LETTER REPORT TO
MATTAPOISETT RIVER WATER SUPPLY PROTECTION ADVISORY COMMITTEE
ON
EVALUATION OF THE AQUIFER SAFE YIELD OF THE MATTAPOISETT RIVER BASIN, MASSACHUSETTS

July 17, 1980

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July 17, 1980

Mr. Ray E. Pickles, Secretary
Mattapoisett River Water Supply
Protection Advisory Committee
2 Spring Street
Marion, Massachusetts 02738

Dear Mr. Pickles:

In accordance with our Agreement of May 29, 1980 we are submitting herewith our letter report detailing our evaluation of the aquifer safe yield for the Mattapoisett River Basin, Massachusetts. The area of investigation lies in the coastal drainage portion of southeastern Massachusetts, as shown on Figure 1. The purpose of this study is to determine the safe yield for development of groundwater in the basin.

The drainage basin of the Mattapoisett River includes large parts of the towns of Mattapoisett and Rochester and smaller parts of Fairhaven, Acushnet, and Middleborough. However, the productive sand and gravel aquifer that lies within the drainage basin is almost entirely within the boundaries of Mattapoisett and Rochester. Under existing legislation, the towns of Mattapoisett and Fairhaven have the right to develop water supply sources within the town of Mattapoisett, and the town of Marion has the right to develop water sources within the town of Rochester.

Existing and Proposed Wells. Fairhaven, Marion, and Mattapoisett have all developed groundwater sources in the valley (see Figure 1). Fairhaven has a tubular wellfield near the mouth of the Mattapoisett River that has a reported capacity of 0.25-0.35 million gallons per day (mgd). The wellfield yield apparently drops to 0.25 mgd during the dry part of the year.

The Town of Mattapoisett has three pumping stations within the valley. Station No. 2 is a tubular wellfield that has a capacity of 0.15-0.2 mgd. Station Nos. 3 and 4 are each a single gravel-packed well, with capacities of about 0.8 and 1.0 mgd respectively.

FIG. 1 MATTAPOISETT RIVER BASIN

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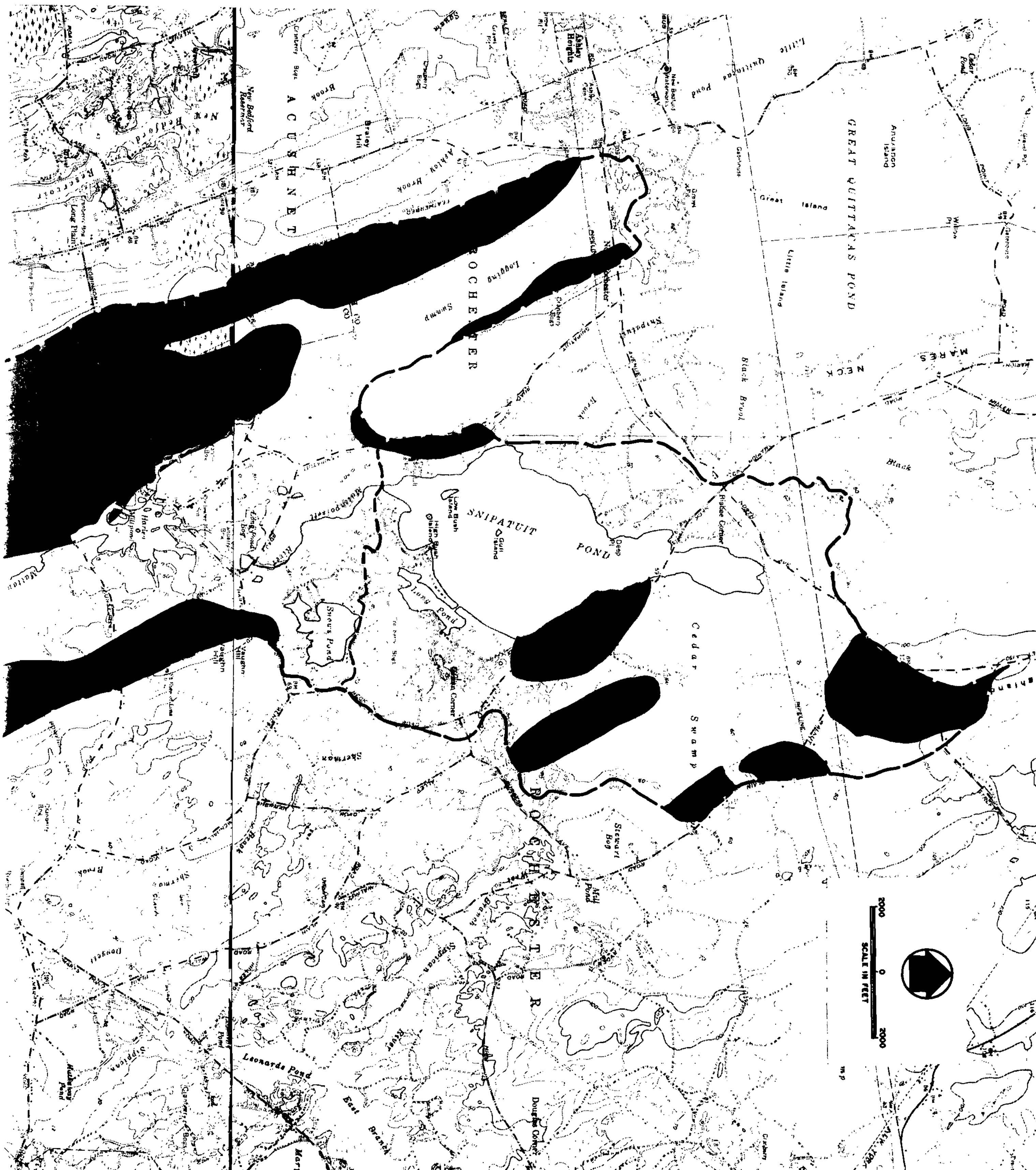

SNIPATUIT POND
GREAT QUITTACAS POND
Little Quittacas Pond
MARES NECK
Cedar Swamp
Long Pond
Snows Pond
Stewart Bog
Leonards Pond
ACUSHNET
ROCHESTER
Great Island
Little Island
Black Brook
SCALE IN FEET
2000
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The town of Marion has one gravel-packed well in the valley in Rochester that has a capacity of 1.0 mgd. Therefore, the total developed groundwater pumping capacity in the sand and gravel aquifer is currently 3.2-3.35 mgd.

All three towns have plans to continue developing groundwater in the valley. As shown in Figure 1, Fairhaven has two sites where production wells are planned, and Marion and Mattapoisett have sites where prolonged pumping tests are planned. However, no further testing or development is being permitted by the Massachusetts Department of Environmental Quality Engineering (DEQE) until a safe yield determination is made for the aquifer. The existing yield estimation of 5.5 mgd is from a previous report on the Mattapoisett River valley, described below.

Previous Investigations. In 1960, a report entitled "Special Report on Ground Water Resources in the Mattapoisett River Valley" was published by the Massachusetts Water Resources Commission. The report contains a general description of the occurrence of groundwater in the Mattapoisett River basin, including the following hydrologic budget:

Average annual precipitation	46 inches	
Average annual runoff	26 inches	56%
Average annual evapotranspiration	20 inches	

Groundwater underflow and changes in soil moisture and groundwater storage were assumed to be negligible. The values used in this hydrologic budget were taken from a 1955 report by Knox and Nordenson entitled "Average Annual Runoff and Precipitation in the New England-New York Area," and are based on climatic data from a base period of 1930-1949.

To estimate the average annual net recharge to the basin, it was assumed that one-third of the annual runoff is groundwater runoff, or water that annually circulates through the groundwater system. This figure of 9 inches, applied over the entire drainage area of almost 24 square miles, resulted in an average net recharge value of about 10 mgd.

The report also contains an estimate of the net recharge during a dry year, 1957, in which precipitation at Rochester was only 35 inches. The average annual evapotranspiration of ?

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20 inches was subtracted from this value to obtain a runoff of 15 inches. Again it was assumed that one-third of the runoff would be groundwater runoff, and the resultant value of 5 inches would result in a least annual recharge of 5.5 mgd for the 24-square mile basin.

In 1978, the U.S. Geological Survey published a hydrologic atlas entitled "Water Resources of the Coastal Drainage Basins of Southeastern Massachusetts, Northwest Shore of Buzzards Bay," prepared in cooperation with the Massachusetts Water Resources Commission. The report includes a delineation of areas of stratified drift, which is the basis of the areas shown in Figure 1. It is the sand and gravel deposits within the stratified drift that make up the aquifer that yields water supplies large enough for municipal development.

The Hydrologic Budget. The 1960 report by the Massachusetts Water Resources Commission concluded that the net recharge to the aquifer in a dry year would be sufficient to sustain an average withdrawal of at least 5.5 mgd. The objective of this study is to calculate a safe yield for the aquifer using the best available methods and all available data to determine if further groundwater development is feasible.

The term "safe yield" is not precisely defined in groundwater development. Often, the yield of a basin is considered to be the average annual groundwater runoff, which is the amount of water that annually circulates through the groundwater system before discharging into the surface water system. The average annual groundwater runoff would be equivalent to the "net annual recharge" value referred to in the 1960 report.

The best way to determine the average annual groundwater runoff is through analysis of streamflow data from a continuously recording stream-gaging station. Unfortunately, no such data are available for the Mattapoisett River. However, reliable estimates of groundwater outflow can be made by calculating a hydrologic budget for the basin to determine total runoff, and then analyzing the geologic composition of the basin to estimate the groundwater portion.

The input component of the hydrologic budget is precipitation, which is the sole source of groundwater in the basin excepting possible small amounts of underflow entering at the northern end. Using the latest "normal" precipitation values of the National Oceanic and Atmospheric Administration for New Bedford (39.77 inches/year), East Wareham (45.41 inches/year), and Middleborough (44.57 inches/year), an annual average precipitation of about 44 inches is obtained. This value is somewhat less than that used in the 1960 report because it is based on a period of time (1941-1970) that includes the drought of the 1960's.

The output from the basin includes runoff and evapotranspiration, neglecting possible small amounts of underflow discharging directly to the ocean. In considering the long-term hydrologic budget, yearly changes in soil moisture and groundwater storage are also neglected since they generally balance if the aquifer is not being consistently overpumped. We estimate an average annual runoff for the basin of about 24 inches. The average annual water loss (mostly evapotranspiration) is thus about 20 inches. These values are based on nearby gaged basins with adjustments made for differences in evapotranspiration and precipitation. For example, the 38-year record for Adamsville Brook in Rhode Island shows an average annual runoff of 24.55 inches, while the 53-year record for Wading River at Norton, Massachusetts shows an average runoff value of 23.27 inches/year.

To determine what amount of the total runoff is groundwater runoff, the geologic composition of the basin is considered. The U.S. Geological Survey (Thomas et al., 1967) has developed curves that relate the percentage of a basin that is underlain by stratified drift to the percentage of total runoff that is groundwater runoff. Figure 1 shows the areas of stratified drift, which are more permeable than the till deposits and tend to be overlain by soils that permit more precipitation to infiltrate to the groundwater system.

One problem in estimating the groundwater runoff from the basin is the fact that the basin has a variable northern boundary. Snipatuit Brook connects Snipatuit Pond to Great Quittacas Pond, which is part of the New Bedford water supply. The direction of flow in Snipatuit Brook depends on the relative elevations of the water levels in the two ponds. It is reported that when New Bedford draws heavily on the Quittacas Ponds during the summer, Snipatuit Brook flows northward. Under other conditions, the brook either flows south or does not flow appreciably in either direction. An attempt was made to compare the relative elevations of the outlets of Snipatuit Brook and the Mattapoisett River from Snipatuit Pond. Where the Mattapoisett River flows out of Snipatuit Pond, a weir with flashboards has been constructed. This weir is operated by the Rochester herring officer, who attempts to maintain high water levels in Snipatuit Pond during the summer while also attempting to support the herring population in the Mattapoisett River. On the day that the weir was inspected (6-20-80), the water level in the lake was about 1.5 feet above the crest of the weir. Unfortunately, the outlet of Snipatuit Brook from Snipatuit Pond could not be inspected due to swampy conditions, so a comparison of outlet elevations is not possible. However, it was noted that while water was flowing into the Mattapoisett River from Snipatuit Pond, no appreciable flow was visible in Snipatuit Brook at North Avenue in either direction.

Due to the uncertainty of the amount of flow that Snipatuit Pond contributes to the Mattapoisett River basin and how much it contributes to the Nemasket River basin, the drainage basin for the pond has been computed separately from the basin downstream from the pond. The following table shows the size of the basins, the percent underlain by stratified drift, the total average annual runoff (based on 24 inches/ year), and the annual average groundwater runoff.

Hydrologic Budget Data

Basin	Area (square miles)	Strat-fied Drift (%)	Total Avg. Runoff (mgd)	Avg. Ground-water Runoff (mgd)
Mattapoisett River below Snipatuit Pond	18.0	38.6	20.6	12.6
Snipatuit Pond	5.5	81.5	6.3	5.3
Mattapoisett River including Snipatuit Pond	23.5	48.6	26.8	17.9

The calculated groundwater outflow figure for the Snipatuit Pond basin may be higher than the actual value. Snipatuit Pond covers one-fifth of the basin, and Cedar Swamp includes a significant portion of the remaining area. These features probably result in rejected recharge which leaves the basin as streamflow after a brief period of storage in the surface system.

The above estimates support the conclusion that an annual average of about 12.5 mgd of water circulates through the groundwater system of the Mattapoisett River basin below Snipatuit Pond. When Snipatuit Pond is included in the drainage basin for at least half of the year, the average groundwater runoff would increase to 15-18 mgd. This is the amount of water that can be withdrawn from the basin groundwater system without permanently lowering the water table or "mining" groundwater more quickly than it can ever be replaced.

A final point to consider before discussing the safe yield is the ultimate disposition of the water consumed. In some cases, a large portion of the groundwater pumped from a basin is returned to the basin through either on-lot disposal or a stream outfall. However, in this case, almost all of the water is removed from the Mattapoisett basin and therefore must be considered to be consumptively used and unavailable.

Safe Yield. To determine a worst case annual groundwater outflow, the driest year of the 1960's drought (1965) was considered. In 1965, precipitation at the three stations near the Mattapoisett basin ranged from about 15.5-17.5 inches below normal (1941-1970). The basin-wide average precipitation for 1965 is estimated to have been 27 inches. Subtracting the average evapotranspiration of 20 inches/year from this low precipitation (the approach used in the 1960 report) would result in an unrealistically low runoff, since evapotranspiration is also lower than average in a dry year.

To determine approximately how much runoff could be expected in a dry year, precipitation and runoff data from the Wading River at Norton were used to produce the following table.

	Average	1965
Precipitation	44.70	27.21
Total Runoff	23.27	10.85
Evapotranspiration	21.43*	16.36*

*Calculated

These data show that, for average annual conditions, the total runoff is about 52 percent of precipitation. This percentage is similar to the 54 percent for our calculated average hydrologic budget for the Mattapoisett River basin. During 1965, runoff was 40 percent of the precipitation. Some of the runoff probably included groundwater that was removed from storage rather than recharge, but the calculations still give an approximate relationship between parameters of the hydrologic budget for an exceptionally dry year. Applying this 40 percent value to the Mattapoisett River basin for 1965, the resultant runoff would be about 10.8 inches.

During dry years, the proportion of total runoff that is groundwater runoff may be higher than average, since variations in yearly total runoff are largely within the surface runoff component (Thomas et al, 1967). However, to be conservative, the same percentages were used to produce the following dry year hydrologic budget.

Basin	Calculated Dry Year Groundwater Runoff(mgd)
Mattapoisett River below Snipatuit Pond	5.7
Snipatuit Pond	2.4
Mattapoisett River including Snipatuit Pond	8.1

The U.S. Geological Survey report (Thomas, et al) which was used above to predict the average annual groundwater outflow was also used to verify this long term minimum groundwater outflow to be expected. Use of those curves produced values of 7.2 mgd for the Mattapoisett River basin below Snipatuit Pond, 2.9 mgd for the Snipatuit Pond basin, and 10.1 mgd for the whole basin. These values are higher than the other calculated values because the minimum total outflow for the basin used to produce the curves was 13.2 inches, a higher value than the 10.8 assumed for our calculations. Based on our calculations, the minimum annual groundwater runoff is about 5.7 mgd for the basin below Snipatuit Pond and 7-8 mgd for the entire basin.

As mentioned previously, safe yield is not a precisely defined quantity in groundwater development. For the purposes of this study, we recommend that the safe yield be defined as the amount of groundwater runoff that is equalled or exceeded in 7 out of 10 years. Again using the relationships developed by the USGS (Thomas, et al), the flows equalled or exceeded 7 years out of 10 are as follows:

Safe Yield Data

Mattapoisett River basin below Snipatuit Pond	9.8 mgd
Snipatuit Pond basin	4.1 mgd
Total basin	13.9 mgd

During the summer, Snipatuit Pond is reportedly prevented from discharging to the Mattapoisett River through placement of flashboards at the spillway. If this is the case, then water from the pond drainage basin will be largely unavailable to the downstream Mattapoisett River basin. Therefore, based on information currently available, a safe yield of 10 mgd is recommended for the basin.

Potential for Induced Infiltration. Due to the arrangement of water rights among the towns, most of the existing and proposed groundwater development is in Mattapoisett, in the downstream part of the basin (see Figure 1). Most of the wells are located close enough to the river to induce infiltration, if geologic conditions are suitable. According to the 1978 USGS Hydrologic Atlas, the flow of the Mattapoisett River below Tinkham Lane is affected by groundwater withdrawals, indicating that streambed and aquifer conditions are favorable. The aquifer at Mattapoisett Well No. 4 contains no fine-grained layers that would impede the vertical movement of groundwater. Wells along that reach of river will, therefore, be able to obtain groundwater runoff in the stream that originated in the upper parts of the basin.

In the vicinity of Wolf Island Road, different conditions are found. A 30-40 feet thick layer of silt and clay overlies the permeable materials. This layer will greatly reduce the vertical flow of water (induced infiltration), so that wells in this area will tend to develop cones of depression that will spread to areas where vertical movement of either recharge or induced infiltration is possible.

Groundwater Storage Utilization. Little recharge to the groundwater system occurs during the six-month growing season from May to October. During this period, wells may obtain water from two major sources. One is groundwater runoff, which supports streamflow during dry periods and is available to wells as induced infiltration under suitable conditions. Since this base flow of streams is usually quite low even during years of normal precipitation, wells must also obtain a significant portion of the total pumpage from a second source, which is groundwater storage. As the cones of depression of the wells deepen and expand, well spacing, depth, and design determine the amount of storage that will be exploitable.

If the recommended safe yield of 10 mgd is developed, sufficient recharge would be available 7 out of 10 years. During the other 30% of the time, storage would be required to support the groundwater withdrawals. In the worst case year in which only 5.7 mgd of groundwater runoff is available, the shortage would be 4.3 mgd.

In a typical stratified drift aquifer with a specific yield of 30 percent, lowering the water table one foot over an area of one square mile during a six-month period of no recharge would release 0.35 mgd of water. Applying this factor to the Mattapoisett River basin below Snipatuit Pond, lowering the water table one foot over an area of about 12 square miles during a six-month period would release 4.3 mgd from storage. Therefore, it appears that ample groundwater storage is available in the aquifer.

During dry periods, the greatest demands for storage will occur in the Mattapoisett part of the aquifer, since both Fairhaven and Mattapoisett have wells there. The closest two wells currently in operation are Mattapoisett No. 3 and No. 4, which are reportedly about 800 feet apart. During the pumping test at the site of Well No. 4, interference from Well No. 3 was noticed. In an aquifer with a transmissivity of 100,000 gallons per day per foot and a storage coefficient of 0.2, pumping 700 gallons per minute for 200 days would cause a drawdown of about 3 feet at a distance of 800 feet from the well (assuming no recharge or discharge boundaries). This amount of interference would probably not have a large effect on the yield of either well except in a prolonged dry period. The spacing of wells in future developments should be based on careful analyses of controlled pumping tests to insure that storage utilization can be maximized.

Conclusions

1. Based on our calculations, the estimated groundwater runoff that is equalled or exceeded 7 years out of 10 in the Mattapoisett River basin below Snipatuit Pond is about 10 mgd.

2. Installation of a continuously-recording stream gaging station in the basin would result in accurate streamflow data that could be used to determine a more precise hydrologic budget for the basin and to monitor the effects of groundwater withdrawals on the surface water system.

3. Uncertainties exist concerning the amount of water that is contributed to the Mattapoisett River by Snipatuit Pond and its associated sub-basin. Apparently the flow from the pond into the Mattapoisett River is almost completely stopped during the summer to prevent the pond level from falling. It may be that water loss from the basin occurs during this period, when heavy demands are placed on the Quittacas Ponds and Snipatuit Pond contributes water to them via Snipatuit Brook. Due to the uncertainties, the Snipatuit Pond sub-basin is not included in the Mattapoisett River basin for the purpose of the safe yield calculations at this time.

4. All three towns are planning to continue developing groundwater in the basin, even though Marion and Mattapoisett both have sufficient pumping capacity to meet their maximum day demands. A favorable result of the fairly intense groundwater exploration in the basin is that land is being taken or purchased for water supply purposes; therefore, well sites are not being lost to residential or commercial development. However, to protect the quality of groundwater in the aquifer, a basin-wide protection plan should be considered.

Recommendations

1. An aquifer safe yield of 10 mgd is recommended for the Mattapoisett River basin. This safe yield value could be adjusted in the future if accurate, continuous stream-gaging data become available.

2. A continuously-recording stream gaging station should be installed in the basin to provide streamflow data necessary for optimum groundwater development and resource management.

3. A determination should be made of the net annual water loss (or gain) from the Quittacas Ponds. If significant water is lost through Snipatuit Brook, an investigation should be made of the feasibility of preventing northerly flow in the brook. An alternative means of being certain that water in the Snipatuit Pond sub-basin is not lost is to develop production wells in the sub-basin. Although this alternative would involve long transmission mains, it would have the advantage of further distributing the pumpage so that more groundwater storage would be accessible. Furthermore, developing groundwater in swampy areas can increase the groundwater portion of the hydrologic budget by lowering the water table and reducing evapotranspiration and rejected recharge.

4. An aquifer protection plan should be created that would, through zoning, protect the quality of groundwater in the basin. The Mattapoisett River basin is a particularly good area for such a plan, for two reasons. First, many good well sites have already been located and developed, so that the protection plan could be focused on those specific sites and not be too generally restrictive, in other areas. Second, most of the water in the basin originates in the towns that have an interest in its protection, so that the potential for a good workable plan is increased.

5. The towns should continue to work together in the development of the basin. Since the distribution of wells is critical to the realization of the full groundwater potential of the basin, the existing water rights arrangements should be evaluated in terms of their impact on full development of the resource.

Very truly yours,

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APPENDIX