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# APPENDIX F

## SONIR COMPUTER MODEL-RELATED DOCUMENTS

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## APPENDIX F-1 SONIR MODEL USER'S GUIDE

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## SONIR MODEL USER'S GUIDE

### **Simulation of Nitrogen in Recharge (SONIR) Nelson, Pope & Voorhis, LLC Microcomputer Model**

July 23, 2021

#### **INTRODUCTION**

SONIR is a microcomputer model developed by Charles J. Voorhis, CEP, AICP and copyrighted with the Library of Congress for exclusive use by Nelson, Pope & Voorhis, LLC (NP&V) in order to simulate the hydrologic water budget of a site and determine total nitrogen and nitrogen present in recharge in connection with land use projects. The model was developed on the Microsoft Excel Spreadsheet (trademark of Microsoft Products) for IBM (trademark of International Business Machines, Inc.) or compatible Personal Computers capable of running Excel. SONIR is updated periodically by NP&V to account for updated references and data in keeping with industry standards and environmental changes. NP&V is a professional environmental planning consulting firm with expertise in water resource management and impact assessment, nitrogen budget modeling, watershed management plans, and groundwater, soil and air sampling and environmental monitoring. Firm qualifications are provided in **Attachment A** of the overall report.

Nitrogen has been identified as a source of contamination primarily from sanitary discharge and lawn fertilization. Nitrogen is of concern as a drinking water contaminant, and there is an established health limit of 10 milligrams per liter (mg/l) in drinking water. Nitrogen is also of concern in surface water, as it is a nutrient that when present in high concentrations can cause algal blooms (including harmful algal blooms, HABs), resulting in biological oxygen demand as algae is biologically decomposed as well as unsafe and potentially toxic conditions in the case of cyanobacteria. Depleted oxygen in surface waters causes conditions unfavorable to fish species and can result in extremely undesirable aesthetic impacts, primarily related to odors. Accordingly, it is necessary to understand the concentration of nitrogen in recharge as well as nitrogen load, as related to a proposed site development, examination of mitigation measures and comparison of alternatives.

Utilizing a mass-balance concept, and applying known hydrologic facts and basic assumptions, it is possible to predict the concentration of nitrogen in recharge to the shallow aquifer underlying a given site. This prediction can in turn be used to determine impacts and significance of impacts in consideration of hydrogeologic factors. Similar techniques have been used to simulate nitrogen in recharge as published by the New York State Water Resources Institute, Center for Environmental Research at Cornell University, Ithaca, New York (**Hughes and Pacenka, 1985**). SONIR is intended to provide a more versatile model based upon the BURBS Mass-Balance concept. SONIR allows for use of the model to predict nitrogen impact from many sources including sewage treatment plants, and further allows for determination of

a wider variety site coverage and recharge components under the hydrologic water budget section. SONIR has more versatility in the input of information, and also provides a printout of each step performed by the model, in order for regulatory agencies and review entities to understand how values are derived.

This text describes in detail the definition of terms, supported by referenced information regarding input of data for the simulation. The concept of determining the concentration of nitrogen in recharge involves a predication of the weight (mass) of nitrogen introduced to the site, as compared to the quantity of recharge resulting from precipitation and wastewater water discharge. Losses due to evapotranspiration and runoff must be accounted for in the simulation. The values and relationship associated with these parameters determines the quantity of recharge which enters the site. The prediction is generally annualized due to the availability of average annual hydrologic data; however, data input can be determined on a seasonal basis if information is available.

The model includes four (4) data sheets identified as follows:

- Data Input Field - Sheet 1
- Site Recharge Computations - Sheet 2
- Site Nitrogen Budget - Sheet 3
- Nitrogen in Recharge Output Field - Sheet 4

All information required by the model is input in Sheet 1- Data Input Field. Sheets 2 and 3 utilize data from Sheet 1 to compute the Site Recharge and the Site Nitrogen Budget. Sheet 4 utilizes the total values from Sheets 2 and 3 to perform the final Nitrogen in Recharge computations. Sheet 4 also includes tabulations of all conversion factors utilized in the model.

It should be noted that the simulation is only as accurate as the data which is input into the model. An understanding of hydrologic principles is necessary to determine and justify much of the data inputs used for water budget parameters. Further principles of environmental science and engineering are applied in determining nitrogen sources, application and discharge rates, degradation and losses, and final recharge. Users must apply caution in arriving at assumptions in order to ensure justifiable results.

Over the past several years, information has become available from the Long Island Nitrogen Action Plan (LINAP), which is useful updating nitrogen budget model assumptions. LINAP included a metadata analysis of all available information to establish recommended nitrogen application rates, leaching rates, population data, pet waste assumptions and updated methods to determine atmospheric deposition. LINAP assumptions were received from the Suffolk County Department of Health Services and the New York State Department of Environmental Conservation as of January, 2017, and are used where appropriate for many updated nitrogen budget analyses in SONIR. A copy of the LINAP assumptions is included as **Attachment A** to this SONIR Model User's Guide.

## SITE RECHARGE COMPUTATIONS

### Overview

SONIR utilizes the basic hydrologic equation for determining the quantity of recharge anticipated by subtracting recharge losses from total precipitation. The quantity of recharge resulting from a given site is determined using the hydrologic budget equation (**Koszalka, 1984; p. 19**):

$$R = P - (E + Q)$$

where:

R = recharge

P = precipitation

E = evapotranspiration

Q = overland runoff

The quantity of recharge must be determined for each type of land use existing on a site, in order to determine the resultant site recharge. Surfaces commonly considered include: impervious surfaces; turfed areas; and natural areas; however, SONIR allows for a variety of land cover types to be considered in the model. In addition, site recharge occurs as a result of irrigation and wastewater discharge. In cases where water is imported to a site via a public water system, this quantity of recharge must be considered as additional water recharged on site. SONIR allows for all of these recharge components to be included in the simulation. Many sites have fresh surface water in the form of lakes and ponds. Precipitation falls upon these surfaces; however, such features generally act as a mechanism for water loss as a result of evaporation. SONIR includes a Water Area Loss component in determining the site Hydrologic Water Budget and in computing recharge nitrogen.

### Data Input - Sheet 1

The following provides a discussion of data sources and assumptions associated with the hydrologic water budget, corresponding to the Data Input Field in Sheet 1 of SONIR:

1. *Area of Site* - The total area of the site (in acres) that is capable of recharging precipitation is entered in this data cell. For sites that include tidal wetlands, the area that is inundated by tidal waters should be excluded, as recharge from these areas should not be considered in the context of nitrogen simulation. For sites that include fresh surface water, the area can be included, provided evaporative water loss from surface water is considered by entering the acreage of surface water in Data Cell 15 noted below.

2. *Precipitation Rate* - Precipitation in the form of rainfall and snowmelt is determined using long-term recorded values from local weather stations. Cornell University maintains the Northeast Regional Climate Center, from which long-term precipitation data for Long Island weather stations is available. Monthly precipitation averages are published for the period 1951-1980 in Thornthwaite and Mather's Climatic Water Budget Method (**Snowden and Pacenka, 1985**). More updated precipitation data from the NOAA National Climatic Data Center for the period 1981 to 2010 was obtained from <http://www.currentresults.com/Weather/New-York/average-yearly-precipitation.php>. The nearest precipitation monitoring stations included Bridgehampton and Brookhaven, NY. Bridgehampton is listed as 50.1 inches per year and Brookhaven is listed as 49.9 inches/year. Data entry is in inches. The more conservative lower value for Brookhaven, NY was used in this simulation.
  
3. *Acreage of Fertilized (SONIR allows multiple categories of fertilizer dependent vegetation to be entered)* - The total area fertilized (in acres) is entered in this Data Cell. This area includes all lawn/turf area that is irrigated and fertilized. If there is no lawn area, a value of zero (0) is entered.
  
4. *Fraction of Land in Fertilized* - No entry need be made in this Data Cell. SONIR will compute the Fraction of Land in Fertilized by dividing the lawn area by total area.
  
5. *Evapotranspiration from Fertilized* - Evapotranspiration is the natural water loss attributed to evaporation and plant utilization. Rainwater that is evaporated and transpired by plants is returned to the atmosphere as vapor. There are various methods for determining evapotranspiration, including direct measure and calculation. A commonly recognized method is the Thornthwaite and Mather Climatic Water Budget Method. Evapotranspiration rates for various locations on Long Island have been determined by the U.S. Geological Survey, as documented in: "Ground-Water-Recharge Rates in Nassau and Suffolk Counties, New York" (**Peterson, 1987; p. 10**). The following general rates as a percent of total precipitation are excerpted from that reference:

<u>Location</u>	<u>Soil Type</u>	<u>Vegetation</u>	<u>ET (in)</u>	<u>ET (%)</u>
Bridgehampton	sandy loam	shallow root	21.2	46.6
	silt loam	shallow root	21.4	47.2
LaGuardia	sand	shallow root	24.2	52.9
	clay loam	shallow root	25.4	55.5
	sandy loam	moderate root	26.2	57.2
JFK Airport	sand	shallow root	22.5	53.8
	clay loam	shallow root	23.9	57.3
	sandy loam	moderate root	25.0	60.0
Mineola	sand	shallow root	22.4	47.8
	sand-silt	shallow root	23.8	51.0
	sandy loam	moderate root	25.1	53.7
	sandy loam	orchards	25.5	54.5

Patchogue	fine sand	mature forest	25.5	53.5
Riverhead	sandy loam	shallow root	22.4	49.3
		orchards	24.8	54.7
Setauket	sandy loam	mature forest	26.8	57.9
Upton	silt loam	deep root	23.9	48.4
	sandy loam	moderate root	23.0	46.5

The most applicable rate for this project is 23.0 inches per year, based on the soils and land cover associated with Upton, NY.

6. *Runoff from Fertilized* - Runoff is the quantity of water that travels overland during a precipitation event. Soil infiltration capacity is the critical factor in determining runoff; however, factors such as slope and vegetation also determine runoff characteristics to a lesser extent on Long Island because of soil conditions. Less urbanized areas of Long Island with characteristically dry soils with groundcover will have a low runoff percentage as a function of total precipitation, as compared to the more urbanized portions of western Long Island. Peterson (1984; p. 14) estimates runoff as a percent of total precipitation for Nassau County (2.1 %); Suffolk County (0.7 %), and Long Island in general (1.0 %). If an average precipitation rate of 45-50 inches per year is assumed, runoff will vary from 0.31 to 0.94 inches. Fertilized areas would be expected to be in the higher end of the range. Judgements of higher and lower runoff can be made on a site-specific basis depending upon slope and groundcover types.
7. *Acreage of Unvegetated* - The total acreage of unvegetated area is entered in this Data Cell. This area includes sand, barren soils, and porous drives and trails. If there is no unvegetated area, a value of zero (0) is used.
8. *Fraction of Land Unvegetated* - No entry need be made in this Data Cell. SONIR will compute the Fraction of Land Unvegetated by dividing the unvegetated area by total area.
9. *Evapotranspiration from Unvegetated* - Evapotranspiration from Unvegetated areas is determined to be 30% of the evapotranspiration for vegetated surfaces due to lack of groundcover vegetation.
10. *Runoff from Unvegetated* - The runoff coefficients noted in the discussion for Data Cell 6 above, are applied to unvegetated areas on a site-specific basis. Runoff in the middle to the higher end of the range (2.1% of precipitation) is expected due to lack of groundcover vegetation.
11. *Acreage of Water (this category could include irrigation ponds and/or other surface water features)* - SONIR considers evaporation from surface water in the computation of site recharge. Surface water, particularly groundwater fed lakes and ponds are a source

- of water loss in the water budget. The quantity of fresh surface water (in acres) is entered in this Data Cell.
12. *Fraction of Land in Water* - No entry need be made in this Data Cell. SONIR will compute the Fraction of Water on the site by dividing the water area by total area.
  13. *Evaporation from Water* - Surface water features will cause evaporation of water in excess of normal evapotranspiration as documented by **Warren et al, 1968**, Hydrology of Brookhaven National Laboratory and Vicinity Suffolk County, New York. It is estimated that the upper limit of evaporation from a large free-water surface is approximately 30.00 inches per year (**Warren et al, 1968; p. 26**). This value is entered in Data Cell 17 as the most accurate approximation.
  14. *Makeup Water* - SONIR allows for consideration of the impact of man-made lakes on site recharge. Lakes are generally lined with an impermeable material. Evaporation occurs from the surface of the lake at a rate of 30.00 inches per year. In order to maintain a constant water level, an on-site well is generally installed to provide make-up water to the lake or pond. The quantity of make-up water is equivalent to the quantity of evaporation, given the fact that the function of the well is to replace water that is evaporated. Therefore, for cases where make-up water is used to maintain a constant water level, a value of 30.00 inches per year is entered in Data Cell 18.
  15. *Acreage of Natural* - The total quantity of natural area (in acres) is entered in this Data Cell. This area includes naturally vegetated areas such as woodland, meadow, etc. If there is no natural area, a value of zero (0) is entered.
  16. *Fraction of Land Natural* - No entry need be made in this Data Cell. SONIR will compute the Fraction of Land Natural by dividing the natural area by total area.
  17. *Evapotranspiration from Natural* - Evapotranspiration from Natural areas is determined in the same manner as described for Data Cell 5 above.
  18. *Runoff from Natural* - The runoff coefficients noted in the discussion for Data Cell 6 above, are applied to natural areas on a site specific basis. Generally lower values in the range of 0.7 % of precipitation are expected due to groundcover and canopy vegetation.
  19. *Acreage of Impervious* - The total area of impervious surface (in acres) is entered in this Data Cell. This area includes paved driveways, parking areas, roofs, roads, etc. If there are no impervious surfaces, a value of zero (0) is entered.
  20. *Fraction of Land Impervious* - No entry need be made in this Data Cell. SONIR will compute the Fraction of Land in Impervious by dividing the impervious area by total area.

21. *Evaporation from Impervious* - Impervious surfaces will allow water to evaporate, particularly during summer months. There is no vegetation; therefore there is no transpiration by plants. Evaporation from Impervious is estimated to be approximately 10 % of total precipitation (**Hughes and Porter, 1983; p. 10**). This value accounts for evaporation from parking lots and other surfaces during summer months, averaged over the entire year. This indicates that recharge/runoff would comprise the remaining 90% of precipitation. This assumption coincides with most drainage computations required by Code Subdivision Regulations for determined leaching pool capacity.
22. *Runoff from Impervious* - The approximation of Evaporation from Impervious would indicate that recharge/runoff would comprise the remaining 90% of precipitation, as there are no other losses from impervious surfaces. In consideration of paved areas, runoff is not transported off the site or to surface water as a loss. Runoff is diverted to leaching pools and allowed to re-enter the hydrologic system beneath a given site. Therefore, in terms of site recharge computations, the value for Runoff from Impervious is zero (0).
23. *Acreage of Other Area (SONIR provides this portion of the model to customize additional cover types)* - This is a general category which can be used to include additional groundcover types in the simulation. Acreage of Other Area is entered (in acres). This Data Cell can be used to include site recharge considerations from a portion of the site that has different hydrologic properties, such as rain gardens, a moist hardwood forest or vegetated freshwater wetland, where evapotranspiration would be high and runoff would be extremely low or is a placeholder to customize data input/analysis.
24. *Fraction of Land in Other Area* - No entry need be made in this Data Cell. SONIR will compute the Fraction of Land in Other Area by dividing the land in other area by total area.
25. *Evapotranspiration from Other Area* - Evapotranspiration from Other areas is determined in the same manner as described for Data Cell 5 above. Value can be varied depending upon the hydrologic properties of the groundcover type. For rain gardens, this value would be high and similar to wetlands and surface water at 30 inches/year.
26. *Runoff from Other Area* - The runoff coefficients noted in the discussion for Data Cell 6 above, are applied to Other Areas on a site-specific basis. Value can be varied depending upon the hydrologic properties of the groundcover type. For rain gardens, no runoff would be expected.
27. *Acreage of Land Irrigated* – Use of water for irrigation purposes is an additional site recharge component not considered in any of the Data Cells above. The quantity of land irrigated on a given site is entered in this Data Cell (in acres).

28. *Fraction of Land Irrigated* - No entry need be made in this Data Cell. SONIR will compute the Fraction of Land Irrigated by dividing the Land Irrigated area by total area.
29. *Irrigation Rate* - The rate of irrigation must be entered in this Data Cell (in inches). Hughes and Porter (**1983; p. 19**) indicated that lawn irrigation is estimated to be about 5.5 inches per year; however, many sources recommend that irrigation be used to supplement natural rainfall to ensure that at least 1 inch of water is applied per week (<http://www.gardening.cornell.edu/homegardening/scene7866.html>). Assuming a growing season after spring when rainfall is more abundant and summer is hotter with typically less rainfall than spring, a 16-24 week period from May through October is used, with an irrigation rate of 1 inch per week. This value (16-24 inches) is entered in Data Cell 29 as the most accurate approximation for subdivision use. Golf courses receive more irrigation.
30. *Number of Dwellings* - The number of dwellings is entered in this Data Cell in order to allow for computation of wastewater disposal from residential use. Wastewater imported to a site, or even withdrawn from on-site wells and recharged through sanitary effluent is an additional recharge component that must be considered. If the project is for a commercial use or utilizes a denitrification system, the number of dwellings should not be entered in the Data Entry Field, as the wastewater flow will include recharge and nitrogen components.
31. *Water Use per Dwelling* - The water use should correspond to the total site non-irrigation water use, divided by the number of units. An average of 300 gpd is used for this analysis.
32. *Wastewater Design Flow (units)* - No entry need be made in this Data Cell if the analysis is for single family homes. SONIR will compute the Wastewater Design Flow by multiplying the Number of Dwellings by the Water Use per Dwelling. If multifamily homes, the wastewater design flow should be used.
33. *Wastewater Design Flow* - SONIR permits the consideration of recharge and nitrogen input based on wastewater design flow if this is more appropriate than a determination based on number of units. This could include residential wastewater flow (e.g., combined units and clubhouse), commercial projects, denitrification systems and sewage treatment plants. SCDHS design flow factors are typically used to determine wastewater design flow. Once computed, the anticipated wastewater flow is entered in this Data Cell.

## Site Recharge Computations - Sheet 2

Once data entry is complete for Site Recharge Parameters, SONIR will complete a series of detailed Water Budget computations for the overall site. The following describes the computations that are performed by the model:

- A. *Fertilizer Area Recharge* - Fertilizer Area Recharge is determined by use of the basic Hydrologic Budget Equation [ $R = P - (E + Q)$ ] as defined previously. The quantity of recharge determined by this method is then multiplied by that portion of the site occupied by Lawn Area to determine the component of Lawn Area Recharge in overall site recharge.
- B. *Unvegetated Area Recharge* - Unvegetated Area Recharge is determined by use of the basic Hydrologic Budget Equation. The quantity of recharge determined by this method is then multiplied by that portion of the site occupied by Unvegetated Area to determine the component of Unvegetated Area Recharge in overall site recharge.
- C. *Water Area Loss* - The Hydrologic Budget Equation is modified to consider Water Area Loss. This is particularly useful in water quantity stressed areas of Long Island. If runoff (Q) is considered be zero (0), then lake storage/recharge without make-up water would be Precipitation minus Evaporation ( $P - E$ ). The resultant quantity of lake storage/recharge is then reduced by the amount of make-up water (M). The final quantity of loss is then multiplied by that portion of the site occupied by water to determine the component of water loss as related to the overall site water budget.
- D. *Natural Area Recharge* - Natural Area Recharge is determined by use of the basic Hydrologic Budget Equation. The quantity of recharge determined by this method is then multiplied by that portion of the site occupied by Natural Area to determine the component of Natural Area Recharge in overall site recharge. This area can also include land that is revegetated to natural conditions.
- E. *Impervious Area Recharge* - Impervious area recharge is also determined using the Hydrologic Budget Equation; however, the value for runoff is zero (0) due to the fact that runoff is controlled by conveyance to on site leaching facilities or is allowed to runoff into depressions where runoff is recharged on site.
- F. *Other Area Recharge* - Other Area Recharge is determined by use of the basic Hydrologic Budget Equation. The quantity of recharge determined by this method is then multiplied by that portion of the site occupied by Other Area to determine the component of Other Area Recharge in overall site recharge.
- G. *Irrigation Recharge* - Irrigation recharge is an additional recharge component artificially added on sites where irrigation occurs. This quantity is determined in the same manner

as the Hydrologic Water Budget except that the irrigation rate (in inches) is substituted for precipitation. The resultant recharge is multiplied by the area of the site that is irrigated, in order to determine the Irrigation Recharge in overall site recharge.

- H. *Wastewater Recharge* - Wastewater is also a recharge component artificially added to a site. SONIR annualizes the wastewater design flow and assumes it is applied over the entire by multiplying Wastewater Design Flow by the Area of the Site, resulting in a per foot measure of wastewater over the site. This is converted to inches to be included in overall site recharge.

Once the eight (8) series of Site Recharge Computations are complete, SONIR totals each individual component to determine Total Site Recharge. The sum of these recharge contributions is that quantity of water that is expected to enter the site on an annual basis due to precipitation, after the development is completed. This value is important in determining the concentration of nitrogen in recharge and is important as a means of determining hydrologic impacts of a project in terms of changes to site recharge.

## **SITE NITROGEN BUDGET**

### **Overview**

The total nitrogen released on a given site must be determined in order to provide a means of simulating nitrogen in recharge. Nitrogen sources include: sanitary nitrogen; fertilizer nitrogen; pet waste nitrogen; precipitation nitrogen; and water supply nitrogen (wastewater and irrigation). The total of these quantities represents total site nitrogen.

### **Data Input - Sheet 1**

The following provides a discussion of data sources and assumptions associated with the nitrogen budget, corresponding to the Data Input Field in Sheet 1 of SONIR:

1. *Persons per Dwelling* – For residential projects the number of persons per dwelling is a demographic multiplier used in the determination of human population of a site. The US Census Bureau publishes data for household population. The average population per household for a senior development is 1.5 persons per dwelling. For single family homes, the household population is based on US Census data for the East Hampton Census Designated Place (CDP), which is 2.41 persons per household.<sup>1</sup>
2. *Nitrogen per Person per Year* – For untreated wastewater, annual nitrogen per person is a function of nitrogen bearing waste in wastewater. For residential land use the population of the development is determined and the nitrogen generated is assumed to

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<sup>1</sup> <https://www.census.gov/quickfacts/easthamptoncdpnewyork>

be 10 pounds per capita per year (**Hughes and Porter, 1983; p. 8**). This value is also consistent with LINAP assumptions.

3. *Sanitary Nitrogen Leaching Rate* - For normal residential systems, Porter and Hughes report that 50% of the nitrogen entering the system is converted to gaseous nitrogen and the remainder leaches into the soil (**Porter and Hughes, 1983; p. 14**). LINAP provides values for leaching from a conventional sanitary system, finding that there is 6% loss/attenuation from the septic tank and 10 percent attenuation from leaching rings/plume, indicating an 84% leaching rate. This rate is used for conventional sanitary system leaching.
4. *Area of Land Fertilized 1* - The area of land fertilized is input in Data Cell 4. This value may correspond to the Acreage of Lawn and/or the Acreage of Land Irrigated, but is not necessarily the same value. This entry should be determined on a site-specific basis.
5. *Fertilizer Application Rate 1* - Fertilizer nitrogen is determined by a fertilizer application rate over a specified area of the site. The fertilizer application rates vary depending upon the type of use. The following table indicates the rate of fertilization as a function of use as excerpted from the Non-Point Source Management Handbook (**Koppelman, 1984; Chapter 5, p.6**):

Residential (contract)	1.5 lbs/1000 sq ft
Residential (unmanaged)	2.3 lbs/1000 sq ft
Commercial	3.5 lbs/1000 sq ft
Golf Course	3.5 lbs/1000 sq ft
Sod Farms	4.0 lbs/1000 sq ft
Recreational Lands	0.2 lbs/1000 sq ft

If a use has a Fertilizer Management Plan then the plan should be consulted for application rates. In addition, a commercial landscaping firm has been interviewed to determine trends in commercial fertilizer application. Various fertilizer formulations are used including 10-6-4, 16-4-8 and 20-10-5 (nitrogen-phosphate-potash) depending upon season. Heavier nitrogen application rates are generally used in the spring. Fertilizer used is 50% organic nitrogen. This is applied in a dry form approximately 2-3 times per year, and a 50-pound bag is applied over approximately 16,000 square feet. Based on this rate if 20-10-5 nitrogen were applied in the spring, and 16-4-8 were applied during summer and fall, this would result in an application rate of 1.5-2.1 pounds per 1000 square feet. The high of this range is a conservative value based on three applications of relatively high nitrogen fertilizer. Judgment must be used to determine the application rates per above and further review of references as appropriate or for specific instances. LINAP fertilization rates are found in **Attachment B**; however, there is no rate for commercial application.

For golf course use, specific information may be consulted regarding empirical data of fertilizer applied for existing golf courses, and/or planned application rates for a given golf course.

For agricultural use, Porter & Hughes (1983) provides information on N-fertilizer application rates that were researched for the study "Land Use and Groundwater Quality in the Pine Barrens of Southampton." Various farm uses were assessed and it was found that nurseries fertilized at a rate of 168.3 lbs/acre of nitrogen (or 3.86 lbs/1000 SF), potato farms applied 175 lbs/acre of nitrogen (4.02 lbs/1000 SF) and vegetable crops applied 140 lbs/acre of nitrogen (3.21 lbs/1000 SF). Other advancements in farming practice are expected to have occurred, such that application rates are less than what was found in 1983.

6. *Fertilizer Nitrogen Leaching Rate 1* - Nitrogen applied as fertilizer is subject to plant uptake (20 to 80%; 50% on average) and storage in thatch and soils (36 to 47%), thereby reducing the total amount of nitrogen leached. The percentage of plant uptake and storage are based on studies cited in the LIRPB's Special Groundwater Protection Area Plan. Those studies estimated a conservative nitrogen leaching rate of 14-15%. LINAP leaching rates are found in **Attachment B**. LINAP estimates leaching rates from residential lawn turf to be 30% and golf course leaching rates to be less, at 20%. Further work by the Cornell University School of Integrative Plant Science, Horticulture Section was consulted as well as references from A. Martin Petrovic, Ph.D. at Cornell University (1990, Petrovic, A.M.). Further review of references from this source finds a useful comparison of turfgrass fertilizer leaching rates from various land cover types including golf courses and lawns. When considering four (4) field studies of golf course fertilizer nitrogen leaching, the leaching rates ranged from 0.02% to 13.2% and averaged 3%. When considering field studies for lawn nitrogen leaching rates, the average was 9.61% (2008, Petrovic, A.M.). The purpose of the document was to advise the Massachusetts Estuary Program on appropriate turfgrass leaching rates for the Pleasant Bay Region on Cape Cod.<sup>2</sup> Though lawn and golf course leaching rates were not substantially different, the results did identify residential lawns as having a higher leaching average leaching rate based on field studies. Local conditions should be considered in terms of the level of detail needed for nitrogen budget analysis; however, a range of 5-10% for golf courses (noted to be greater than the average of 3% from field studies) is supported for golf courses, particularly when subject to a Golf Course Management plan to properly prepare soils and turf for maximum nutrient uptake.
7. *Area of Land Fertilized 2* - More than one fertilizer nitrogen input is provided in order allow consideration of mixed use and/or golf course projects where land is fertilized at different rates.

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<sup>2</sup> Hydrogeologic conditions on Cape Cod are similar to Long Island due to glacial origin, bays and estuaries.

8. *Fertilizer Application Rate 2* - Fertilizer Application Rates for this entry can be determined based upon Data Cell 5 above.
9. *Fertilizer Nitrogen Leaching Rate 2* - Fertilizer Nitrogen Leaching Rates can be determined based upon Data Cell 6 above.
10. *Outdoor Cat Population* – This section of SONIR considers LINAP information for pet waste nitrogen. Pet waste nitrogen results from the excretion of domestic pets in the outside environment. There is relatively little definitive information concerning this nitrogen source; however, several references were located and are analyzed herein. The 208 Study provides a table of nitrogen concentration in manure for various animals, not including dogs or cats. Total nitrogen values in the range of 0.30-0.43 lbs/day/1000 lbs live weight are reported for cattle, sheep and horses (**Koppelman, 1978; Animal Waste report p. 3**). It is assumed that dogs constitute the major source of animal waste that would be present in the yards of residential developments. Cat waste would be significantly less due to the lesser live weight of cats and the fact that many cat owners dispose of cat waste in solid waste by using an indoor litter box. If an average of 0.35 lbs of nitrogen is assumed for dogs, and an average of 25 pounds live weight is assumed per dog, then the total annual nitrogen per pet would be 3.19 lbs/year. The only other reference identified for this User Manual that approximates nitrogen in pet waste is Land Use and Ground-Water Quality in the Pine Barrens of Southampton (**Hughes and Porter, 1983; p. 10**). This reference assumed an application rate of 6.5 lbs/acre of nitrogen. Pet waste was assumed to be deposited evenly over all turf. This assumption was not correlated to population density or pet density, but only to turfed acreage. In comparison of the two values, the per pet value corresponds to approximately 2 turfed acres. For the purpose of this model, the value of 3.19 lbs/pet/year is considered to be the most justifiable value for pet waste and is entered in this Data Cell.

Pet waste is also subject to a leaching rate factor. Pet waste is generally found to be a minor contributor of nitrogen in an overall nitrogen budget. A conservative leaching rate of 50% of the nitrogen applied to the ground to be removed through N reduction processes.

LINAP examined pet waste and has revised some of the assumptions that came from prior reports based on a metadata search of available literature through January 2017. LINAP estimates indoor and outdoor cat populations at 1.16 cats/household and 0.74 cats/household, respectively, and an outdoor dog population of 1.4 dogs/household. LINAP further estimates the pounds of nitrogen per year at 3.22 lbs/year for cats and 4.29 lbs/year for dogs, and further estimates a volatilization rate of 75% or a leaching factor 25%. These updated assumption values are used in this document, subject to consideration of the type of land use anticipated. Single family residential use would be expected to have a higher population of cats, and greater potential for outdoor

occupancy. Multiple family use would be expected to have a lower population of cats and a lower likelihood of outdoor pet occupancy, with more indoor cats and therefore greater use of litter boxes and alternative disposal of cat waste (i.e., landfill disposal as compared to land surface defecation). For multiple family and senior citizen MF use, a lower cat population would be expected (on the order of one-quarter), and some uses may prohibit cats. Adjustments can be made as needed to reflect practical rates and expected conditions.

11. *Cat Waste Nitrogen Load* - This is quantified as 3.22 lbs/year of nitrogen per cat for outdoor cats per LINAP. This would apply to single family residential use. For multiple family use, indoor cats are assumed.
12. *Outdoor Dog Population* – This is quantified as 1.4 dogs/household per LINAP. This would apply to single family residential use. For multiple family use, a lower dog population would be expected, and some uses may prohibit dogs. Adjustments can be made as needed to reflect practical rates and expected conditions.
13. *Dog Waste Nitrogen Load* – This has been updated to 4.29 lbs/year of nitrogen per dog per LINAP. This would apply to single family residential use. For multiple family use, less dogs as well as effective “pick up after your pet” programs are assumed, resulting in one-quarter the expected Dog Waste Nitrogen Load for multifamily and senior MF housing.
14. *Pet Waste Nitrogen Leaching Rate* – This has been included as 25% based on LINAP assumptions, which seem reasonable due to waste deposited on the ground and subject additional “weathering” and volatilization in the surface environment prior to recharge.
15. *Adjusted Pet Waste (if applicable)(days/year occupied)* – This entry allows for an adjustment for seasonal communities where year round occupancy is not expected. An estimated occupancy rate is inserted in this cell.
16. *Area of Land Irrigated* - No entry need be made in this Data Cell. This value is the same as Data Cell 27 of the Site Recharge Parameters and SONIR will transfer the data entry to this Cell.
17. *Irrigation Rate* - No entry need be made in this Data Cell. This value is the same as Data Cell 29 of the Site Recharge Parameters and SONIR will transfer the data entry to this Cell.
18. *Irrigation Nitrogen Leaching Rate* - Hughes and Porter (**1983; p. 10**) states “plant uptake and gaseous losses are assumed to remove at least 85% of the nitrogen entering in precipitation.” Irrigation nitrogen would be expected to be subject to the same losses

as applied to fertilizer leaching; therefore, a leaching rate in the range of 10-15% can be assumed and entered in this Data Cell.

19. *Atmospheric Nitrogen Application/Load* – This section reflects LINAP information. Nitrate-nitrogen concentrations in precipitation have been reported to be on the order of 1-2 mg/l in Nassau and Suffolk Counties (**SCDHS, 1987; p. 6-4**), with some evidence of decrease since preparation of the SCCWRMP. While turfgrass leaching has been extensively documented and found to reduce leaching as a result of plant uptake and thatch/root zone processes, natural areas in sandy soils may result in less uptake. A factor of 15% had been applied to precipitation nitrogen as based on Hughes and Porter) (**1983; p. 10**).”

LINAP has conducted more updated research regarding Atmospheric Deposition. An Atmospheric Deposition Application/Load is assumed to be 0.041 lbs/1000 SF of land area. This is then subject to various leaching rates depending on the type of groundcover.

20. *Atmospheric N Leaching Rate (Natural/Wetlands)* – The estimated leaching rate value for natural area/wetlands is 25% per LINAP.
21. *Atmospheric N Leaching Rate (Turf 30%/Golf 20%)* – The estimated leaching rate value for turfed areas is 30% and for golf course turfed areas is 20% per LINAP.
22. *Atmospheric N Leaching Rate (Agriculture; Impervious; Other)* - Agricultural land leaching is estimated to be 40% as are other surfaces not specifically identified as natural, wetlands, turf or golf turf.
23. *Nitrogen in Water Supply* – An entry cell for nitrogen in water supply is provided if this is needed for analysis.
24. *Nitrogen in Commercial/STP Flow 1* - This data entry allows SONIR to compute the quantity of nitrogen resulting from commercial discharge, denitrification systems and/or sewage treatment plants. Total nitrogen in community wastewater is identified as having a total nitrogen concentration of 20 mg/l in weak effluent; 40 mg/l in medium strength effluent, and 85 mg/l in strong effluent (**Metcalf & Eddy, Inc, 1991**). . For comparison purposes, it is recommended that a value of 50 mg/l be used for total nitrogen concentration in sanitary systems.<sup>3</sup> Properly functioning denitrification systems and sewage treatment plants are capable of reducing total nitrogen to less than 10 mg/l in accordance with discharge limitations. A value of 10 mg/l can be entered in this data cell for such systems or other applicable value dependent on specific

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<sup>3</sup> SCDHS General Guidance Memo #28 includes guidelines for siting proposed or expanded STPs; this memo indicates: “A total nitrogen concentration of 50 mg/l may be used when calculating the equivalent mass loadings.”

treatment efficiencies. A value of 8 mg/l is commonly used to demonstrate improved treatment efficiencies. Alternative wastewater systems for single family homes are being considered in Suffolk County; such systems are achieving treatment to reduce nitrogen to the range of 19 mg/l. The SONIR model computes the number of pounds of nitrogen in sanitary discharge as a function of concentration. The absolute nitrogen is utilized in the model; however, it must be recognized that from the discharge point, nitrogen is nitrified through conversion of ammonia to nitrate in the leaching area beneath the discharge point. Further, natural transformation in the form of denitrification occurs as a result of bacteria. This causes release of nitrogen gas and may account for further reduction of 50% or more subsequent to discharge (**Canter and Knox, 1979; pp. 77-78; Hughes and Porter, 1983; p. 14**). As a result SONIR is conservative in predicting the concentration of nitrogen in recharge, and when natural denitrification of sanitary effluent is considered, actual concentration would be less.

25. *Nitrogen in Commercial/STP Flow 2* – An additional entry cell is provided for an alternative concentration should this be needed for analysis.

## Site Nitrogen Budget - Sheet 2

Once data entry is complete for Nitrogen Budget Parameters, SONIR will complete a series of detailed computations to determine the individual component of nitrogen from each source and the total nitrogen for the overall site and use. The following describes the computations that are performed by the model:

- A. *Sanitary Nitrogen - Residential* - SONIR establishes the site population using the number of units on the site, and the demographic multiplier. The nitrogen load factor is then applied and reduced by the leaching rate, resulting in the total residential nitrogen component. If the project is for a commercial use or residential sanitary wastewater flow is used to determine nitrogen from residential, then the resultant value should be zero (0).
- B. (B) *Cat Waste Nitrogen* – The pet waste nitrogen was determined on a per pet basis; however, the number of pets for a given residential project must be determined. In order to correlate the number of pets to human population, a ratio was determined using information contained in the 208 Study, wherein it was estimated that there is 1 dog per 5 residents in suburban areas and 1 dog per 7 residents in urban areas (**Koppelman, 1978; Animal Waste Report, pp. 6**). This results in an average number of dogs based upon of 17% of the human population. Accordingly, this multiplier is used based upon the population of a land use project in order to estimate the nitrogen waste from pets. The pet waste nitrogen is subject to reduction as a function of the leaching rate, leading to the total pet waste nitrogen in pounds.”

More recent analysis s provided based on LINAP assumptions which determine both Cat Waste and Dog Waste Nitrogen by using an updated pet population (number of pets per dwelling), an updated pet waste nitrogen load and an updated leaching rate. Cat Waste Nitrogen uses the numbers inserted in the Nitrogen Budget Parameter sheet in SONIR as described above.

(B') *Dog Waste Nitrogen* - Dog Waste Nitrogen is also determined by using an updated pet population (number of pets per dwelling), an updated pet waste nitrogen load and an updated leaching rate. Dog Waste Nitrogen uses the numbers inserted in the Nitrogen Budget Parameter sheet in SONIR as described above.

- C. *Sanitary Nitrogen (Commercial/STP)* - SONIR utilizes the Commercial/STP Flow that is converted to liters and multiplied by the nitrogen concentration in waste. This provides a weight of nitrogen in milligrams, which is converted to pounds for the total nitrogen from this component.
- D. *Water Supply Nitrogen (other than wastewater, if applicable)* - SONIR utilizes the residential wastewater design flow to compute the weight of nitrogen contributed from the water supply. The method of calculation is the same as Sanitary Nitrogen (Commercial/STP). For commercial projects, this value is accounted for in the Commercial/STP Flow and as a result, the value is zero (0).
- E. *Fertilizer Nitrogen 1 (Fertilized Landscaping)* - This calculation utilizes data entry from the Area of Land Fertilized 1, in the Data Input Field, to determine the weight of fertilizer nitrogen applied to the area. The area is multiplied by the application rate and reduced by the leaching rate documented previously to arrive at total weight.
- F. *Fertilizer Nitrogen 2 (Optional Fertilization Rate)* - If fertilization rates vary, the Area of Land Fertilized 2, is utilized to determine nitrogen from this source.
- G. *Atmospheric Nitrogen* – Analysis is provided based on LINAP assumptions which determine Atmospheric Deposition using the Nitrogen Budget Parameters outlined above. The deposition rate of 0.041 lbs/1000 SF is multiplied by the square footage of each cover type, and then subject to an individual leaching rate based on the cover type. Section G computes the resultant Atmospheric Deposition.

- H. *Irrigation Nitrogen* - Although a very small component, the Irrigation Nitrogen is determined using the Irrigation Recharge  $R(irr)$  computed in the Site Recharge Computations, over the irrigated area of the site to produce a volume of irrigation recharge. The Irrigation Recharge value is used in order to account for reduction of recharge due to evapotranspiration, since this component is only intended to determine nitrogen leaching into soil as a result of irrigation nitrogen in the water supply. This value is converted to liters and multiplied by the concentration of nitrogen in irrigation water supply. The Irrigation Nitrogen Leaching Rate (expected to be the same as for precipitation) is applied to the weight to determine the total nitrogen from this source.

Once the eight (8) series of Site Nitrogen Budget computations are complete, SONIR totals each individual component to determine the Total Site Nitrogen. This value is used in determining the weight per volume ratio of nitrogen in recharge as computed in Sheet 4 of the SONIR model.

#### **FINAL COMPUTATIONS AND SUMMARY**

SONIR utilizes data generated in Sheets 2 and 3 of the model to compute a mass/volume ratio for nitrogen in recharge. Nitrogen in recharge is converted from pounds to milligrams in order to provide units compatible for mass/volume concentration. Likewise, the quantity of site recharge is applied over the site in order to determine an overall volume number for site recharge. This is then converted to liters. The final computation divides the total weight of nitrogen in milligrams, by the total volume of recharge in liters, to arrive at the Nitrogen in Recharge ratio in milligrams per liter (mg/l). This concentration represents the Final Concentration of Nitrogen in Recharge, which is highlighted on Sheet 4.

Sheet 4 also provides a site recharge summary in order to compare recharge between natural conditions, a proposed project and/or alternatives. Total Site Recharge is presented in both inches, and as a volume in cubic feet/year, gallons/year and million gallons/year (MGY). The final sheet also summarizes the Conversions Used in SONIR. Conversions are standard conversion multipliers as found in standard engineering references.

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SONIR is a valuable tool allowing for versatile determination of site recharge as determined from many components of site recharge. SONIR determines the weight of nitrogen applied to a site from a variety of sources as well. SONIR is a fully referenced model utilizing basic hydrologic and engineering principals, in a simulation of nitrogen in recharge. Input data should be carefully justified in order to achieve best results. SONIR can be used effectively in comparing land use alternatives and relative impact upon groundwater due to nitrogen. By running the model for Existing Conditions, Proposed Project conditions and/or alternative land

uses, comparison of impacts can be made and mitigation can be evaluated for consideration in land use decision-making. Questions, comments or suggestions concerning this model should be addressed to: Nelson, Pope & Voorhis, LLC, 572 Walt Whitman Road, Melville, New York 11747.

## **SIMULATION OF NITROGEN IN RECHARGE (SONIR)**

### **NELSON, POPE & VOORHIS, LLC MICROCOMPUTER MODEL**

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