HYDROGEOLOGIC STUDY

WAYLAND AQUIFER

Prepared for:

Water Department
Wayland, Massachusetts

Prepared by:

Goldberg-Zoino & Associates, Inc.
Newton Upper Falls, Massachusetts

File No. A-2870
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June 29, 1982
File No. A-2870

Mr. John Roche
Water Department
Wayland, Massachusetts 01778

Re: Hydrogeologic Study
Wayland Aquifer

Dear Mr. Roche:

In a report to you dated July 13, 1981, GZA summarized the hydrogeologic framework of Wayland's groundwater supply system and developed estimates of the hydraulic characteristics of the aquifer materials penetrated by the Town wells. At that time, GZA noted that three of the Town wellfields (Meadow View, Happy Hollow, and Chamberlain) were close enough to the Sudbury River to be hydraulically connected to it under pumping conditions. GZA further suggested that a sensitivity analysis be conducted to evaluate whether the termination of induced infiltration from the Sudbury River could affect the yields of the wells involved.

With your approval, GZA has proceeded with this approach and undertaken an analysis of well yields under worst case conditions (i.e., no flow in the Sudbury River). As we have discussed with both you and the MDC's consultants, the purpose of this analysis is to provide a first cut at the maximum "worst case" impact which could result. The "no flow" condition is used for analytical purposes only, and does not represent GZA's opinion regarding the effect of the MDC's proposed diversion on river flow.

The logic behind a sensitivity analysis of this sort is straightforward: if well yields are not affected by the worst possible conditions (i.e., no flow in the Sudbury), then they will not be affected by better conditions (i.e., reduced flow in the Sudbury). On the other hand, the limited nature of this type of analysis does not allow the quantitative evaluation of less-than-extreme cases. In other words, a well failure under the "worst case" conditions of the sensitivity analysis does not necessarily indicate a failure under proposed reduced flow conditions.

GZA's methodology and conclusions are described in detail in the attached Technical Appendix. The three analytical methods used by GZA resulted in different estimates of drawdown at the municipal wells, with the more conservative methodologies resulting in greater drawdown. For each wellfield, GZA's analysis indicated that some level of pumpage could probably be sustained without induced infiltration from the Sudbury River. However, under the extreme "worst case" conditions postulated by GZA, each wellfield failed under pumpage at the maximum rated capacity for at least one set of analytical assumptions.

The results of GZA's sensitivity analysis thus indicate that an impact on the Wayland wells by the proposed MDC diversion cannot be completely ruled out on the basis of the data available at this time. The groundwater model being prepared by the MDC's consultants could therefore be an important tool in predicting the impact of the diversion on Wayland's wells. Consequently, GZA encourages the careful development of this model, and, unless otherwise directed by the Wayland Water Department, will continue to interface with IEP in an effort to produce a model which will better reflect actual conditons at the at well sites.

Very truly yours,

Lawrence Feldman

LF:crp

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TABLE OF CONTENTS

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TECHNICAL APPENDIX

SENSITIVITY ANALYSIS METHODOLOGY AND CONCLUSIONS

1.00 INTRODUCTION

In order to develop a preliminary evaluation of the effects of a lowering of the Sudbury River on Wayland's water supply wells, GZA has analyzed a simplified "worst case" situation as suggested in our report of July 13, 1981. In essence, this analysis examined drawdowns at the three wellfields closest to the Sudbury River (Meadow View, Happy Hollow and Chamberlain) assuming that the river was not present (i.e., that the groundwater level was at or below the bottom of the riverbed).

GZA's intent in using this approach was to assess whether the Wayland municipal well yields could be sustained on the basis of areal recharge to the aquifer alone. If this were the case, it would be clear that loss of well yield was not a significant concern relative to the proposed MDC Sudbury River diversion.

In preparing this analysis, it was assumed that the criterion governing the safe yield of the Wayland wells was failure due to a lowering of the water table below the top of the well screen.

2.00 ANALYTICAL METHODS AND ASSUMPTIONS

Three analytical equations were utilized to compute drawdown at the municipal wells. In all cases, the bottom of the aquifer was assumed to be approximately coincident with the bottom of the well screen.

An equation developed by Todd (1980) was first used to evaluate conditions at the three sites. This analysis assumes that the aquifer is unconfined (water table), homogeneous, and isotropic, and that areal recharge (infiltration due to precipitation) is applied uniformly above the aquifer within the radius of influence. The analyis also assumes the well fully penetrates the aquifer, the water level is fixed at the radius of influence of the well, and all groundwater flowing to the well is derived from areal recharge.

A second equation, from Boreli (1955), was used to refine the previous estimates. This equation is based on the same assumptions as the Todd Equation, but in addition accounts for the effects of partial penetration. This equation is essentially a correction factor for the Todd (1980) equation, since near the well the use of Todd's equation results in drawdowns that are too large due to the assumption that flow to the well is completely horizontal. The use of the Boreli method to this study is warrented because the Wayland wells are not fully penetrating.

Finally, the transient Theis method (Walton, 1970) was also used to evaluate drawdowns after given period of pumping. As used in this study, this method assumes that the aquifer is unconfined, isotropic, homogeneous, and of infinite lateral extent; that the pumping well fully penetrates the aquifer; and that all flow at the well comes from the aquifer.

In all three of the equations utilized, the most important parameter is the aquifer transmissivity, a measure of the ease with which groundwater moves through the aquifer which takes into account both permeability and aquifer thickness. Values of transmissivity for the Wayland wells were estimated in our July 13, 1981 report. Since a low transmissivity value results in a larger drawdown, the values of transmissivity used in the present analysis are the more conservative estimated at that time.

3.00 ANALYSES OF INDIVIDUAL WELLFIELDS

In performing its "worst-case" analysis on the Meadow View, Happy Hollow, and Chamberlain wellfields, GZA assumed that all water pumped must be drawn from local areal recharge to the aquifer rather than from induced infiltration from the Sudbury River. Calculated radii of influence for these three sites under maximum pumping conditions (see Tables 1-3) were 4230 feet, 5600 feet, and 4730 feet respectively. In each case, the entire idealized cone lies within mapped glacial deposits, so impermeable boundary conditions are not involved. Areal recharge to the glacial deposits was conservatively estimated at 6 inches/year.

Note that the equations utilized in this study do not account for well loss, the drawdown associated with groundwater movement to the well through the gravel pack and wellscreen. These values were estimated from published results of step drawdown test analyses for wells that had total drawdowns similar to the Wayland Supply Wells.

3.10 MEADOW VIEW WELL

The Meadow View well is the Wayland well closest (450 feet) to the Sudbury River. GZA's estimate of the transmissivity for the aquifer at this well, as reported in our July 13, 1981 report, is 50,000 gpd/ft. The pump test done at this site resulted in a drawdown of 7.1 feet at the pumping well cluster after pumping 212 gpm for 5 days. Assuming groundwater levels are the same level as the Sudbury River bottom near the wellfield, then a saturated thickness of about 50 feet is present at the Meadow View well. This value assumes the tip of the well is located at the bottom of the aquifer.

Table 1 shows the drawdowns computed at the Meadow View Well for various pumping rates and assumed transmissivities. The estimated drawdowns due to well loss shown in Table 1 were determined based on step drawdown data reported by Labadie and Helweg (1975). Values in parentheses were derived using the Todd equation.

Of the scenarios considered, only the computation combining the low transmissivity of 25,000 gpd/ft with the maximum drawdown due to well loss shows failure to occur by the total drawdown exceeding the maximum available saturated thickness of 40 feet. All other cases for the rated capacity of 400 gpm or less, including the highest past monthly rate (300 gpm) and the highest yearly average (210 gpm), leave at least 10 feet of water above the top of the wellscreen. Based on these results, it is GZA's opinion that the Meadow View well should be able to sustain a pumping rate of at least 300 gpm from areal recharge alone.

3.20 HAPPY HOLLOW WELLS

The two Happy Hollow supply wells are approximately 1200 feet from the Sudbury River. GZA's estimate of the most probable transmissivity at this site is 75,000 gpd/feet; this value could be as high as 150,000 gpd/feet. As noted above, the lower value is also the most conservative for estimating drawdowns at the wells. Assuming natural groundwater levels are at the bottom of the Sudbury River, the total available drawdown at the Happy Hollow site is 37 feet.

Well losses at Happy Hollow were estimated based on an aquifer test at the wellfield. This test pumped the largest flow rate of any test performed in Wayland and showed a drawdown of 8 feet occuring in the Happy Hollow #2 well after pumping

700 gpm for 2 days. Since most of this drawdown is due to losses through the aquifer, 2 to 5 feet would be a conservative estimate of well loss during this test. Inasmuch as two days may not have been a sufficient duration for the well to stabilize, steady state well losses were assumed to be on the order of 4 to 10 feet for a pumping rate of 700 gpm. These well loss approximations are in reasonable agreement with values of 3 and 8 feet as shown in Labadie and Helweg (1975) for a pumping rate of approximately 700 gpm.

Table 2 indicates that the only case in which the water level drops below the top of the well screen is that in which both wells are pumped at their rated capacity (700 gpm at #2 and 500 gpm at #1) and the Todd equation is used. This table also shows that pumping only Happy Hollow #2 at the rated capacity of 700 gpm may result in a water level only 3 feet above the top of the well screen. Other computations for the past maximum monthly pumping rate (510 gpm) and maximum yearly pumping rate (300 gpm) give drawdowns that are at least 10 feet above the top of the well screen.

Based on these results, it is GZA's opinion that the Happy Hollow wells should be able to maintain a combined pumping rate of 700 gpm based on areal recharge alone.

3.30 CHAMBERLAIN WELL

The proposed Chamberlain well will be located 600 feet from the Sudbury River. GZA has estimated the transmissivity of the underlying aquifer to be on the order of 30,000 gpd/feet. A pump test conducted at this site gave a drawdown of 21.7 feet at a distance of 2 feet from the well after pumping 430 gpm for 16 days. The saturated thickness at the site is at least 55 feet, and values of 55 feet and 60 feet were used in the equations. The total available drawdown at this site during August, when the Sudbury is generally lowest, is approximately 46 feet.

Since the transmissivity is rather low at this site, the Todd equation is believed to be in large error, as shown in the first row of Table 3 where an aquifer drawdown of 32 feet was calculated with the Boreli equation and 48 feet with Todd's equation. Consequently, only the Boreli expression was used in subsequent calculations. A well radius of 1 foot was used in accordance with the proposed installation as reported by the D. L. Maher Company.

Well losses were difficult to predict at this site. Two sets of published step drawdown data (Labadie and Helweg, 1975) indicated that total drawdown would be approximately 23 feet while pumping close to 400 gpm, the rate used for the Chamberlain pump test. A reduction of the data by the authors showed well losses to be only .5 foot in one case and 11 feet in another; the latter figure was assumed to represent the drawdown due to well loss at Chamberlain. Table 3 shows that the well fails or approaches failure for all cases considered. In should be noted that in this case the drawdown from the transient analysis could not be reduced to the watertable equivalent, which will be larger than 32.3 feet.

4.00 SUMMARY AND CONCLUSIONS

Several analytical methods were used to estimate whether present well yields could be sustained if only areal recharge to the aquifer were considered. Calculations included a consideration of drawdown due both to pumpage and to well loss.

On the basis of these calculations, GZA has estimatd that under the more conservative sets of aquifer and pumping conditions, well failure would occur at each wellfield. Since the hydraulic characteristics of the Sudbury River aquifer in Wayland could not be reliably determined with the existing data, and since GZA's analysis indicated that failure could conceivably occur at any of the three wellfields considered, further consideration must be given to the potential impact on these wells of lowering the Sudbury River.

REFERENCES

Bouwer, H., 1978, Groundwater Hydrology, McGraw-Hill 480 p.

Labadie, J. W. and Helweg, O. J., 1975, "Step Drawdown Test Analysis by Computer", Ground Water 13: 438-444.

Todd, D. K, 1980, Groundwater Hydrology, John Wiley & Sons, 535 p.

Walton, W. C., 1970, Groundwater Resource Evaluation, McGraw-Hill 664 p.

GZA

A-2870

TABLE 1 - MEADOW VIEW SITE COMPUTATIONS

SITE	ANALYSIS	TRANSMISSIVITY T gal/d/ft. PERMEABILITY K gal/d/ft^2	PUMP RATE Q (gpm)	COMPUTED WATERTABLE AQUIFER DRAWDOWN S_a (FT)	ESTIMATED DRAWDOWN DUE TO WELL LOSS S_w	MAXIMUM ESTIMATED TOTAL DRAWDOWN $S_T=S_a+S_w$	MAXIMUM AVAILABLE TOTAL DRAWDOWN (to top of well screen)	MINIMUM REMAINING WATER LEVEL ABOVE TOP OF SCREEN
Meadow View	Steady State Watertable eq. ( )	T=50,000 K= 1,000	400 (rated capacity)	15.3 (19)	3-10	25 (29)	40	15 (11)
	"	T=25,000 K= 500	400	31 (46)	3-10	41 (56)	40	failure (failure)
	"	T=50,000 K= 1,000	210 (highest yearly average)	9	1-3	12	40	28
	"	T=25,000 K= 500	210	20	1-3	23	40	17
	Transient after pumping 90 days	T=50,000 K= 1,000	400	20 (22.5 for artesian partial penetration)	3-10	30	40	10
	"	T=50,000 K= 1,000	300 (approx. highest monthly average)	14	3-10	24	40	16

NOTE: All drawdown values in feet.
Figures in parentheses were calculated using Todd equation.

TABLE 2 - HAPPY HOLLOW SITE COMPUTATIONS

SITE	ANALYSIS	TRANSMISSIVITY T gal/d/ft. PERMEABILITY K gal/d/ft.^{2}	PUMP RATE Q (gpm)	COMPUTED WATERTABLE AQUIFER DRAWDOWN S_a (FT)	ESTIMATED DRAWDOWN DUE TO WELL LOSS S_w	MAXIMUM ESTIMATED TOTAL DRAWDOWN $S_T=S_a+S_w$	MAXIMUM AVAILABLE TOTAL DRAWDOWN (to top of well screen)	MINIMUM REMAINING WATER LEVEL ABOVE TOP OF SCREEN
Happy Hollow	Steady State Watertable eq. ( )	T=75,000 K= 1,364	700 @ #2	18 (24)	4-10	28 (34)	37	9 (3)
	"	T=110,000 K= 2,000	700 @ #2	9 (15)	4-10	19 (25)	37	18 (12)
	"	T=75,000 K= 1,364	500 @ #2	13 (19)	2-5	18 (24)	37	19 (13)
	"	T=75,000 K= 1,364	700 @ #2 500 @ #1	23 (28)	4-10	33 (38)	37	4 (failure)
	"	T=75,000	300 @ #2	7.7 (8.3)	1-3	11 (12)	37	26 (25)
	Transient after pumping 90 days	T=75,000	700 @ #2	24 @ #2	4-10	34	37	3
	"	T=110,000	700 @ #2	16	4-10	26	37	11
	"	T=75,000	510 @ #2	17	2-5	22	37	15

NOTE: All drawdown values in feet.
Figures in parentheses were calculated using Todd equation.

TABLE 3 - CHAMBERLAIN SITE COMPUTATIONS

SITE	ANALYSIS	TRANSMISSIVITY T gal/d/ft. PERMEABILITY K gal/d/ft.^{2}	PUMP RATE Q(gpm)	COMPUTED WATERTABLE AQUIFER DRAWDOWN S_a (FT)	ESTIMATED DRAWDOWN DUE TO WELL LOSS S_w	MAXIMUM ESTIMATED TOTAL DRAWDOWN $S_T=S_a+S_w$	MAXIMUM AVAILABLE TOTAL DRAWDOWN (to top of well screen)	MINIMUM REMAINING WATER LEVEL ABOVE TOP OF SCREEN
Chamberlain	Steady State eq. ( )	T=30,000 K=545	500	32 (48)	11	43 (59)	46	3 (failure)
		T=25,000 K=454	500	39	11	50	46	failure
		T=30,000 K=500	500	32	11	43	46	3
	Transient after pumping 90 days	T-30,000	500	32.3 (1)	11	44	46	2

NOTE: All drawdown values in feet.
Figures in parentheses were calculated using Todd equation.

(1) Assumes artesian conditions. Correction for drawdown under water table conditions would result in increased drawdown.