TABLE 2: COMPUTATION OF GROUNDWATER OUTFLOW FROM WATERSHED AREAS

Stream Watershed (Name and Acreage) (1)	Percent Stratified Drift (2)	Average Groundwater Outflow (gpd/mi^2) (3)	Average Groundwater Outflow Total Watershed (gpd) (4)	Total Groundwater Outflow (gpd) (5)	Total Groundwater Outflow (gpd) (6)	Recommended Long Term Potential Yield (gpd) (7)
1. Trout Brook (400)	86.5	792,000	495,000	198,000	415,800	297,000
2. Hazel Brook (727)	72.7	729,000	828,098	331,239	695,602	496,858
3. Mill Brook (1,057)	71.6	724,500	1,196,557	478,623	1,005,107	717,934
4. Hayward Br. (1,269)	37.7	549,000	1,088,564	435,425	914,393	653,138
5. Pine Brook (1,245)	38.8	553,500	1,076,730	430,692	904,453	646,038
6. Snake Brook (1,469)	39.5	558,000	1,280,784	512,313	1,075,858	768,470
7. Dudley Brook (643)	78.8	760,500	764,064	305,625	641,813	458,438
8. Sudbury River I (106)	86.8	793,800	131,473	52,589	110,437	78,884
9. Sudbury River II (448)	33.3	519,300	363,510	145,404	305,348	218,106
10. Sudbury River III (264)	76.5	745,200	307,395	122,958	258,212	184,437
11. Lake Cochituate (305)	100.0	855,000	407,461	162,984	342,267	244,476
12. Charles River (202)	67.3	702,000	221,568	88,627	186,117	132,941
TOTALS: 8,135			8,161,204	3,264,479	6,855,407	4,896,720

Notes: Column (5) gives Long Term Minimum Outflow
Column (6) gives Outflow Exceeded 7 Years in 10

No determination has been made of groundwater recharge from the Sudbury River

Reference: By Cervione and others, 1972.

TABLE 3: COMPARISON OF HISTORICAL YIELDS AND DRAWDOWNS WITH RECOMMENDED POTENTIAL YIELDS AND MAXIMUM DRAWDOWNS FOR THE GIVEN WELL AND RELATED UPLAND WATERSHED

	Average Annual Yield in MG 1967-79	Maximum Yield and Drawdown 1977		Highest Yield for Each Well and Maximum Drawdowns			Long Term-Total Groundwater Outflow From Table XII (MG)	Recommended Long Term Yield From Groundwater Outflow Table XII	Recommended Maximum Drawdown Based on Approximate Well Depth x .60	
	MG	MG	DD (FT)	Year	MG	DD (FT)	MG	MG	Depth (FT)	DD (FT)
Happy Hollow										
#1	93	70	14'9"	1977	70	14'9"	328 from Dudley Brook & Sudbury River II Watersheds	235	55	33
#2	179	249	14'9"	1977	249	14'9"			55	33
Baldwin Pond										
#1 #2	73	77	14'9"	1971	135	14'8"	40 from Sudbury River I Watershed	28	55	33
#3	118	103	14'9"	1971	112	14'8"				
Meadow View										
#1	90	121	24'11"	1977	121	24'11"	94 from Sudbury River III Watershed	67	53	32
Campbell Road										
#1	33	4	13'10"	1970	162	18'0"	151 from Trout Brook Watershed	108	55	33
Totals	586	624			849		613	438		

Note: Recharge to the wells from the Sudbury River surface and groundwater regime is not reflected in the projection of groundwater outflow computations.

during that year. Looking at the worst case (maximum annual discharge for each well during this period), the yield reached 849 million gallons. If the demand were present, it is possible that this volume of water could be produced because each well record has demonstrated that these maximum yields are possible without any effects from well interference. Since the upland areas cannot provide up to 600 million gallons annually, then groundwater stored in aquifers connected with the Sudbury River must contribute a portion of the total yield discharged for the wells. The presence of this river is therefore a valuable component in fulfilling the Town's water supply needs. Despite the Sudbury River's contribution, every effort should be made to maintain peak storage in upland ground watersheds.

Both the historical and recommended maximum drawdowns for each well are shown in Table 3. Drawdowns should not exceed 32 to 33 feet of the entire saturated thickness of the aquifer. This determination in made based on the fact that peak aquifer yield occurs around 60% to 67% of well depth in groundwater and decreases sharply thereafter (Groundwater and Wells, 1975). According to maximum drawdown levels, none of the aquifers have been pumped to their maximum potential. Drawdowns to a depth of 32 feet are not advisable unless it is evident that there will be sufficient recharge in the area to restore groundwater levels and thereby avoid a long term loss of storage.

V. Recommendations

RECOMMENDATIONS

A. Water Supply

In Part III of this report, the historical use of water in the Town was discussed with specific emphasis on the relative use of each well. Happy Hollow #2 and Baldwin Pond #3, with the highest discharge rates of 700 gpm and 650 gpm, respectively, were shown as having provided, on the average, a greater portion of the total water supply during the years 1967 to 1979, Figure 16. The disparity between individual well use during this same period is reflected in Figure 17. Based on these observations it appears that a program is needed for withdrawal of groundwater from the Town's water supply aquifers. A simple management plan including a schedule of well use based on recharge potential, aquifer characteristics, well design and performance could provide guidance to the Town for better control of groundwater production and use. In this way the available water supply can be regulated to meet the Town's needs and to sustain the highest potential yields on a long term basis.

The hydrologic cycle and the yearly trend in consumer use are important factors to consider in adopting a water management plan. In the winter, water surplus is normally present both in groundwater and surface water reservoirs, e.g., ponds, streams and rivers. In the summer, surface water availability is usually much less than groundwater. Consequently, a scheme for water utilization in Wayland should consider taking advantage of surface water during wet seasons, and conserving groundwater storage for drier periods. The wells determined to have the best hydraulic connection with the Sudbury River and flood plain could be relied upon in the spring while the other wells are rested. When demand peaks in the summer and river flow is reduced, a shift could be made to the less active wells. Implementation of this kind of strategy would vary based on the physical limitations within each aquifer.

One important advantage of following a utilization plan for all the wells is that a maintenance program can be suited to the level of well use. The frequency of routine work and inspections should reflect the age and condition of each pump, performance of the gravel pack well and duration of pumping. Timely maintenance could help to avoid problems of encrustation, clogged well screens, loss of aquifer permeability or pump efficiency and unexpected shutdowns.

The map of aquifer favorability, Plate VIII, shows the areas of deep saturated thickness where the best opportunity for developing additional groundwater supplies are located. The installation of test wells in the future should be concentrated in these areas because of the vast amount of groundwater storage. The difficult challenge is finding glacial materials which exhibit good permeable characteristics. Most of the deep aquifer areas are classified as moderate or high favorability, and have already been tested for possible well sites. Other locations with the same designations are limited because of nearby residential development. Future investigations for water supply should begin in the favorable areas, particularly at locations where existing wells are found and additional yield may be possible.

On Plate VIII an area around each well has been highlighted for groundwater protection. Each designation contains important upland and lowland sand and gravel recharge areas and the cones of influence expected with normal use. In these areas an effort should be made to educate the landowners about the importance of good land use practices.

B. Protection Techniques

1. Education-Conservation

For many years Wayland residents have been fortunate in receiving a seemingly endless supply of good quality water. The public's general consumption increased to a peak level in the last few years and for this and other reasons, the need for consumers to develop a better understanding of water resources became evident. Today people are now more aware of the importance for protecting surface and groundwater supplies and should begin to adopt good conservation practices. Public response can be developed through informative and persuasive programs initiated by the Town. Some approaches which the Town may pursue are described below.

(1) Prepare educational pamphlets, letters, diagrams, etc., to distribute in a Town-wide mailing or with the water bills. This would be an expansion on the current efforts by the Water Department to inform the public about water use. Ideas like water-saving devices, conservation practices and voluntary land use controls could be emphasized.

(2) Seek voluntary cooperation from business, industry, recreation (golf courses) and municipal facilities to reduce excess water consumption.

(3) Local newspapers could be a good source for disseminating information like a monthly report on the water supply situation, special problems or requests.

(4) Libraries and other municipal buildings could be used for educational programs, displays, etc. The school system could provide additional programs in this regard.

(5) Implement water conservation techniques such as increased fees, surcharges during peak usage or schedules for high volume users. In times of drought more severe steps such as water bans or use limitations may become necessary.

2. Land Use Regulations

a. General Background

In the early 1970's, both Federal and State governments recognized the need to address water pollution problems and set out to deal with them by enacting the Clean Water Acts and similar water resource protection legislation. The responsibility of investigating and controlling large sources of municipal and industrial contamination was initiated by agencies within these governments, but the magnitude of the job frequently exceeded available manpower. In many cases this resulted in the inability of the Federal and State officials to deal with pollution problems particularly at the local level. As the interest in protecting surface and groundwater resources became more widespread in Massachusetts, new laws were enacted and existing regulations strengthened. The laws currently applicable to wetland environments are the State Clean Waters Act, Coastal and Inland Wetlands Restriction Act and Wetlands Protection Act. The Massachusetts Department of Environmental Quality Engineering has promulgated regulations for controlling contaminants in drinking water supplies, and for permitting sewage disposal systems in accordance with Title 5 of the State Environmental Code. These laws and regulations have some provisions which bear on groundwater values in a general respect, but none adequately cover the protection of groundwater resources. The DEQE has a requirement that public water supply wells (gravel packed) must have all the land area within a 400 foot radius under the control of the municipality. Acquisition of the property is the best method for controlling land uses within this area. Although the 400 foot protection district is valuable, it is often insufficient because discharging wells can influence areas over a much greater distance.

b. The State's Role

A major problem for communities in adopting effective land use regulations is the lack of legal and administrative leadership from the State. According to Lapping (1980) very little work has been accomplished throughout the New England states to deal with water supply, quality, allocation and use. In 1977 Massachusetts issued a Water Supply Policy Study to encourage communities to develop strategies for water resource protection and utilization, but response has been slow. Lapping (1980) reported that researchers have examined the institutional network and management processes in state governments and concluded that there is a lack of comprehensive planning, agency coordination and legal framework for water resource protection. The report indicates that "Massachusetts has no legislatively or administratively mandated, integrated comprehensive water resource planning or management mechanisms." and, "...no administrative mechanism to assess and resolve water resource issues". This has created difficulties for many communities that need strong controls to protect their local water supplies.

c. The Town's Role

In some towns the residents have taken it upon themselves to adopt local bylaws to regulate land use, and when challenged, the issue of constitutionality has been pursued in the courts. One of the most significant issues raised in opposition to local control has been "taking without just compensation". Landowners claim a loss of value by the imposition of use regulations. Although the legality of municipal authority to regulate has been questioned, several cases have been upheld by the courts. In Turnpike Realty Co. v. Town of Dedham (362 Mass. 221, 1972), the Massachusetts Supreme Judicial Court allowed the municipality's use of "police power" to regulate flood plains and wetlands for the health, safety and welfare of the community. In a more recent court case, Lovequist v. Gardner (1979), the Town of Dennis' wetlands bylaw was upheld when challenged by a developer. The court ruled in favor of protecting the local groundwater supply because of the potential impacts related to the proposed wetland alterations.

The inability of State agencies to provide direction to the cities and towns and the difficulties local communities face in establishing legal controls is largely due to the lack of technical understanding of the groundwater regime. Only recently has the need of hydrogeologic investigations come into real focus for the communities subject to development pressures. Many studies have now been initiated (some completed) and the "state of the art" has been developed to the point where legislative and administrative mechanisms could be implemented by the State. The cost of implementing groundwater resource protection will be high and may even seem prohibitive for some communities. Yet, the number and extent of local water supplies are limited and, if lost, the cost of seeking alternative sources may be even greater.

d. Existing Local Regulatory Authority

Wayland is one of many communities in the Commonwealth that has no formal mechanism for groundwater protection. The current flood plain bylaw pertains primarily to the Sudbury River. It is administered by the Zoning Board of Appeals through the office of the Building Inspector. Alterations of land or water in the Flood Plain District (FPD) requires a special permit. Before a permit can be issued, the proponent must file an application and plans with the Appeals Board, which holds a public hearing and subsequently renders a decision based on the merits of the proposal and potential impacts on the environment.

The Flood Plain District includes the lower portions of several of the major brooks flowing towards the Sudbury River. In order to extend local wetland protection further upstream on these watercourses, the Town also adopted a Watershed Protection District (WPD). The provisions of this bylaw are similar to, although less stringent than, the flood plain regulations and only apply to a narrow strip of land along each side of the main brooks and smaller tributaries.

In order to protect wetland areas beyond the WPD, the Town must rely on the applicability of the Massachusetts Wetlands Protection Act (WPA), M.G.L. Chapter 131, Section 40, which gives regulatory authority to the local Conservation Commission. In addition, the WPA can be applied to wetlands included in the FPD and WPD.

e. Adoption of New Regulatory Authority

The laws and regulations currently available to the Town are very useful, but are clearly not adequate to provide the kind of protection necessary for preserving the Town's water supply. The Town can pursue the adoption of new zoning regulations under authority of the Zoning Enabling Act and the Home Rule Amendment to the State Constitution. Non-zoning water resource protection techniques can also be passed by the Town under general municipal powers pursuant to the M.G.L. Chapter 40, Section 21. Several towns have passed non-zoning wetlands bylaws which parallel the State Wetlands Protection Act. This mechanism was first started by the Town of Dennis and is now being considered by many other communities across the State. The procedure for appeal under this kind of bylaw is to the courts rather than through the administrative procedures required by the Massachusetts Department of Environmental Quality Engineering.

In order for Wayland to consider implementing zoning or non-zoning regulations, a very important step must be accomplished first. The Town should begin to develop a comprehensive land use plan which would set forth policies and goals that are in the interest of the health, safety and welfare of the community. The plan should specify the land and water resource values that need to be protected, and present formal and informal mechanisms by which these interests can be preserved. Once a viable plan is formulated, it should be approved by the Town. The best forum for adopting a comprehensive land use plan is at Town Meeting. Once accepted, the plan can then be implemented through the passage of zoning and non-zoning bylaws. Such bylaws should be supported by technical studies and information which will justify future Town action and provide a stronger defense if challenged in court. Recent court decisions have been favorable to bylaws which are based on land use plans adopted by communities. It is therefore highly recommended that Wayland begin the process of developing a comprehensive land use plan for the purpose of adopting any future water resource protection techniques.

f. Strengthening Existing Local Regulatory Authority

With the aid of this groundwater study, Wayland should begin to strengthen its existing local bylaws and administrative procedures. It is important that land use in the affected drawdown areas around the Town wells and the productive recharge areas be properly controlled. In the significant groundwater areas, standards for the installation of sewage disposal systems should provide a greater degree of protection. For instance, the regulations could consider:

(1) The replacement of highly permeable soils with a finer more absorptive soil. Currently there is no limitation on the maximum percolation rates allowable for system construction.

(2) The substitution of larger holding tanks. This permits a greater storage capacity for solids to be decomposed and can extend the life of the leaching fields.

(3) The requirement of greater vertical clearance above the water table to allow for more soil filtration and treatment of effluent.

(4) The initiation of a yearly inspection program and regular maintenance when required.

(5) The adoption of measures to prevent the disposal of chemicals, oils, acids and similar contaminants into the system and ultimately into the ground.

Subdivision regulations can be administered so as to protect water resources by:

(1) Controlling impervious coverage and storm drainage design so as to minimize the loss of infiltration and maximize recharge.

(2) Encouraging overland flow to increase soil-water contact and enhance natural purification.

(3) Requiring revegetation to control erosion and sedimentation, delay runoff rates and purify water runoff.

(4) Clustering or coordinating new construction on less sensitive areas of a development site.

(5) Incorporating the use of conservation restriction or easements on important hydrologic areas.

(6) Restricting site alterations to prevent wetlands destruction and modification of groundwater conditions.

(7) Restricting on-site disposal of waste materials as to substance, location and clearance above the water table.

Zoning regulations can be used to protect water resources by:

(1) Controlling the density and intensity of development over important hydrogeologic areas.

(2) Limiting the spread of impervious surfaces (pavement, buildings, etc.) on land zoned for business and commercial uses, where such uses may impact groundwater resources.

(3) Restricting encroachment within wetlands and flood plains.

(4) Controlling gravel removal sites to avoid detrimental impacts on local surface and groundwater conditions.

(5) Incorporating procedures and guidelines for the proper installation of underground fuel, waste, or chemical storage facilities.

(6) Adopting bylaw provisions for controlling the transportation, storage, use and illegal disposal of hazardous wastes.

In addition to working within existing regulatory authority, the Town could consider adopting a mechanism for protecting its groundwater supply. Other communities within the Commonwealth are looking at aquifer zoning as a specific overlay protection district on existing land uses and zoning requirements. The basic components of an aquifer zoning bylaw are criteria for delineating protected areas, list of permitted and prohibited uses and provisions for granting special permits. Some of the reasons for establishing aquifer zoning are embodied in the points raised in the previous section. The general purpose is to promote land uses (within the influence of the Town wells) which are compatible with the Town's water supply.

C. Recommendations for Further Technical Investigations

Previous discussion has already indicated the need to obtain additional data on wells where information is inadequate or unavailable; and to quantify the river recharge-well discharge relationships in each water supply aquifer. This could be accomplished by installing observation wells within the cones of influence and measuring drawdown response. The wells would also be useful to monitor changes in water quality and storage. A list of specific questions which should be answered for each well site is given below:

(1) The frequency and duration with which river flow (high and low) affects groundwater storage and replenishment in each aquifer.

(2) The percent of total volume discharged from each pumping well that consists of upland groundwater as compared to water derived from river flow computed on a monthly basis. The emphasis is to quantify well dependence on the Sudbury River depending on flow and flood levels.

(3) The maximum practical drawdown level each aquifer can sustain without any serious detrimental effects on aquifer performance, water quality and long term yield.

(4) The extent and significance of well interference when more than one well is discharging from the same or contiguous aquifer.

(5) The potential for development of additional wells in existing production areas without significantly affecting the available water supply.

An inventory of the flood plain sediments should be completed in order to identify areas where the river is hydraulically connected to the underlying aquifer. This could be done in the summer through visual inspection and shallow hand auger borings. The results could be mapped in relation to Plate VII for future studies.

Within each major watershed, the water budget components should be estimated to compare the proportion of total rainfall lost as storm runoff with the amount recharged into the groundwater regime. Storm drainage systems should be reviewed to determine major discharge points, local flood potential and relative pollution loads. An inventory of the storm systems has already been completed and is available for this recommended study.

The Water Department's program of testing for new well sites should concentrate on those areas identified in this report as having optimum groundwater potential. Because of the presence of the Sudbury River and deep buried valleys, the Town can continue to take advantage of any recharge influence on these underlying aquifers.

BIBLIOGRAPHY

Baker, John A., Henry G. Healy and O. M. Hackett, 1964. Geology and Ground-Water Conditions in the Wilmington-Reading Area, Massachusetts. USGS Water Supply Paper 1694, 77p.

Bradley, Edward, 1964. Geology and Ground-Water Resources of South-Eastern New Hampshire. USGS Water Supply Paper 1695, 79p.

Brown, R. H., et.al. (Editors), 1972. "Ground-Water Studies" including Supplements 1-3, UNESCO, Paris.

Cervione, Michael A., David L. Mazzaferro, Robert L. Melvin, 1972. Water Resources Inventory of Connecticut, Part 6, Connecticut Water Resources Commission. Connecticut Water Resources Bulletin No. 21.

Commonwealth of Massachusetts, DEQE, 1977. Drinking Water Regulations, 41p.

Crosby, Irving B., 1939. Groundwater in the pre-glacial buried valleys of Massachusetts. Journal of New England Water-Works Association 53: 372-383.

Department of Public Works, 1979. Personal Communication. Bridge Division, Boston, Massachusetts, Boring Logs.

D. L. Maher Company, 1979. Personal Communication. Water Supply Contractors, North Reading, Massachusetts, Well Records.

Dunne, Thomas and Luna B. Leopold, 1978. Water in Environmental Planning. W. H. Freeman and Company, San Francisco, 818p.

E. R. Sullivan Well Contractor, 1979. Personal Communication. Bolton, Massachusetts, Well Records.

Federal Water Pollution Control Administration, 1968. Water Quality Criteria-Public Water Supplies: Report of the National Technical Advisory Committee to the Secretary of the Interior: Federal Water Pollution Control Administration, pp. 18-26.

Feth, J. H., 19 . "Water Facts for Planners and Managers", Water in the Urban Environment, 29p.

Flint, Richard F., 1971. Glacial and Quaternary Geology, John Wiley and Sons, Inc., New York, 892p.

Fortin, R. L., 1979. Town-wide Well Data Survey. Wayland, Massachusetts.

Goldthwait, James W., 1905. The sand plains of glacial lake Sudbury. Bulletin of the Museum of Comparative Zoology, Harvard College, Vol. XLII, Geological Series vol. VI, No. 6, pp. 265-301.

Ginsberg, Edward, 1979. Personal Communication. Metropolitan District Commission, Framingham, Massachusetts, Aqueduct Boring Logs.

Groundwater and Groundwater Law in Massachusetts, 1976. Massachusetts Division of Water Resources, 92 p.

Ground Water Manual, 1977. A Water Resources Technical Publication, U. S. Department of Interior, Bureau of Reclamation, U. S. Government Printing Office, Washington, D.C. 480p.

Ground Water and Wells, 1975. Johnson Division, UOP Inc., Saint Paul, Minnesota, 440p.

Haley and Aldrich, Inc., 1972. Pollution Study Proposed Sanitary Landfill. Wayland, Massachusetts, 4p. plus maps and logs.

Hansen, Bruce, 1979. Personal Communication. USGS, Boston, Massachusetts, Well Records and Boring Logs.

Hansen, Wallace R., 1953. Late Tertiary and Pleistocene drainage changes in the Hudson and Maynard Quadrangles, Massachusetts. Journal of Geology, 61: 353-362.

Hansen, Wallace R., 1956. Geology and Mineral Resources of the Hudson and Maynard Quadrangles, Massachusetts. Geological Survey Bulletin 1038, 104p.

Heath, Ralph C. and Frank W. Trainer, 1968. Introduction to Groundwater Hydrology, John Wiley and Sons, Inc., New York, 284p.

Hem, J. D., 1959. Study and Interpretation of the Chemical Characteristics of Natural Water. USGS Water Supply Paper 1473, 269p.

I.E.P., Inc., 1978. The Base Flow Value of the Glaciolacustrine-Glacialfluvial Deposits, Snake Brook Headwaters; and Hydrologic Impact of Gravel Excavation and Proposed Pond, Mainstone Farm Development, Wayland, Massachusetts, 12p.

Koteff, Carl, 1974. The morphologic sequence concept and deglaciation of southern New England: in Glacial Geomorphology. D. R. Coates, Editor, Publications in Geomorphology, State University of New York, Binghamton, N.Y., 398p.

Koteff, Carl, 1963. Glacial lakes near Concord, Massachusetts. USGS Prof. Paper 475c, pp. 142-144.

Koteff, Carl, 1964. Surficial Geology of the Concord Quadrangle, Massachusetts. USGS Map GQ-331.

Lapping, Mark, B., 1980. The State of Water Resource Planning and Management in New England--An Overview of Institutional Frameworks and Issues, Water Resources & Economic Development Conference, Ashland, Massachusetts. October, 1980, 17p. plus tables.

Leopold, L. B., 1968. Hydrology for urban land planning. USGS Circular No. 554.

Linenthal, Eisenberg, Anderson, Inc., 1979. Sand Hill Sanitary Landfill Report, Wayland, Massachusetts, 55p. and maps.

MacConnell, William P. and Marcia Cobb, 1974. Remote Sensing 20 Years of Change in Middlesex County, Massachusetts, 1951-1971. Bulletin No. 622, pp. 148-149.

Massachusetts Turnpike Authority, 1979. Personal Communication. Wellesley, Massachusetts, Highway Boring Logs.

Moon, Dr. Kenneth A., 1970. Municipal waste disposal and groundwater pollution. Massachusetts Audubon Society, 43p.

Motts, Ward S., 1977. Hydrology and groundwater resources of Sudbury, Massachusetts, 233p. and maps.

Nelson, Arthur E., 1974. Surficial Geologic Map of the Natick Quadrangle, Middlesex and Norfolk Counties, Massachusetts. USGS Map GQ-1151.

Nelson, Arthur E., 1974. Surficial Geologic Map of the Framingham Quadrangle, Middlesex and Norfolk Counties, Massachusetts. USGS Map GQ-1176.

Nelson, Arthur E., 1975. Bedrock Geologic Map of the Natick Quadrangle, Middlesex and Norfolk Counties, Massachusetts. USGS Map G2-1208.

Pollock, S. J., D. F. Farrell and W. W. Caswell, 1969. Water Resources of the Assabet River Basin, Central Massachusetts. USGS Hydrologic Investigations Atlas HA-312.

Reed, Donald E. (Consulting Geologist), 1978. Leachate Investigation Existing Sanitary Landfill, Wayland, Massachusetts, 10p., tables, maps and logs.

Roche, John, 1979. Personal Communication. Water Department, Wayland, Massachusetts, Well Records.

Water Department, 1979. Personal Communication. Framingham, Massachusetts, Well Records.

Water Department, 1979. Personal Communication. Natick, Massachusetts, Well Records.

Weston Geophysical Engineers, Inc., 1970. Geophysical Survey-Seismic Results Proposed Wayland Dump Site for Refuse Disposal Planning Committee. 8p. and profiles.

DEFINITION OF TERMS

Cone of Influence (depression)--Space within the saturated zone that is de-watered by a pumping well such that the water table surface or piezometric level conforms to the shape of an inverted cone around the well.

Confined Aquifer (artesian)--Saturated zone which has an overlying confining (impervious) layer such that water in the aquifer is under pressure. If penetrated by a well, water will rise to a level until it is in equilibrium with the atmospheric pressure. This level is called the piezometric water level.

Consolidated Material--Solid rock consisting of natural materials tightly bonded together, i.e. bedrock, ledge.

Drawdown--Lowering of a water level as water is withdrawn from a well.

Groundwater Discharge--The release of water from the saturated zone to the land surface.

Groundwater Recharge--Precipitation that falls on the earth, infiltrates into the soil and becomes part of the saturated zone.

Hydraulic Gradient--The change in static head per unit of distance in a given direction.

Hydrograph--A graph showing stage (height), flow, velocity or other property of water with respect to time.

Permeability-(hydraulic conductivity)--The capacity of a pervious material (soil or rock) to transmit water under pressure (hydraulic head). Expressed in terms of coefficient of permeability defined as the rate (velocity) of flow of water in gallons per day through a cross sectional area of one square foot under a hydraulic gradient of 100% at a temperature of 60°F.

Porosity--The percentage of the total volume of material (soil or rock) occupied by openings. Expressed as the ratio of the volume of pores to the total volume of porous material.

Saturated Thickness--Thickness of an aquifer below the water table.

Specific Retention--The water held in a material (soil or rock) after all the water capable of draining by gravity has been released. Expressed as the percent of volume of water retained by molecular attraction to the total volume of the fully saturated material.

Specific Yield (storage capacity)--The capacity of a material (soil or rock) to release water from storage under a force of gravity. Expressed as the percent of volume of water drained by gravity to the total volume of fully saturated material.

Transmissibility (transmissivity)--The capacity of an aquifer to transmit water. Expressed in terms of a coefficient of transmissibility defined as the rate of flow of water in gallons per day through a vertical strip of aquifer under a hydraulic gradient of 100% at the prevailing water temperature.

Unconfined Aquifer (water table aquifer)--The saturated zone is free of any confining influence such that the water is at atmospheric pressure and can fluctuate up or down.

Unconsolidated Material--Loosely packed materials consisting of sand, gravel, silt and clay size granules.

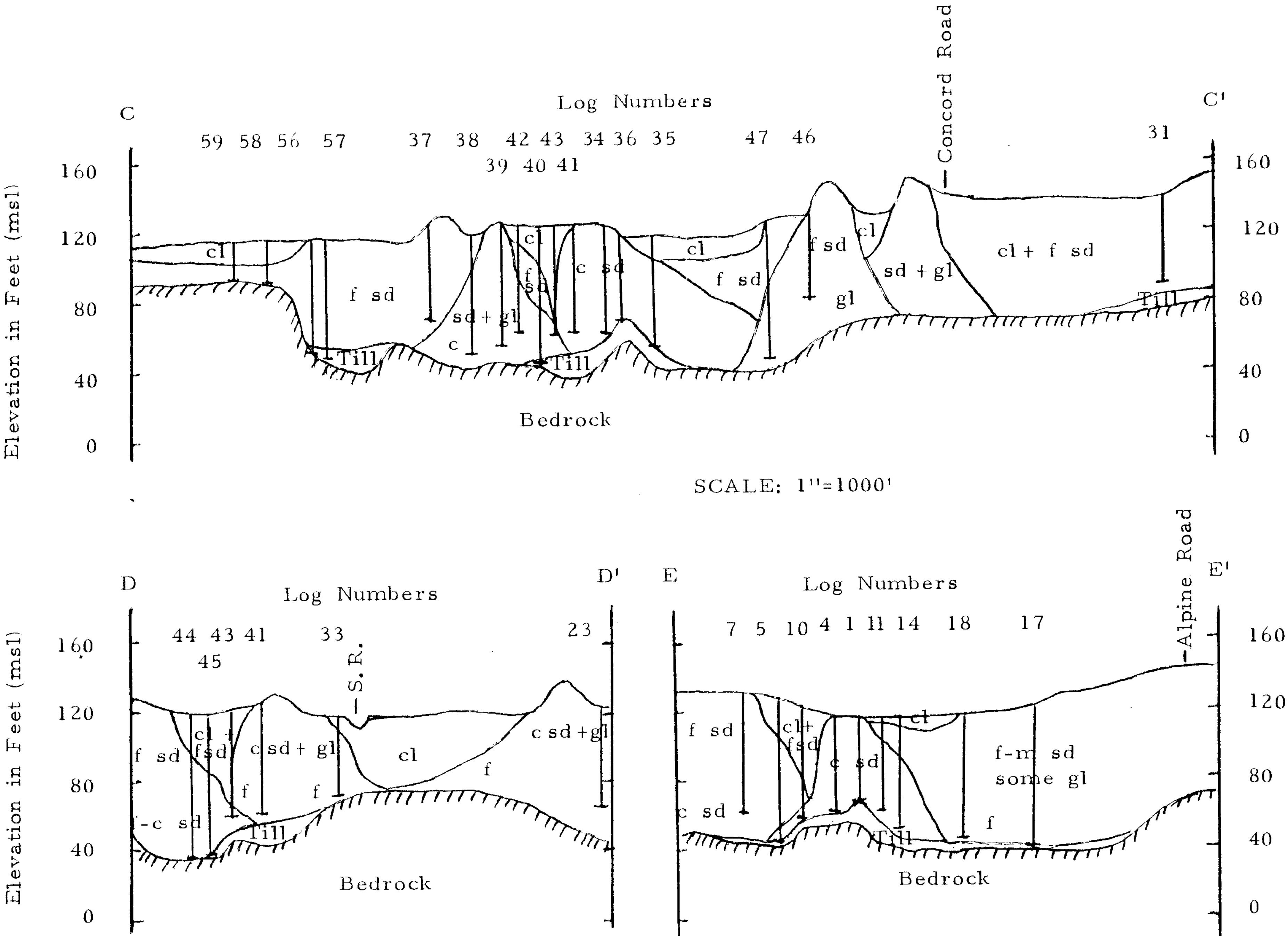
APPENDIX

A. List of Profiles

B. List of Tables

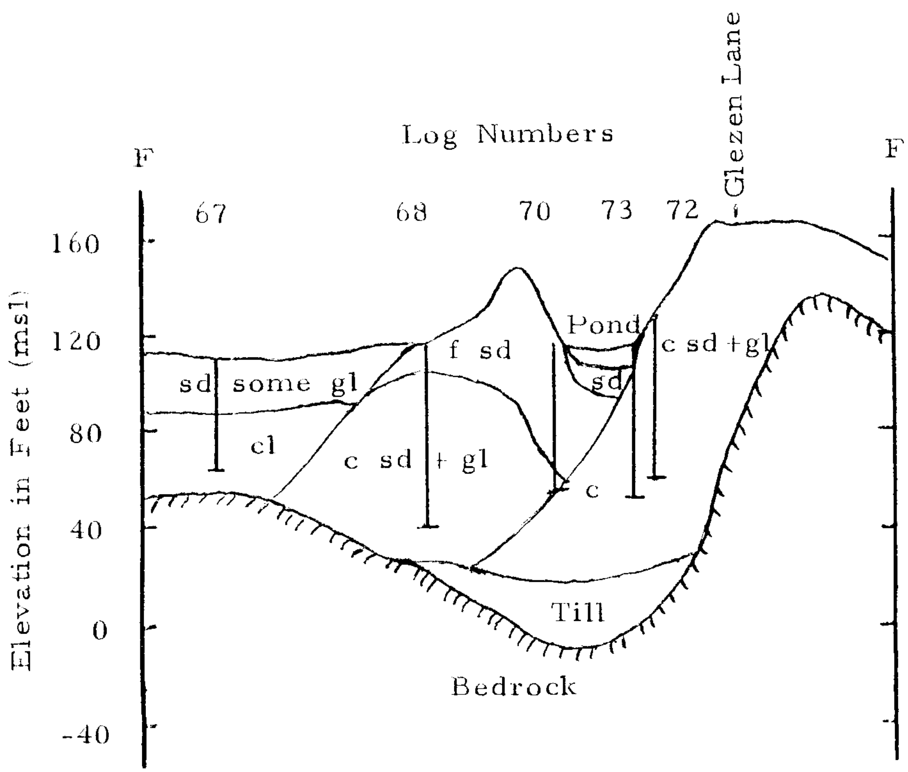
C. List of Figures

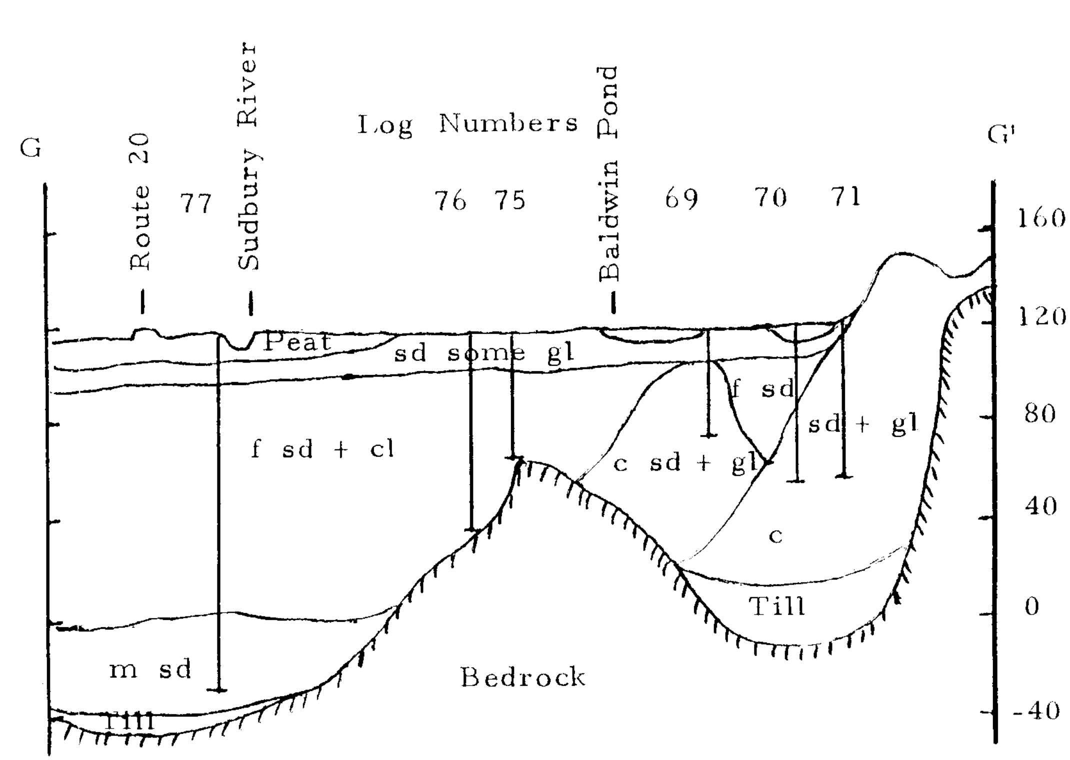
D. List of Plates



Profile I:

Profile of Gelogic Conditions Based on Interpretation of Well + Boring Logs in the Castle Hill / Spruce Tree Lane Area.





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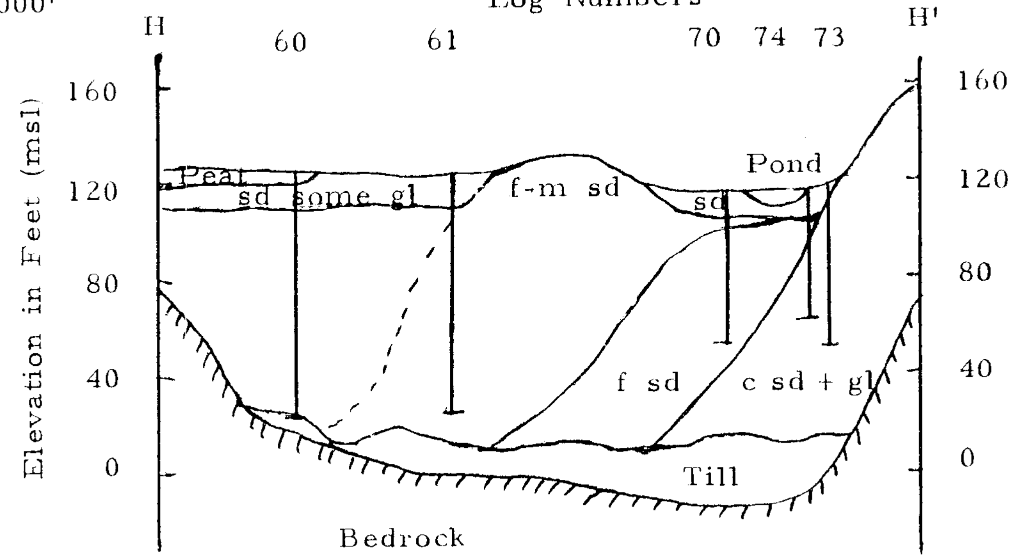
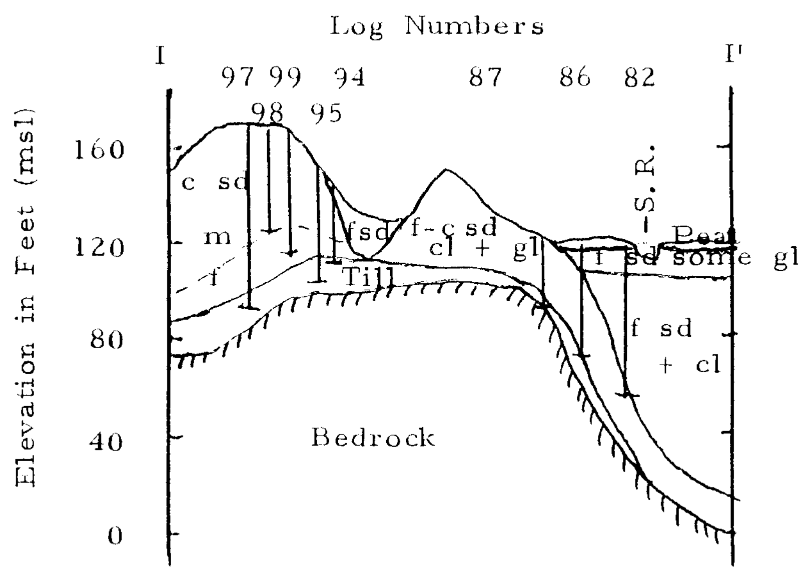
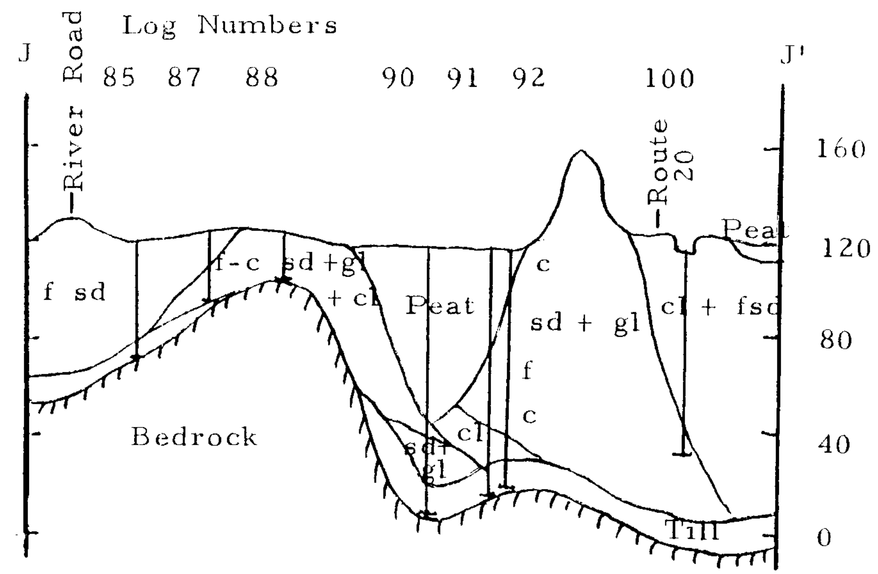


Profile II:
Profile of Geologic Conditions Based on Interpretation of Well + Boring Logs in the Baldwin Pond Area.





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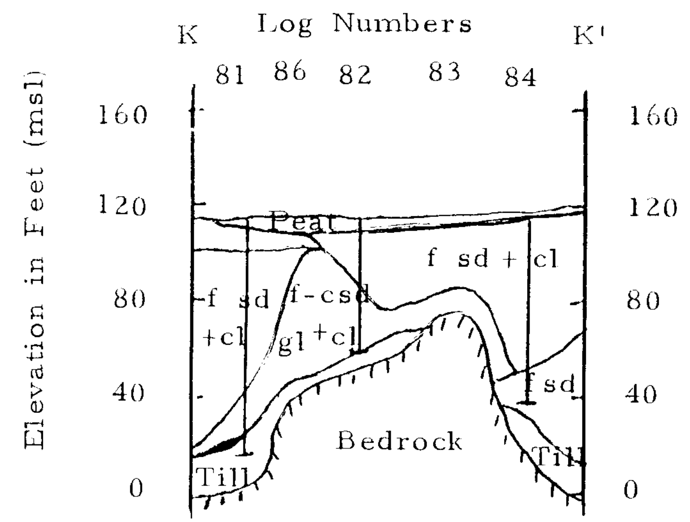
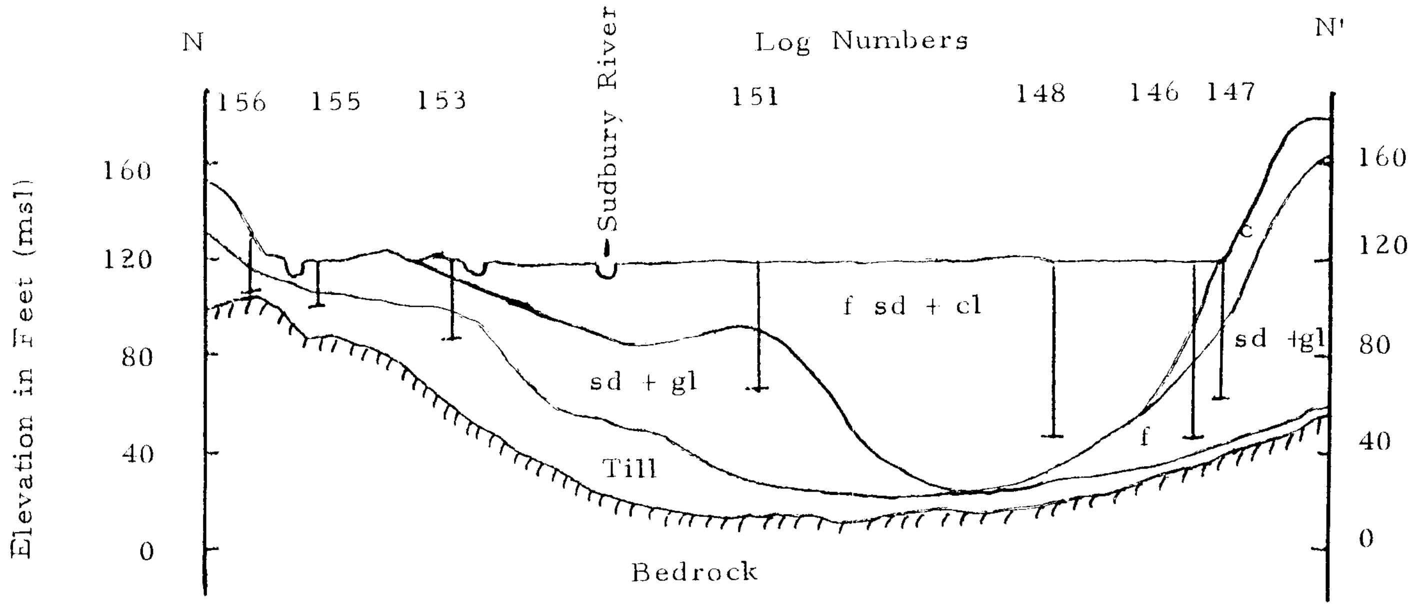


<u>Profile III:</u>
Profile of Geologic Conditions Based on Interpretation of Well + Boring Logs in the Sand Hill Area.



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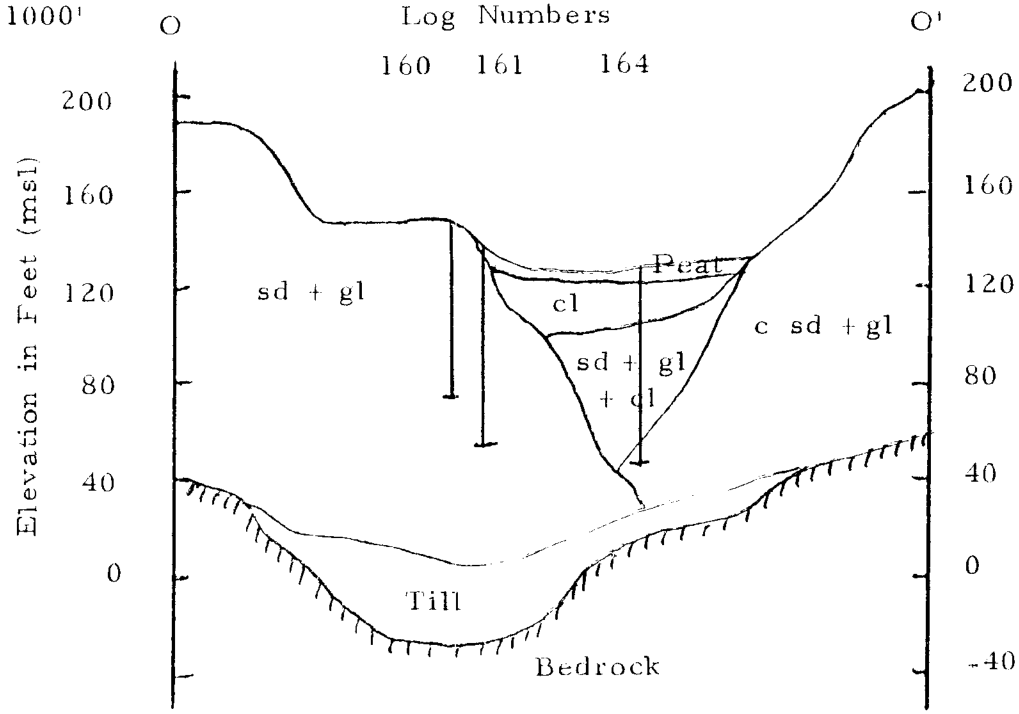
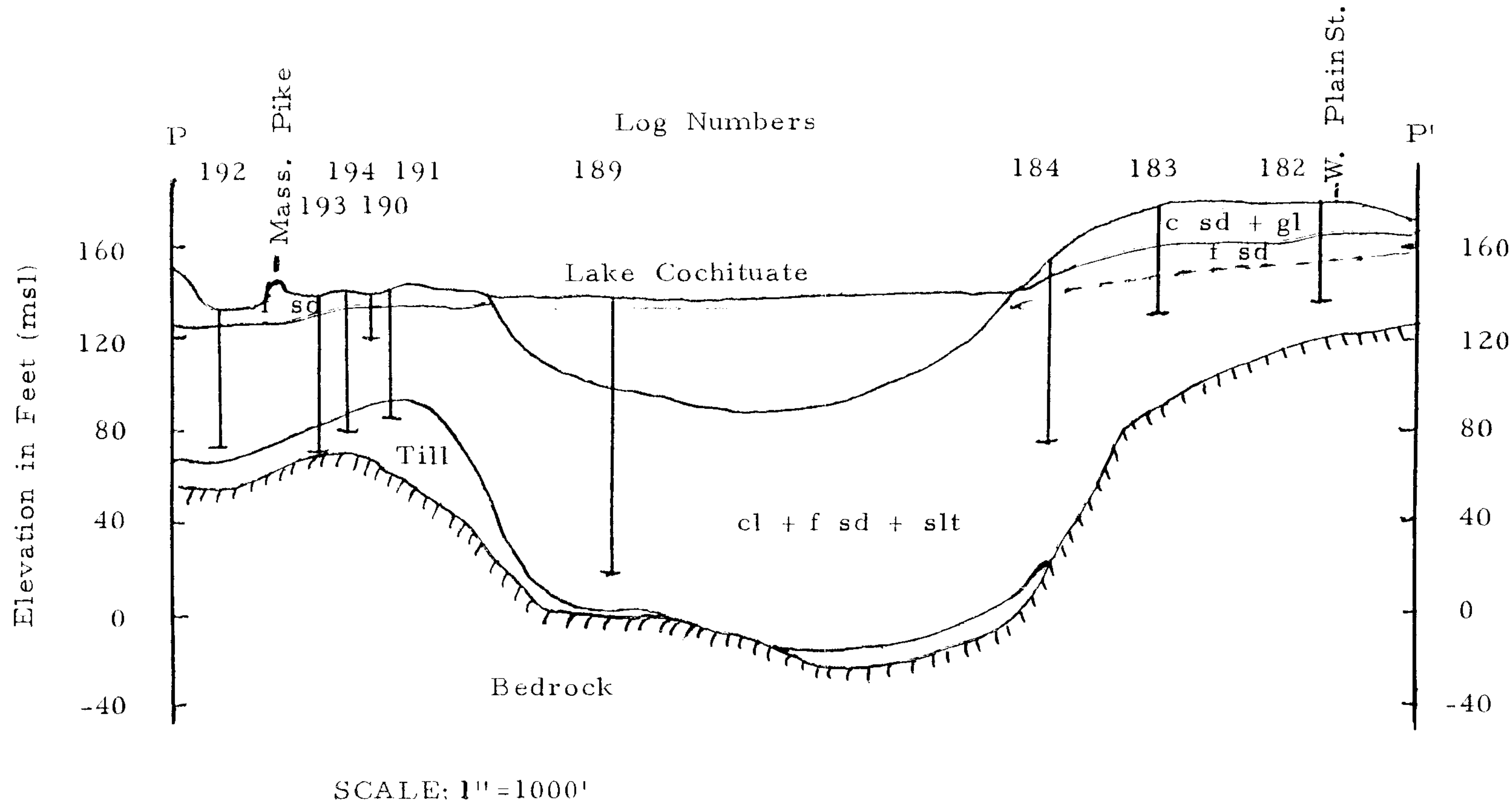


Profile IV:
Profile of Geologic Conditions Based on Interpretation of Well + Boring Logs in the Pod Meadow Area.



Profile V:
Profile of Geologic Conditions Based on Interpretation of Well + Boring Logs in the Cochituate Lake Area.

TABLE I

SURFACE WATERSHED AREAS

	Watershed	Area in Wayland (Acres)	Area in Other Town (Acres)	Total Area (Acres)
1.	Trout Brook	294	106	400
2.	Hazel Brook	591	136	727
3.	Mill Brook	1,050	7	1,057
4.	Hayward Brook	630	646	1,276
5.	Pine Brook	867	378	1,245
6.	Sudbury River			
	I	106	None	106
	II	448	None	448
	III	264	55	319
7.	Dudley Brook	643	None	643
8.	Snake Brook	1,469	Not Determined	1,469
9.	Lake Cochituate	305	Not Determined	305
10.	Charles River	202	Not Determined	202
	Remaining Sudbury R.	3,299	1,328	3,299
	TOTALS:	10,168		11,496

TABLE II

SUMMARY OF LAND USE INVENTORY
1951-1971

Type	1951 Area/acres	1951 Percent	1971 Area/acres	1971 Percent	Percent Change
Forest	4,604	45	4,318	42	- 3
Agriculture & Open Land	3,011	30	1,319	13	-17
Wetland	1,565	15	1,527	15	less than 1
Urban Land	988	10	2,724	27	+17
Outdoor Recreation	0	0	235	2	+ 2
Mining, Waste Disposal	0	0	45	1	+ 1

Reference: MacConnell, William P. and Marcia Cobb, 1974. Remote Sensing 20 Years of Change in Middlesex County, Massachusetts 1951-1971, Bull. No. 622, pp. 148-149.

TABLE III

WAYLAND ZONING BREAKDOWN

Zone Designation	Acres	Percent
Residence 20,000	1,506	14.81
Residence 30,000	746	7.34
Residence 40,000	4,405	43.32
Residence 60,000	3,345	32.90
Limited Commercial	100	.98
Industrial	4	.04
Business A	33	.32
Business B	11	.11
Rufuse Disposal	18	.18
	10,168	100.00
Overlay Zoning		
Flood Plain Zone	2,452	24.11
Planned Unit Development	356	3.50
Historic District	81	.79

TABLE IV

DESCRIPTION OF GEOLOGIC MATERIALS

GLACIAL DEPOSITS

	Lake/Spillway Elevation (msl)		Description
I. Lake Sudbury:			
Wayland Stage	Qls1	200'+	(Qls1, Qls1*, Qls2, Qls2* Qls3, Qls5, Qlsw, Qlsc)
High Level Weston Stage	Qls2* Qc4	195' 177'	Glacial lake and stream deposits consisting of sand, gravel and silt, poor to moderately sorted and stratified in the form of deltas, knobs, kettles, terraces and outwash.
High Level Cherry Brook Stage	Qls1*	160'	
Low Level Weston Stage	Qlsw	157'	
Low Level Cherry Brook Stage	Qls2 Qls3 Qls5 Qlsc Qlsb	155' 165' 155' 155' 155'	(Qc4) Meltwater deposits consisting of sand and gravel in contact with stagnant ice, poorly sorted and stratified occurring in the form of kettles, knobs, eskers and ice channel fillings.
II. Lake Charles			(Qlsb)
Happy Hollow Stage	Qc2	151'	Glacial lake bottom deposits consisting of well sorted and stratified fine sand, silt and clay size granules.
Morses Pond Stage	Qo1 Qo2	137' 137'	
East Natick Stage	Qlc2	166'	(Qc2) Same as Qc4.
Cochituate Stage	Qlc3 Qlcc	156' 156'	(Qlc2, Qlc3, Qlcc) Same as Qls1, etc.

(cont'd.)

TABLE IV (continued)

GLACIAL DEPOSITS

	Lake/Spillway Elevation (msl)	Description
		(Qo1, Qo2) Glacial stream deposits consisting of medium to coarse sand and gravel, well sorted and stratified occurring as outwash or terraces in association with ice contact deposits.
III. Undifferentiated	Qsg	(Qsg) Stratified deposits of sand, gravel and silt with variable characteristics and forms of origin.
IV. Till	Qt	(Qt) Ice laid deposits over bedrock or other till consisting of mixed combinations of gravel, boulders, sand, silt and clay size materials, poorly sorted with little or no stratification.
V. Holocene Deposits		(Qs)
Swamp/Muck	Qs	Peat, muck, silt and sand overlying older deposits.
Allivium	Qal	
Artificial	Af	(Qal) Poorly stratified sand, silt, gravel and clay granules washed from older glacial materials and deposited in low lying flood plains.
		(Af) Areas where geology has been altered by cuts or fills.

TABLE V

METHODS FOR HYDRAULIC ANALYSIS OF WELL SITES

NON-EQUILIBRIUM METHOD (Theis, 1935) (From Heath and Trainer, 1968)

Permits an analysis of aquifer conditions before equilibrium between the rate of withdrawal and rate of recharge is reached.

$$^{**}T = \frac{114.6Q\ W(u)}{h_0 - h} \qquad ^{**}S = \frac{uT}{1.87\ r^2/t}$$

**Formulas primarily applicable to confined aquifers.

- T = coefficient of transmissibility in gpd/ft
- S = storage coefficient
- Q = pumping rate in gpm
- h_0-h = drawdown in feet at any point in the vicinity of the well discharging at a constant rate
- r = distance in feet from the discharging well to the point where drawdown is measured
- t = time in days since pumping started
- $W(u)$ = "well function of u"

MODIFIED NON-EQUILIBRIUM METHOD (Jacob and Cooper, 1940) (From Ground Water and Wells, 1975)

Permits analysis of aquifer conditions before equilibrium between the rate of withdrawal and rate of recharge is reached when values of W(u) are sufficiently small, i.e. less than 0.05.

**Time Drawdown Formula

$$T = \frac{264\ Q}{\text{change in } h} \qquad S \doteq \frac{0.3\ Tt_0}{r^2}$$

**Distance Drawdown Formula

$$T = \frac{528\ Q}{\text{change in } h} \qquad S = \frac{0.3\ Tt}{r_0^{\ 2}}$$

**Formulas primarily applicable to confined aquifers.

- T, S, Q = Same as above
- t_0 = intercept of the straight line at the zero drawdown, in days
- r = distance in feet from the pumping well to the observation well where drawdown measurements were made
- change in h = drawdown in feet across one log cycle
- t = time in days since pumping started
- r_0 = intercept at the zero drawdown of the extended straight line, in feet

Note: At least three separate observation wells at different distances from the pumped well with simultaneous measurements are needed to use the Distance Drawdown Formula.

(cont'd.)