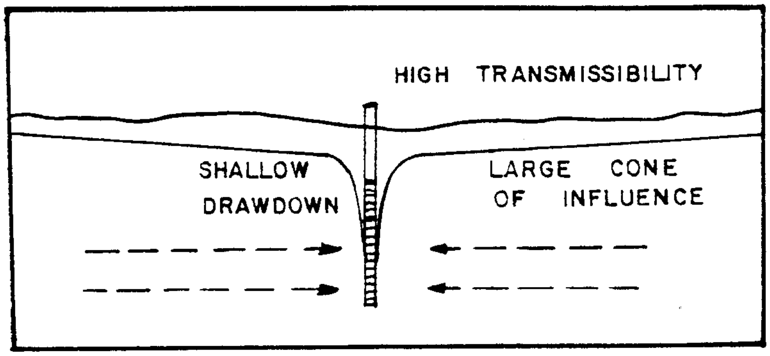
of influence (or depression) will cover a large surface area. The opposite results would occur in the same aquifer having a low value for T, assuming no change in other factors which can influence drawdown, (Groundwater and Wells, 1975). Examples of these conditions are shown in Figure 9.



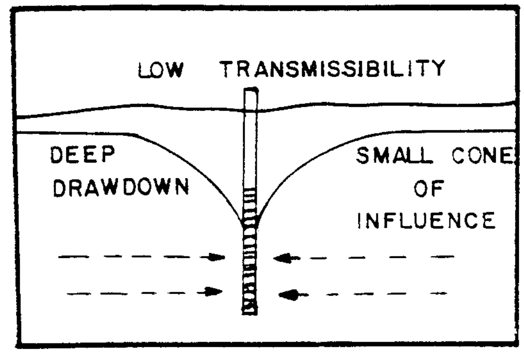


Figure 9: Comparison of the shape of the cone of depression with different rates of transmissibility. Pumping rate and aquifer characteristics are the same in both cases, (Groundwater and Wells, 1975).

F. Analysis of Well Hydraulics

1. Aquifer Drawdown in General

Upon withdrawal of water from an aquifer, initial drawdown of the water table occurs near the well as water is removed from storage. The boundary between the saturated zone and dewatered zone develops into a cone shape with its apex pointing down. The form and size of the cone differs depending on the pumping rate, duration and aquifer characteristics within the area of influence of the well. With continued pumping the cone of influence (or depression) expands to a wider area and increases in depth, thus it is able to intercept a greater volume of water with each increment of enlargement. The expansion rate diminishes until it reaches a point where no further change takes place, thus, a condition of equilibrium is established. The volume of groundwater flowing into the well equals the rate of withdrawal. Equilibrium is reached because 1) aquifer storage was sufficient to sustain a constant discharge without any further increase in the cone of influence, 2) the cone intercepted a surface water body inducing water into the aquifer, 3) the cone increased to a broad area under the land surface and received recharge from precipitation, or 4) the cone received water from an overlying, adjacent or underlying aquifer which may not have been connected under normal flow conditions (Ground Water and Wells, 1975). Depending on the hydraulic properties of the aquifer, equilibrium conditions can be established within a few hours, days or weeks after pumping begins. Several examples of drawdown cones are shown in Figure 8b-d.

2. Methodology

After the cone of influence becomes steady, the aquifer characteristics can be determined by the equilibrium method developed by Theim (1906) for confined and unconfined conditions. If the cone of influence does not reach stability after prolonged pumping, the Theis (1935) non-equilibrium and Jacob (1940) modified non-equilibrium methods are used. Various authors have derived formulas for calculating hydraulic characteristics under equilibrium and non-equilibrium conditions. The formulas pertinent to this study are those presented by Heath and Trainer (1968), Ground Water Manual (1977) and Ground Water and Wells (1975), which are more fully described in the Appendix.

The non-equilibrium methods are primarily suited for confined aquifers, although they can be used with care in unconfined aquifers if the assumptions are fulfilled. With Jacob's modified non-equilibrium method, two analytical techniques are possible. The distance drawdown approach relates water level change in at least three observation wells with distance from the discharging well. The time drawdown approach relates water level change in one or more wells with time since pumping started. In both cases the relationship can be plotted on semi-logarithmic paper as a straight line. From these graphs the transmissibility, storage coefficient, and cone of influence can be determined.

Aquifer characteristics and test procedures can complicate drawdown data such that the methods described above will not give adequate results. The effects of impermeable or recharge boundaries and leakage from other aquifers have been previously discussed. Other factors which can affect the cone of influence in response to discharge include well design (pipe diameter, size and pattern of well screen openings), penetration depth, groundwater entrance velocity, radial flow, delayed drainage conditions and well interference. A more complete explanation of these factors is given in Ground Water Manual (1977) and Ground Water and Wells (1975).

Using aquifer test data, subsurface logs and other information available for the Campbell Road and Meadow View wells, drawdown analyses were completed and are more fully described in the following sections. Aquifer analyses have not been done for the Happy Hollow and Baldwin Pond well fields because of the lack of drawdown test data.

3. Campbell Road Well

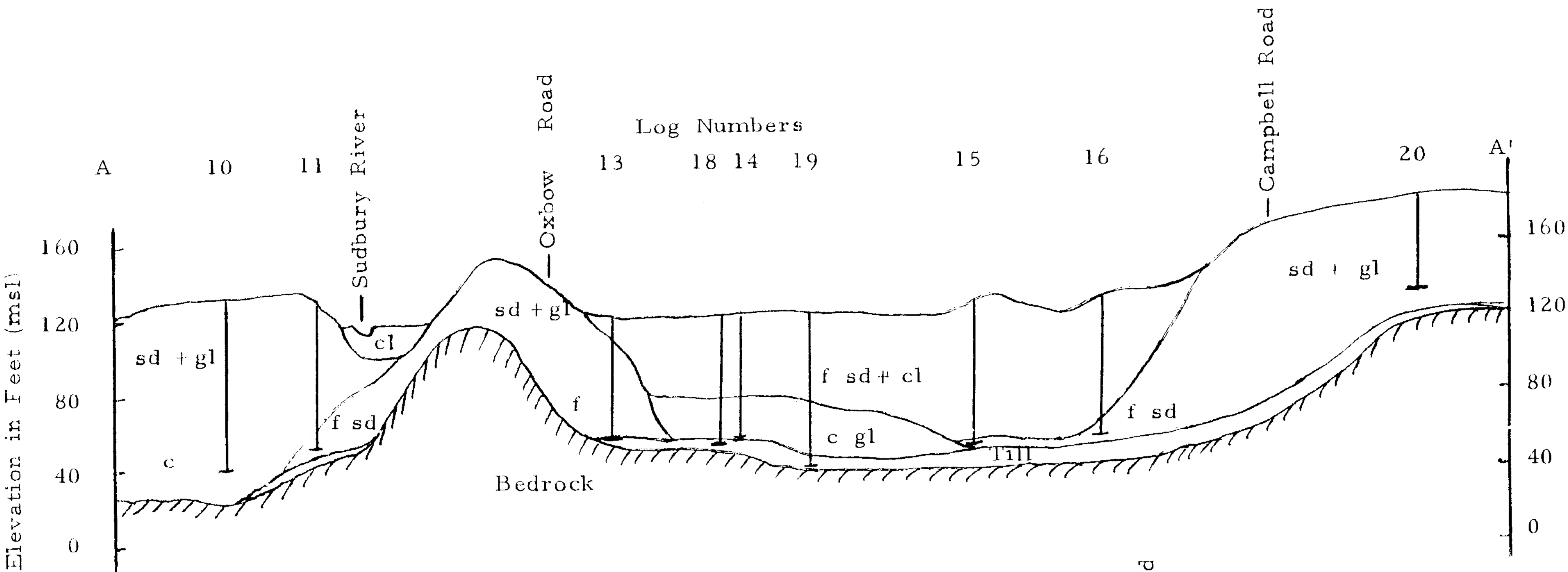
a. Geologic Description

The Campbell Road well is located in the Trout Brook watershed at the north end of Wayland. The well penetrates to an approximate depth of 55 feet. Vertical stratification consists of a layer of fine sand and clay overlying fine to medium sand and gravel. Below these materials a thin veneer of till covers the bedrock surface which is at 65 feet below ground level (Profile 1). Because part of this aquifer has a semi-permeable layer overlying coarser sediments, groundwater occurs under artesian conditions. When test wells penetrated through this layer, water projected four feet above the land surface due to a head pressure forcing water out of the ground. The height to which this rise occurred is referred to as the piezometric level.

b. Drawdown Analysis

In April 1962, drawdown measurements were taken in three observation wells while the aquifer was pumped for a period of 166 hours. After several days of continuous pumping, the cone of depression approached a steady state as water levels continued to decline very slowly. The values for transmissibility (T) and storage coefficient (S) were determined by using the Jacob modified non-equilibrium method. Distance drawdown and time drawdown graphs are plotted in Figure 10.

Based on the distance drawdown line using observation wells A and B and the time drawdown lines for observation wells A, B and C, T was 220,000 gpd/ft and values for S were very small indicating artesian conditions.



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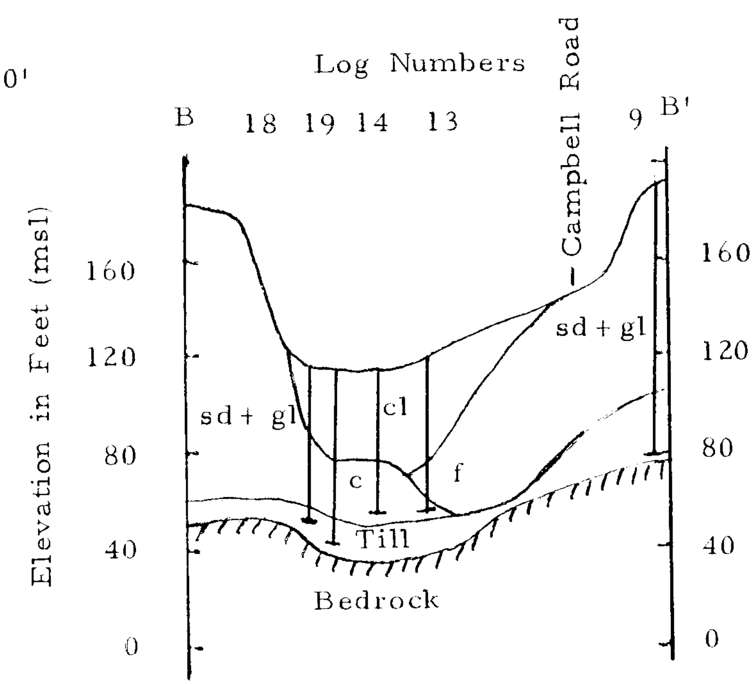
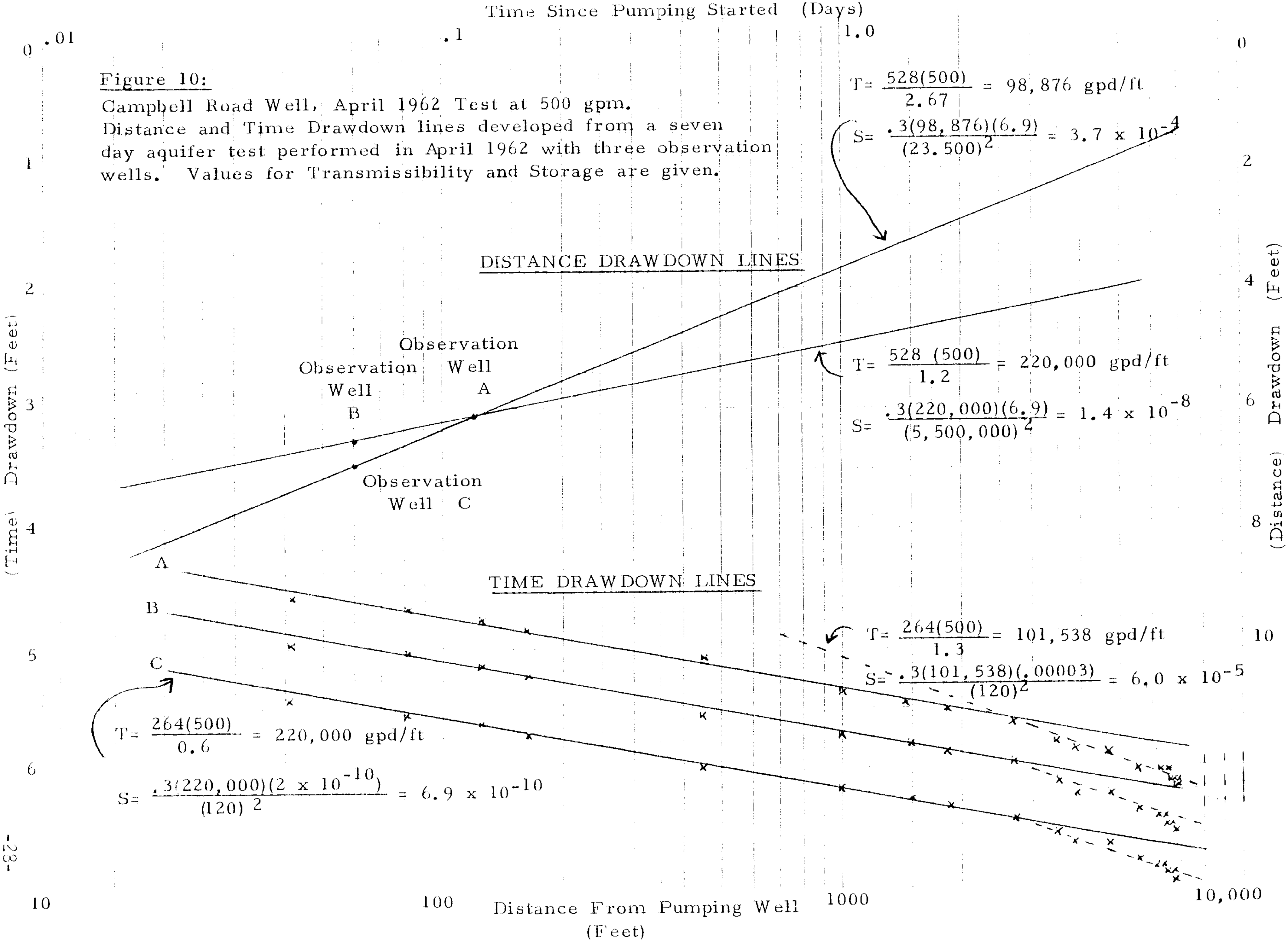


Profile 1:
Profile of Gelogic Conditions
Based on Interpretation of
Well+Boring Logs in the
Campbell Road Area.

Figure 10:
Campbell Road Well, April 1962 Test at 500 gpm.
Distance and Time Drawdown lines developed from a seven day aquifer test performed in April 1962 with three observation wells. Values for Transmissibility and Storage are given.



Using the distance drawdown analysis for observation wells A and C or the steeper slope of the time drawdown lines which occurred near the end of the aquifer test, values for transmissibility dropped to 98,876 gpd/ft and 101,538 gpd/ft, and the storage coefficients approached values more indicative of an unconfined aquifer.

From available information on the geologic sediments in this area, fine sand and clay are found north and east of the well, while coarse, highly permeable sand and gravel are located to the south and west. The differences in the T and S values may be due to a change in permeability as the drawdown cone expanded further into the aquifer and encountered finer materials. A second consideration is the possibility of a change in the performance of the aquifer from confined to unconfined conditions. This could occur if the aquifer is dewatered to the extent that the piezometric level is lowered below the stratified sediments which produce the confining effect. More testing is necessary to ascertain the reason for these differences.

When the test well was pumped for a long period, the piezometric level was lowered. It remained in this position after the pumping stopped (and the aquifer became stabilized) because a certain volume of groundwater had been removed from storage. In order for the piezometric level to have risen above this position, the aquifer must have been recharged by an outside source. Several possible sources of recharge were precipitation, infiltration from overlying unconfined surface water or groundwater, or infiltration from the adjacent Sudbury River flood waters.

Several years after Campbell Road well was installed, the drawdown level within the cone of depression began to drop significantly as large quantities of water were removed from the aquifer. For example, very high use of the well from 1969 to 1971 resulted in the greatest drawdown recorded for this aquifer, i.e., 18 feet. After 1971, the Campbell Road well was used very little and the aquifer was able to recover to a range of drawdowns from 8 to 12 feet. In recent years, the drawdown measurements have been normal fluctuating 3 to 5 feet below the land surface datum.

c. Area of Well Influence

It is important to know how far out from the discharging well the cone of influence extends when the aquifer is being pumped. For discussion purposes, the cone is visualized as having a circular shape on a plane parallel to the earth's surface. Yet, it should be noted that quite often the cone assumes an irregular shape because the aquifer is not homogeneous and permeability varies throughout the geologic deposits.

For the Campbell Road test well, the cone of influence was determined from the distance drawdown line that provided a value of 98,876 gpd/ft for transmissibility. By extending this line until it intersects zero drawdown on the semi-logarithmic paper, the radius of the cone of influence can be determined for the pump rate and period of discharge.

The Campbell Road well as currently installed was designed with a 400 gpm pump rate. Using this figure and the T value stated above, a series of distance drawdown lines have been graphed for several time increments of discharge. In Figure 11, the radii of the cones are shown for periods of continuous discharge lasting 4, 8, 10, 14, 20 and 24 hours. For example, if the well discharges for a period of 8 hours at a rate of 400 gpm, the influence of the cone may extend 5,738 feet. The confined nature of the aquifer and the extreme flatness of the drawdown slope are reasons for the far-reaching influence of the drawdown cone. A range of 4,000 to 6,000 feet for the cone of influence under normal use of this well indicates that the water level (corresponding to the piezometric level) in the upland area near Route 126 would be lowered upon withdrawal of water from this aquifer.

As a final note, by plotting the radii at zero drawdown with duration of pumping, a curve can be prepared from which the cone of influence can be read directly for any given period of discharge. A graph of this relationship is shown in Figure XVIII in the Appendix.

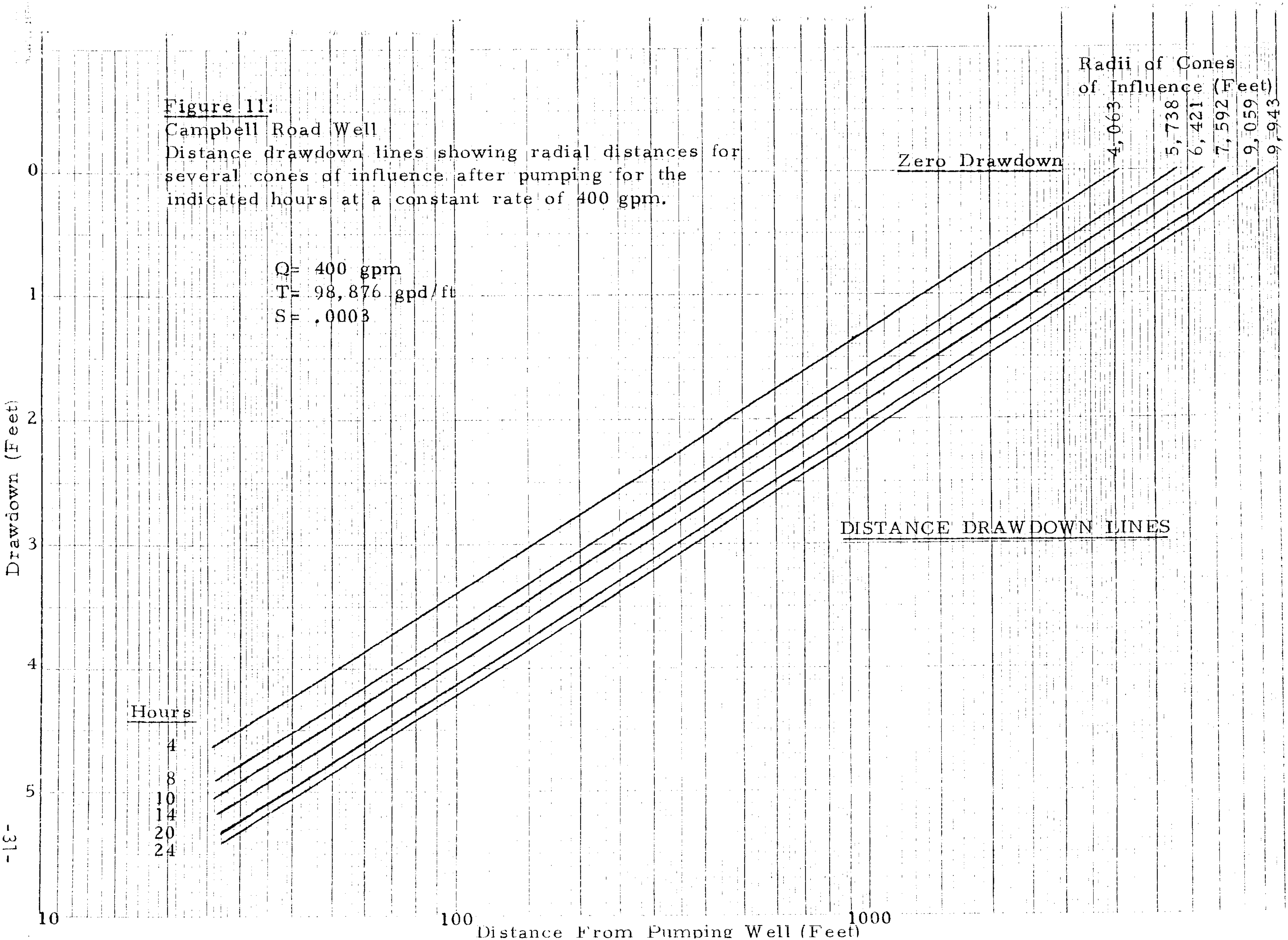


Figure 11:
Campbell Road Well
Distance drawdown lines showing radial distances for several cones of influence after pumping for the indicated hours at a constant rate of 400 gpm.

4. Meadow View Well

a. Geologic Description

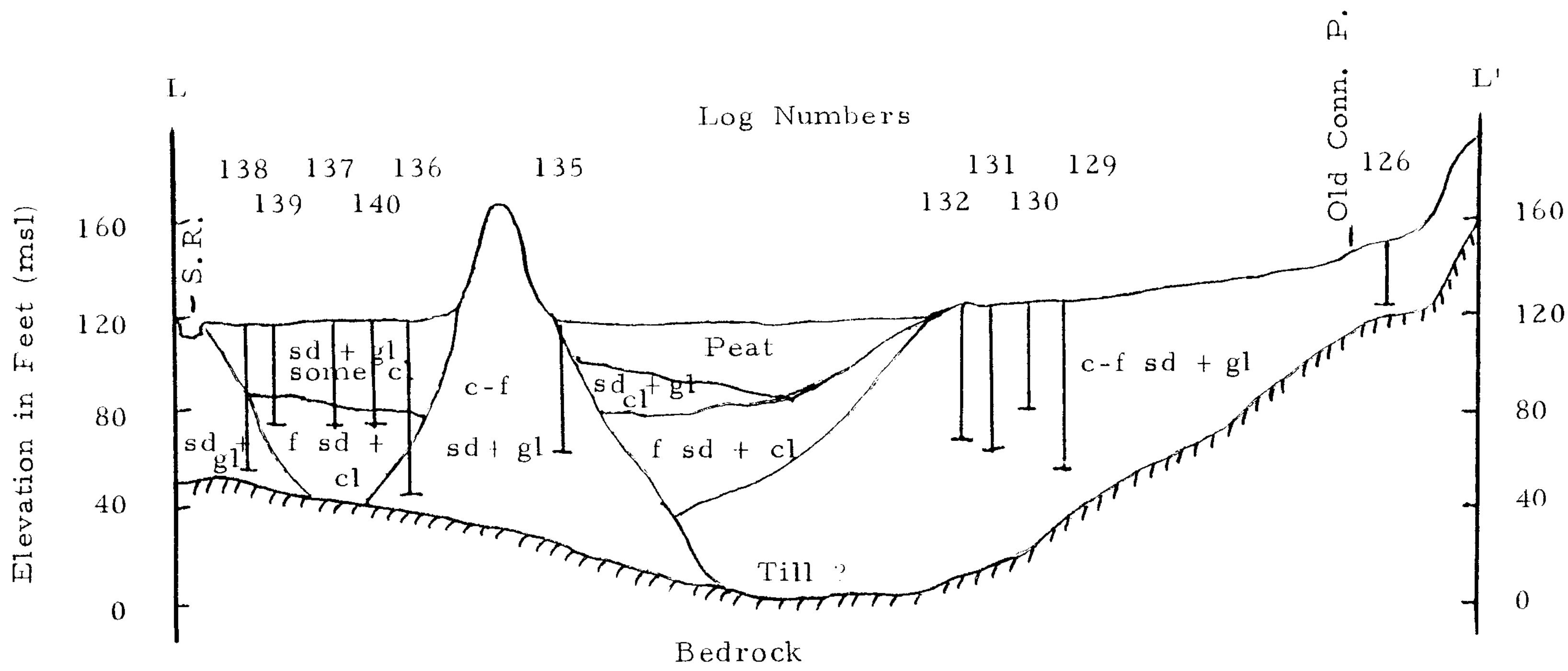
The Meadow View well is located along the southwest boundary of the Town in the flood plain approximately 600 feet from the Sudbury River. Test wells show approximately 53 feet of stratified fine to medium sand and gravel with traces of clay. The bedrock floor is estimated at a depth of 70 to 80 feet. Installed in 1972, the present well is positioned on the edge of a broad, pre-glacial, buried valley comprising a large groundwater reservoir, Profile 2.

b. Drawdown Analysis

In May 1966 an aquifer test was conducted for a continuous five day period. Note that this test was done near the end of a 3 to 4 year drought which was at its worst in 1965. Three observation wells were installed north, east and southeast of the discharging well to measure drawdown levels. The cone of influence expanded until it reached a steady shape and water levels approached equilibrium conditions. From these data aquifer analyses have been done using the Theim and (Jacob) distance drawdown methods. From the straight line graphs, Figure 12, values for transmissibility were 32,000 to 33,000 gpd/ft; the storage coefficient by the Jacob method was .019.

Measurements of groundwater levels before and after pumping showed a drop from observation well A to B and from B to C. Well A was closest to the river and well C was farthest away representing a gradient from the river into the underlying formation. Under these conditions, the river was serving as a source of recharge to the aquifer, although the rate and volume of this contribution are unknown.

Normally the graph of drawdown data would show the influence of river recharge on a discharging well. The time drawdown line would become nearly horizontal when the cone of influence intercepts a recharge boundary. A boundary effect was not reflected by the drawdown data because the hydraulic connection with the river was not sufficient to sustain a high volume of induced infiltration. Therefore, the cone of influence extended out into the aquifer beyond the bed of the river after prolonged pumping.



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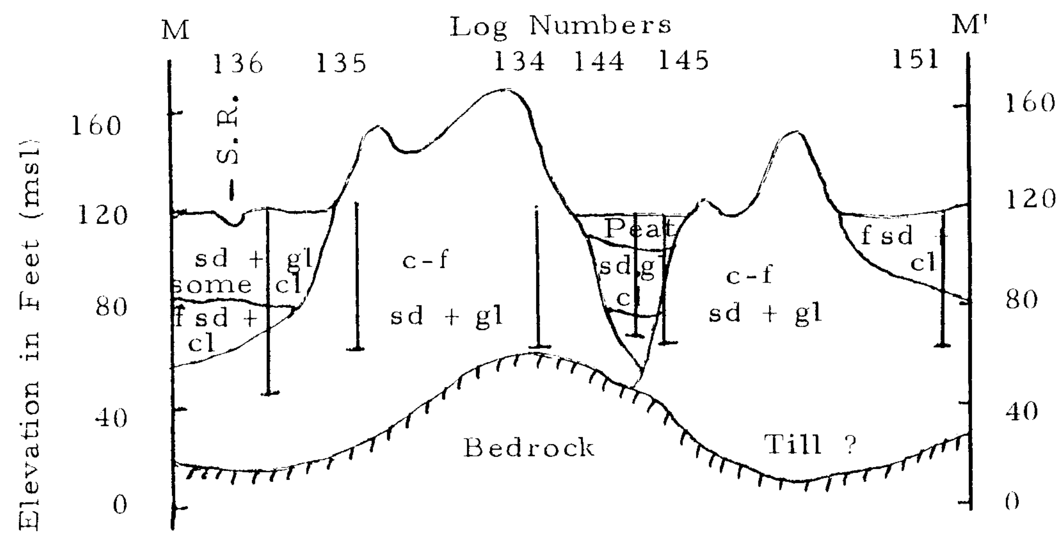
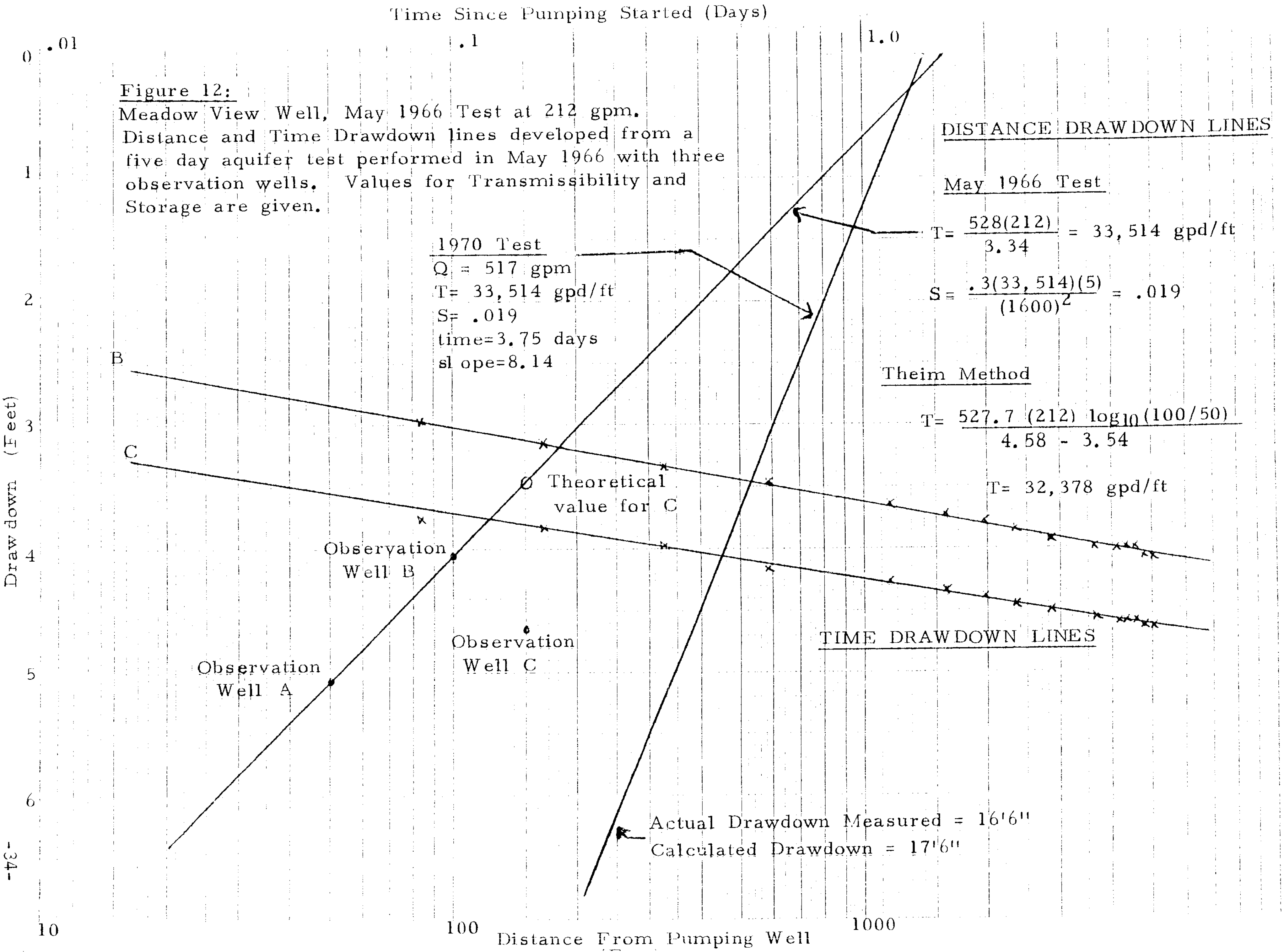


Profile 2:
Profile of Geologic Conditions Based on Interpretation of Well + Boring Logs in the Meadowview/Happy Hollow Area.


Time Since Pumping Started (Days)
.01
.1
1.0
0
1
2
3
4
5
6
Draw down (Feet)
Figure 12:
Meadow View Well, May 1966 Test at 212 gpm.
Distance and Time Drawdown lines developed from a five day aquifer test performed in May 1966 with three observation wells. Values for Transmissibility and Storage are given.
1970 Test
Q = 517 gpm
T= 33,514 gpd/ft
S= .019
time=3.75 days
sl ope=8.14
DISTANCE DRAWDOWN LINES
May 1966 Test
T= 528(212) / 3.34 = 33,514 gpd/ft
S= .3(33,514)(5) / (1600)2 = .019
Theim Method
T= 527.7 (212) log10 (100/50) / 4.58 - 3.54
T= 32,378 gpd/ft
B
C
Theoretical value for C
Observation Well B
Observation Well C
Observation Well A
TIME DRAWDOWN LINES
Actual Drawdown Measured = 16'6"
Calculated Drawdown = 17'6"
10
100
1000
Distance From Pumping Well

c. Area of Well Influence

The Meadow View well has been designed to pump at a rate of 400 gpm. The radii of the cones of influence expected for this discharge rate, given various durations of pumping, are shown in Figure 13. The radii at zero drawdown plotted with duration of pumping is given in Figure XI, in the Appendix. The circumference of the cones are nearly circular in shape except for some distortion southeast of the well as the distance from the river increases. The approximate location of several cones of influence are shown on the 200 scale locus map, Figure 14.

Figures IV and V illustrate the relative degree to which groundwater fluctuations were affected by well discharge and related hydrologic factors. The influence of precipitation, upland runoff-recharge and river flow on groundwater levels can be interpreted from Figures VII, VIII, and IX in the Appendix. Several observations about the relationship between the Meadow View and Happy Hollow wells can be made based on a comparison of this information.

Between 1973 and 1975, precipitation and runoff in the Sudbury River followed a normal pattern. In addition, groundwater fluctuations at Cochituate State Park showed a similar rise and fall during these years. Yet despite these normal trends, drawdown measurements at Meadow View dropped as much as four feet from 1973 to 1974. This decrease was not attributed to a dramatic change in well discharge because Meadow View yielded about 100 million gallons per year from 1973 to 1975. The lower groundwater levels are believed to be caused by a very large increase in the use of Happy Hollow #1 and #2 from 1973 to 1974. A similar comparison can be seen for the first six months in 1976.

In a broader context by comparing the use of Happy Hollow #1 and #2 before and after 1974, Figure V shows a definite transition from low to high yields. Simultaneous with this general increase in use, the trend in groundwater fluctuations at Meadow View dropped to lower levels.

These comparisons give rise to the conclusion that both the Happy Hollow and Meadow View wells are discharging water from the same underground

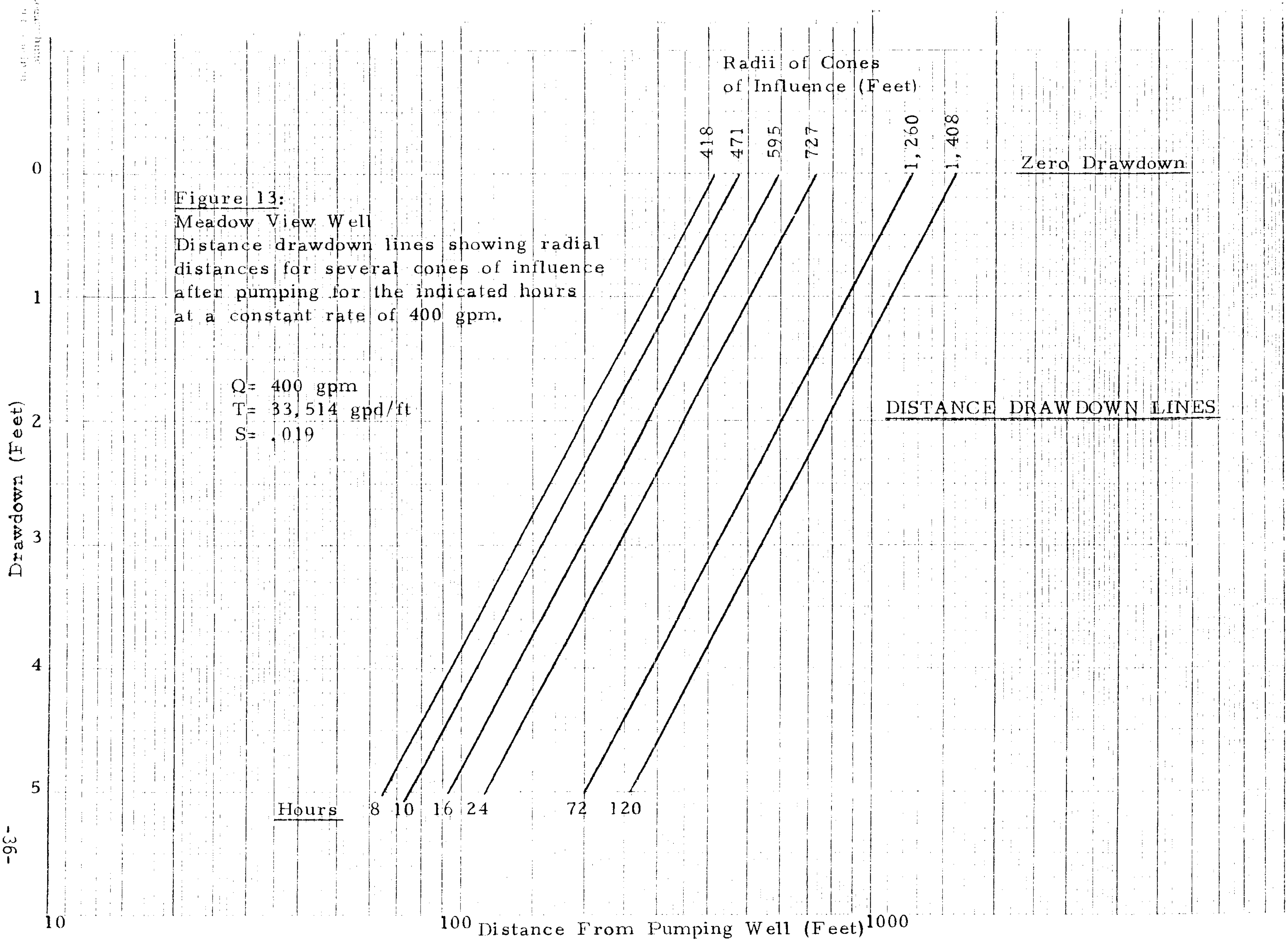


Figure 13:
Meadow View Well
Distance drawdown lines showing radial distances for several cones of influence after pumping for the indicated hours at a constant rate of 400 gpm.

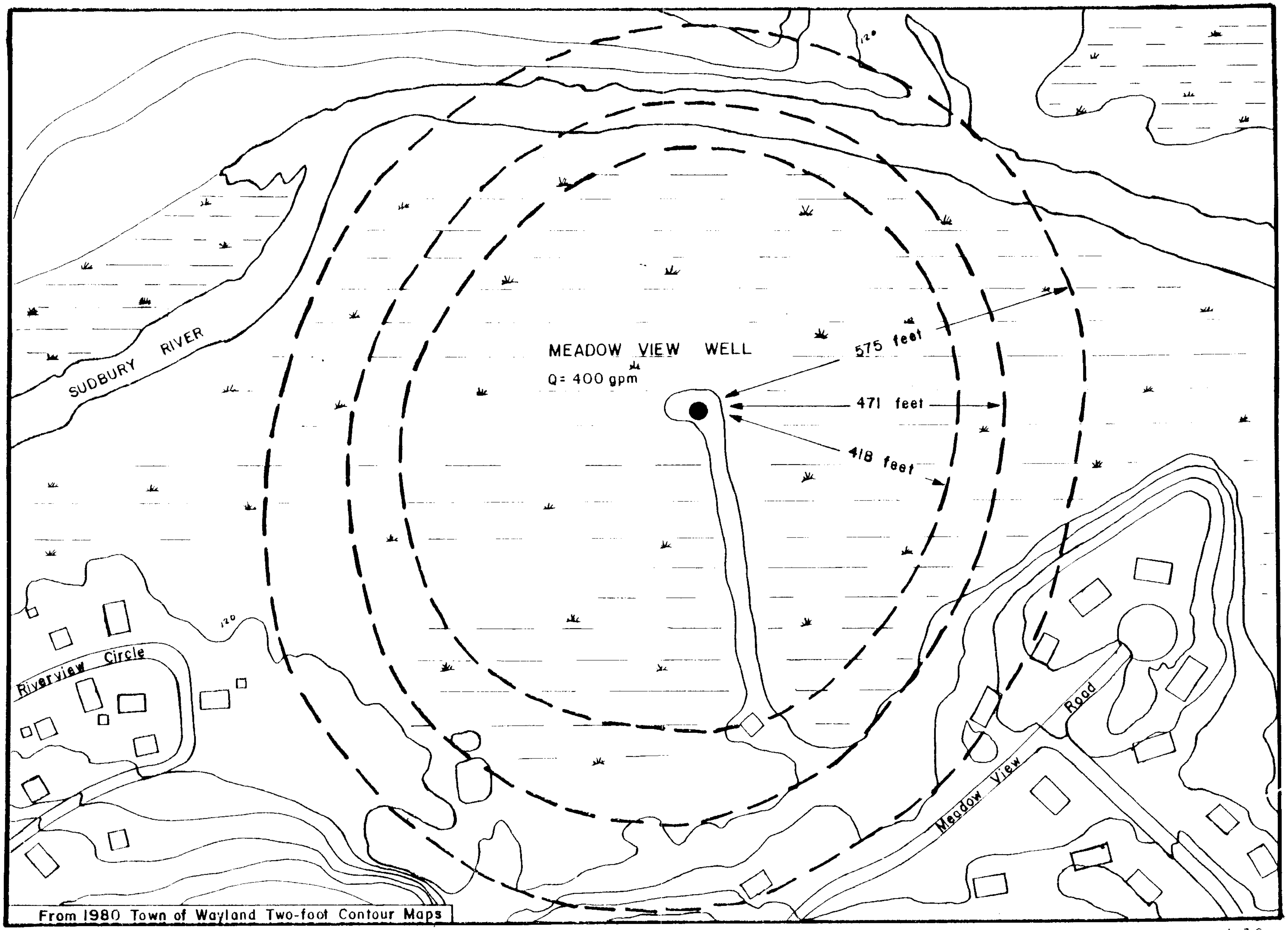


Figure 14: Meadow View Well. Showing approximate location of cones of influence at zero drawdown after 8, 10 and 16 hours of continuous pumping at a rate of 400 gpm. Slightly irregular cone shape due to recharge effect closer to the river and a water table gradient sloping to the south.

reservoir and furthermore, that the surficial geologic deposits are hydraulically connected.

Another reason why drawdown levels at Meadow View were deeper than other municipal wells is because of the aquifer's low transmissibility. In order for groundwater to be pulled into the well under less permeable conditions, the cone of depression develops a steeper slope which provides the hydraulic head necessary to maintain a sustained flow.

III. Municipal Water Supply

A. Historical Trends in Use
B. Well Yields
C. Water Quality
   1. Iron and Manganese
   2. Nitrate-Nitrogen
   3. Sodium and Chloride

MUNICIPAL WATER SUPPLY

A. Historical Trends in Use

The total annual yield of water pumped by the Water Department reached a peak of 625 million gallons in 1977. The demand for water has increased during the last several decades because of rapid suburban growth beginning in the early 1950's, Figure 15. Prior to 1954 consumption remained below 100 gallons per person per day, yet since 1967, this figure has steadily increased reaching 135 gallons per person per day in 1978. The trend towards higher consumption was attributed to the widespread use of modern appliances, swimming pools and similar residential conveniences. Growth in the number of homeowners using water for gardening and landscaping has also been a contributing factor.

To meet the increasing demand, Wayland established seven wells at four different locations along the Sudbury River flood plain. Installed between 1947 and 1972, the wells are commonly referred to as Campbell Road #1, Baldwin Pond #1, #2, #3, Happy Hollow #1, #2 and Meadow View #1. The pumping capacities of these wells are given in Table X in the Appendix. In the last few years, total annual yield has fluctuated around 600 million gallons. All wells are gravel packed design and are located in deep unconsolidated (granular) deposits above the bedrock surface ranging approximately 50 to 60 feet deep. They are linked by a network of water mains to two standpipes (enclosed storage reservoirs) on Reeves Hill. From these standpipes water is distributed throughout most areas in Town.

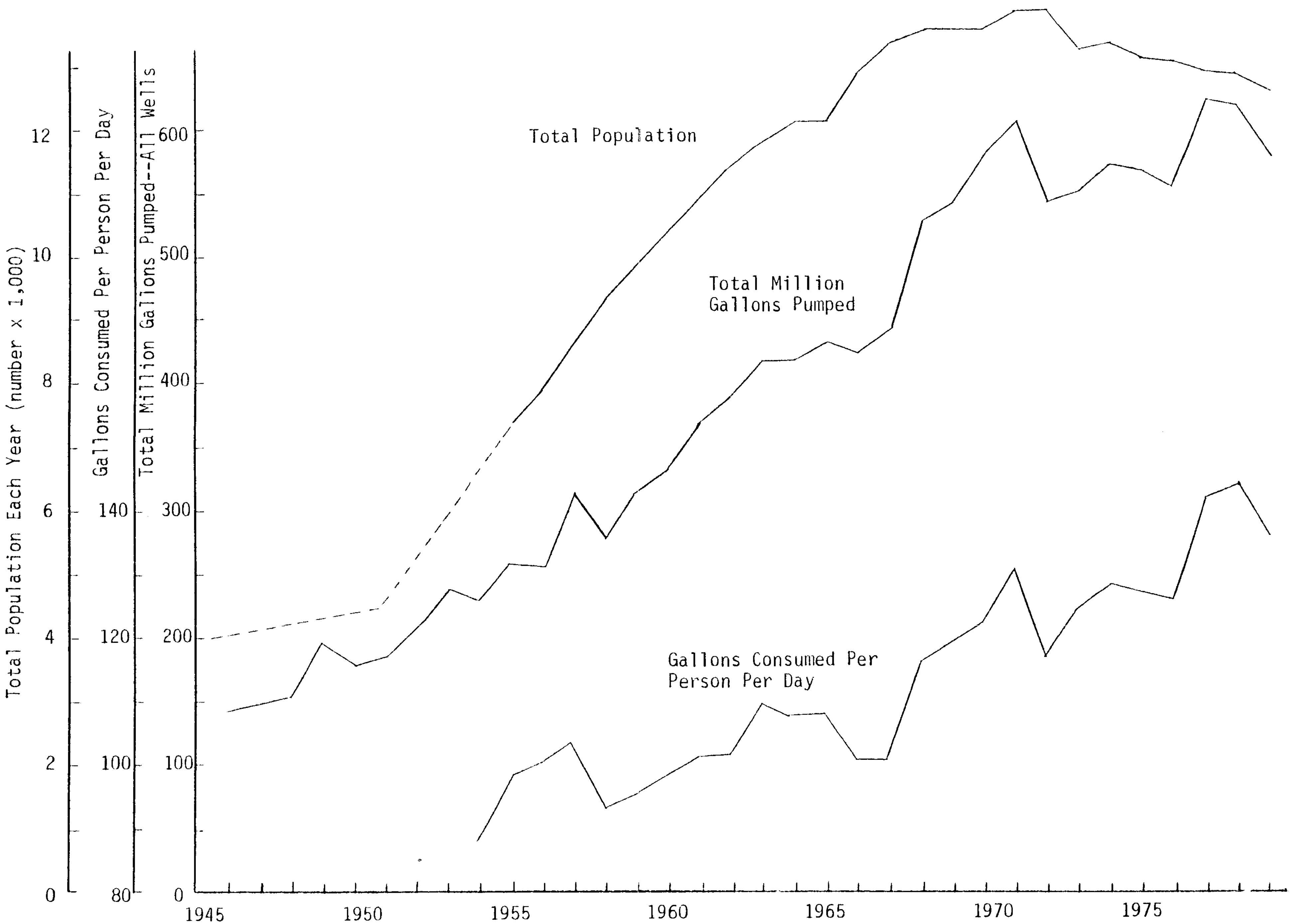


Figure 15: Comparison of population growth and water use for the years 1945 to 1979.

B. Well Yields

From pumping records provided by the Water Department, average monthly yields (from 1967 to 1979) were calculated and plotted in Figure 16. The total yield for all wells shows that the change in use corresponds to seasonal variations in climate. Peak demand has generally occurred throughout the summer reaching a maximum in July. By comparing the yield of each well, it is evident that the Town had relied primarily on Happy Hollow #2 and Baldwin Pond #3 between 1967 and 1979. Prior to 1962, Happy Hollow #1 and #2 and Baldwin Pond #3 were the only wells in operation. Records indicate a total of 368 million gallons pumped in 1961. This is more than half of the total amount pumped today with seven wells in operation.

Baldwin Pond #1 and #2 were used very heavily in the spring and summer months when compared to the fall and winter. Meadow View and Campbell Road were operated to a lesser degree in terms of average monthly withdrawal, but the range in yield was narrow throughout the period of record. For instance, Meadow View fluctuated between 6.5 and 9.5 million gallons, whereas the use of Baldwin Pond #1 and #2 varied widely from 2.5 to 10.5 million gallons. Since this graph only represents average conditions, the actual daily yield could have been much higher or lower.

A comparison of yield on a yearly basis is shown in Figure 17. Production at Meadow View and Happy Hollow #1 has been fairly consistent from 1967 to 1979. During the last five years peak use has occurred at Happy Hollow #2 and to a lesser degree at Baldwin Pond #3. In 1970, Campbell Road well was pumped heavily and the aquifer was extremely dewatered. Since then it has been used on a limited basis and allowed to recover. More consistent use within the limits of normal, annual groundwater replenishment is necessary in order to maintain a long term available water supply.

Average monthly yield, Figure 16, can be compared with average monthly drawdown, Figure 18. Although Meadow View was not pumped as much as the Happy Hollow or Baldwin Pond sites, the average drawdown was much higher throughout each month of the year. In addition, the range in water level fluctuations was greater than in the other wells for reasons described in the previous section of this report.

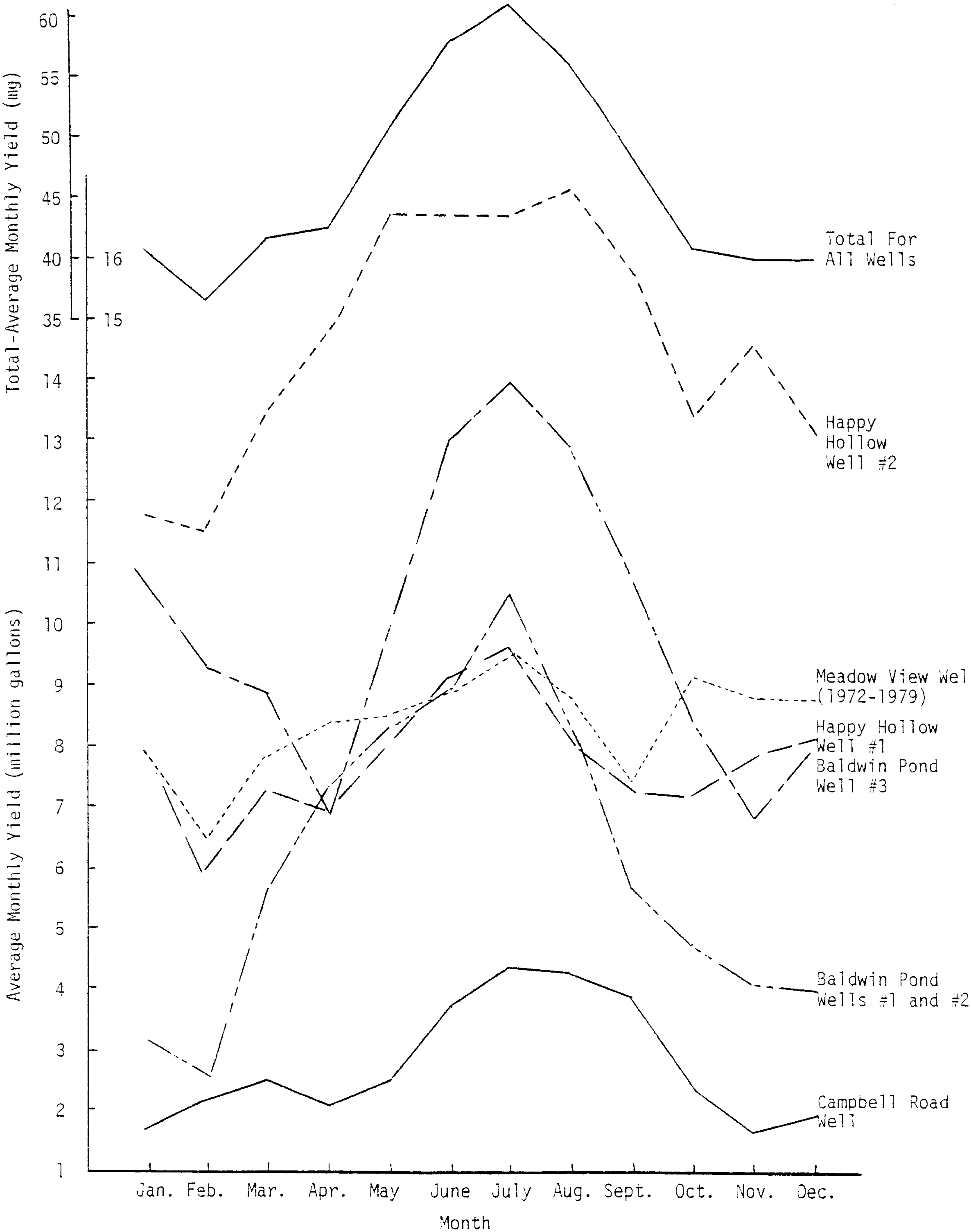


Figure 16: Average monthly yield-comparison of individual well and total well use during the years 1967-1979.

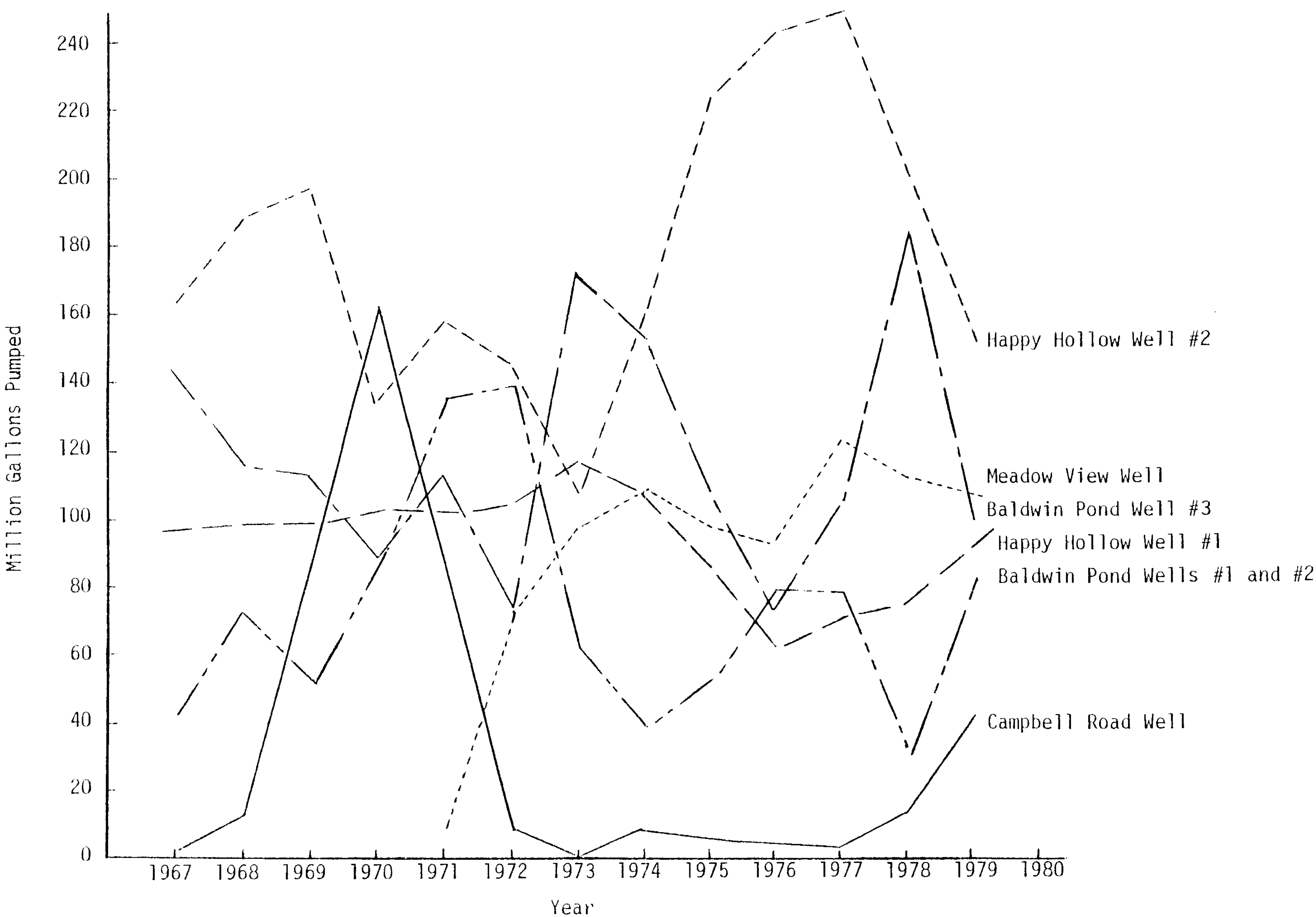


Figure 17: Comparison of the annual yield of individual wells for the period 1967-1979.

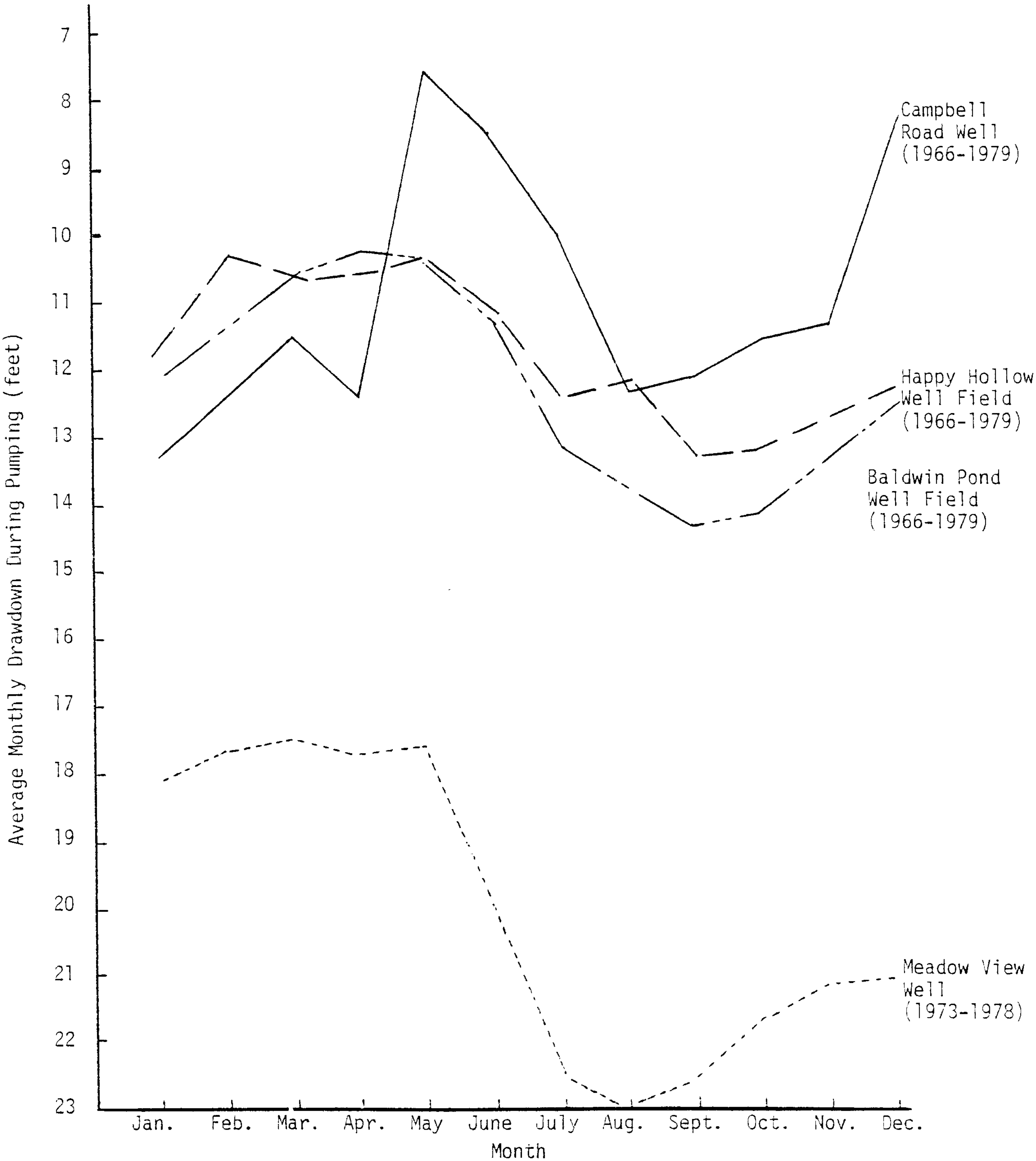


Figure 18: Average monthly drawdown during pumping for individual well fields during the years specified.

Average monthly fluctuations in the Campbell Road drawdowns were limited to a narrow range of a few feet which is not unusual for groundwater under confined conditions. Drawdowns in May and December probably reflect times during the record period when the well was used very little.

C. Water Quality

Records of groundwater quality have been collected for all municipal wells since their initial operation. A summary of these data is included in the Data Supplement report. A compilation of the range of water quality parameters measured in all the wells is shown in Table 1. In a majority of the wells standard tests were run on samples collected (at most) four times a year until the early 1970's when this was reduced to one or two times per year. Exceptions occurred when more information was needed to monitor a suspected contamination problem. The lack of more frequent testing limits this evaluation to a review of trends and general relationships. The results of the testing program show no suspect problems with regard to turbidity, color, odor, sediment load, pH, alkalinity, hardness, calcium, magnesium, silica, sulfate, copper, potassium and free amonia. Noticeable changes did occur in measurements of iron, manganese, nitrate-nitrogen, sodium, chloride and specific conductance.

Additional data was collected in 1979-1980 by the Massachusetts Department of Environmental Quality Engineering. A program was initiated to test for hazardous chemicals in groundwater supplies throughout the Commonwealth. Wayland's wells were sampled in February 1980 and all wells were found to be free of any hazardous materials.

1. Iron and Manganese

Iron and manganese are normally found in groundwater in the New England area. Usually the concentration of manganese is lower than iron. Iron and manganese content in groundwater is related to the kind of rock constituents and the acidity of the water. Carbon dioxide produced by the decomposition of organic matter and as a by-product of photorespiration at night, can enter the groundwater, increase the acid concentration (H_2CO_3) and, under anaerobic conditions, dissolve iron and manganese from the

TABLE 1: MAXIMUM AND MINIMUM WATER QUALITY MEASUREMENTS

Comparison of parameters in Town wells based on samples collected within the indicated period of record.

Parameter (ppm)	Campbell Road Max.	Campbell Road Min.	Baldwin Pond #1 Max.	Baldwin Pond #1 Min.	Baldwin Pond #2 Max.	Baldwin Pond #2 Min.	Baldwin Pond #3 Max.	Baldwin Pond #3 Min.	Happy Hollow #1 Max.	Happy Hollow #1 Min.	Happy Hollow #2 Max.	Happy Hollow #2 Min.	Meadow View Max.	Meadow View Min.
Turbidity	1.0	0.0	4.0	0.0	4.0	0.0	1.0	0.0	4.0	0.0	4.0	0.0	1.0	0.0
Sediment	0.0	0.0	2.0	0.0	2.0	0.0	0.0	0.0	1.0	0.0	2.0	0.0	0.0	0.0
Color	3.0	0.0	75.0	0.0	15.0	0.0	7.0	0.0	10.0	0.0	10.0	0.0	5.0	0.0
Odor	1.0	0.0	3.0	0.0	2.0	0.0	1.0	0.0	2.0	0.0	3.0	0.0	1.0	0.0
pH	7.1	6.2	7.4	6.3	7.5	6.2	8.4	6.5	6.9	6.1	7.0	6.3	7.1	6.3
Alkalinity	68	24	70	15	62	6	54	29	45	23	52	17	61	38
Hardness	136	44	107	37	107	30	110	46	94	48	134	52	91	57
Calcium	24.0	11.2	32.0	13.0	32.0	13.0	38.0	13.8	25.0	16.5	37.0	19.2	27.0	15.4
Magnesium	5.9	3.2	7.8	4.5	7.8	4.5	6.2	2.9	6.5	4.1	10.0	5.5	5.9	3.2
*Sodium	10.0	5.0	12.0	6.5	12.0	6.5	13.0	6.0	23.0	11.0	38.0	17.0	18.0	8.0
*Iron	0.1	0.0	0.36	0.01	0.50	0.00	0.12	0.00	0.4	0.0	0.25	0.00	0.10	0.00
*Manganese	0.78	0.00	0.47	0.00	0.47	0.00	0.14	0.00	0.06	0.00	0.04	0.00	0.07	0.00
Silica	19.0	9.0	21.0	9.4	21.0	9.4	21.0	10.0	17.0	7.2	22.0	11.0	20.0	11.0
Sulfate	58.0	21.0	53.0	10.5	53.0	14.5	50.0	17.0	34.0	14.0	32.0	15.0	36.0	16.0
*Chloride	23.0	9.0	24.0	7.0	24.0	4.2	21.0	10.0	41.3	6.2	135.0	6.2	40.0	13.0
*Spec. Cond.	250	160	280	180	280	180	290	110	297	200	380	220	260	190
Nitrite	.001	.000	.007	.000	.007	.000	.015	.000	.006	.000	.009	.000	.004	.000
*Nitrate	1.9	0.2	5.2	0.0	6.0	0.0	9.3	0.1	5.2	0.8	5.6	0.3	3.7	1.0
Copper	0.05	0.00	0.12	0.00	0.12	0.00	0.06	0.00	0.16	0.00	0.06	0.00	0.22	0.00
Potassium	3.0	1.7	4.1	0.6	3.9	0.6	2.2	1.3	3.1	1.4	8.0	1.4	5.0	1.8
Free Amonia	.05	0.00	0.12	0.00	0.07	0.00	0.04	0.00	0.02	0.00	0.05	0.00	0.03	0.00
Period of Record	1970-1980		1953-1980		1955-1980		1970-1980		1953-1980		1956-1980		1972-1978	

*Indicates parameters which are specifically discussed in the text of this report.

Source: Water Quality Data Collected by the Wayland Water Department.

unconsolidated rock. When this groundwater solution is exposed to air or bicarbonate, iron and manganese are precipitated out of solution. Certain bacteria are also known to change soluble forms of iron and manganese to an insoluble hydroxide. These minerals, whether soluble or insoluble, are not considered to be a health hazard although they can be highly objectionable. Precipitated forms can clog well screens, water mains, pipes, etc., and can stain plumbing, clothes, etc.

Iron and manganese have not appeared in any significant amounts in the Meadow View or Happy Hollow wells, although in 1970 concentrations began to increase in the Baldwin Pond wells. Some accumulation of iron and manganese deposits have already been observed in water mains leading from the main pumping station. Wetlands directly adjacent to the Baldwin Pond wells are probably the primary source of organic acids within the cone of influence of these wells. During pumping these acids are pulled into the aquifer where they dissolve iron and manganese which is later precipitated upon withdrawal. Elevated levels were also present in the Campbell Road well in 1970 due to high pumping rates. The Meadow View and Happy Hollow wells are located in aquifers overlain, partly or wholly, by wetland deposits, yet there has been no significant accumulation of these minerals. Either iron bearing minerals were lacking, acid production was limited or it was neutralized by alkaline minerals, or there was little hydraulic connection between the wetlands and underlying deposits. Each year the river inundates these wetlands and accumulation of these dissolved minerals at the surface are likely to be flushed downstream.

Testing in other locations in the Town has revealed groundwater with high iron and manganese content. For example, east of the new Wayland landfill a test well penetrated through 30 feet of peat into fine sand and clay containing high levels of iron.

2. Nitrate-Nitrogen

Nitrate-nitrogen is a common constituent in groundwater (usually at low levels), because it is an end product in the breakdown of wastes and other materials. Nitrate is readily soluble in water and therefore can remain in solution in groundwater for a long time. Nitrate content can vary considerably depending on its source such as plant material, animal waste, human waste (sewage systems), fertilizer and certain bacteria and related factors. The recommended limit for nitrate in drinking water is 45 ppm because of possible hazards to human health. Nitrate in all the Town wells has not exceeded the State standard of 10 ppm. The Happy Hollow wells have experienced a slight increase during the period of record, Figure I in the Appendix. This increase appeared during the mid to late 1960's and there is no clear reason why this came about. The highest increase in nitrate occurred in Baldwin Pond #3, Figure III. Baldwin Pond #1 and #2 have also been affected when prolonged pumping of these wells pulled nitrate into the cones of influence. The Water Department suspected the cause to be a nearby stockpile of manure, which is known to contain large quantities of organic nitrogen. Subsequent to the stockpile's removal, the nitrate concentration dropped to a lower level.

One other example of high nitrate was found in the Castle Hill area. It was attributed to animal waste from a pheasant farm that had previously existed in the vicinity of the test well.

3. Sodium and Chloride

Sodium and chloride is normally found at low levels in the groundwater. Both are highly soluble once they dissolve and remain in solution almost indefinitely. The standard limit for sodium in drinking water is 20 ppm. Records show that the concentration of sodium in all wells other than Happy Hollow has always remained below this level. In 1970 Happy Hollow #1 and #2 exceeded 20 ppm because of salt contamination. Other common sources of sodium in groundwater include mineral deposits, sewage disposal systems and sea water.

Chloride is usually found in concentrations of 10 ppm or less. When chloride content exceeds 20 ppm, sources of contamination such as road salt, sewage disposal systems or animal wastes may be affecting groundwater quality. A chloride content greater than 250 ppm is considered to be undesirable for municipal water supply. Chloride has never reached this limit in any of Wayland's wells. Although in the late 1960's and early 1970's, chloride content in the Happy Hollow well rose very sharply due to a nearby stockpile of road salt. The highest recorded level of chloride reached 135 ppm in Happy Hollow #2 in April 1971. Even after the salt was removed, chloride remained in the aquifer at high levels for several years. After nine years of flushing by precipitation, chloride content is not a problem, although it still measures 40 ppm. In 1971 Happy Hollow #1 showed a chloride level of 38 ppm. Since that time, the concentration has increased to nearly the same level as Happy Hollow #2. A comparison of the February 1980 measurements shows Happy Hollow #1 with 41.3 ppm and #2 with 42.0 ppm.

One interesting point to note is the corresponding relationship between chloride fluctuations in the Happy Hollow wells and the Meadow View well, Figures I and II in the Appendix. There are no water quality data for Meadow View prior to 1972. Beginning in March 1972, there is a sharp rise and subsequent fall in chloride in both Happy Hollow #2 and Meadow View, and to a lesser extent in Happy Hollow #1. This is partly due to the similarity of sampling dates. Yet, because chloride levels are moving up and down in both wells during the same months, this is a further indication that the two areas are hydraulically connected.

There is approximately 4000 feet between the Happy Hollow wells and the Meadow View well located near the Sudbury River. Because of this separation, a certain amount of lag time would normally be expected for a plume of dissolved chloride to move through the aquifer from the Happy Hollow area to a point near the river. A careful look at this relationship reveals that in the spring of 1970 and 1971, records of discharge in the Sudbury River show average or below flow conditions in response to moderate precipitation the previous winter. Recharge to the aquifer in the Happy Hollow area was not extensive as evidenced by greater drawdowns throughout the year. The first plume of dissolved chloride was washed into the aquifer and began to move towards the river. The following spring of 1972 was a much wetter year, i.e., river discharge was greater and groundwater levels were elevated by increased recharge. A second plume of chloride infiltrated into the ground at Happy Hollow. The arrival of the first plume in the Meadow View well occurred around August 1973. The chloride content had dropped from 135 ppm to 40 ppm as it spread through the groundwater. The second plume was less concentrated and apparently did not show up at a level high enough to be distinguished as a peak increase. In 1975 and 1977 large volumes of water were pumped at Meadow View and chloride rose to above normal levels. This was probably due to the interception of a large amount of residual chloride in a plume moving through the aquifer at a greater distance from the well. Note in Figures I and II that the fluctuations as described above were reflected by similar trends in the sodium levels.

Chloride content in the Baldwin Pond aquifer has increased slowly during the past 10 years to around 20 ppm. Figure III, Baldwin Pond #1 and #2 show slightly higher concentrations than #3. Because chloride levels fluctuated so frequently, it appears that one or more outside sources may be involved. The manure stockpile discussed earlier could have generated some chloride, yet the chloride trend did not follow the nitrate trend. When nitrate was high and chloride low in the #3 well, the reverse was true for wells #1 and #2. Other possible sources of chloride were sewage systems, road salt or dissolved chloride in the Sudbury River. Sewage systems are scattered, therefore they could not have been a problem. Road salt may have been a possible source because of winter application along Route 27 which is located near the well. Salt runoff into the River at the old landfill just upstream on Route 20 could have been another possible source if surface water was induced into the aquifer during pumping. Since the available data is not very extensive for any given year, a firm conclusion cannot be made. Further testing and subsurface investigations are needed to identify the influence of these wells during pumping.

IV. Conclusions

A. Water Supply

1. Quality
2. Quantity

CONCLUSIONS

A. Water Supply

1. Quality

At the present time the quality of water derived from Wayland's wells can be described as good to excellent. The quality of groundwater can be affected by point and non-point sources of pollution from local land use practices. In Wayland the pattern of land use in relation to the water supply aquifers is such that the potential risk of groundwater contamination is low. This is because a certain degree of protection is provided by low density residential zoning in upland recharge areas and by flood plain zoning in the lowland areas surrounding the wells. In addition, commercial-industrial uses are in watersheds which are not directly involved with the water supply areas. Roads and residences within the important recharge areas and within the influence of the discharging wells should not present any major problems to groundwater quality, so long as sewage disposal systems and road salt are used with proper care. Sewage systems should meet acceptable design standards, be adequately maintained and used only for domestic waste. The practice of disposing toxic cleaners, solvents, oils, thinners, pesticides and other chemicals into sewage systems should be discontinued.

Even though the topographic, hydrogeologic and cultural features pertaining to the present siting of the Town's wells constitute a lesser threat to the water supply, several specific land uses should be recognized as a potential hazard to the groundwater resources. In Plate VIII, different types of point and non-point sources of pollution are identified. The potential threat of pollution from the landfill sites, west of the Sudbury River, to the Baldwin Pond well field, east of the river, cannot be ignored even with the extent of assurance provided by earlier hydrologic investigations. Previous conclusions were based on the expected movement and time of travel of contaminants from the landfill sites towards the Sudbury River, but there has not been any analysis of well influence and possible inducement effects. Observation wells should be installed to monitor water quality and drawdown during pumping.

2. Quantity

Wayland currently uses 600 million gallons of groundwater on an annual basis. As the community continues to grow there will likely be an increased demand for water. The land resources available for further development may be known, but the question of an adequate water resource base has not been answered. Many factors influence the water budget within the Town, and the foremost of these is the total amount of direct precipitation falling within, or storm runoff flowing through, the study area. The principal source of surface flow is the Sudbury River. The river and groundwater regimes represent the maximum available water supply during any given year.

An estimate of groundwater flow from the major watersheds in the Town can be made using a method applied by Cervione, et.al. (1972). This method has been improved in recent years as a result of extensive studies on groundwater discharge from small drainage areas in Connecticut. Motts (1977) utilized this procedure to estimate groundwater availability and long term sustained yield in Sudbury, Massachusetts. Based on Cervione's work and additional information collected by Motts, an evaluation of groundwater outflow in Wayland was completed and is listed in Table 2.

In Table 3, the computed groundwater outflow is shown in relation to total well yield. Comparing the average, maximum and worst case total yield figures with the long term recommended potential groundwater outflow, i.e., 438 million gallons per year, it is clear that the recharge areas in the upland watersheds associated with these wells cannot satisfy the Town's needs. During the period 1967 to 1979, the average use was 586 million gallons per year. A maximum usage of 624 million gallons occurred in 1977. This figure was determined by combining the highest recorded yield from all the wells