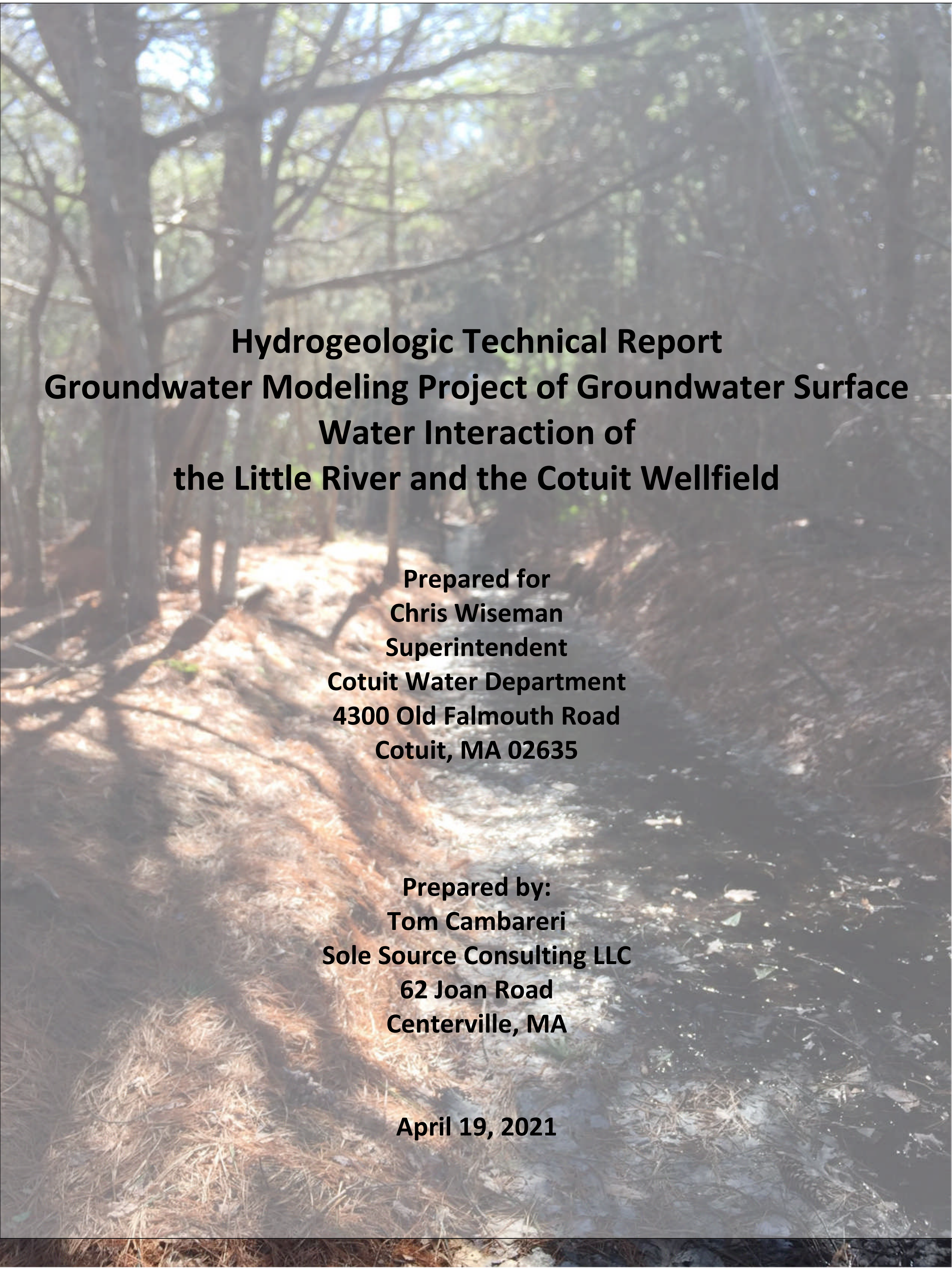

Hydrogeologic Technical Report
Groundwater Modeling Project of Groundwater Surface Water Interaction of the Little River and the Cotuit Wellfield

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April 19, 2021

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Acknowledgements

We thank the Cotuit Water Commissioners Scott Horsley, Mark Robinson and Thomas Hoppensteadt and Chris Wiseman, Superintendent and Jennifer Nash for their input and assistance. Thank to also to Tim Mc Cobb for helpful discussions about the USGS Sea Rise Model and its ongoing Rivers Projects. was extremely helpful Hoang Tran of Aquaveo Inc. was instrumental for his help with the model software. In memory of Mike Frimpter former Chief of the MA USGS Water Resources Division who was a mentor and friend to many in this field.

Picture credits to Mark Robinson Figure 2a. Cover and Figure 2b credits to Tom Cambareri

Introduction

Concern about the possible effect of seasonal pumping rates at the nearby Sampsons Mill Wellfield on flow in Little River in Cotuit resulted in several actions by the Cotuit Water Commissioners to suspend new private lawn irrigation installations in 2019-21 while the problem was studied. To better understand the interaction of pumping and flow in the river the Cotuit Water Department (CWD) retained Sole Source Consulting in 2021 to evaluate the impacts of pumping and water table drawdown on the Little River and its associated wetlands under various pumping scenarios and to determine a “safe yield” based upon no substantial impacts. This report describes the field activities and groundwater modeling effort for that evaluation.

Little River is approximately 10,300 feet long. The USGS (Cotuit quadrangle) topographic map shows that the river begins at Lovells Pond and extends under Route 28, Putnam Avenue and Old Post Road to Cotuit Bay. Little River occupies a former glacial outwash meltwater channel, similar to other small streams flowing to Nantucket Sound, such as Marstons Mills River, Mashpee River and Santuit River. These channels are pervasive along the margin of Cape Cod and are referred to as *pamets* after the geologic type local in Truro. In some cases, pamets are incised deep enough into the outwash plain that present day groundwater intersects them and discharges to make a sustained flow. In many cases the channels are too shallow and are referred to a dry pamets. In other cases, a pamet is in that zone where the downstream bed is wet with groundwater, but the upstream segment is dry. In the late 1860s cranberry agriculture was a new profitable trade and many of the dry or partially dry pamets and low-lying areas of Cape Cod were ditched, dredged and dug to make commercial cranberry bogs. Notable conversions for cranberry and herring runs include Centerville, Mill Creek, Bumps River, Skunknet River, Marstons Mills River and Little River.

The amount of natural water and flow in Little River depends on the level of water table measured in relation to mean sea level. The riverbed was explored on several days over the course of the study during the winter of 2021, a particularly dry period.

In March, the north portion of the river from Lovells Pond to Sampson Mill Road was explored. The outlet from Lovells Pond is a buried metal drainpipe about 150 feet long that discharges into an abandoned sump that at one time was equipped with a pump that would direct water into a channelized drain that ran south to the abandoned bogs south of Route 28, presumably for bog irrigation. Flow from the pond was not observed this March and the stagnant water in the sump was lower than the streambed to the south. No moving water was observed along this length in the winter of 2021. There are three sets of abandoned bogs with widths of 200, 400 and 200 feet perpendicular to the river with lengths of 200 to 1000 and 200 feet between Route 28 and the Sampson Mill Road. These bogs are all abandoned with heavy brush and trees and observable dikes and cut channels and abandoned flow structures. Water was first observed in the bottom of the channels about 1,500 feet south of Route 28.

In February, a minimal amount of water in the riverbed was observed to be frozen so it could be walked over from Captain Samadrus Road to north of the powerlines. South of Sampson Mill Road there are five sets of abandoned bogs with lengths of 200 to 1000 ft. Several bogs or wetlands to the west of Putnam Avenue were reportedly dredged to make “backyard” ponds in the early 1970s. Perceptible flow was observed in the stream channel near the subdivision tennis courts flowing into the man-made ponds this winter.

Variable rates of stream flow in Little River has been observed in the past. Groundwater fluctuations in the area can be reviewed by reviewing records from the USGS Water Table Index wells (Figure 1). Some of these index wells have monthly records for more than 50 years. The AIW 306 well near the High School has a 46-year record of monthly measurements and is now a real-time recording device. The redline level shows that recent March 2021 groundwater conditions are on the low end of normal for this time of the year. In April 2020, the water table was three feet higher than the March 2021 level and in the above- normal range. There are observations of water flow at Sampson Mill Road in March 2020 compared to dry in March 2021 Figure 2). The straight-line decline from April 2020 records plummeting water levels from drought conditions through most of 2020.

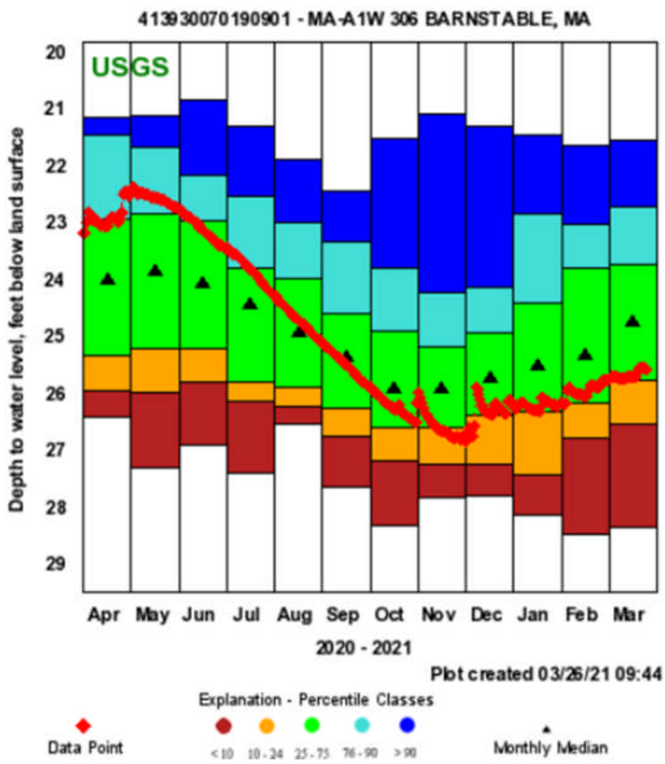


Figure 1 Groundwater Level Fluctuations

Figure 2 Little River at Sampson Mills Road a) March 2020 and b) March 2021

The USGS has recently been evaluating river flows and chemistry on the Cape. It made measurements on Little River in September 2019 and as recently as March 2021. Flow measured below Lovells Pond and at Old Post Road was approximately 0.47 cubic feet per second (cfs) or 40,000 cubic feet per day (cfd) with minimal flows at Captain Samadrus Road and Sampson Mill Road in 2019. No flow was observed in March 2021 at any station with only minimal flow at Old Post Road (0.25 cfs). The difference in recorded water levels at the USGS Index well (Figure 1) between those time periods is approximately 3 feet, which makes all the difference in flow in Little River. In other words, natural fluctuation during drought periods can account for a dry bed in Little River, even without water supply drawdown from pumping CWD wells.

There are no actual water table measurements available in the Sampson Mill Wellfield and Little River. A field visit with the Water Superintendent was successful in locating several 1979 test wells. It is recommended that the 2 ½-inch test wells and the streambed of the Little River be surveyed for elevation. It is also recommended that observation well(s) at Little River and the intervening pond (so-called Schoolhouse Pond) be installed and supplied with data transducers. These relative levels are necessary to accurately gauge groundwater surface water and pumping interactions.

Cotuit Water Supply Wells

The Cotuit Water Department (CWD) has five operating wells referred to as Stations 1 through 5 (Table 1). The original Main Station was installed in 1937 and was comprised of a series of five 6-inch tubular wells that ran along a length of the channelized Little River north of Route 28. The wellfield was manifolded into the main pump station. A pump test performed on Tubular well #5 in 1979 indicated a yield of 360 gpm from that single well. The other tubular wells were unproductive, and the Main station was subsequently declared inactive and serves as the administrative building for the Department. Station 3 is in the Cotuit historic village area approximately 2,900 feet west from the mouth of Little River. It was previously referred to as the Diesel Station and in 1977 pumped at a rate of 275 gpm. It was subsequently changed to electric power and has a nominal contribution of water (10%) to the system. Station 1, 2 and 4 are located between Route 28 and Sampson Mill Road and for this report are referred to the Sampson Mill Wellfield. Station 1 was installed in 1964. Station 2 was installed in 1972 and Station 4 was installed after a 1979 Pump Test. Station 5 is 6,500 feet west of Little River and is located north of Route 28 near the Mashpee boarder on the west side of the Santuit River. It is the most recent well installed in 1992.

Water Department staff take daily measurements of drawdown in the production wells to evaluate efficiency. Review of the information indicates that drawdown in the production wells does not vary, meaning the drawdown caused by the pumping on the groundwater is consistent given their relative rates. Stations 3 and 5 are removed from the Little River, so the study is focused on Stations 1, 2, and 4.

Table 1 Cotuit Water Department Supply Wells

Well	MA DEP #	Install Date	Rated Capacity (GPM)	Depth	Screen	Static	Drawdown
Cotuit 1	4020003-02G	1964.00	500.00	50.00	10.00	21.30	11.30
Cotuit 2	4020003-04G	1972.00	500.00	50.00	10.00	30.70	15.20
Cotuit 3	4020003-03G	1951.00	350.00	40.00	10.00	22.30	5.40
Cotuit 4	4020003-05G	1979.00	500.00	62.00	10.00	30.10	17.90
Cotuit 5	4020003-06G	1998.00	1200.00	125.00	20.00	59.60	18.50
Main	4002000-01G	1937.00	Inactive				
		Well #5 1979 Test	250.00	36.08	10.00	6.40	8.40

Pump Rates

Cotuit Water Department has an annual average pumping rate of approximately 0.6 MGD over the last 10 years. The Summer the average pumping is 1.17 MGD and in the off-season it is as low as 0.3 MGD. The total annual pumping increased 56% as and the number of accounts increased by 34% over the last 29 years and (Figure 3). The average water use per account over the last 10 years is 96,277 GPY or approximately 264 gpd per account. The account water use increased by approximately 16 % from 1991. The increase in pumping is correlated to the increase of total accounts and demand per account. Other factors are climate and economic. The Water Management Act Permit modified by DEP in 2018 authorizes an average annual daily pumping rate of 0.64 MGD, comprised of 0.27 MGD from the Registered wells (Stations 1, 2, and 3) plus 0.37 MGD from the permitted wells (Stations 4 and 5). The DCR-Office of Water Resources estimated Cotuit's 20-year water demand to increase up to 0.81 MGY by 2030. The Cotuit Water District has applied to increase the 20-year Permit authorization accordingly.

The 5 operational wells have a total rated capacity of 3,050 gpm or 4.4 Million gallons per day (MGD) (Table 1). The WMA Permit allows maximum day pumping up to the rated capacity of individual wells within the overall annual authorization. Pumping records over the last 10 years was compiled to evaluate the actual pumping rates under different conditions. Owing to the Cape's high summer population and seasonal irrigation the pumping rates fluctuate about 2-3 times from off season to summer season. These rates are used for scenario input for the groundwater model to evaluate seasonal pumping effects on the watertable. The individual wells have different capacities and characteristics that translate to different pumping rates over the year. Monthly pumping rates of the wells were compiled and graphed so appropriate individual pump rates could be selected for the groundwater model.

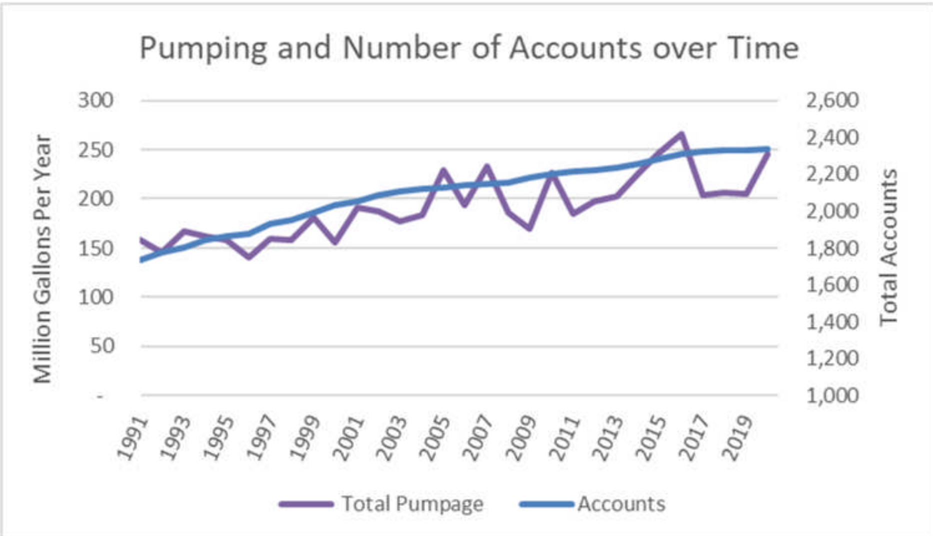


Figure 3 Cotuit Annual Pumping and Number of Accounts from 1991 to 2020

Monthly pumping over the last ten years is dominated by Station 5 at 30% the annual average pumping followed by Stations 4, 1, and 2 in the Sampson Mill Wellfield at about 20% each and Station 3 in the Village at 10% (Figures 4 and 5).

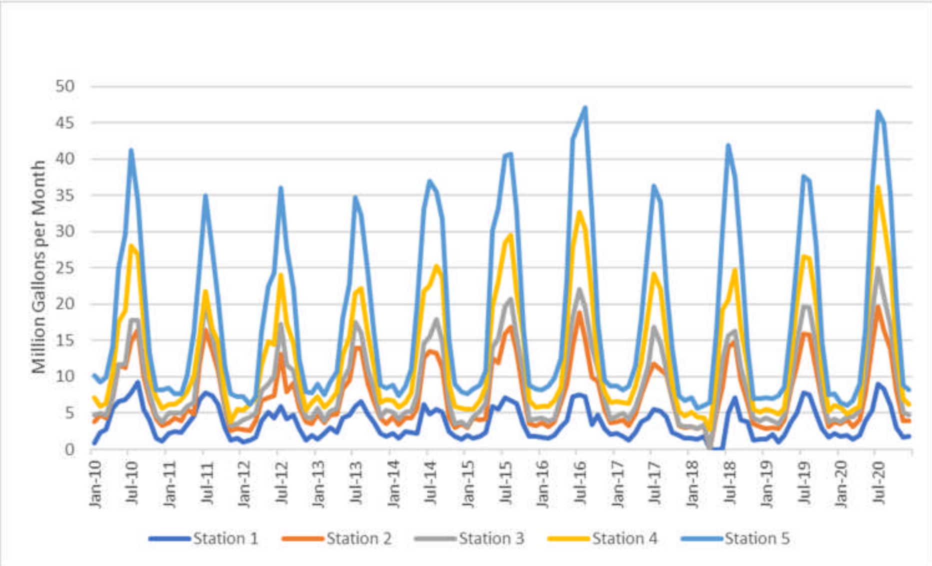


Figure 4 Cotuit Monthly Pumping for Individual Wells

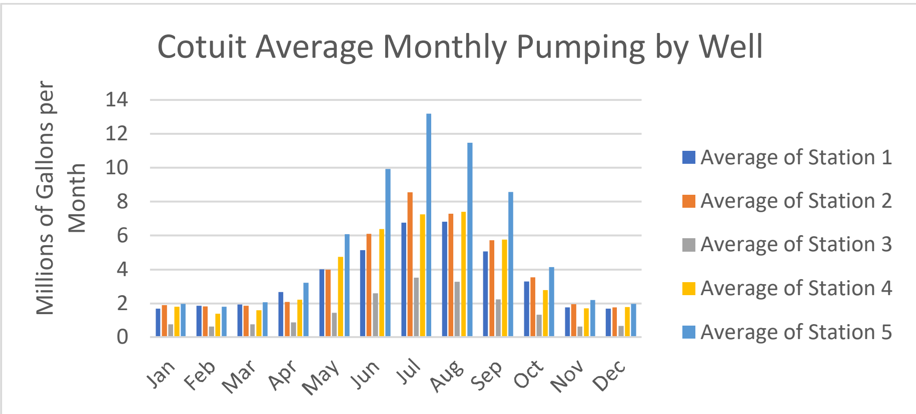


Figure 5 Average Monthly Pumping Rate for 2010 to 2020

Seasonal pumping is the three-month summer average and a six-month off season to capture the extremes of the pumping year that exclude the in-between shoulder months (Table 3). These pumping rates are used in the groundwater model to represent average, summer and off season pumping.

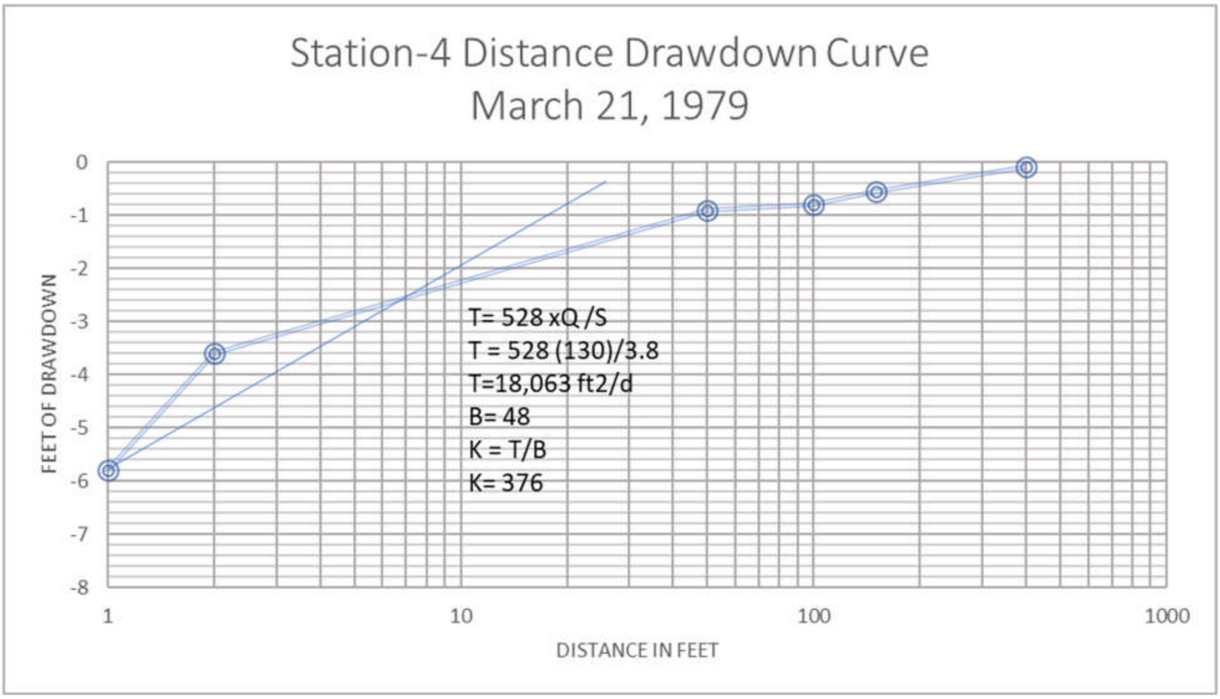
Table 2 Annual and Seasonal Average Pumping Rates

	CO-1	CO-2	CO-3	CO-4	CO-5	Sum
Summer 3 Month Ave	6,235,515	7,306,939	3,119,212	7,003,333	11,520,697	35,185,696.97
GPD	207,851	243,565	103,974	233,444	384,023	1,172,856.57
gpm	144.34	169.14	72.20	162.11	266.68	814.48
ft3/d	27,783.79	32,557.77	13,898.37	31,204.98	51,333.14	156,778.05
6 Month Off Season Ave	2,032,136	2,136,652	800,045	1,835,091	2,357,879	9,161,803.03
GPD	67,738	71,222	26,668	61,170	78,596	305,393.43
gpm	47.04	49.46	18.52	42.48	54.58	212.08
ft3/d	9,054.66	9,520.35	3,564.79	8,176.67	10,506.08	40,822.54
Monthly Annual Ave	3,554,295	3,877,712	1,557,227	3,726,447	5,546,515	18,262,196.97
GPD	118,477	129,257	51,908	124,215	184,884	608,739.90
gpm	82.28	89.76	36.05	86.26	128.39	422.74
ft3/d	15,836.99	17,278.05	6,938.59	16,604.05	24,713.79	81,371.46

Pump Tests and Aquifer Parameters

Pump test reports were obtained from the Water Department Office for Stations 4 and Station 2 conducted in 1979 and 1971, respectively. The pump test drawdown and recovery data were compiled and graphed to determine the yield from the wells. The pump tests were conducted according to procedures of the day but prior to more sophisticated means and requirements presently required to better characterize aquifer parameters. The available data is sparse but can be used to estimate hydraulic conductivity for the groundwater model. Hydraulic conductivity is an essential parameter to characterize the permeability, or the ability of groundwater to flow through the porous sands. Hydraulic conductivity ranges over several orders of magnitude from low values for silts and clays to extremely high values for gravel and fractured bedrock. This will be discussed further in the groundwater model section.

The pump test includes the measurement of drawdown of the watertable over time beginning at the start of the test. This data is compiled and graphed on semi-log for the Cooper-Jacob method to calculate the transmissivity from which hydraulic conductivity is determined. Drawdown measurements in today's methods are taken with digital pressure transducers that can record levels every fraction of a second. The available pump tests for Station 2 and 4 start with a first measurement at 1 minute well after critical data is missed. The four-day pump test for unconfined aquifers such as Cape Cod and an inverse test referred to as a recovery test begins when the well is shut down can yield useful data. The sparse data for time-drawdown and recovery test generated hydraulic conductivity results with a wide margin from over 700 ft/d to 180 ft/d. The plot of drawdown over distance from the well is another method to calculate hydraulic conductivity (Figures 6). The near well data points indicate hydraulic conductivity from 375 ft/d to 195 ft/d with an average of 275 ft/d. These are reasonable values for use in the model. Station 4 is the closest well to Little River at approximately 1,025 ft. The amount of drawdown recorded at 400 feet from Station 4 after pumping for four days is ~ 0.1 feet. It is recommended that informal pump tests be conducted with pressure transducers to provide corroboration of drawdown and hydraulic conductivity at some point in the future.



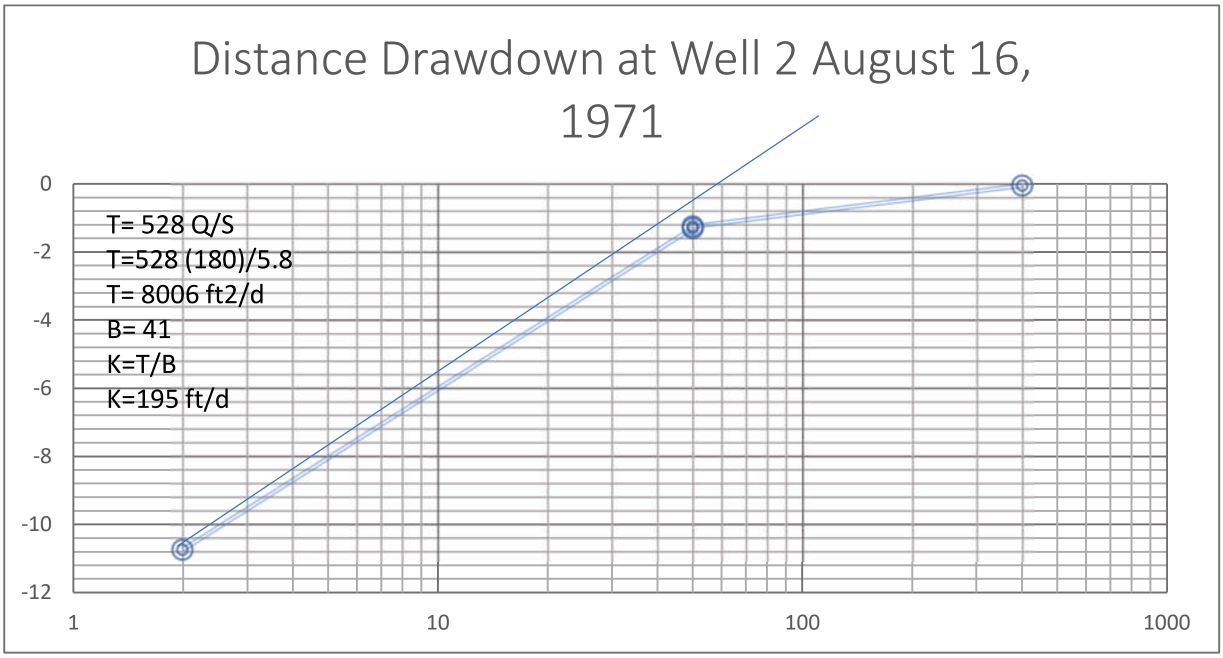


Figure 6 Distance Drawdown Plots for Station 4 and Station 5

Groundwater Model

The USGS developed groundwater models of the Sagamore and Monomoy Lens in 2004 (Walter and Whealan) using the USGS three-dimensional, finite-difference groundwater model MODFLOW-2000 (Harbaugh, et al., 2000). The 2004 model has been the used as the basis of numerous Zone II delineations and watershed boundaries to coastal embayments as well as the definition of pond and stream watersheds for the land use analysis of the MEP technical reports and subsequent DEP and EPA approved Total Maximum Daily Loads. In 2016 the USGS developed the Sea Level Rise (SLR) Model of the Upper and Lower Cape. The model includes the measured ground surface, updating the layering to simulate the water table in the top layer of the model, and more detailed stratigraphic information (Walter et al., 2016). Lidar data (accurate surface elevations based on laser measurements) was imported to allow for the prediction of sea level rise impacts on groundwater. In 2019 the USGS released the latest version of the SLR Model with updated recharge arrays. The 2019 USGS groundwater model was used as the base model for the Cotuit study to evaluate the groundwater surface water interactions in the Sampson Mill Wellfield using the GMS preprocessing software by Aquaveo Inc.

The SLR Model is comprised of a 400 by 400 foot grid from the Cape Cod Canal to Nauset Marsh. Initial simulations of Little River indicated that the 400 by 400 grids were too coarse for a detailed evaluation of the Little River, so the gird was refined to a 100 by 100 foot grid for the Cotuit Model (Figure 7). The Cotuit Model 100-foot grid spans from the west side of the Santuit River to the east side of Eagle Pond and from Lovells Pond to the north to Cotuit Bay to the south. The refined Cotuit Model is not separate but part of the SLR Model so no artificial boundaries between the local and regional model are required.

a

b

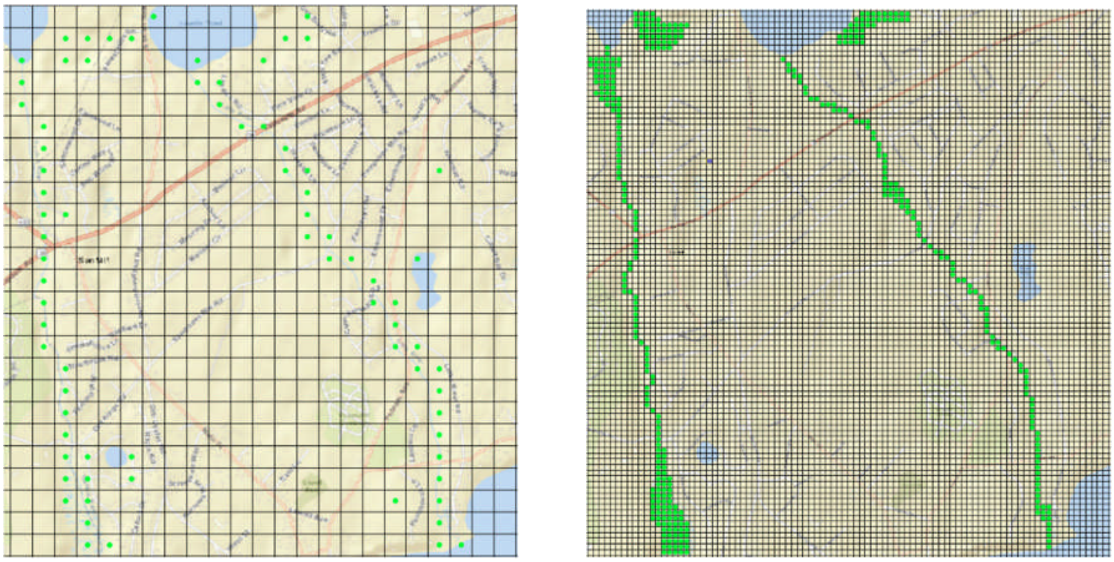
Figure 7 Model Comparisons a) USGS SLR Model Grid and b)100 ft Grid for the Cotuit Model

Cotuit Model

Streams and rivers in the SLR Model are represented as drains from the aquifer. Each drain cell requires a specified conductance or leakance term, that represents the ability of groundwater to move into or discharge from the aquifer into the river, and stream bed elevation, that is used by the model in conjunction with the elevations of the water table.

Stream bed conductance terms (6927 ft^2/d) from the SLR Model were proportionally input into the Cotuit Model. Additional drain cells were specified for a broader area to represent the array of cranberry bog ditches that receive groundwater discharge. Elevation data from the SLR Model of the Little River Stream Bed was apportioned to the new 100 ft2 Drain cells. The Little River is comprised of 125 grid cells, also called cells in the Cotuit Model (Figure 8).

The hydraulic conductivity (HK) valves of the SLR Model were kriged or estimated from known values to areas with unknown data by the USGS for the SLR Model. The SLR model has 21 layers in the Cotuit area. The first 6 layers represent the upper aquifer from the water table at generally 20 ft in the center of the model to approximately -50 below sea level. Layers from 7 to 15 are from -50 to -150 ft below sea level and represent a lower permeability zone. The last layers 16 to 23 end at -260 feet below sea level with the lowest permeability. The model layers follow established stratigraphic concept of the Cape Cod Aquifer. The SLR Model kriged HK values in the upper aquifer includes a low permeability ridge running SW to NE with an HK ranging from 50 to 74 ft/d. An HK of 275 ft/d was imported into layers 1 to 6 in the Cotuit



b

Figure 8 Grid and Drain Specification (Green Cells) for a) USGS SLR Model and b) Cotuit Model

Model as estimated from the pump tests from the Cotuit wells as discussed above (Figure 9). Ponds are represented as high HK is simulate groundwater flow through character of kettle ponds. The USGS SLR rise model is fully calibrated as imported into the GMS software. No changes other than those described above were made to the general steady state model. Additional parameter sensitivity runs were conducted for variations of drain conductance, hydraulic conductivity and drain bed elevation. Higher HK and drain conductance values resulted in greater river flow and lower stream bed elevations resulted in lower flow than higher bed elevations.

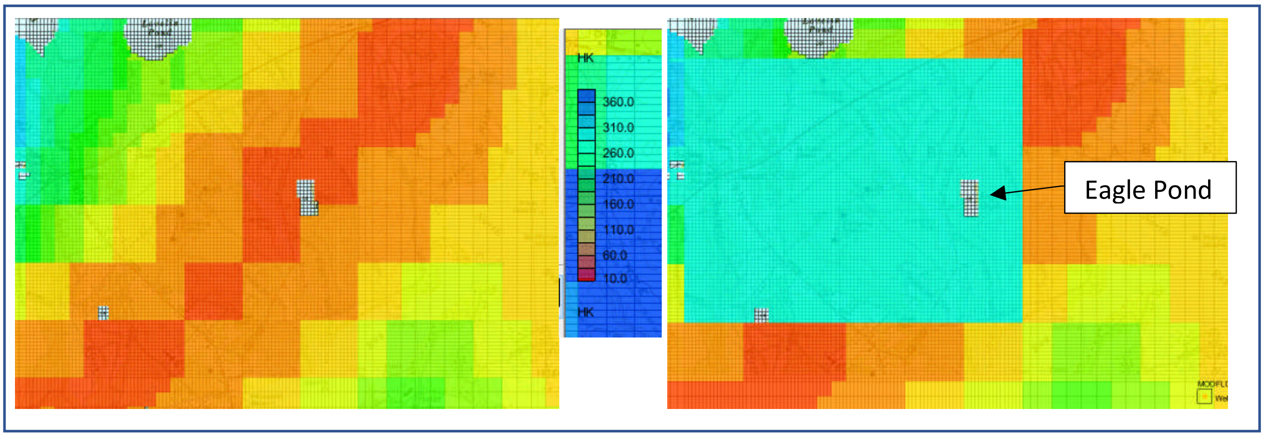


Figure 9 Hydraulic Conductivity of the a) SLR and b) Cotuit Models

Model Scenarios and Calibration

The results of the model runs are from steady state conditions. This means the results are from a condition that exists for 24 hours 7 days a week forever. Steady state conditions are run to evaluate average conditions. The Cotuit model was calibrated by the USGS for steady state conditions using average water levels from over 600 observation points across the Cape. A calibration for Cotuit Model after modifications was also run using the USGS observation points (Figure 10). The absolute residual and range indicate a good fit for the steady state model.

There are no observation points within the Cotuit study area. A more accurate calibration for the Little River area would include establish observation points within the study area as recommended above. For the purposes of this study the results show relative interactions between the aquifer and river and the change in groundwater levels for different pumping rates.

The pumping scenarios include the average pumping conditions for steady state conditions. The model then was run for a non-pumping condition as if the wells did not exist. Simulations that bracket off-season and summer demand used the pumping rates from Table 2 for each well. These bookend simulations are extreme because they represent a low or high pumping rates for a 24/7 condition. Therefore, those results are presented to qualitatively gage the effect of extreme conditions. When actual measurements become available it is recommended that the models be run in a transient condition that incorporates the time into the pumping simulations.

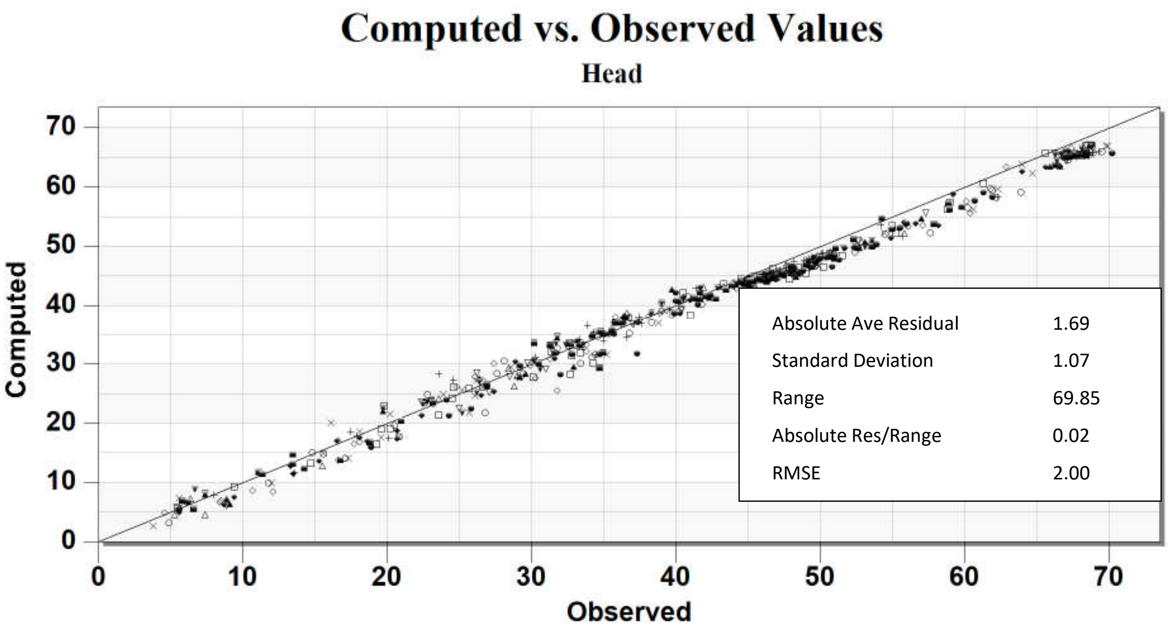


Figure 10 Observed vs Simulated Values for Calibration

The results of the groundwater flow model are presented as maps (Figures 11 to 14) showing water table contours, flow volume in cubic feet per day (CFD) from the aquifer into each drain cell and particle tracks showing the source of water to the wells and river. The volumetric flow for three river segments is compared. The three segments include: entire river, a segment from Route 28 to Sampson Mill Road, and from Route 28 to Putnam Avenue (Figure 11).

Results

Simulated River and Groundwater Flow

Except for the non-pumping scenario, none of the simulations, show groundwater flow into the drain cells of the upper river near Lovells Pond. The same result was observed in the USGS SLR Model. The color key in each map shows the amount of flow in CFD into each drain cell. The low drain cell flow (400 CFD) into the river's upper reaches increases along its length downgradient to a flow of 3600 CFD near Old Post Road and then decreases at it reaches the bay. The least number of low flow dark blue cells are seen in the non-pumping scenario (Figure 12). The number of dark blue cells in the upper river increase with each increase of pumping indicating a reduction of flow.

Particle tracking was utilized with the MODPATH module of the GMS software. The package shows how groundwater flows in the model by either forward or backward tracking of placed particles. A rule of thumb is that groundwater flows perpendicular to the water table contours. Nine particles were placed at each of the wells and pairs of particles were placed along selected drain cells of the Little River. <u>The particle paths to the wells shows that groundwater flow to the pumping wells does not originate from the Little River.</u> Instead, groundwater from areas directly upgradient flow towards the wells. The width of the groundwater area captured by the well referred to as the zone of contribution increases with pumping. The ZOC widths for non-

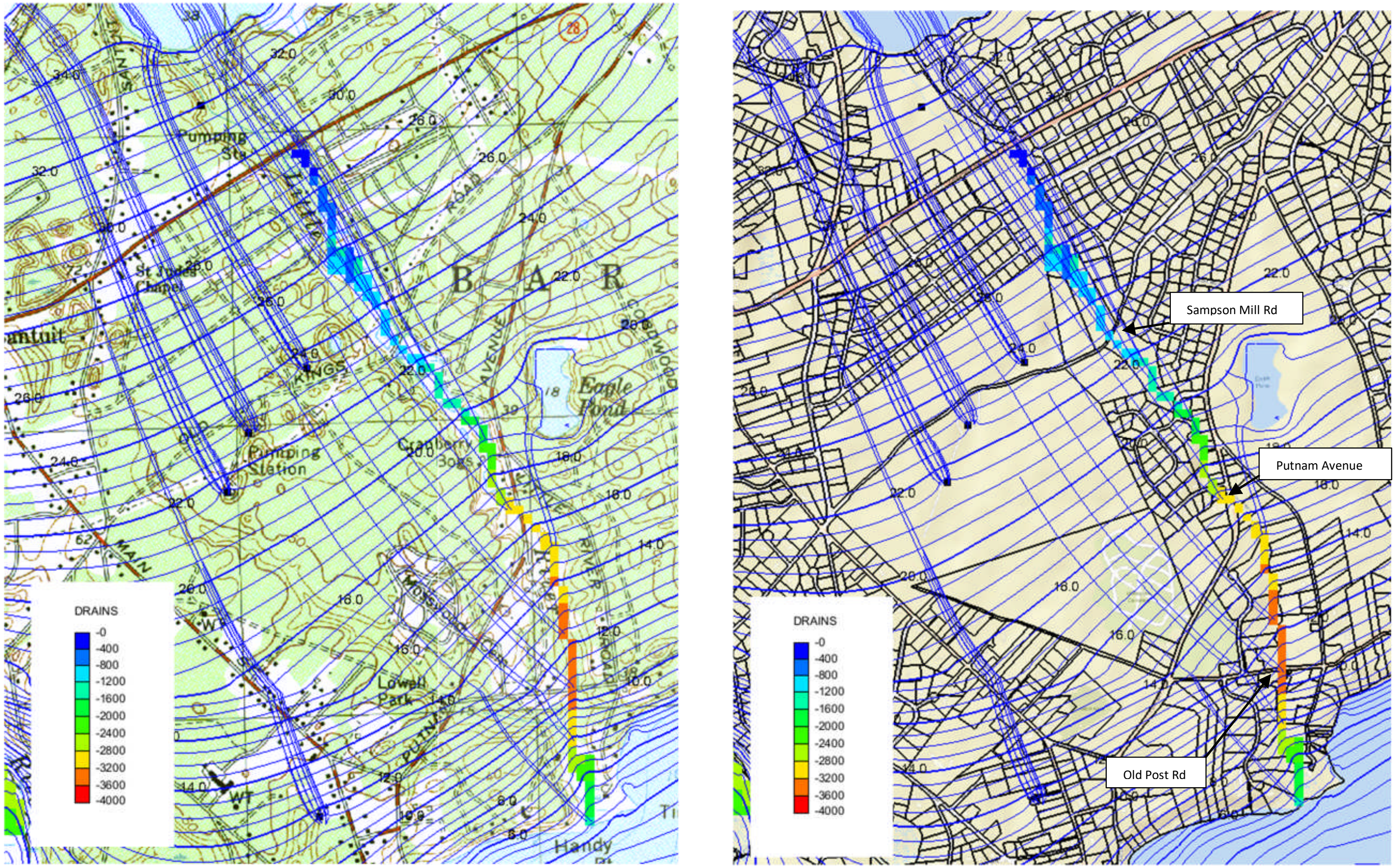


Figure 11 Average Annual Pumping from the Sampson Mill Wellfield.

Water Contour Interval is ½ ft with 2-foot contour in Bold. Drain flow is shown in ft^3/day by color. Reverse particle tracks for the wells and selected points on the Little River are shown. The width of the capture area areas to the wells is approximately 235 ft.

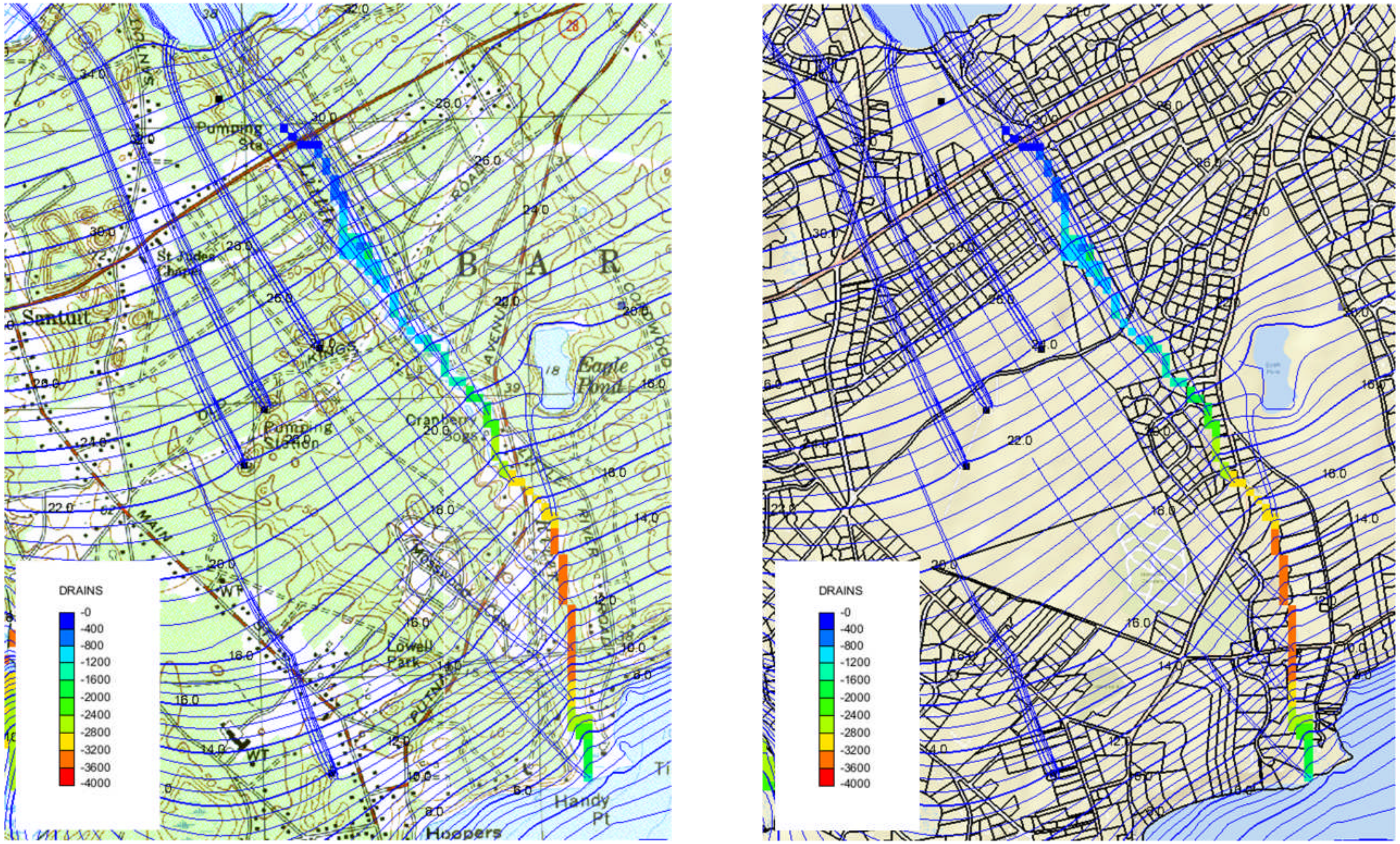


Figure 12 Off-Season Pumping from the Sampson Mill Wellfield under a Steady State Condition

Water Contour Interval is ½ ft with 2-foot contour in Bold. Drain flow is shown in ft^3/d by color. Reverse particle tracks for the wells and selected points on the Little River are shown. The width of the capture area areas to the wells is approximately 145 ft.

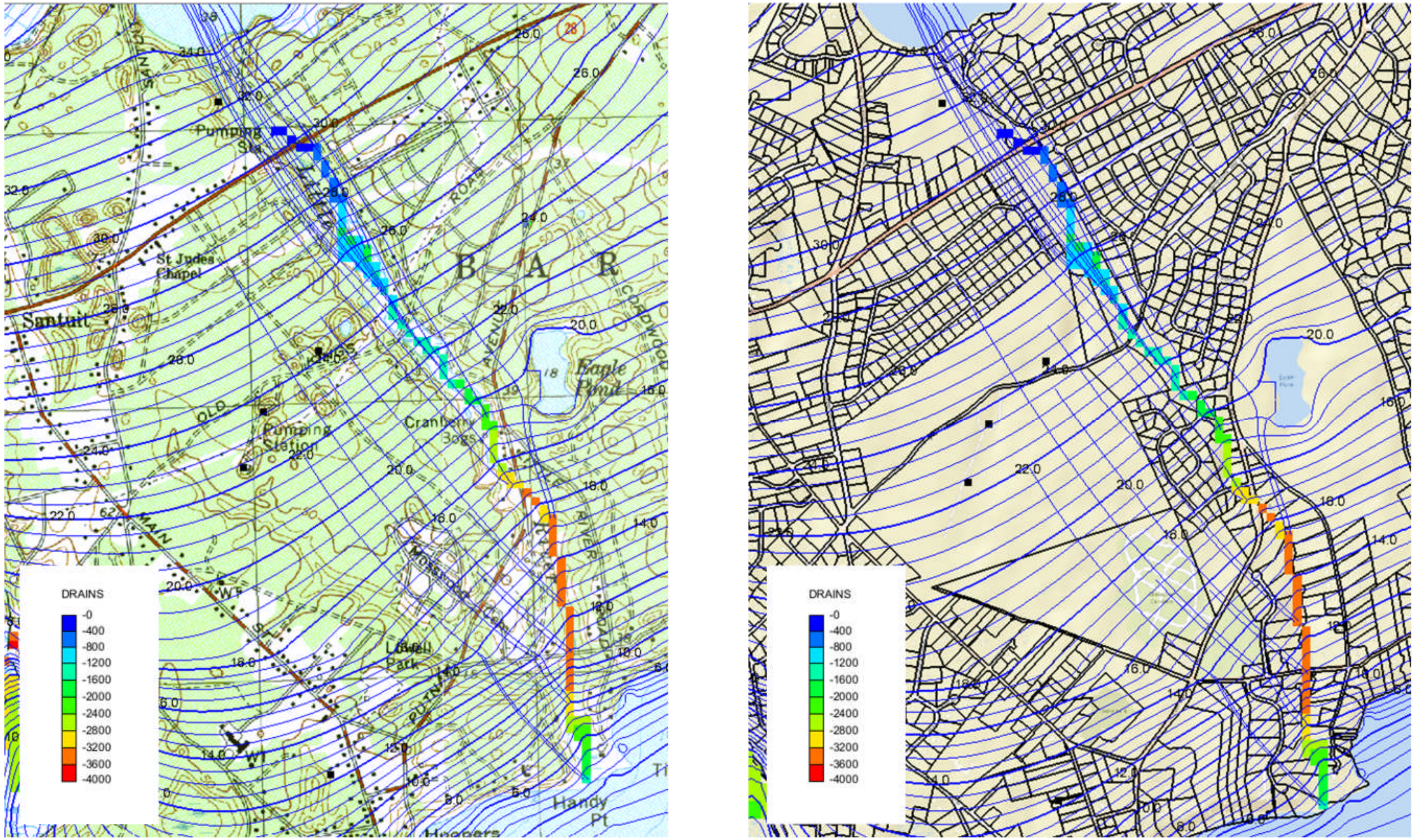


Figure 13 Non-Pumping Condition from Sampson Mill Wellfield under a Steady State Condition

Water Contour Interval is ½ ft with 2-foot contour in Bold. Drain flow is shown in feet3/d by color. Reverse particle tracks for the wells and selected points on the Little River are shown.

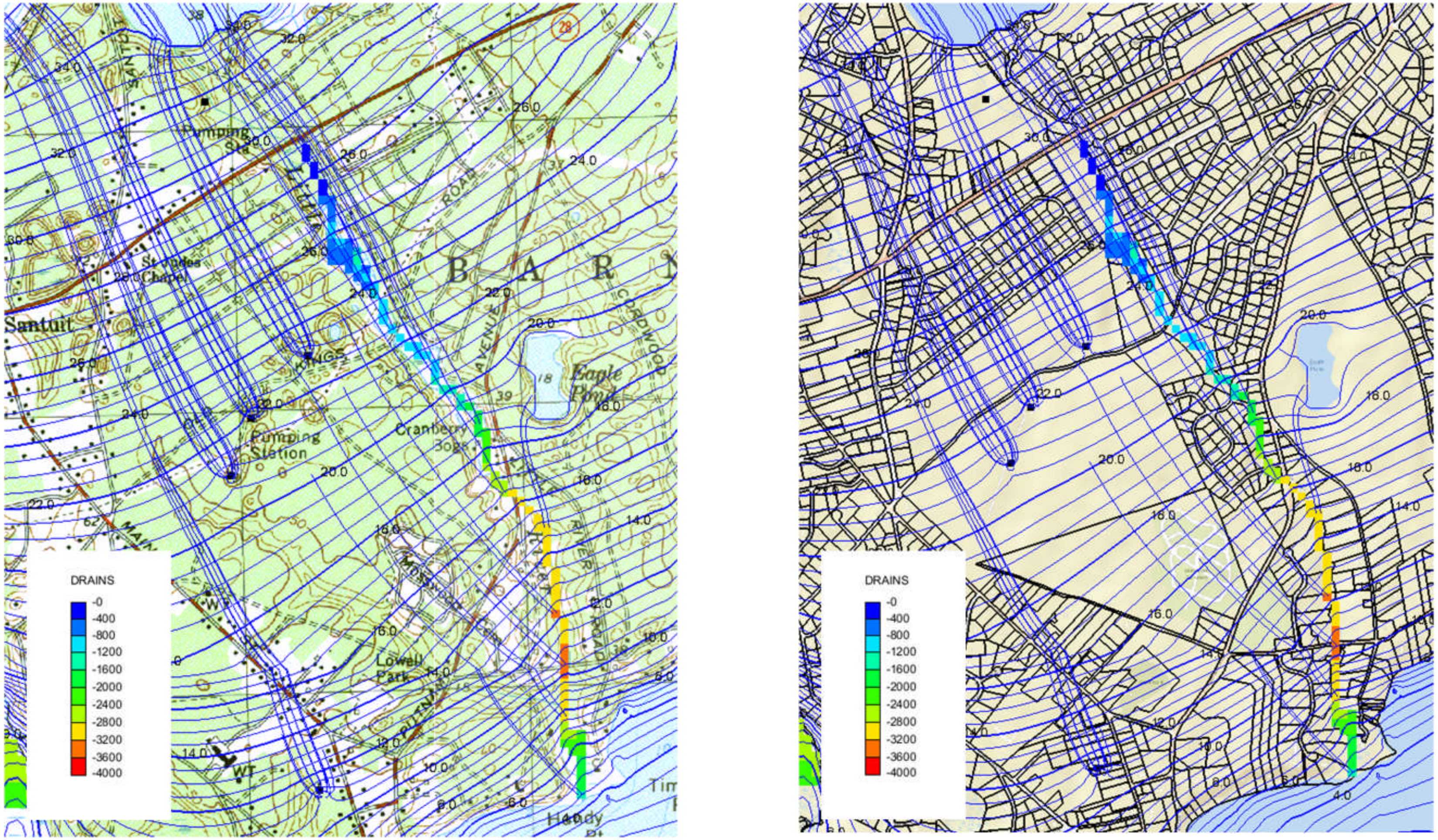


Figure 14 Summer Pumping from the Sampson Mill Wellfield under a Steady State Condition

Water Contour Interval is ½ ft with 2-foot contour in Bold. Drain flow is shown in ft3/d by color. Reverse particle tracks for the wells and selected points on the Little River are shown. The width of the capture area areas to the wells is approximately 366 ft.

seasonal, average, and summer pumping are 145 feet, 235 feet, and 366 feet, respectively. Little River is located perpendicular to groundwater contours, so the particle paths indicate the contributing area to the River is along its margins extending upgradient along is length. Below Putnam Avenue the river turns oblique to the groundwater flow field and the contributing area is offset to the west and north west.

Flow into the drain cells of the Little River were summed for the three segments on Table 3. The first box shows the flow in cubic feet per day (CFD) which is the model output. Drain flow in the second box has been converted to cubic feet per second (cfs) which is a typical term for river flow. Both boxes show the difference in flow between the scenarios. The third box shows the percent difference in flow between the pumping scenarios and the non-pumping condition.

Table 3 Simulated Drain Cell Flows in the Little River by CFD, CFS, and Percent difference from Non-Pumping.

Pumping Scenarios	Pumping Rate (GPD)	Little River Flows in Cubic Feet per Day		
		Entire River	28 to Putnam Ave	28 to S.Mill Rd
Non Pumping	zero	209,996	86,709	36,452
Off Season	200,129	202,797	81,546	32,295
Average	371,948	196,193	79,811	30,352
Summer	684,860	184,112	70,876	24,952
		Difference from Non-Pumping CFD		
Off Season	200,129	7,199	5,163	4,157
Average	371,948	13,803	6,898	6,100
Summer	684,860	25,884	15,833	11,500

Pumping Scenarios	Pumping Rate (GPD)	Little River Flows in Cubic Feet per Seccond		
		Entire River	28 to Putnam Ave	28 to S.Mill Rd
Non Pumping	zero	2.43	1.00	0.42
Off Season	200,129	2.35	0.94	0.37
Average	371,948	2.27	0.92	0.35
Summer	684,860	2.13	0.82	0.29
		Difference from Non-Pumping CFS		
Off Season	200,129	0.083	0.060	0.048
Average	371,948	0.160	0.080	0.071
Summer	684,860	0.300	0.183	0.133

		Percent Decrease from Non-Pumping		
Off-Season to Non-Pumping		3%	6%	11%
Average Pumping to Non-Pumping		7%	8%	17%
Summer Pumping to Non- Pumping		12%	18%	32%

The non-pumping flow simulation for Little River segments for its entire length, from Route 28 to Putnam Avenue, and, from Route 28 to Sampson Mill Road conditions the simulated Little River flows are 2.43 CFS, 1.00 CFS, and 0.42 CFS. Under average pumping conditions the flow for Little River segments for its entire length, from Route 28 to Putnam Avenue, and, from Route 28 to Sampson Mill Road is 2.27 CFS, 0.92 CFS and 0.35 CFS respectively. This is a percent flow decrease of 7%, 8% and 17% for those segments respectively. The percent of flow reduction increases under summer pumping conditions to 12%, 18% and 32% respectively. Under less off-season pumping the flow reduction is less at 3%, 6% and 11% respectively. Although the source of groundwater to the wells does not originate from the river, pumping decreases the overall height of the water table so that less groundwater discharges into the river.

A graph of discharge into each of the 130 drain cells from Lovells Pond to Old Post Road shows the incremental decrease of flow to drain cells from non-pumping to average and summer pumping conditions (Figure 15). The cumulative flow of discharge into the river's drain cells increases significantly along its length (Figure 16). The fluctuating line segment of the graph between Route 28 and the Power Lines is variable flow to multiple drain cells representing the interior and marginal cells of the wide portion of the river and its abandoned cranberry bog tributaries. The simulation shows no groundwater discharge from Lovells Pond to Route 28. Low flows begin at Route 28 through the fluctuating area of the cranberry bogs to Sampson Mill Road. Flow into drain cells increases significantly just prior to Captain Samadrus Road and then levels off at a high rate (~3,000 CFD) after Putnam Avenue to Old Post Road. The steep increasing cumulative flow rate curve is sustained through that area.

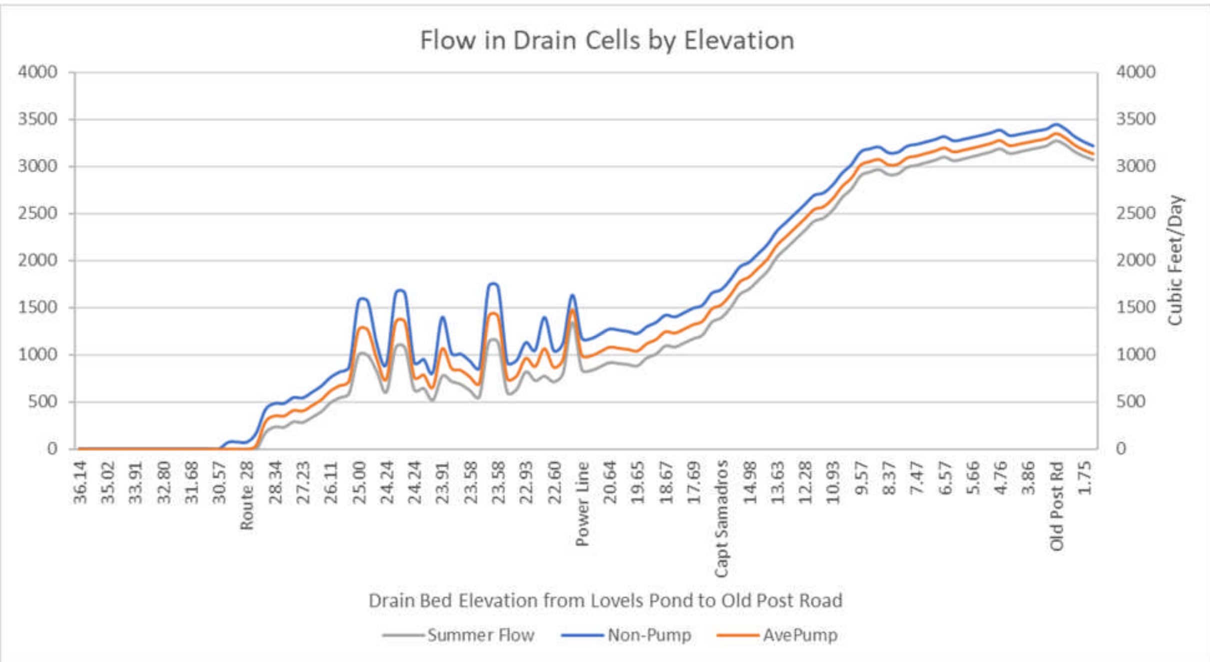


Figure 15 Flow into Drain Cells along the Length of Little River.

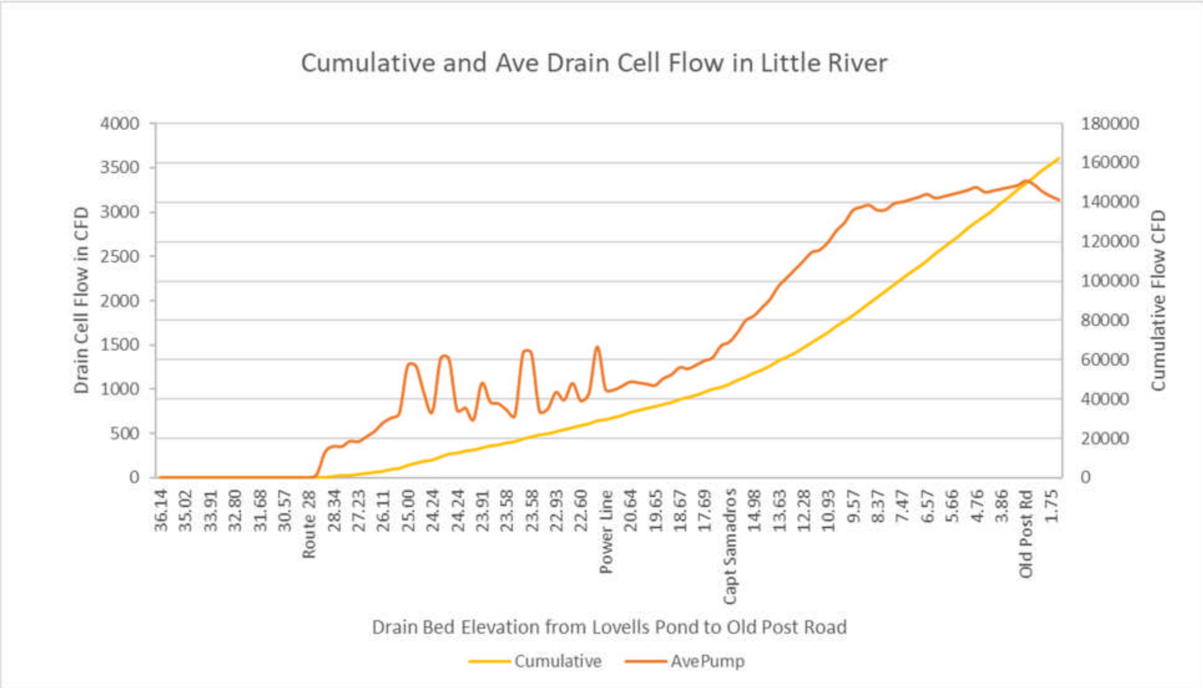
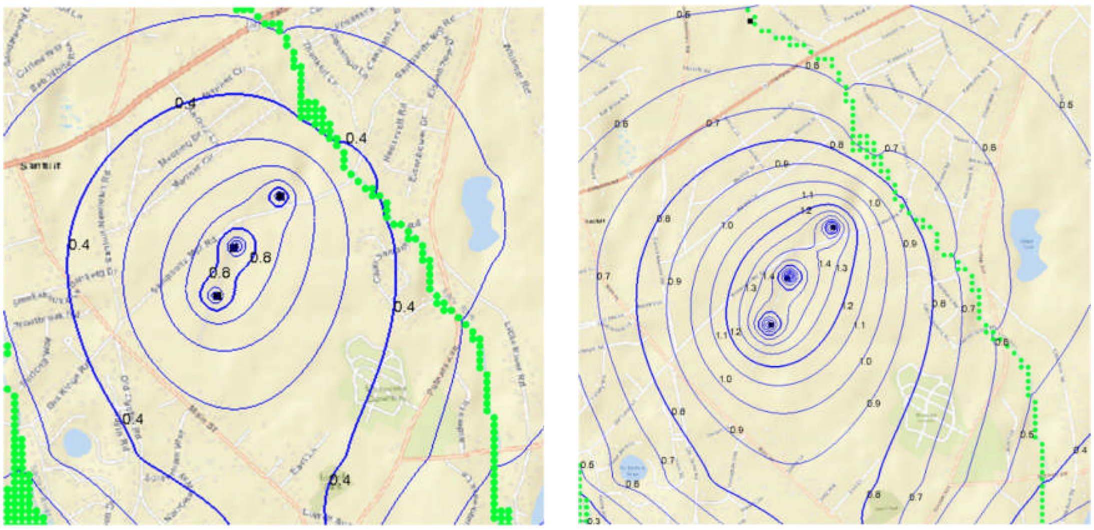


Figure 16 Drain Cell and Cumulative Flow into the Little River

Water Levels

The decrease of simulated flow in Little River is caused by the overall lowering of the water table due to pumping. The drawdown between non-pumping and average and summer pumping conditions indicates a lowering of the water table at Little River at Sampson Mill Road of approximately 0.40 feet and 0.80 feet respectively (Figure 17). The USGS Index well for this area has a total fluctuation of nearly 7 feet (Figure 1). Presently the water levels are on the low end of normal for the period of record at the Index well (Figure 1). The fluctuation of the water table in response to drought and wet years has a substantial effect on the flow of water to wetlands, streams, and ponds on Cape Cod. The additional drawdown by pumping can exacerbate conditions during transitional water levels from wet to dry. A study by the USGS (Walter and Whealen, 2004) on the overall impacts of pumping from Cape Cod public supply wells on the ponds and streams reported, "Changes in pond levels and stream flows arising from seasonal effects of pumping typically are substantially less than the variability caused by changes in natural recharge." The impacts are more significant if wells are near surface waters.



a) b)

Figure 17 Drawdown from Non-Pumping Condition in feet for:

a) Average Pumping and b) Summer Pumping

Zone II

The Water Commissioners expressed interest in revisiting the Zone II delineation for their Wells. A Zone II is defined under a set of extreme conditions consisting of pumping at the full capacity of the wells for a period of 180 days and no recharge. The Cotuit model is not setup for this specific transient simulation. Also, the DEP has a process to submit revisions for Zone IIs starting with a proposal under the regulations to do so. That being said, Zone II results can be approached through the use of the Cotuit Model under steady state conditions to compare to the existing Zone II by inputting the full capacity pumping at each well (Table 1). As indicated earlier Cotuit Water's full pumping capacity is 4.4 Million gallons per day. Summer pumping is 1.17 or 27% of the rated full capacity. The scenarios result in conservative capture areas for protection purposes (Figure 18). In some cases, the trajectory of groundwater flow can change over seasonal variations so the conservative Zone II can accommodate those potential changes. Those full capacity rates are otherwise not achievable in practice nor acceptable in regard to impacts. The simulated Zone IIs are approximately 830 wide and results in a 41 percent reduction of flow in the Little River as seen by the lack of reported drain flow and the significant decrease of flow to drain cells along the lower river (compare Figure 11 to Figure 18). The Cotuit Model simulated Zone IIs are smaller than the present Zone IIs. Additional work to pursue a Zone II delineation is outside this scope.

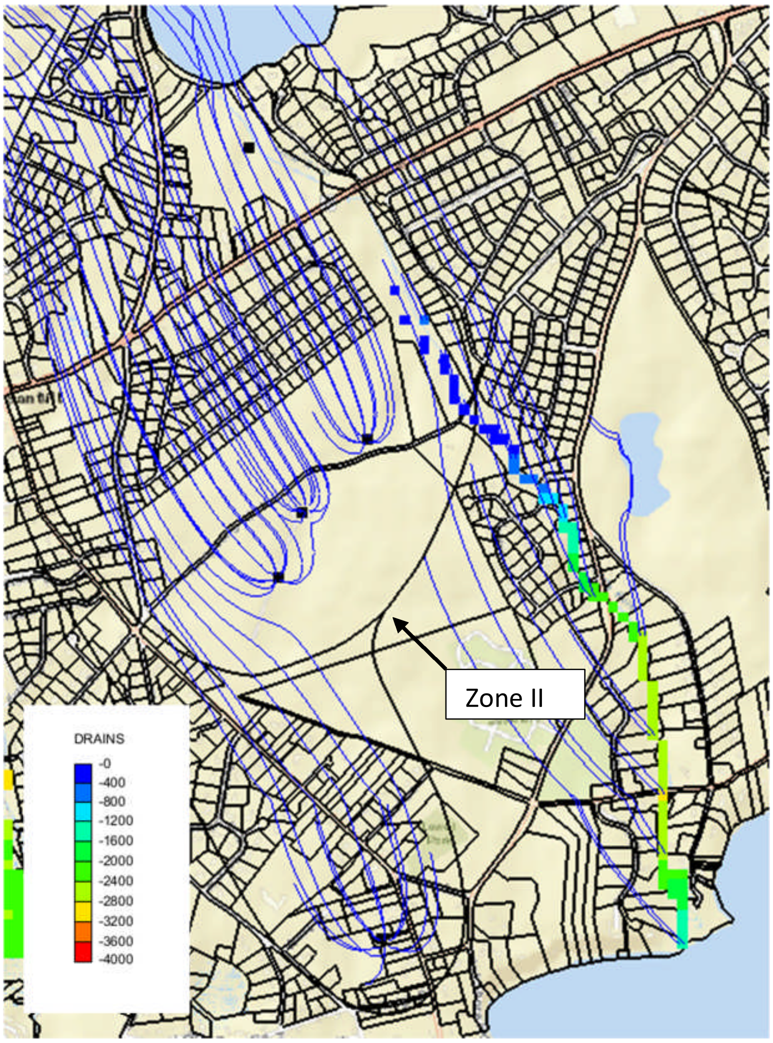


Figure 18 Particle Paths at comparable Zone II Pumping Rate Simulation under Steady State and the Existing Zone II Boundary

Discussion

Simulation of the Cotuit wellfield pumping using off-season, average and summer rates show decrease in relative stream flow in Little River by 3%, 7% and 12% from non-pumping conditions, respectively. The Route 28 to Sampson Mill Road segment incurs a significantly greater percent reduction than the entire river at 11%, 17%, and 32%, respectively. Although the percent flow reductions are greater in the upper portion compared to the entire river, the actual flow reduction is less. The actual flow reduction for the summer to non-pumping rates between the entire and Route 28 to Sampson Mill Road segments are 0.3 CFS and 0.13 CFS (194,000 GPD and 86,000 GPD). The reported flow reduction for the average pumping condition to non-pumping rates is 0.16 and 0.07 CFS (104,400 GPD and 45,000 GPD) for the two segments respectively. These rates of flow are relatively small and difficult to measure.

The simulated flow reductions are relative. Observations over time indicate that flows in the river can vary from significant to low and for some segments none. Depending on the conditions pumping can have a variable degree of impact. When groundwater levels are low and there is no observed flow, the impact of pumping rates is practically negligible since the additional lowering of groundwater would occur well below the stream bed. These are the conditions that exist now. But even during low conditions if the levels are at or just below the stream bed additional lowering can dry out the hyporheic zone which are areas of the streambed and near-stream aquifers through which stream water flows. When groundwater is at an average level and transitioning to drier conditions then the lowering of water levels by pumping can exacerbate low flow conditions. If groundwater levels are significantly high, then the impact of pumping is likely less.

The simulated amount of flow at Sampsons Mill Road from non-pumping to summer pumping conditions ranges from 0.42 to 0.29 CFS. Measurements by the USGS in March 2020 when groundwater levels were on the high side of normal (Figure 1) the flow was 0.525 CFS. In March of this year there was no flow to measure. Corroborating measured river flow to groundwater conditions is recommended prior to considering a pumping management threshold. In the interim, reducing the amount of summer pumping may in accordance with DEP conservation standards provide a margin of safety for the river during dry periods.
https://www.mass.gov/doc/massachusetts-water-conservation-standards-2/download

Conclusions

The presence or absence of surface water in the upstream half of Little River is conditioned upon three factors: surface flow from Lovells Pond; seasonal and year to year fluctuations in the height of the water table; and extreme pumping rates of the CWD Sampsons Mill wellfield during the summer season when irrigation demand is highest. Of the three factors, the water table fluctuations are the most significant, especially during declared drought conditions, though summer pumping rates can exacerbate those surface water levels in Little River. Pumping rates is also the one factor that can be modified by deliberate actions of the CWD.

Recommendations

Establish a groundwater level management threshold for Little River to modify pumping schedules during critical groundwater periods. This would require the collection of actual field information through several incremental steps.

1. Identify several locations for manual and digital water level data collection in the river and nearby monitoring wells and surface waters. Including:

    a. Install drive points for manual water levels.
    b. Install secure observation wells for the use of data loggers.
    c. Locate and evaluate test wells for the deployment of data loggers.

2. Obtain existing elevation Benchmark data along the river and well stations to survey elevations.

3. Conduct quarterly flow measurements at road crossings.

4. Evaluate the pipe connection at Lovells Pond.
    a. Consider the impacts of unclogging the pipe.
    b. Observe pre and post conditions.

5. Conduct and evaluate informal pump test using a single data logger of Station 4 initially and then Stations 2 and 1.

6. Coordinate with USGS Rivers Project to obtain measured stream flows.

7. Revisit the Cotuit Groundwater Model to incorporate field data.

Model Qualifications

The Cotuit Groundwater Model was derived from the USGS 2019 Sea Level Rise Model. In the applying finer discretization, parameters for drains were modified according to size reduction and elevations were distributed accordingly. Stream bed elevation and water level data were not available in the study area. The results presented are relative based on the available parameters in the regional model. Other parameters to consider are seasonal pumping at the COMM Hayden wellfield and flows to the Santuit River.

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Attachments

Available on Request
Field notes with Pictures for February 13 and March 2, 2021
Time Drawdown Graphs