********** Technical Memorandum **********

To: William McCullough, SGOD
From: Brian Howes, Ph.D. and Roland Samimy, M.S.
Date: February 21, 2006
RE: Hammonasset River – Griswold Airport Salt Marsh, Scott Warren Memo 1/30/06

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We have reviewed the memorandum (1/30/06) by Scott Warren to Margaret Welch regarding his thoughts on our measurements presented in the 12/26/05 Technical Memorandum to SGOD. Our overall conclusion is that the key assumptions and conclusions made in the commentary are inaccurate. We have attempted to provide information and calculations to elucidate these areas and also to bring forward data and information to aid in the overall assessment of the Airport site. Since some of the assumptions originally stem from others (e.g. B.L. Companies) and have been previously dealt with by others, they have not been fully dealt with again here. It is important to note that the continuing use of numbers in calculations that have been previously contested, but with no further supporting data or addressing of the issues previously raised, required some amount of repetition of previous commentary.

We will address comments, below, using the headings in the Warren Memo.

Groundwater Discharge onto Tidal Wetlands.

The author states, "*engineering estimates and my observations of the width of the upper border vegetation both suggest that a small fraction of the groundwater at the proposed development site breaks out to move directly onto the marsh surface.*"
And further, "*Current groundwater flux from the site is estimated by BL Companies at 300,000 gal day^{-1}…*"

Both of these statements are pivotal to an evaluation of freshwater and nitrogen effects on the adjacent wetlands and water quality of the Hammonasset River Estuary. The observations referred to are not clearly defined or presented. It appears that the "observations" relate to visual flows and the width of the bordering *Phragmites australis* vegetation. Furthermore, the estimate of groundwater discharge is based upon analysis by BL Companies, which has been analyzed previously by SGOD by Robert Schreiber. There are problems with both points.

(1) One cannot make observations of plant communities and make conclusions as to volumetric freshwater discharge. As noted the freshwater enters the estuarine systems in diffuse seepage and potentially small springs. We made direct measurements in the wetlands adjacent the Griswold Airport site and quantified a freshwater discharge from only 5 sites of >70,000 gal/d (Howes & Samimy Technical Memorandum of 12/26/05). Since the measurements focused on the major pathways for discharge, a water balance approach was used to gauge the total freshwater discharge.

(2) The water balance approach is based upon groundwater recharge rates and the land area, which discharges to the estuary. In previous work by BL Companies, an approximate land area of ~3 million square feet was used. At an annual recharge rate of 22" (BL Companies) or 24" (our estimate) this yields a freshwater discharge from the land to the sea of ~110,000 to ~120,000 gal/d. These calculations strongly support the direct measurements of discharge, previously reported (12/26/06 Tech Memo).
(3) The 300,000 gal/d estimate cited by Warren appears to be based upon a Darcy's Law calculation by BL Companies, which gave a 300,000 to 600,000 gal/d freshwater discharge (cf. Schreiber analysis). This type of calculation is generally difficult to perform accurately, due to the need for accurate, site specific data. The calculation basically relies on estimates of hydraulic gradient and hydraulic conductivity (K). Hydraulic conductivity is difficult to determine accurately even in the best of circumstances. An error in an estimate of K of 3 fold (or even 10 fold) is very common. Given that other measures of freshwater discharge generally agree and that Darcy's Law estimates of discharge under the conditions at the Airport Site are generally not robust, a value of ~100,000 gal/d should be taken as the "best estimate" possible with presently available data.

Warren Memo, "*Assuming ca. 5% of groundwater from the proposed septic system reached the marsh through direct breakout at the marsh upland interface*".

This 5% assumption is not substantiated by any data and directly conflicts with direct measurements within the wetlands at the Airport site. The measured 70,000 gal/d freshwater discharge from only 5 sites is >60% of the 110,000 gal/d calculated from the water balance and this is a highly conservative estimate. It is simply not valid to use the 300,000 gal/d (or their higher 600,000 gal/d) as the freshwater inflow given the method used to derive it and the need to explain where all the "extra" water is coming from.

Warren Memo, *discussion of change in ambient N_{total} concentration in groundwater.*

(1) The concentration in groundwater is not particularly relevant. The impacts on the estuarine habitats are driven primarily by the total loading of nitrogen relative to the removal rates through flushing etc. Therefore it is the total nitrogen load from the proposed development, which is significant to evaluating its effect on the already nitrogen overloaded waters of the Hammonasset River Estuary. The estuary has already been evaluated and judged to be impaired by nutrients loading by CT-DEP. At present the goal is to lower total nitrogen loading to this estuary and the downgradient waters of Long Island Sound. The CT-DEP's assessment is consistent with the loss of eelgrass bed area in the lower estuary and the observations of reduced productivity and changes in bed configuration.
(2) Based upon the permitted discharge of 52,000 gal/d (max) at 10 mg N/L, the septic system at the site will be permitted to contribute 728 kg N yr^{-1} to the estuary. However, this is only a fraction of the nitrogen loading increase from

the Airport site from the proposed development. Additional nitrogen loading will occur from the increased impermeable surface area and fertilizer applications. These must also be included, as they will increase the loading from the site to well over 1000 kg N yr^{-1}. This is a significant amount of additional nitrogen.

(3) It is not clear how the groundwater "mixing" calculations were performed, but in these types of aquifers, contaminants tend to form plumes and do not uniformly mix into the ground water.

A. Freshwater Impacts Sub-section.

"*Both personal observations and the literature argue that the vast bulk of groundwater moves seaward through glacial sands of the aquifer, below peat and marine clays…. In very shallow marshes breakouts may also occur as springs, some distance from the upland; the Hammonasset/Clinton Harbor marshes, however, tend to be relatively deep, and I have not seen any indication of such "mid-marsh" springs on this system.*"

(1) The general statement is only partially correct. The statement as presented needs to be reconciled with several facts. First, direct measurements of groundwater discharge at the Griswold Airport site indicate that freshwater discharge to the tidal creeks and at the upland edge is occurring and accounts for a significant portion of the upland freshwater recharge. The literature as far back as Alfred Redfield in his seminal work on New England salt marshes indicated that groundwater moves up through the bottoms of tidal creeks and he presents both supporting data and provides the mechanism by which this can occur. We and others have further documented his findings in New England marshes in both the scientific literature and in USGS Reports. The literature clearly indicates that groundwater inflow is primarily at the upland edge and through the creek bottoms.

(2) Groundwater moving from uplands to the Hammonasset River estuarine waters under the wetland will discharge directly through groundwater seepage to the estuary, causing further nitrogen enrichment of this impaired system. The pattern of groundwater seepage to estuarine waters has been documented in the literature for shallow New England drowned river valley estuaries.

Overall, the discussion regarding groundwater discharge and freshwater inputs does not contain any data or analysis to address the measured freshwater discharges or the water balance volumes. Reference to the literature is non-specific. The repeated statements of "personal observations" are difficult to interpret, as no specific information or data is provided.

The good overall agreement between the measured freshwater inflow and that estimated from the water balance approach runs counter to the comments in the Warren Memo and supports the contention that freshwater from the Griswold Airport site is discharging to the Hammonasset River Estuary. This is fully consistent with

hydrologic principals and results of hydrologic studies of the land-sea interface in salt marsh and estuarine systems.

Warren Memo, discussion of freshwater impacts related to Phragmites:
"*Impacts from a small increase of groundwater discharging directly on the marsh surface are likely to be relatively minor, with the principal effect of broadening the brackish vegetation belt o the upper border. This would be a concern with such well established Phragmites; development at this site, however, will be tied to a program of Phragmites control.*"

This comment appears to agree with previously stated concerns that additional freshwater input to the wetlands adjacent the Airport site will support expansion of the existing stands of *Phragmites*. The contention is that as long as Phragmites control is put in place that this expansion will be mitigated and therefore not an issue. The problem with using Phragmites control to address a "permanent" environmental change (freshwater inflow) is that the control will have to be continuing. Therefore, the application of herbicides, burning, mowing+herbicides, etc. will have to be linked to a monitoring program and repeated as needed.

Nitrogen Impacts and N Loading to Clinton Harbor Sub-sections.

Warren's Memo indicates that only a fraction of the septic input (10,000 liters/d) be used to calculate the nitrogen load to the upland border. As stated above, the total loading to the estuary is what is critical to gauge impact from the proposed development at the Airport site. This includes the wastewater effluent nitrogen, AND nitrogen from rapid infiltration of stormwater and runoff from impermeable surfaces, and fertilizers. The estuary responds to nitrogen from all sources and a TMDL for this system (which is 303(d) listed as impaired by excess nutrients) will take into account the total loading from the site. It is significant that the system is currently overloaded with nitrogen and that in the future the State will be preparing a TMDL towards reducing the N loading below present levels.

We have not fully quantified the nitrogen loading from the proposed development at the Airport site. However, as the maximum discharge allowed is 52,500 gal/d at 10 mgN/L, the wastewater loading to the estuary would be 728 kgN/yr. Given that the evidence is that the groundwater from this site discharges to the Hammonasset River Estuary, this would be the maximum allowable load from this source. However, other N sources must also be included which depend upon the specific areas of plantings and lawns and their fertilization regimes. In addition, the high impermeable surface area indicates a further increase in N loading from stormwater. Accounting for these sources needs to be performed, but will certainly increase the N loading to the estuary by >1000 kg N/yr.

The Warren Memo suggests that the N loading from the proposed development to the estuary will have an insignificant impact on the currently nitrogen impaired waters. This is done through several arguments.

(1) *The nitrogen does not discharge to the Hammonasset, but offshore to the Sound*. This argument is not supported by (a) the direct measurements of freshwater discharge adjacent the site, (b) the hydrology expected from what is a "peninsula", (c) any stratigraphic data, or (d) hydrologic principals. There is simply no data to support offshore discharge in the Sound, while there is data to support discharge within the estuary.
(2) The Warren Memo indicates that nitrogen flux from the Airport site is presently relatively high, 949 kgN/yr, so the development will not represent a major increase in loading from the site. This is difficult to understand, given the present land-use at the site and the proposed future high density development. However, the information presented clarifies the position. The Warren Memo uses the inflated groundwater flow of 300,000 gal/d rather than the 100,000 gal/d calculated from water balance. This yields a 3 fold higher estimate of loading from the site (949 kgN/yr at 300,000 gal/d compared to 316 kgN/yr at 100,000 gal/d). Using the maximum permitted discharge and very rough addition N loads from the other sources (total 1000 kgN/yr) indicates that the proposed development will increase the nitrogen loading from 316 kgN/yr to >1300 kgN/yr. This is a large increase in N loading from the site. Note that even with the reduced current loading estimate, the load is possibly too high as the method used to derive the estimate is not fully documented.
(3) The Warren Memo states that the Hammonasset River Estuary has a high nitrogen load and the proposed development "*will have no discernable impact on surrounding marshlands, embayment water quality, or any potentially existing eelgrass stands*". This misses that the Nitrogen Load to the system is currently too high and needs to be reduced. The proposed development will be allowed to add about 1 metric ton of nitrogen per year into the estuary. A study of the eelgrass stands in indicates that they are stressed and declining, more nitrogen loading will further the loss as the estuary is beyond its ability to assimilate further nitrogen inputs without degradation.
(4) The Warren Memo attempts to calculate the nitrogen entering the lower estuary from the upland watershed from an estimate of freshwater flow and nitrogen levels measured by CDM at site SW1 for the Town of Clinton. The estimate presented is 576,893 kgN/yr (average) and 38,818 kgN/yr (low flow). The freshwater flow value was sourced to CT-DEP. We conducted a simple water balance approach to the Hammonasset River above the Airport Site and derived an estimate of average freshwater flow of 40.9 million gallons per day, similar to the CT-DEP average of 36.5 million gallons per day. This is excellent agreement and also supports the use of the water balance approach for the Airport site groundwater flow estimates discussed above. The Warren Memo uses the CT-DEP flow data and an estimate of nitrate concentration at SW1 (11.44 mgN/L) to derive a total annual nitrogen load of 576,893 kgN/yr from the upper watershed to the lower estuary. It also notes that the level is even higher

due to the fact that nitrate is only a fraction of the total nitrogen pool. The analysis does not take into account that the nitrogen concentration in the river will vary seasonally or with flow rate. However, most troubling is the extraordinarily large magnitude of the total N load value itself for a watershed like that of the Hammonasset River Estuary.

a. First, the total watershed nitrogen load can be compared to the total nitrogen load on an areal basis. The upper Hammonasset Watershed based upon a CT-DEP website data has an area of 22,900 acres, which using the Warren Memo nitrogen load, yields a nitrogen input to the estuary of 25.2 kgN/acre/yr (i.e. per acre of watershed). This value can be compared to the published Long Island Sound watershed analysis (LIS Study, www.longislandsoundstudy.net/pubs/reports/Tmdl.pdf), which combines the Hammonasset watershed with coastal watersheds to the west through New Haven. This is termed Zone 3 and is the south central coastal watershed (LIS Study Figure 2). This area generally corresponds with Watershed Basin 5 in the study (LIS Study Figure 3), which has a land area of 482 square miles. The total nitrogen load from this watershed zone to the Sound is 2.8 million kg N/yr, inclusive of point and non-point sources and atmospheric inputs. This translates to an areal loading of 9.1 kgN/acre/yr. Since the zone 3 watershed contains much more heavily developed land than typical of the Hammonasset River, it should have a higher N loading per acre. Instead the less heavily developed Hammonasset Watershed is purported to have almost 3 times the areal loading (25.2 kgN/acre/yr versus 9.1 kg/acre/yr).
b. It is possible to check the Warren Memo existing nitrogen loading from the perspective of how many people would have to be on septic-systems in order to generate the stated nitrogen load. Based upon 2.1 kgN/yr per capita reaching groundwater from a septic system, it would take ~275,000 people to produce 576,893 kgN/yr. Clearly, this overestimates the watershed population by ~ 10 fold. Note that although we did check U.S. census figures, the precise population within the watershed was not determined for the present analysis, although the combined populations of Madison, Clinton and Killingworth is only about 40,000.
c. The apparent overestimate of the existing watershed loading to the Hammonasset River Estuary in the Warren Memo is further indicated by data presented in the Memo's Table 2. This table compares surface area nitrogen loading of 4 other estuaries. The Memo indicates that the Hammonasset River Estuary has a nitrogen loading 11-480 times higher per hectare than the 4 other estuaries presented (2404 kgN/ha/yr in Table 1 versus 5-203 kgN/ha/yr for comparative estuaries in Table 2). This is highly unlikely given the watershed land-uses in the Hammonasset River estuary versus some of the other systems.
d. The estimate of the existing watershed loading to the Hammonasset River Estuary is not consistent with its estuarine habitat quality compared to estuaries in Table 2 in the Warren Memo. One of the estuaries presented for comparison to the Hammonasset River estuary in Table 2 is Waquoit

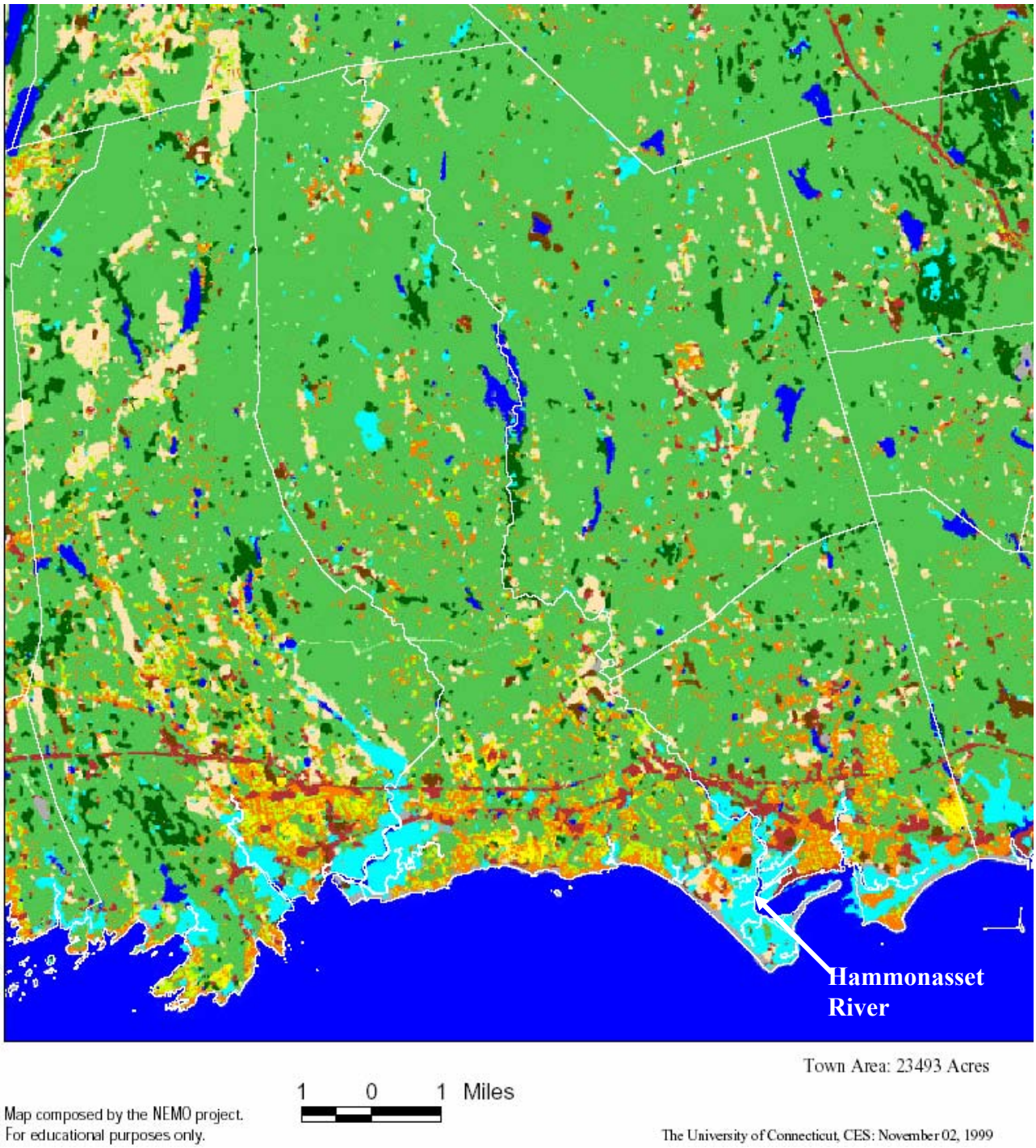
Bay, MA. This estuary has less than 2% of the loading per hectare of water surface than presented in the Warren Memo for the Hammonasset River Estuary. This is surprising given that the Hammonasset may still support some eelgrass and has recorded beds in the 1990's. Waquoit Bay lost almost all of its eelgrass beds in the main basin prior to 1990, again at a very much lower annual nitrogen loading. In addition, the boundary condition water for Waquoit Bay (Vineyard Sound) has high water quality, while Long Island Sound has concerns over nitrogen loading. This ecological information indicates that the existing nitrogen loading value in the Warren Memo is very much overestimated (and therefore the relative importance of a future load from the Airport site is greatly underestimated).

e. As part of the evaluation of the Warren Memo, efforts were made to determine the actual site of the nitrogen data collection (SW1). This investigation confirmed that while the samples were collected in the "river" they were assayed for nitrate by ion chromatography. Further examination of the data set indicated that the water quality data was collected on the outgoing tide and frequently was quite saline. The result is that the nitrate concentration in the freshwater entering the head of the estuary would have to be 2 to 3 times higher than the 11.44 mg $N\text{-}NO_3$/L suggested. Neither the 11.44 mg $N\text{-}NO_3$/L nor a higher value in the incoming freshwater is consistent with other estuarine or river systems of this type. In fact, if the salinity of the water at site SW1 averaged 20 ppt, then the freshwater that fed the site would have a nitrate concentration of ~30 mg $N\text{-}NO_3$/L, approximating the typical concentration of undiluted effluent from an on-site residential septic system! Even without dilution of the water by salt water, the average value at site SW1 would be higher than the drinking water standard for Nitrate. This does not seem possible as the 11.44 mg $N\text{-}NO_3$/L value represents the average nitrate concentration of all freshwater entering from the upper watershed. It should therefore approximate the average groundwater concentration throughout the watershed. This simply is not consistent with groundwater quality in the region and the land-uses (i.e. nitrogen sources) within the upper watershed (see land-use figure below).

Based upon these 5 lines of evidence (a-e) it is clear that the watershed nitrogen loading to the Hammonasset River estuary is several to many fold overestimated in the Warren Memo. The result is that the Airport site has a very much greater impact on the nitrogen loading to the lower estuary then purported. Given that (a) the Hammonasset Watershed is less developed than is average for the south central coast (zone 5 to LIS), (b) the loading to this estuary from the comparative estuary analysis (Table 2 of Warren Memo) seems at least 10 fold too high, and (c) that the Warren Memo does not include nitrogen from development of the Airport site from sources other than wastewater, it must be considered that the proposed development of the Airport site is an important nitrogen source to the already nutrient impaired waters of the estuary. While the exact contribution has not been estimated, a best estimate given present information would be

that between 2% (average flow periods) and >20% (low 7Q10 flow periods) of the nitrogen to the estuary would be from the Airport site post-development. While >20% is almost certainly an overestimate, 2% is also certainly an underestimate during the critical summer period when the estuary is most susceptible to degradation from nitrogen inputs and river flows are generally low. In estuarine nitrogen management sources contributing on the order of 2%-5% are important, especially considering that only 20%-30% of the existing watershed nitrogen loading may need to be removed in order to restore the estuarine habitats.

Overall, the Warren Memo supports the need for concern regarding increased freshwater inflow and expansion of Phragmites sites. In fairness, the memo indicates that Phragmites control is planned to mitigate this problem, but the concern and need for perpetual mitigation remain. The analysis of freshwater discharge in the Memo does not add any new data, but relies on opinion and does not address the several lines of evidence that freshwater from the Airport site discharges to the estuary, not to Long Island Sound. Similarly, the repetition of inflated groundwater values (300,000 gal/d) based upon a relatively inaccurate approach, and failing to take account for multiple differing lines of evidence that the value is more on the order of 100,000 gal/d is not compelling. The Memo also suggests that groundwater flow may be to Long Island Sound rather than to the wetlands and waters directly adjacent the site, but fails to provide a mechanism. In contrast, the literature supports the transport to the adjacent waters, starting with work by A.C. Redfield and the data from the site is consistent with predictions from various studies of New England salt marshes. The nitrogen analysis presented in the Warren Memo appears to grossly overestimate the existing nitrogen loading to the estuary from the overall watershed (probably by ~10 fold) and underestimate the load from the Airport site (post-development). The net effect is that the proportional nitrogen contribution from the Airport site is many fold higher than stated in the Memo, most likely it will represent on the order of 2%-10% of the load depending on river flow rates and season. However, as the estuary is already nutrient impaired, this is an important new source of nitrogen.



Land-uses within the Hammonasset River Watershed. Light lines show town boundaries. Note the very light development within the watershed. Colors follow the code presented on the following page. Map from University of Connecticut Web site.

Explanation

White outline is the Town boundary

Land Cover Categories

- Comm./Indust./Pavement
- Resid./Comm., Rural Resid.
- Turf & Tree Complex
- Turf & Lawn
- Grass/Pasture & Hay
- Exposed soil/Cropland
- Open/Shrub
- Deciduous Forest
- Coniferous Forest
- Water
- Wetland
- Exposed Ground & Sand

The University of Connecticut Laboratory for Earth Resource Information Systems compiled 28 land cover categories from 1995 Landsat TM satellite imagery. The process involves using computer programs to separate the reflective characteristics of the surface into unique cover and land use types. The map resolution is controlled by the satellite image at 30 meters per pixel.

For printing NEMO condensed the categories to the 12 shown in the key.

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