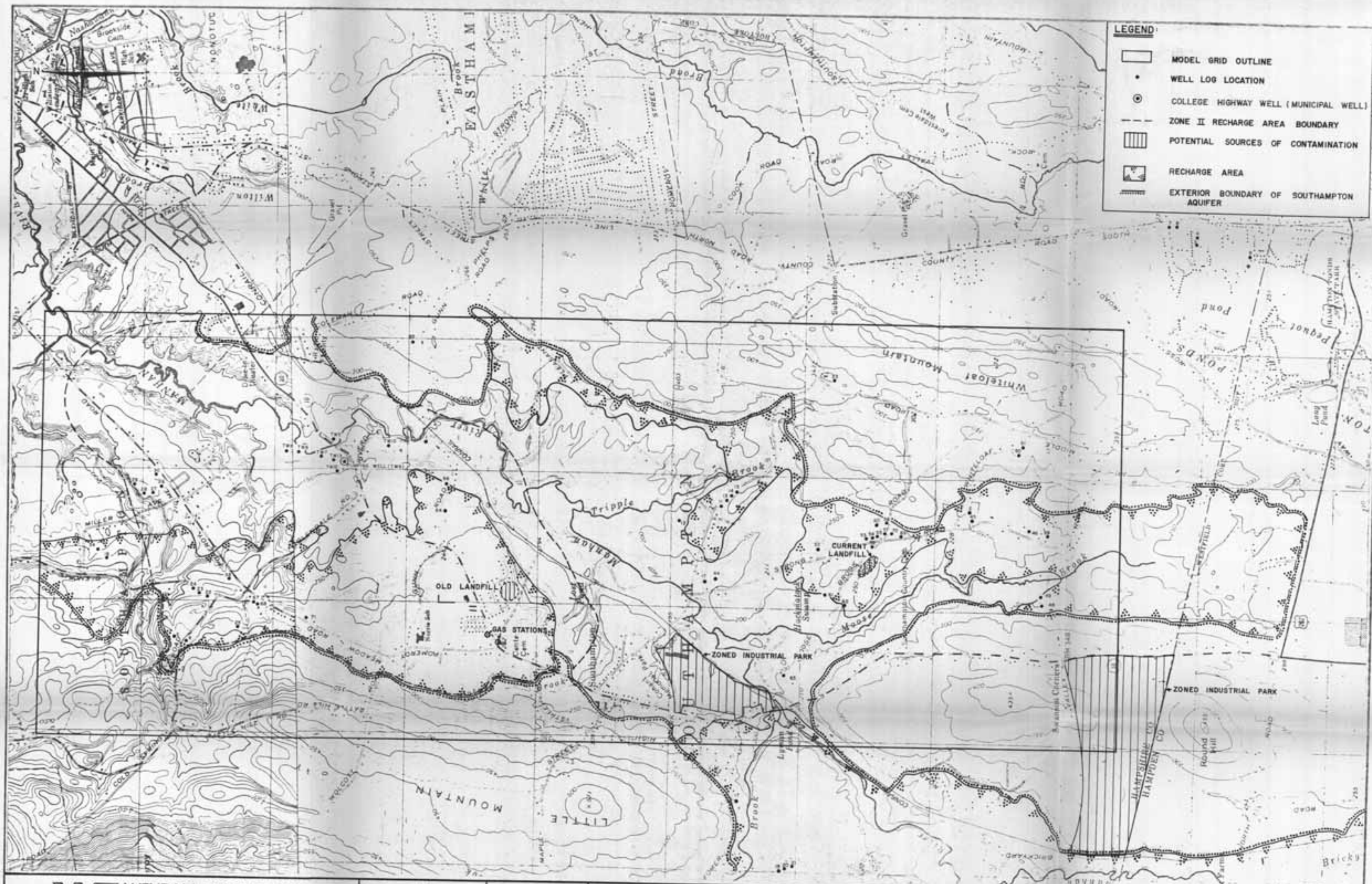
SOUTHAMPTON AQUIFER PROTECTION STUDY
SOUTHAMPTON MA

PLATE I
SURFICIAL GEOLOGY MAP

Sheet 1 of 8
Project No. 06308 HF



WEHRAN ENGINEERING CONSULTING ENGINEERS	Drawn by: SB Checked by: HB Date: 11/23/81	Scales 1" = 1,000'		SOUTHAMPTON AQUIFER PROTECTION STUDY SOUTHAMPTON MA	PLATE 2 CONTOUR MAP OF BEDROCK / TILL SURFACE AND ACTIVE NODES	Sheet 2 of 8 Project No.



WEHRAN ENGINEERING
CONSULTING ENGINEERS

Drawn by: GB
Checked by: AG
Date: 11/24/87

Scales: 1" = 1,000'

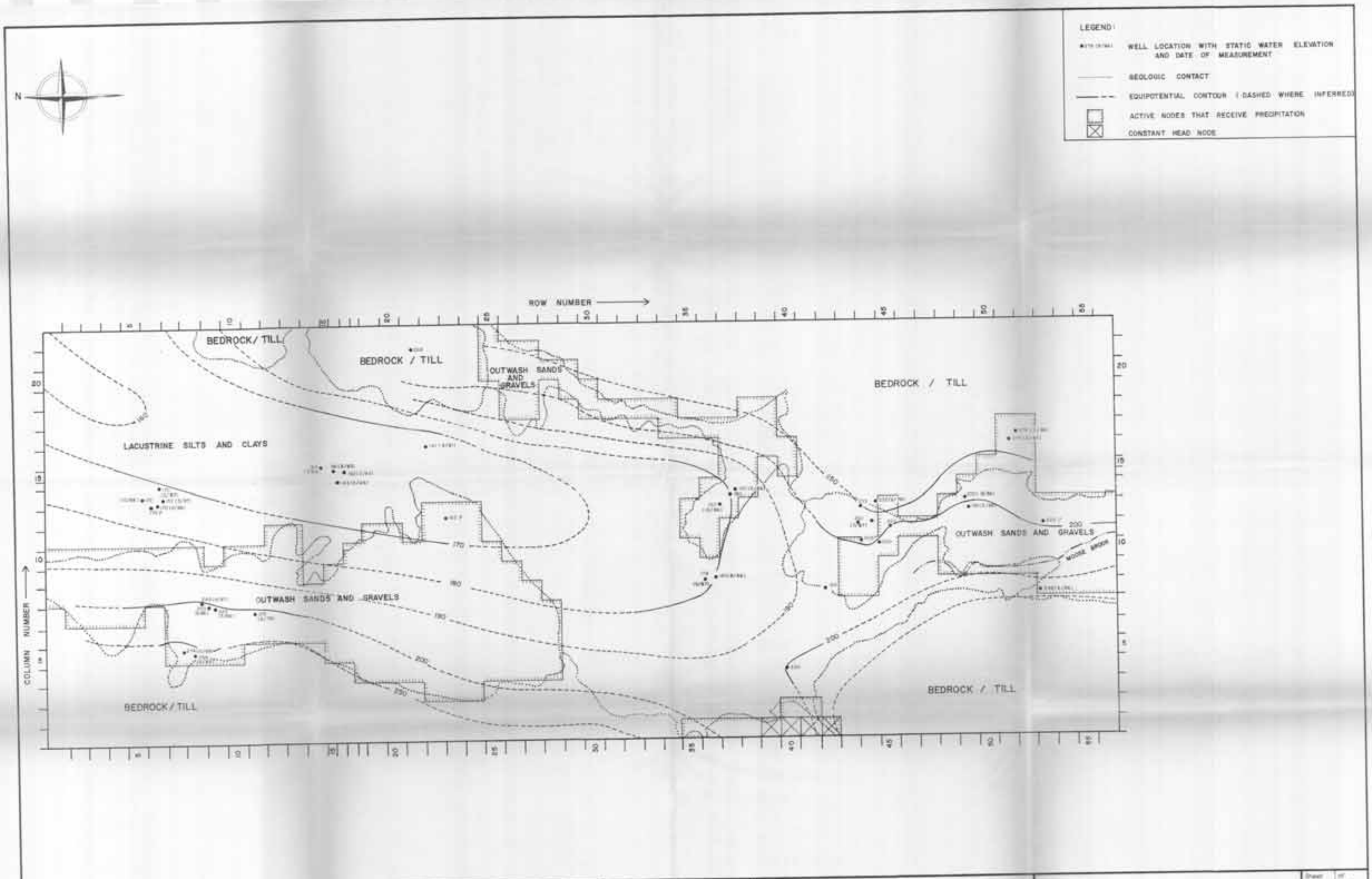
NOTE: WELL LOCATIONS ARE APPROXIMATE BASED ON VERBAL DESCRIPTIONS. THEY MAY BE SHIFTED SLIGHTLY DUE TO DISTORTION DURING MAP REPRODUCTION.

SOUTHAMPTON AQUIFER PROTECTION STUDY

SOUTHAMPTON MA

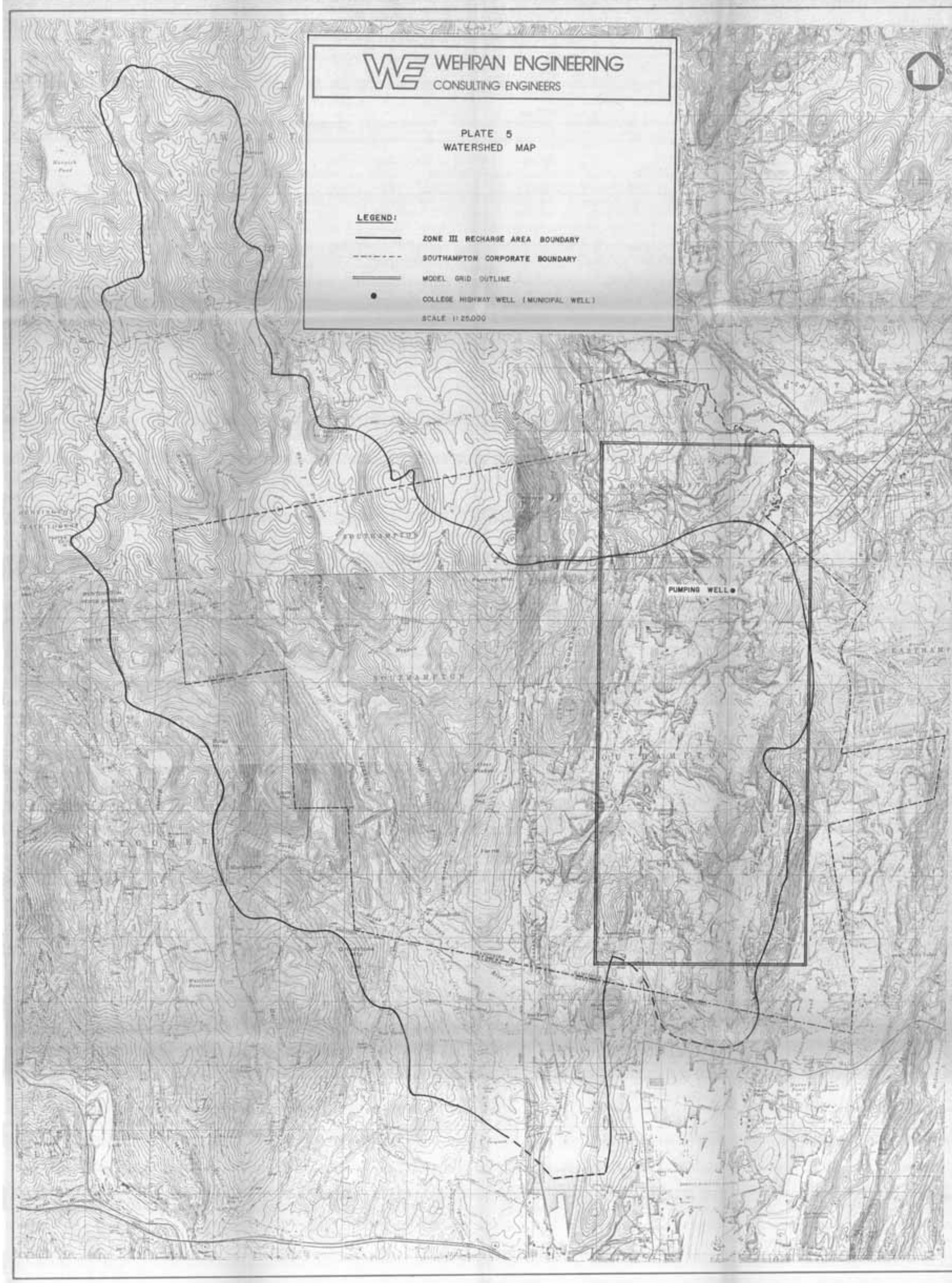
PLATE 3
SITE MAP

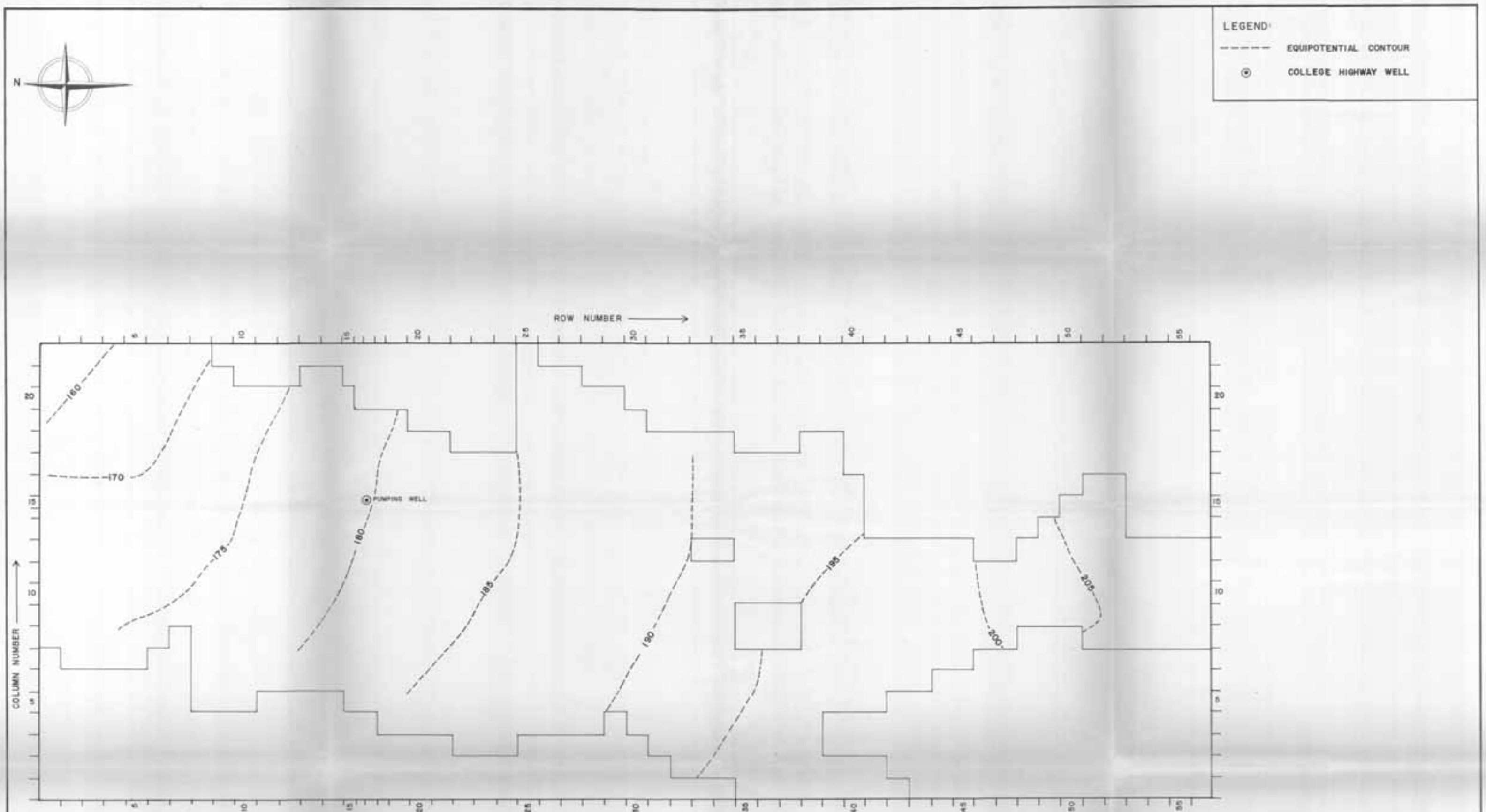
Sheet 3 of 8
Project No. 06308 HF



WEHRAN ENGINEERING
CONSULTING ENGINEERS

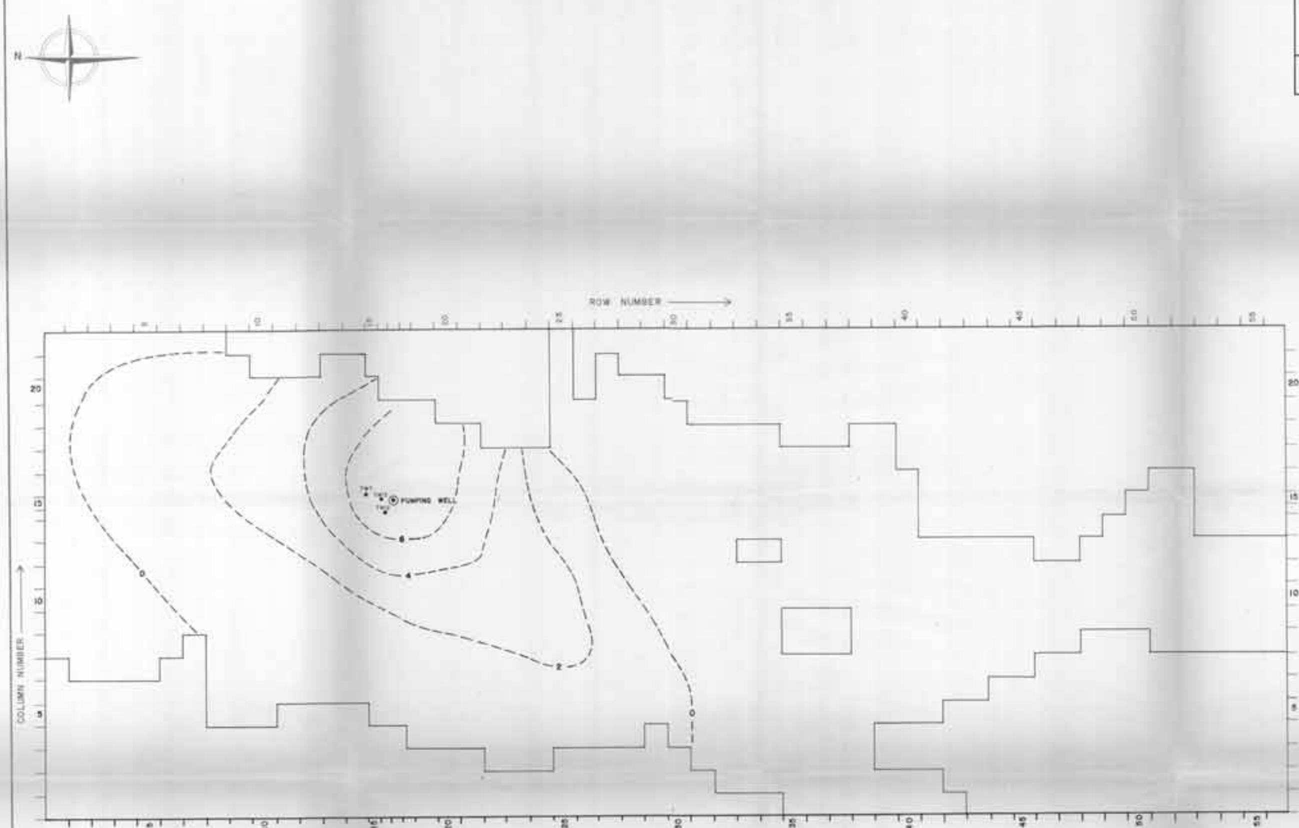
Drawn by:	Scale: 1" = 1,000'	SOUTHAMPTON AQUIFER PROTECTION STUDY	PLATE 4	Sheet 4 of 8
Checked by:		SOUTHAMPTON	CONTOUR MAP OF PIEZOMETRIC SURFACE	Project No.
Date:				


WEHRAN ENGINEERING
CONSULTING ENGINEERS
PLATE 5
WATERSHED MAP
LEGEND:
ZONE III RECHARGE AREA BOUNDARY
SOUTHAMPTON CORPORATE BOUNDARY
MODEL GRID OUTLINE
COLLEGE HIGHWAY WELL (MUNICIPAL WELL)
SCALE 1:25,000
PUMPING WELL
SOUTHAMPTON



WEHRAN ENGINEERING CONSULTING ENGINEERS	Drawn by: Checked by: AB Date: 11/24/81	Scales 1" = 1,000'		SOUTHAMPTON AQUIFER PROTECTION STUDY SOUTHAMPTON MA.	PLATE 6 CONTOUR MAP OF CALIBRATION RUN HYDRAULIC HEAD

Sheet of
Project No. 06308 HF



LEGEND:

- — — — — EQUIPOTENTIAL CONTOUR
- ⊙ COLLEGE HIGHWAY WELL
- • OBSERVATION WELL

NOTE: 180 DAYS PUMPING AT 550 GPM WITH NO RECHARGE

WEHRAN ENGINEERING
CONSULTING ENGINEERS

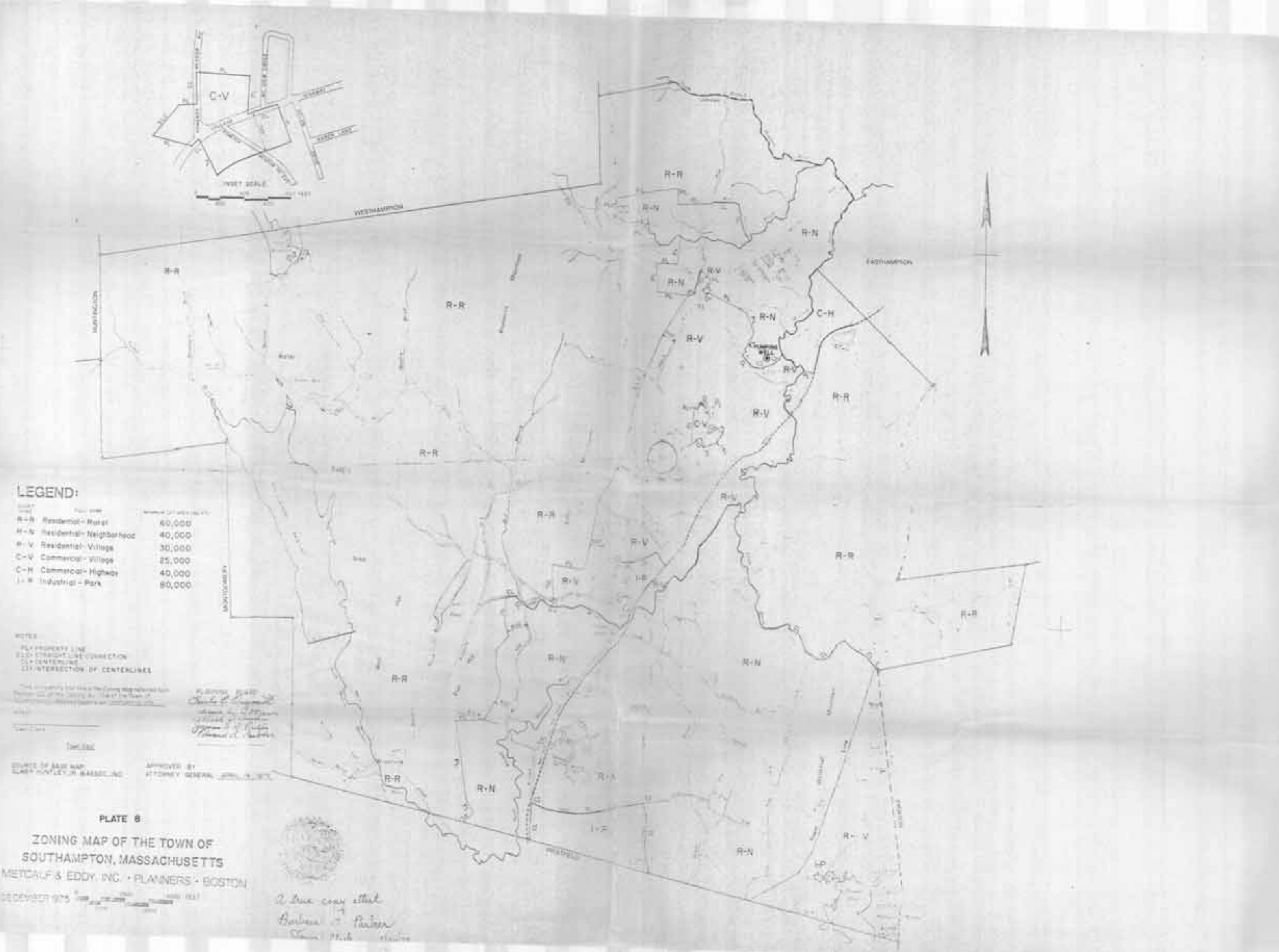
GB
RG
11/25/83

1" = 1,000'

SOUTHAMPTON AQUIFER PROTECTION STUDY

SOUTHAMPTON

PLATE 7
CONTOUR MAP OF DRAWDOWN
UNDER SIMULATED PUMPING CONDITIONS


C-V
INSET SCALE
WESTHAMPTON
HUNTINGTON
MONTGOMERY
EASTHAMPTON
R-R
R-N
R-V
C-V
C-H
I-P
PUMPING WELL
LEGEND:
R-R Residential - Rural 60,000
R-N Residential - Neighborhood 40,000
R-V Residential - Village 30,000
C-V Commercial - Village 25,000
C-H Commercial - Highway 40,000
I-P Industrial - Park 80,000
NOTES
CL = CENTERLINE
INTERSECTION OF CENTERLINES
APPROVED BY
ATTORNEY GENERAL
PLATE 8
ZONING MAP OF THE TOWN OF
SOUTHAMPTON, MASSACHUSETTS
METCALF & EDDY, INC. · PLANNERS · BOSTON

Are You Poisoning Your Water?

If someone were to drop a poisonous substance into your community's water supply, the act would be considered a serious crime and a state of public emergency would be declared.

But when you dump a can of paint thinner down the drain or throw out an old car battery with the trash, no alarms are sounded, no news flashes are issued. Yet, the impact on your water resources could be just as disastrous.

That is not a far-fetched statement. The average household contains between three and ten gallons of materials that are hazardous to human health or to the natural environment. Collectively, these materials can poison our water if they are not stored carefully and disposed of properly.

What Is A Hazardous Material?

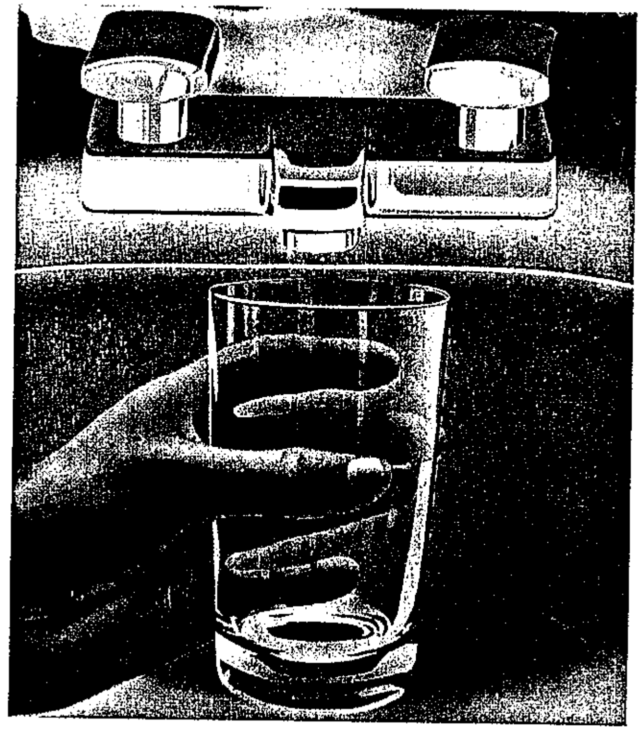
The United States Environmental Protection Agency considers a substance hazardous if it can catch fire, if it can react or explode when mixed with other substances, if it is corrosive, or if it is toxic. In addition, EPA has designated four hundred specific substances (such as battery acid) to be hazardous.

This definition includes many things that you probably are storing right now in your garage, basement, bathroom, or kitchen. Some, like paint thinner or car batteries, are pretty obvious, but there are many that you might not ordinarily think of such as polishes, insecticides and glues.

Dangers Of Hazardous Waste

The improper disposal of household hazardous wastes can cause problems for the entire community. Wastes can be explosive or highly flammable. Sewers have exploded and garbage trucks have burned because people have carelessly discarded flammable or reactive wastes.

Hazardous wastes can also be corrosive. The acid from discarded auto batteries can eat away many substances. Some wastes are poisonous to humans or wildlife, while others can cause cancer, birth defects or other serious medical problems.



Where Do We Put Them

One of the worst ways to dispose of many hazardous materials is to "just dump them down the drain." Wastewater treatment plants are not designed to handle certain types of hazardous wastes.

Unfortunately, disposing of wastes in a landfill has not proven an effective solution either. Without special design, the modern sanitary landfill is not equipped to accept hazardous wastes. Hazardous wastes improperly disposed of in a landfill can pollute the environment through the groundwater, surface water and air.

If the public can not dispose of most hazardous wastes in the sewer system or a landfill, what can be done? This brochure describes some preventive measures you can take in your home to reduce the quantity of waste you must dispose. The Household Hazardous Wastes chart indicates the best way of dealing with most hazardous materials found in the home.

First: Reduce The Amount

You do not need a Ph.D. in Chemistry to reduce hazardous wastes in your home. The following suggestions can help:

- ☐ Before you buy a product, read the label and make sure that it will do what you want. Once you buy something you are also responsible for disposing of it properly.
- ☐ Do not buy more than you need. That way, you will not need to dispose of the surplus.
- ☐ Read and follow direction on how to use a product and dispose of the container. (There is a good reason why the labels say "do not incinerate" or "do not mix with bleach.")

Second: Take Care Of The Wastes

Even if you reduce the wastes that must be dealt with as outlined above there is still the question of what to do with what is left over.

Recycling is an excellent way of handling some hazardous wastes. Used motor oil, paint thinners and some other solvents can be refined and reused just as aluminum cans are. Local civic groups can help you identify recycling programs.

Incineration is another effective means of dealing with some hazardous wastes. However, a specially designed incinerator is needed to destroy hazardous materials. "Incinerators" in your home, such as your fireplace or wood stove, can not get hot enough to destroy hazardous wastes and should **never** be used to destroy wastes.

Take your household hazardous wastes to a licensed contractor. Your local wastewater treatment operator can give you more information on this matter, along with details on other methods of disposing of hazardous materials.

The Household Hazardous Waste Chart will guide you in disposing of potentially hazardous materials around your home. You should display this chart where you store hazardous wastes.

Remember to never dump hazardous wastes on the ground, and always check the chart before pouring them down the drain.

HOUSEHOLD HAZARDOUS WASTE CHART

The following chart prepared by the Water Pollution Control Federation will help you establish the most effective means of disposing of typical hazardous wastes used around your home or garden.

Blue dots (●) indicate products which can be poured down the drain with plenty of water. If you have a septic tank, additional caution should be exercised when dumping these items down the drain. In fact, there are certain chemical substances that cannot be used with a septic tank. Read the labels to determine if a product could damage the septic tank.

Yellow diamonds (◆) indicate materials which cannot be poured down the drain, but can be safely disposed of in a sanitary landfill. Be certain the material is properly contained before it is put out for collection or carried to the landfill.

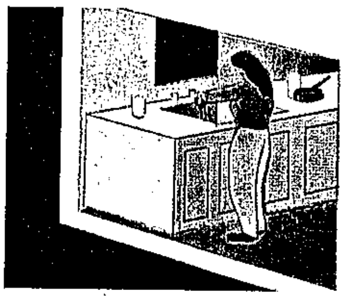
The red boxed squares (▣) indicate hazardous wastes which should be saved for a community wide collection day or given to a licensed hazardous wastes contractor. (Even the empty containers should be taken to a licensed contractor).

Green packages (❖) in the fourth column indicate recyclable material. If there is a recycling program in your area, take the materials there. If not, encourage local officials to start such a program.

For more information on the safest way to dispose of these and other products contact the United States Environmental Protection Agency. We suggest that you note here these important phone numbers in your local area:

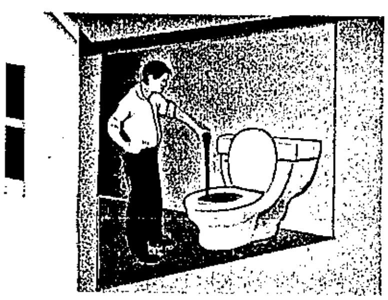
Hazardous Waste Management Agency ☎ ______________

Poison Control Center ☎ ______________



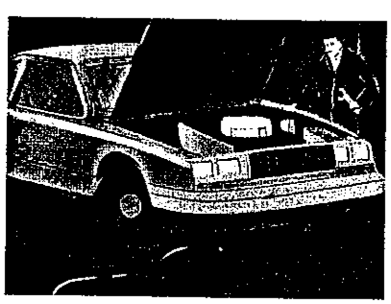
KITCHEN

Type of Waste	●	◆	▣	❖
Aerosol cans (empty)		◆		
Aluminum cleaners	●			
Ammonia based cleaners	●			
Bug sprays			▣	❖
Drain cleaners	●			
Floor care products			▣	
Furniture polish			▣	
Metal polish			▣	
Window cleaner			▣	
Oven cleaner (lye base)	●			



BATHROOM

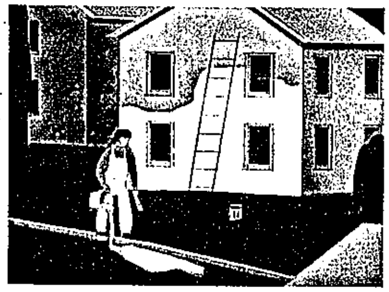
Type of Waste	●	◆	▣	❖
Alcohol based lotions (aftershaves, perfumes, etc.)	●			
Bathroom cleaners	●			
Depilatories	●			
Disinfectants	●			
Permanent Lotions	●			
Hair relaxers	●			
Medicine (expired)	●			
Nail polish		◆		
Nail polish remover			▣	
Toilet bowl cleaner	●			
Tub and tile cleaners	●			



GARAGE

Type of Waste	●	◆	▣	❖
Antifreeze			▣	
Automatic transmission fluid			▣	
Auto body repair products		◆		
Battery acid (or battery)			▣	❖
Brake fluid			▣	
Car wax with solvent			▣	
Diesel fuel			▣	❖
Fuel oil			▣	❖
Gasoline			▣	❖
Kerosene			▣	❖
Metal polish with solvent	●			

Metal polish with solvent	●			
Motor oil			■	❖
Other oils			■	
Windshield washer solution	●			

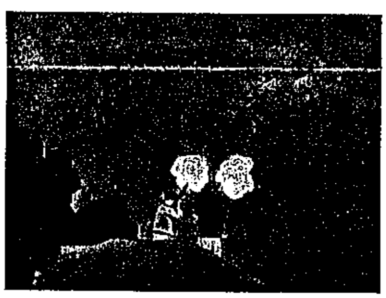


WORKSHOP

Paint brush cleaner with solvent			■	❖
Paint brush cleaner with TSP	●			
Aerosol cans (empty)		◆		
Cutting oil			■	
Glue (solvent based)			■	
Glue (water based)	●			
Paint — latex	●			
Paint — oil based			■	
Paint — auto			■	
Paint — model			■	
Paint thinner			■	❖
Paint stripper			■	
Paint stripper (lye base)	●			
Primer			■	
Rust remover			■	
Turpentine			■	❖
Varnish			■	
Wood preservative			■	

GARDENING

Fertilizer			■	
Fungicide			■	
Insecticide			■	
Rat poison			■	
Weed killer			■	



MISCELLANEOUS

Ammunition			■	
Artists' paints, mediums			■	
Dry cleaning solvents			■	❖
Fiberglass epoxy			■	
Gun cleaning solvents			■	❖
Lighter fluid			■	
Mercury batteries			■	
Moth balls			■	
Old fire alarms			■	
Photographic chemicals (unmixed)			■	
Photographic chemicals (mixed and properly diluted)	●			
Shoe polish		◆		
Swimming pool acid			■	

The preceding chart is based on information from the United States Environmental Protection Agency's Hazardous Waste regulations.

For information on obtaining copies of this brochure contact:
WATER POLLUTION CONTROL FEDERATION • 601 WYTHE STREET • ALEXANDRIA, VA 22314-1994

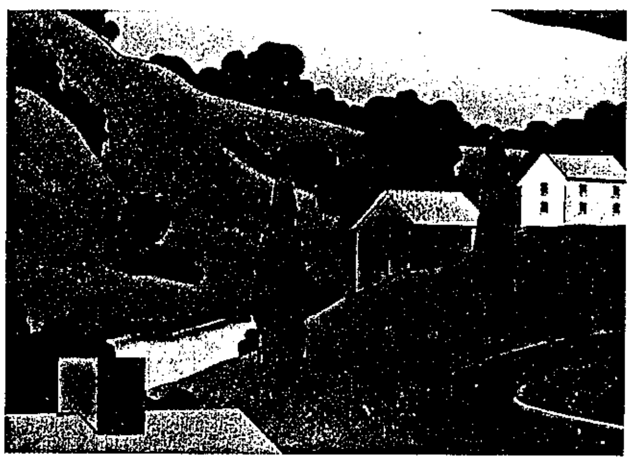
What You Can Do In Your Community

By working together, the people in a community can plan and create effective systems for managing hazardous wastes. Many communities have begun to sponsor Hazardous Waste collection days. These efforts have helped reduce the amount of hazardous waste in many areas while heightening public awareness of the problem.

Successful collection efforts in many cities have helped officials protect their community's wastewater treatment plants and groundwater from hazardous waste contamination. Many communities were able to collect thousands of pounds of hazardous materials on the strength of a one or two day effort. If your community has a program for disposal of hazardous wastes, please support it.

We also encourage you to:

- ☐ Learn as much as you can about your wastewater treatment plant and share that information with your family and friends. Clean water is for everyone.
- ☐ Learn about your community's landfill system and special programs for the disposal of hazardous wastes.
- ☐ Contact your state hazardous waste agency. They can provide information on companies which are licensed to handle hazardous wastes along possible funding sources for such efforts.



What The Future Holds

Billions of dollars have been spent to clean up our lakes and streams. Many millions more have been spent to build and maintain adequate sanitary landfills.

Modern wastewater treatment plants have led us all to expect clean water and a safe environment as a part of our everyday lives. We now realize that we can not just discharge our wastes into a stream or bury hazardous waste without thinking about their impact on the environment.

For that reason and others, household hazardous waste collection has really caught on. Communities throughout the world have begun to develop programs to deal with household wastes. These efforts need to be expanded to include as many areas as possible.

For details on what you can do, contact your local wastewater treatment facility, Department of Public Works or Sanitation District. Or, for further information you can contact:

Water Pollution Control Federation
601 Wythe Street
Alexandria, VA 22314-1994

Direct inquiries to the Public Education department.

HAZARDOUS WASTE

WHAT YOU SHOULD & SHOULDN'T DO