REPORT ON

NITROGEN LOADING ANALYSIS FOR GROUNDWATER SUPPLIES

FOR

THE SUDBURY WATER DISTRICT SUDBURY, MASSACHUSETTS

REVISED - MAY 1994

H_2O ENGINEERING CONSULTING ASSOCIATES, INC.

H_2O Engineering Consulting Associates, Inc.

6 Page Place, Woburn, MA 01801
Telephone (617) 933-6961 Fax (617) 935-1877

May 11, 1994

Board of Water Commissioners
Sudbury Water District
199 Raymond Road
Sudbury, MA 01776

RE: Nitrate Loading Analysis

Dear Commissioners:

As requested, the report on Nitrogen Loading Analysis for Groundwater Supplies for the Sudbury Water District, submitted in January 1994, has been revised. Enclosed in this revision is two additional Nitrogen Loading Analysis Models adjusted to the future development buildout condition of the District.

The first additional model accounts for the condition of

1. Five (5) persons and 10,000 square feet of lawn per house in the future development buildout of the District and

2. The existing houses have only three (3) persons per house

The second additional Model was performed for the condition of:

1. The same as the first model: Five (5) persons and 10,000 square feet of lawn per house in the future development buildout of the District and

2. The existing houses also have five (5) persons per house.

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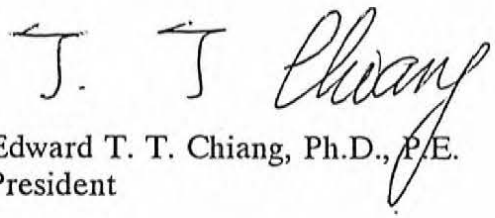
The results of these models are tabulated and Pie graphed in Appendix C and Appendix D of this report for your study.

Should you have any questions, please call our office.

Very truly yours



Edward T. T. Chiang, Ph.D., P.E.
President

enclosures

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H_2O Engineering Consulting Associates, Inc.

水利工程顧問

6 Page Place Woburn, MA 01801
Telephone (617) 933-6961, 933-9369 Fax (617) 935-1877

January 7, 1994

Board of Commissioners
Sudbury Water District
199 Raymond Road
Sudbury, MA 01776

RE: Nitrogen Loading Analysis for Groundwater Supplies of the Sudbury Water District

Gentlemen:

In accordance with our agreement, H_2O Engineering Consulting Associates, Inc., is pleased to submit our report on the results of the Nitrogen Loading Analysis for the Groundwater Supplies of the Sudbury Water District.

Purpose of Nitrate Loading Analysis:

Due to the revisions to Massachusetts DEP Drinking Water and Wellhead Protection Regulations, a Nitrate Loading Analysis for the Zone II area of all Sudbury Water District's existing wells and possible future wells must be conducted. The only alternative to that is to default to the State's maximum zoning allowance of 440 gallons per 40,000 square feet land area per day. The study predicts the concentration of nitrogen loading on groundwater at the buildout condition according to existing zoning, land use regulations and bylaws. If the concentration of Nitrogen Loading on groundwater exceed the limits set by the Massachusetts DEP, the zoning, land use regulation, the bylaws may have to be revised.

Scope of Nitrate Loading:

A. Data Collection - Information used to perform the analysis include the following:

o Sudbury zoning bylaws and Zoning maps

- o Assessors maps and Records for the Zone II areas surrounding all public supply wells
- o Available aerial photos for the Zone II areas
- o Available wetland maps and Zone II maps
- o Pumping records and Water quality data
- o Large water use data within Zone II areas, especially commercial and industrial users
- o Hydrologic maps and Topographical maps.

B. Buildout Analysis: A mass-balance accounting model shall be used and calibrated for current and future development within Zone II areas under existing Sudbury Board of Health regulations, zoning bylaws and maps.

C. Nitrogen Loading Analysis: Nitrogen Loading Analysis of Zone II areas for the Raymond Road Aquifer, Hop Brook Aquifer and Well 5 are conducted. Inputs to the model will include nitrogen from septic systems, lawn fertilizers, pavement and roof runoff, and natural precipitation. Using these calibrated models, the concentrations of nitrogen in the production wells under buildout conditions will be determined. The concentrations of nitrogen are defined as the total load of nitrate divided by the total volume of water. The total load of nitrate includes load of nitrate from recharge and load of nitrate from source.

D. Report and Meeting: After the completion of the Nitrate Loading Analysis, a report will be prepared to present the findings.

Summary:

Protection of groundwater quality for public water supply has become a priority environmental issue, especially for sources from unconfined aquifers such as Sudbury Water District's wells. The degradation of groundwater quality due to subsurface wastewater disposal systems, lawn fertilizers, and agricultural activities have become a serious problem. Nitrate concentrations in groundwater have been considered a good monitor of the level of groundwater degradation. Therefore, modeling existing nitrate concentration in groundwater and predicting the nitrate concentration due to the land use activities is necessary for possible change of land use in the future to control the level of groundwater quality degradation.

To complete the tasks, H_2O Engineering Consulting Associates, Inc., has teamed with Dr. Michael H. Frimpter of Horsley & Witten, Inc., an expert in the field of modeling nitrate concentration in groundwater.

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Nitrogen Loading Analyses were conducted for four Zone II wellhead protection areas for the Sudbury Water District for existing and buildout development conditions. The four Zone II areas include the following:

- Raymond Road Aquifer - Wells 2, 4, 6, 7 and 9
- Hop Brook Aquifer - Wells 3, 8 and 10
- Well 5 Zone II area (Zoned as Research District)
- Future Well 11 Zone II area

With the exception of Future Well 11, all other Zone II areas were determined based on field test data and computer analysis, and all have been approved by DEP.

Based on the calibrated mass-balance accounting model developed by Dr. Michael H. Frimpter, all four Zone II area nitrate concentrations at buildout condition will be below the maximum contaminant level(MCL) of 10 mg/l set by the U.S. Environmental Protection Agency and the Massachusetts DEP. However, the State DEP recommended planning goal limits for nitrate concentration is 5 mg/l. The following table indicates the analyses results:

SUMMARY OF MODELED NITRATE CONCENTRATION

ZONE II AREA OF WELL	NITRATE CONCENTRATION (Mg/l)		
	CONDITION		PERCENTAGE INCREASE
	CURRENT DEVELOPMENT	BUILDOUT DEVELOPMENT	
WELL No.5	2.25	7.98	254.7%
WELL No. 11	1.16	2.46	112.1%
HOP BROOK AQUIFER WELL 3, 8, AND 10	3.91	4.20	7.4%
RAYMOND ROAD AQUIFER WELLS 2, 4, 6, 7, AND 9.	3.35	3.85	14.9%

The largest increase of nitrate concentration would be at Well 5 Zone II due to the fact that current land use and the possible future land use based upon current zoning bylaw is significantly different. A major portion of the Well 5 Zone II area is undeveloped at present (sand pits, grass and wooded). The buildout prediction is based on this area as zoned Research District with allowable maximum 1000 gallons per day per acre wastewater disposal rate. The result indicated that the nitrate concentration in Well 5 will reach to about 8.0 mg/l, exceeding the State recommended planning goal limit of 5.0 mg/l by a significant margin.

The estimated Well 11 Zone II area currently has little development. This area, developed or not developed, would not heavily degrade the groundwater quality due to the major portion of this area is wetlands and owned by the State Fish and Game and National Wild Life Refuge.

Appendix A includes maps of the four Zone II areas.

Appendix B contains the analysis report prepared by Dr. Michael H. Frimpter of Horsley & Witten, Inc.

Recommendations:

Although the analysis indicated that the buildout Nitrogen Loading in all four Zone II areas will not exceed the MCL set by the U.S. EPA and the State DEP, it is very important that these sources be protected. The following is recommended:

A. The District working with the Sudbury Board of Health and Planning Board should review any subdivision and development of land within Zone II areas so to make sure that all:

   - o future sub-surface wastewater disposal systems be designed and installed properly.
   - o Repairing or modification of existing wastewater disposal systems are upgraded to the latest standards.

B. Land owners within the Zone II areas should be educated to minimize the use of lawn fertilizers.

C. For industrial zoned areas, the type of industry and commerce which will generate hazardous wastes should not be allowed to locate within Zone II area.

D. Given the potential impact to Well 5 by the Research District full buildout, Sudbury Water District should work with Sudbury Planning Board to reconsider the

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1000 gallons per day per acre limit of the wastewater generation allowances in the Research District.

H_2O Engineering Consulting Associates, Inc., wishes to express our appreciation for the cooperation, data research, and assistance received from the District staff, especially Mr. Carroll and Mr. Leupold, of the Sudbury Board of Health.

H_2O Engineering suggests that two copies of the report be submitted to DEP (Northeast Region, Woburn and DEP Main Office, Boston) for their review and comment.

Should have any questions, please contact us.

Very truly yours,

Dr. Edward T.T. Chiang, P.E.
President

Enclosures

APPENDIX A

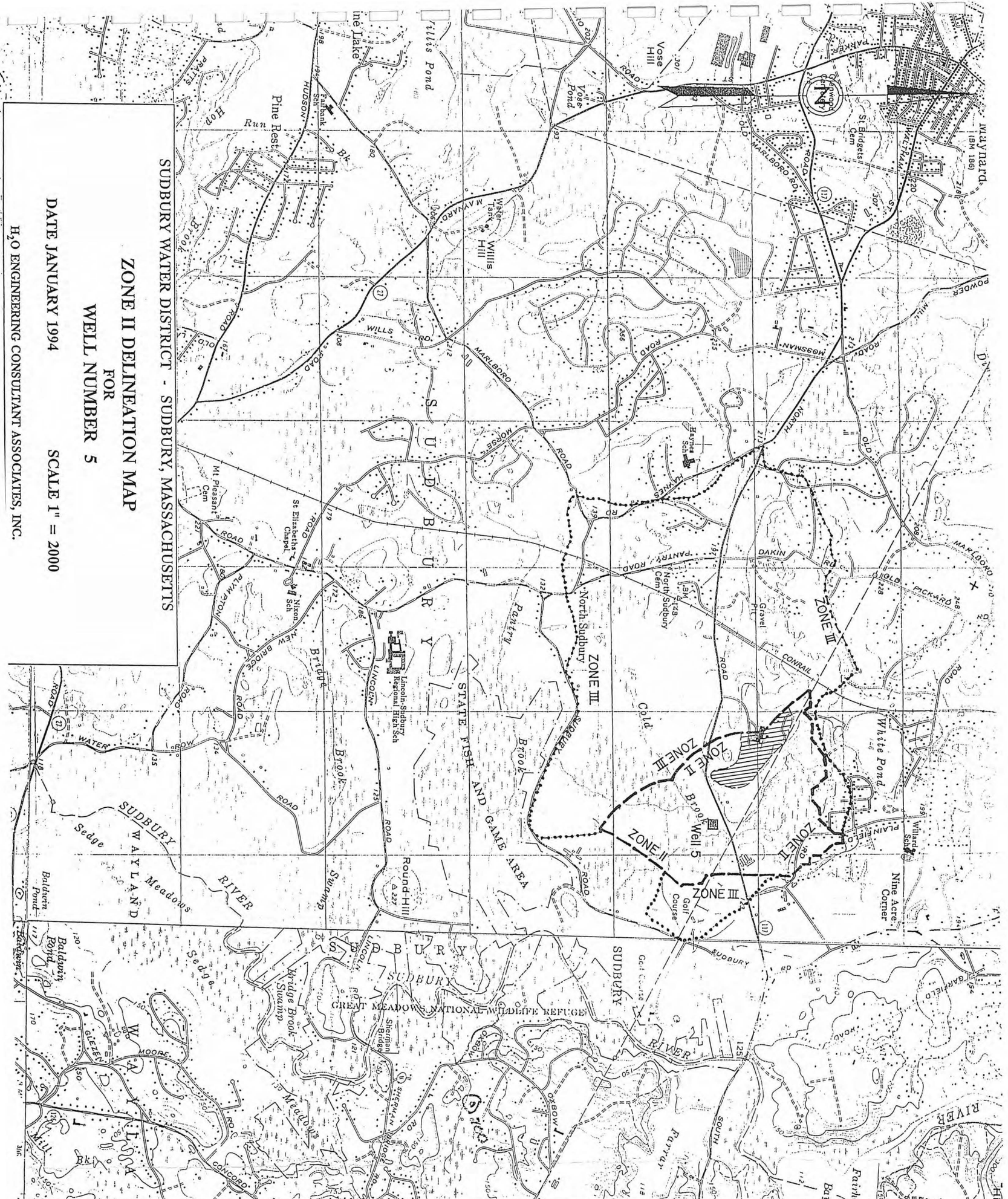
ZONE II DELINEATION MAP

ZONE II DELINEATION MAP
FOR
WELL NUMBER 5

SUDBURY WATER DISTRICT - SUDBURY, MASSACHUSETTS

DATE JANUARY 1994 SCALE 1" = 2000

H_2O ENGINEERING CONSULTANT ASSOCIATES, INC.



- MUNICIPALITY – SUDBURY, MA
- PWS IDENTIFICATION #
- NAME OF WATER SUPPLY – SUDBURY WATER DISTRICT
- WATER PURVEYOR – SUDBURY WATER DISTRICT
- SOURCE IDENTIFICATION
- PROJECT PROPONENT – SUDBURY WATER DISTRICT
- TITLE OF STUDY/PURPOSE OF DELINEATION – APPROVAL OF NEW SOURCE
- U.S.G.S. QUADRANGLE NAME(S) – MAYNARD
- CONSULTANT/DATE OF STUDY SUBMITAL – H2O ENGINEERING CONSULTING ASSOC. INC. AUGUST 1993
- LATITUDE/LONGITUDE OF SOURCE 42°25' 05"/72°23' 05"

EXPLANATION OF MAP SYMBOLS

5 EXISTING WELL

NORTH ARROW

MAP SCALE: 1= 24,000

	SIGNATURE	DATE
WATER PURVEYOR		SEPT 2, 1993
PROJECT PROPONENT		
REGIONAL WATER SUPPLY CHIEF		
CONSULTANT	I. T Chaney	Sept 20, 1993

LEGEND

- EXISTING PUMPING STATION
- PROPOSED PUMPING STATION
- ZONE II BOUNDARY
- ZONE III BOUNDARY

ZONE II

ZONE III

U S MILITARY RESERVATION
NATICK LABORATORIES

Willis Pond

Pine Lake

Pine Rest

Boons Pond

White Pond

Millpond

Carding Millpond

Puffer Pond

Lose Pond

Cranberry Bogs

Cranberry Bog

Lose Hill

Glenwood Cemetery

Green Meadow Sch

High Sch

Fairbank Sch

Curtis Jr High Sch

Horse Pond Rd Sch

Redstone Sch

Wayside Inn

Tippling Rock

Blanford Pond

Hager Pond

Mt Ward Tanks

Marlborough Sewage Disposal

Weeks Cem

Sudbury

Wells

SUDBURY WATER DISTRICT - SUDBURY, MASSACHUSETTS

ZONE II DELINEATION MAP

FOR WELL NUMBER 3, WELL NUMBER 8, WELL NUMBER 10

DATE JANUARY 1994

SCALE 1:25000

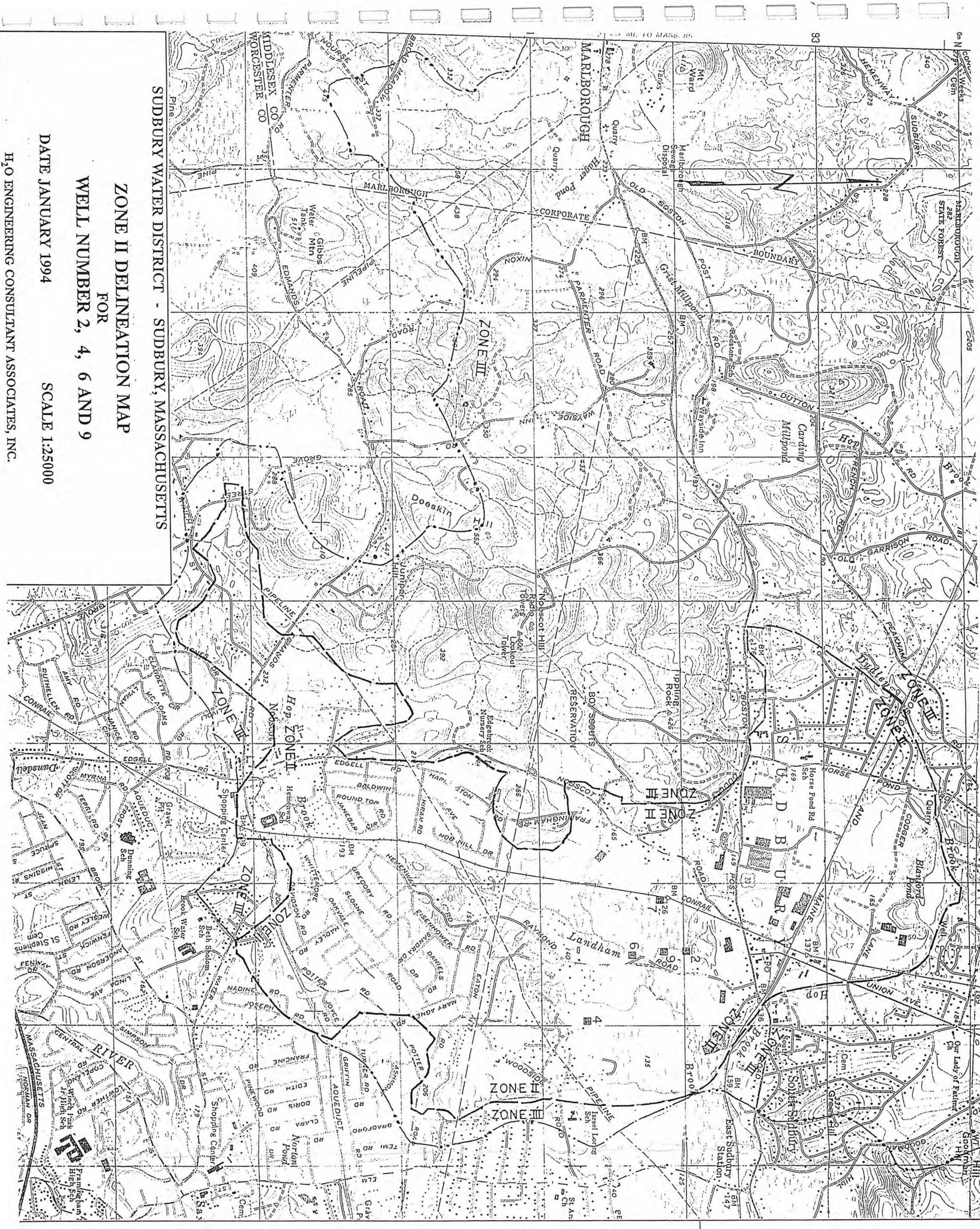
H_2O ENGINEERING CONSULTANT ASSOCIATES, INC.

ZONE II DELINEATION MAP
FOR
WELL NUMBER 2, 4, 6 AND 9

SUDBURY WATER DISTRICT - SUDBURY, MASSACHUSETTS

DATE JANUARY 1994 SCALE 1:25000

H2O ENGINEERING CONSULTANT ASSOCIATES, INC.



- MUNICIPALITY – SUDBURY, MA
- PWS IDENTIFICATION #
- NAME OF WATER SUPPLY – SUDBURY WATER DISTRICT
- WATER PURVEYOR – SUDBURY WATER DISTRICT
- SOURCE IDENTIFICATION #
- PROJECT PROPONENT – SUDBURY WATER DISTRICT
- TITLE OF STUDY / PURPOSE OF DELINEATION – APPROVAL NEW SOURCE
- U.S.G.S. QUADRANGLE NAME(S) – FRAMINGHAM
- CONSULTANT/DATE OF STUDY SUBMITAL – H2O ENGINEERING CONSULTING ASSOC. INC. 1/1992
- LATITUDE / LONGITUDE OF SOURCE – 42 21.27'/ 71 25.23'

SIGNATURES	DATE
WATER PURVEYOR	
CONSULTANT	
PROJECT PROPONENT	
REGIONAL WATER SUPPLY CHIEF	

EXPLANATION OF MAP SYMBOLS

9 EXISTING WELL

NORTH ARROW

MAP SCALE : 1:25000

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PRELIMINARY ZONE II FOR WELL #11
(WITH WELL #5 IS PUMPING)

APPENDIX B

HORSLEY & WITTEN, INC. REPORT

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NITROGEN LOADING ANALYSES FOR GROUND-WATER SUPPLIES SUDBURY WATER DISTRICT SUDBURY, MASSACHUSETTS

EXECUTIVE SUMMARY

Nitrogen loading analyses were conducted for four Zone II wellhead protection areas for the Sudbury Water District for existing and buildout development conditions. The buildout analysis represents a worst case, in all of the land in the Zone IIs is developed to the maximum extent permitted by land use zoning regulations. The Zone IIs for all of the wells except well 11 have been approved or are pending approval by the Massachusetts Department of Environmental Protection, Division of Water Supply. A conceptual Zone II developed by H_2O Engineering was used for well 11. Town of Sudbury Assessors data, maps obtained from the Town Engineer's Office, septic system design data from the Town Board of Health and water use data from the Water District were used to prepare model input data to estimate nitrate, as N, concentrations for the four well fields.

The calculated nitrate concentrations for current conditions at all of the well fields were well below the 10 mg/l (milligram per liter) MCL (Maximum Contaminant Level) used by the US Environmental Protection Agency and the Massachusetts Department of Environmental Protection, and below a recommended planning goal of 5 mg/l. Modeled nitrate concentrations for buildout conditions for all four well fields were well below the MCL, but nitrate in well 5 slightly exceeded the 5 mg/l recommended planning goal.

These estimates were compared to actual measured nitrate concentrations in the well fields and the models were calibrated for attenuation of nitrate within the renovation zone between the bottoms of leaching facilities and the water table. The modeled and calibrated nitrate concentration estimates are summarized in Table 1. The final calibrated model estimates represent the most reasonably expected predictions.

TABLE 1. SUMMARY OF MODELED NITRATE CONCENTRATIONS

WELLFIELD	NITRATE, in mg/l CURRENT	BUILDOUT	CALIBRATED
Well 5	2.25	5.23	3.67
Well 11	1.16	2.46	1.73
Wells 3,8 &10	3.91	4.20	3.27
Wells 2,4,6,7 &9	3.35	3.85	2.76

The greatest nitrate loads were from septic systems, but Hop Brook which transports the Marlborough East Sewage Treatment Plant effluent, with elevated nitrogen concentrations, to the Sudbury River was a significant source for wells 3, 8 and 10 in the East Street area. A series of pie diagrams are presented to show the relative importance of the various sources of nitrate.

At the request of the Sudbury Water District, an additional development scenario was performed by Horsley and Witten, Inc. to evaluate the impact of changing the potential future land use in the Zone II of well 5. In this "what if" scenario it was assumed that a 103.9 acre property was rezoned from research use to use with a permissible 1,000 gallons per day per acre wastewater disposal rate. This conversion, at buildout, yielded an average nitrate concentration in well 5 of 7.98 mg/L, exceeding the recommended planning goal limit of 5.0 mg/l by a significant margin. Additional development questions can be tested by applying the models which are now calibrated to the Sudbury Water District's Zone IIs.

Except for the land use change scenario in the Zone II for well 5, the modeled levels of nitrate do not appear to be a threat to the District's water quality. Modeled concentrations are averages, and from time to time the actual concentrations should be expected to vary both above and below the modeled concentrations. In those Zone IIs containing multiple wells, concentrations would also be expected to vary from well to well, in addition to from time to time. These kinds of variation or imprecision are inherent in the estimating method and are justification for recommending a planning goal of 5 mg/l, one half the MCL.

INTRODUCTION

Ni ed for four wellhead protection areas
fo Sudbury, Massachusetts. The
M ironmental Protection) requires that
th water to a public supply well (Zone II)
be which produce 100,000 gallons per day
or napped, it is possible to control land
us ground water quality. As a step in
th r quality within the delineated zones,
ni f the impact of future development
or ell water. These results can then be
us the water supply, through zoning
an ge restrictions and other measures.

N ninant that poses a health hazard.
A te, as N, in drinking water supplies
ha ams per liter) by the U.S.

Bruce Morgan / Mark Nelson
Horsley + Witten

NLA Build-out for Well #5
Zone II seems to have
included Zone III

1/13/95

Environmental Protection Agency and the Massachusetts Department of Environmental Protection. Nitrogen originates from a variety of natural and anthropogenic sources, including sewage, fertilizers (residential lawns and agricultural), livestock, pet wastes, induced infiltration of surface waters, precipitation, landfills, wildlife, and minerals. Disposal of sewage through septic systems or individual on-site sewage disposal systems is commonly a dominant source of nitrogen in ground water. The assessment of the current and future impacts of all sources of nitrogen on ground water quality used for Sudbury was a two step process. The first step was to account for the sources through summation of current development and land uses and all potential future sources as defined by allowed land uses and Sudbury's Regulatory Program. The second step was to calculate mass-balance dilution of the nitrogen and water within the aquifer which contributes to wells.

BUILDOUT ANALYSES

In order to evaluate the impacts of both existing and potential development on the Sudbury Water District's water supplies, a buildout analysis was conducted for four wellhead protection areas (Zone IIs); for Route 117 (well 5), Pantry Brook (well 11), East Street (wells 3, 8 and 10), and Raymond Road, (wells 2, 4, 6, 7 and 9). The mapped zones were provided by the Sudbury Water District and H_20 Engineering. The zone for new well 11 in the Pantry Book area was conceptual and not the result of ground water modeling. The zones for East Street and Raymond Road well fields are modeled and approved by DEP. The zone for well 5 along Route 117 was modeled and recently submitted to DEP for approval.

These land use analyses are used to determine existing and potential levels of development within the contributing areas to each well field based on local regulations. Sudbury's zoning maps and regulations are a "blueprint" for the future development in these areas. This blueprint results in land development which will eventually be the major control of ground water quality for these water sources, particularly with respect to nitrogen loading. The purpose of the analyses is to determine what level and type of development will occur in each Zone II if it is "built out" to saturation according to current zoning. By estimating the saturation limit of development in each Zone II, potential future levels of nitrogen loading may be predicted.

The primary purpose of the buildout analysis was to evaluate the impacts of changing land use on ground-water quality. The analyses focused on the Zone IIs, since this is the land area which, by definition, contributes water to the wells. First, existing levels of development were documented and tallied based on a review of assessor's maps and data.

The land use data were supplemented with septic system design capacities for commercial and industrial properties obtained from the Sudbury Board of Health, and by water bills from the Sudbury Water District for commercial and industrial properties which use septic systems for wastewater disposal (Table 2). Second, future levels of development were predicted based on current zoning requirements and available properties. Factors such as land use codes, minimum lot size, frontage requirements, maximum building and pavement coverage, and wetlands constraints were used to compute the potential development. Virtually all of the remaining developable land in these zones in Sudbury was coded residential (RA).

The buildout analysis assumed that each zoning district would be developed for the greatest nitrogen loading use allowed by right. For example, for lots zoned as Residential, it was assumed that the property would be developed as residential, the development which would produce the greatest nitrogen loading.

The results of the buildout analyses are summarized for the four Zone IIs in Tables 3-6. All of the potential development was assumed to discharge wastewater through septic systems both in Concord and Sudbury. In Framingham, the number of residences, apartment buildings (699 units), and one school were counted from a 1986 aerial photograph made for the Topographic Division of the U.S. Geological Survey. That part of the Raymond Road well field in Framingham was assumed to be built-out to saturation, and to be sewered to Boston Harbor by way of the Metropolitan Water Resources Authority sewerage system.

The resultant potential increase in the number of at buildout for each of the four Zones IIs was 145 in in the Pantry Brook Zone II, 69 in the East Street Zon Raymond Road Zone II. The 320 additional reside well zone is believed to be over estimated because actually needed. The zone is a preliminary and c based upon a conceptual model.

Track additional development is taking place in Framingham at Hollis St/Water St.

NITRATE LOADING ANALYSES

Below the water table, nitrate acts conservatively. It remains unattenuated and persists in the water. Prior to it's entering the water saturated zone in the ground, nitrogen is subjected to several denitrifying processes which deplete the load of nitrogen in water. Denitrification occurs in the soil and in the unsaturated zone between a septic system system leaching facility and the water table, thereby reducing the concentrations of nitrogen in the water which may eventually become drinking water. It is the unreactive or conservative property of nitrogen below the water table which allows the calculation of estimates of nitrate concentrations in well water (nitrate

loading analyses). The approach and fundamental equations used for the mass-balance analyses for the four Sudbury Zone IIs is outlined in "A Mass-Balance Model for Predicting Nitrate in Ground Water" by Frimpter, Donohue and Rapacz in the New England Water Works Association Journal Vol. CIV, No. 4, December 1990. The model accounts for water recharge from waste water, precipitation and surface water and accounts for nitrogen from septic systems, lawns, several categories of agriculture, sewage system leakage, sewage plant disposal, landfills, induced infiltration of surface water, and precipitation.

Although storm runoff from paved areas may be directed out of a Zone II by way of storm sewers, thereby affecting the nitrogen and water balance, such is not the case in Sudbury. In zones from which runoff from pavement is exported to beyond the limits of the Zone II, storm runoff from pavement may have a significant effect on the mass-balance. In Sudbury, water from paved areas is discharged onto land within the Zone IIs, and sensitivity analyses of the impact of this drainage treatment on nitrate concentrations at the wells showed changes of 0.01 mg/L, or less. Because of the insensitivity of the model results to the area of pavement and roofing in Sudbury, it was not included in the final model calculations.

The analyses were completed for all four of Sudbury's Zone IIs under both current (Tables 7-10) and buildout conditions (Tables 11-14). Current condition calculations were then compared to currently measured nitrate concentrations in the water produced by each of the wells (Table 15) in order to assess the accuracy of the calculations and to provide a basis for model calibration. The mass-balance model does not initially account for denitrification which takes place between the septic system leaching facility and the water table. The attenuation of nitrogen owing to denitrification is a function of percolation rates, temperature, depth to the water table and other site-specific characteristics which is interpreted from the difference between the calculated and measured current nitrate concentrations in the wells. This difference was then used to calibrate the model to predict more realistic buildout projections of nitrate concentration.

In some places, it has been possible to track a nitrate concentration trend over time and use the extrapolation of the trend to calibrate the mass-balance model for denitrification. Because the nitrate concentrations for the Sudbury wells did not vary significantly, nor show a definable trend over about 16 years (Table 16), this method of calibration was not used.

Calibration of the model is accomplished by adjusting (reducing) the "N-conc. in septic effluent (mg/l)" input value from 40 to some lower value in order to yield a final concentration which more closely estimates the measured concentrations. For the calibrated nitrate mass-balance models applied to

Sudbury an adjustment was selected which resulted in a 50 percent reduction in the difference between the original calculated and measured current nitrate concentrations. This difference represents the denitrification change which occurs between the leach system and the water table, and perhaps some other local site-specific factors which affect nitrate concentrations. A reduction from 40 to 25 mg/l (about 1/3) between leach field effluent and the water table was attributed to denitrification. This adjustment is considered conservative and assumes that about half of the difference between modeled and measured nitrate is due to travel time delay (nonequilibrium) rather than denitrification. The calibrated models were used to recalculate final buildout estimates of nitrate concentration for each of the four Zone IIs (Tables 16-19).

DISCUSSION OF RESULTS

None of the water supplies seem to be seriously threatened by excessively high concentrations of nitrate. However, the analyses reveal the relative magnitudes of the different source in the four different zones, which may suggest conditions which might be addressed with management controls to improve future water quality.

Well 5, Near Route 117

The concentration of about 3.7 mg/l for well 5 near Route 117 in the valley of Cold Brook is attributed to several factors, the most important being that the model calculates an average recharge rate for the entire Zone II at the low rate of slightly less than 6 inches per year. This is explained by the relatively low permeability of the aquifer material and the low permeability of wetlands near the well which inhibit recharge of ground water and induced infiltration of surface water. On the other hand, the buildout assumes an approximate doubling of capacity of the septic system serving the so called Unisys property, and predicts an increase of single family residences from 100 to 245 in the most permeable sandy recharge areas about the well and wetland. Some reduction of the potential discharge of wastewater through septic systems in this area would provide a greater margin of safety. As shown in pie diagrams of the sources of water and sources of nitrate (Figures 1 and 2), septic system discharges and fertilizers applied to lawns account for most of the nitrate in this Zone II.

An additional buildout scenario for the Zone II about well 5 was prepared in order to assess the potential water quality impacts of contemplated land use changes. For this new buildout scenario, it was assumed that the so-called Unisys property in the northern part of Sudbury would be zoned differently so that 100,000 gallons of wastewater per day per acre could be discharged to the ground by way of septic systems. Two model runs were made to simulate possible conditions. In the first case, the wastewater discharge from the Unisys property was increased from 15,045 gallons per day to 25,000 gallons

per day assuming conversion of 10 acres (Table 20). This change caused nitrate concentrations to increase from 3.67 mg/l to 4.04 mg/l. In the second case, the previous estimated expansion of waste water disposal under buildout was eliminated and all of the 103.9 acres of property previously reserved for research activities was converted to uses that would allow discharge of 100,000 gallons per day per acre (Table 21). This new situation yielded an average nitrate concentration of 7.98 mg/l, significantly exceeding the 5 mg/l planning limit and approaching the MCL. The dominant source of nitrogen in this additional scenario is septic systems (Figure 3).

Well 11, Near Pantry Brook

The estimated concentration for new well 11 near Pantry Brook is based on an overly large (conservative) preliminary Zone II Most likely both the area and the nitrate concentrations would be somewhat lower than the estimated 1.73 mg/l. In order to adjust for the bias introduced by using such a large Zone II, a larger rate of withdrawal from wells in the zone was assumed. This approach resulted in a more reasonable 10.27 inches of recharge rather than about 5 inches. We estimate that the actual recharge rate in this area to be about 16 inches and believe that this adjustment yields a more reasonable 1.73 mg/l estimate for nitrate. Because well 11 was not being pumped, the nitrate concentration from water samples is not representative and could not be used to calibrate the model. The approximate calibration factor for the other zone IIs (reduction from 40 to 25 mg/l) was applied to this well to develop the "calibrated" estimate. Here again, septic systems and lawns are the source of nitrate (Figure 4) and both precipitation and induced infiltration of surface water (Pantry Brook) are the main sources of water (Figure 5).

Wells 3, 8 and 10, East Street Near Hop Brook

Estimated nitrate concentrations for the wells 3, 8 and 10 in the East Street area adjacent to Hop Brook are relatively high, 3.27 mg/l. Although septic systems and lawns are a source here, a major source is Hop Brook which has an average 3.85 mg/l of nitrate calculated from reports from a number of sources including Revised Tables of May 1993 from "Hop Brook Ponds System Study, Sudbury, MA", by Whitman and Howard, "Concord and Sudbury Rivers Water Quality Analysis" (Hogan, P. M., 1975), "The Sudbury River Basin Water Quality Management Plan" (Dorfman, R. S. 1988), and "Source, Movement, and Effects of Nitrogen and Phosphorus in Three Ponds in the Headwaters of Hop Brook, Marlborough, Massachusetts" (Briggs and Silvey, 1984). About 30 percent of the water and nitrate is derived from the stream. Decrease of nitrate in the stream water can be expected to result in a proportional decrease in nitrate in the well water. The relative proportions of water derived from Hop Brook, wastewater return flow and infiltration of precipitation are shown in Figure 6. The relative contributions of nitrate from different sources, notably Hop Brook, is shown in Figure 7.

Wells 2, 4, 6, 7 and 9, Raymond Road Area

The calibrated mass-balance nitrate model estimated an average 2.76 mg/l for wells in the Raymond Road Zone II at buildout. This Zone II contains a larger percentage of commercial and industrial properties than the other zones, and a wastewater disposal facility. The Zone is large (2,581 acres) and is capable of producing a large amount of water (4.6 million gallons per day). The calculated recharge rate from precipitation is 16.53 inches per year, a very reasonable value, and about 60 percent of the water is derived from recharge of precipitation (Figure 8). Although most of the nitrate is from septic systems and lawns in this Zone II, leakage from the sewer system in Framingham, and discharge to the Zone II from a STP (sewage treatment plant) at the Raytheon property along Route 20 in Sudbury are additional sources (Figure 9). A standard sewer leakage rate of 10 percent was assumed for the sewered part of the zone in Framingham.

Historically, discharges from the Raytheon STP were in excess of 10 mg/l at the property boundary, but recent data from the Sudbury Board of Health indicates that the level has decreased to about 10 mg/l, and may go lower. Lithologic logs from test wells at the Raytheon site suggest the property is underlain at depth by fine grained glaciolacustrine deposits and that there may not be a direct connection between this area and the aquifer that sustains the wells in the Raymond Road area. If fine tuning of the nitrate loading in this Zone II becomes needed, perhaps a more detailed description of this part of the aquifer and Zone II would also be warranted.

Wells 2 and 9 have relatively low concentrations of nitrate (Table 15) although they are closest to the Raytheon STP. The relatively high nitrate concentrations measured in well 4 on Warren Road (Table 15) are more likely to be the result of discharges to septic systems to the south of the well than from the Raytheon STP.

Nitrate concentrations of about 2.5 mg/l for Hop Brook near the downstream part of the Zone II below the confluence with Allowance Brook were taken from reports by the Massachusetts Division of Water Pollution Control (Hogan, P. M., 1975, and Dorfman, R. S., 1988).

The model calculations are for an average concentration in the Raymond Road Zone II, but the 5 wells are distributed in different locations within the zone. The model yields only an approximate average concentration for all of the wells assuming that they are all withdrawing water at full permitted capacity. Because the sources of nitrate are not uniformly distributed about the zone, considerable differences in nitrate concentrations can be expected in the water from the different wells. Should there appear to be a threat to one or more of the wells, it would be possible to apply a ground water model to

delineate separate Zone IIs for each well and then reconfigure the buildout information developed for this study in order to prepare mass-balance nitrate model calculations for each of the separate zones.

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TABLES

TABLE 1 - WATER BILLS AND SEPTIC SYSTEM DESIGN FLOW FOR NITRATE LOADING IN ZONE II SUDBURY, MASSACHUSETTS

Zone II	Name	Number	Street	Map	Water Bill	Design Flow
A	Sperry-Rand Corporation	142	North Road	C11		14,900
A	Fire Station #3	268	North Road	C10	145	
Total	Well 5					15045
B	Josiah Haynes School	169	Haynes Road	C09	834	
B	School for Special Learning	98	Haynes Road	D09	104	
B	Lincoln-Sudbury Regional High School	390	Lincoln Road	F10	649	
Total	Well 11					1587
C	Fairbank School	40	Fairbank Road	F06	6058	
C	Sudbury Housing Authority	48	Fairbank Road	F06	359	
C	Sudbury Housing Authority	50	Fairbank Road	F06	140	
C	Sudbury Housing Authority	52	Fairbank Road	F06		
C	Sudbury Housing Authority	54	Fairbank Road	F06	386	
C	Ephraim Curtis Middle School	22	Pratt's Mill Road	H07	994	
Total	Wells 3,8 & 10					7937
D	Nancy C. Grellier	736	Boston Post Road	K05	8	
D	Sudbury Pines Nursing Home	642	Boston Post Road	K06		2,000
D	Sudbury Medical Center Trust	616	Boston Post Road		522	
D	Massachusetts Fire Fighters Academy	592	Horse Pond Road			9,000
D	State Police Crime Lab	592	Horse Pond Road			900
D	PLM Corporation	578	Boston Post Road		9863	
D	Fire Station #2		Boston Post Road	K07		
D	Raytheon Company	528	Boston Post Road			50,000
D	Union Ave Paris Trust	490	Boston Post Road			6,494
D	Young, Bloom, Fields Realty Trust	476	Boston Post Road			
D	Sudbury Plaza Trust	505	Boston Post Road		49	
D	Star Market	507-525	Boston Post Road			4,515
D	Sullivan Tire Company (+gas station)	477	Boston Post Road		201	670
D	Paris Trust	29	Union Ave			
D	Paris Trust	31	Union Ave		1458	
D	EB Realty Trust	33	Union Ave			2,400
D	Mutual Realty Trust of Sudbury	34	Station Road	K08	364	
D	Mutual Realty Trust of Sudbury	38	Station Road			
D	Station Road Auto Body & Garage, Inc.	40	Station Road		238	
D	Garage - Interstate Gas and Oil Corp	237	Nobscot Road			300
D	Garage - Interstate Gas and Oil Corp	239	Nobscot Road		132	
D	One Union Avenue Realty Trust	1	Union Ave		682	
D	Fifteenth Union Avenue Turst	15	Union Ave		126	
D	Sudbury Post Office Realty	18	Union Ave		271	
D	Vet. (McNeill)	21	Union Ave			255
D	Sudbury Inn Associates	22	Union Ave		127	
D	G. Burton Mullen	23	Union Ave			
D	Overhead Door Warehouse	25	Union Ave			100
D	Plywood Warehouse	27	Union Ave			100
D	G. Burton Mullen	28	Union Ave		633	
D	G. Burton Mullen	39	Union Ave		164	
D	The Precourt Realty Trust No. 1	44	Union Ave		608	
D	The Precourt Realty Trust No. 1	46	Union Ave		16	

TABLE 1 - WATER BILLS AND SEPTIC SYSTEM DESIGN FLOW
FOR NITRATE LOADING IN ZONE II
SUDBURY, MASSACHUSETTS

Zone II	Name	Number	Street	Map	Water Bill	Design Flow
D	Edward H. and Diane R. Perkins	50	Union Ave		211	
D	Edward L. Tucker (Flintab?)	55	Union Ave		818	
D	Granco Realty Trust	56	Union Ave		534	
D	Sudbury Dental Center	57	Union Ave		1775	
D	Granco Realty Trust	60	Union Ave		605	
D	UNUM	64	Union Ave		329	
D	Macot Realty Trust	65	Union Ave		449	
D	Macot Realty Trust	71	Union Ave			
D	Ed Tucker (Capaccio Env. Eng, Inc.)	75	Union Ave		774	
D	Auto Meister	80	Union Ave		131.5	
D	E.R. Schofield	80	Union Ave		249	
D	Ed Tucker (Rug Store)	81	Union Ave		104	
D	Sudbury Union Nominee Trust	83	Union Ave			
D	Chen's Family Realty Trust (Resturant)	394	Boston Post Road			2100
D	US Realty Trust	400	Boston Post Road			
D	Lee A. Young	407	Boston Post Road			
D	G. Burton Mullen (Resturant)	410	Boston Post Road			1,740
D	Sudbury Police Station	415	Boston Post Road		234 gpd	
D	1776 Realty Trust	418	Boston Post Road		463	
D	1776 Realty Trust	420	Boston Post Road			
D	Sudbury Crossing Assoc. Realty Trust	421	Boston Post Road			
D	1776 Realty Trust	424	Boston Post Road			
D	Anastasios & Anna Rokas	426	Boston Post Road			
D	Anastasios & Anna Rokas	428	Boston Post Road			
D	Colonial Auto of Sudbury, Inc.	430	Boston Post Road			
D	Mobil Oil Corporation	434	Boston Post Road			
D	Sudbury Crossing Assoc Realty Trust	435-437	Boston Post Road			4,600
D	Health Stop	440	Boston Post Road			210
D	Francis J. Vanaria, Jr.	444	Boston Post Road			
D	1776 Plaza	439-457	Boston Post Road			3,491
D	First Federal S & L Assoc. of Lowell	450	Boston Post Road			
D	V.S.H. Realty, Inc.	454	Boston Post Road			
D	Arthur T. & Bernice M. Reiders	460	Boston Post Road			
D	V.S.H. Realty, Inc.	470	Boston Post Road			
D	Closed Gas Station	465	Boston Post Road		0	
D	Sudbury Water District	199	Raymond Road	L08		
Total	Raymond Rd. (wells 2, 6, 7, 4, & 9)					110813
	minus Bartlett (9,863)					100950

TABLE 2. SUDBURY ZONE II BUILDOUT
ZONE II A

Map	Lot	Use Code		Zoning	# Acres	# Existing Dwelling Units	# Grand-Fathered Vacant Lots	Frontage	Minimum Frontage	Minimum Lot Size	# Potential ANR Lots	# Potential Subdiv. Lots	Total Developable Lots (G+O+Q)
Sudbury Lots													
C09	ALL	101		RA		18							18
C09	ALL	130		RA		1							1
C09	24	101	1	RA	5	1	0	550	180	.91	1	3	5
C09	31	101	1	RA	7.46	2	0	438	180	.91	0	6	8
C09	604	101	1	RA	7	1	0	265	180	.91	0	6	7
C10	ALL	101		RA		36							36
C10	ALL	130		RA		3							3
C10	2	101	1	RA	2	1	0	283	180	.91	0	1	2
C10	25	101	1	RA	2.03	1	0	344	180	.91	0	1	2
C11	300	404	1	RES	103.34	1		2222	200	8.00	9	3	13
C12	ALL	101		RA		1							1
D10	ALL	101		RA		23							23
D10	400	101	1	RA	16.5	0	0	340	180	.91	1	13	14
D11	ALL	101		RA		7							7
D11	205	101	1	RA	6.39	1	0	494	180	.91	1	4	6
D11	500	79	1	RA	84.27	0	0	1450	180	.91	7	68	75
E10	ALL	101		RA		3							3
Sudbury Total					233.99	100	0				19	105	224
Concord Lots													
E14	ALL	101		RA		1							1
E15	ALL	101		RA		15							15
E15	3426	101	1	RAA	4.67	1	0	300	200	1.82	0	2	3
E16	ALL	101		RA		1							1
E16	ALL	130		RA		1							1
Concord Total					4.67	19	0				0	2	21
Totals					238.66	119	0				19	107	245

TABLE 3. SUDBURY ZONE II BUILDOUT
ZONE II B

Map	Lot	Use Code		Zoning	# Acres	# Existing Dwelling Units	# Grand-Fathered Vacant Lots	Frontage	Minimum Frontage	Minimum Lot Size	# Potential ANR Lots	# Potential Subdiv. Lots	Total Developable Lots (G+O+Q)
C08	ALL	130		RA		1							1
C09	ALL	101		RA		29							29
C09	40	101	1	RA	1.82	1	0	398	180	.91	0	1	2
C10	ALL	101		RA		1							1
D08	ALL	101		RA		20							20
D08	ALL	130		RA		1							1
D08	217	101	1	RA	5.1	1	0	280	180	.91	0	4	5
D09	ALL	101		RA		57							57
D09	1	101	1	RA	3.25	2	0	300	180	.91	0	2	4
D09	2	101	1	RA	4.11	1	0	479	180	.91	1	2	4
D09	24	101	1	RA	4.78	1	0	437	180	.91	1	3	5
D09	113	101	1	RA	2.88	1	0	363	180	.91	0	2	3
D09	200	101	1	RA	13.35	1	0	365	180	.91	0	11	12
D09	202	101	1	RA	2.73	1	0	508	180	.91	1	1	3
D09	213	101	1	RA	2.56	1	0	231	180	.91	0	2	3
D09	214	101	1	RA	2.85	1	0	238	180	.91	0	2	3
D09	215	101	1	RA	2.36	1	0	232	180	.91	0	2	3
D10	ALL	101		RA		9							9
D10	ALL	130		RA		1							1
D10	503	101	1	RA	5.54	1	0	884	180	.91	3	2	6
D10	504	130	1	RA	4.36	0	0	463	180	.91	2	2	4
D11	ALL	101		RA		3							3
D11	ALL	130		RA		2							2
D12	200	71	1	RA	42	1	0	890	180	.91	3	34	38
D13	ALL	101		RA		5							5
E08	ALL	101		RA		39							39
E08	ALL	130		RA		2							2
E08	400	71	1	RA	49.1	0	0	1430	180	.91	7	37	44
E08	600	71	1	RA	66.5	1	0	2320	180	.91	11	49	61
E09	ALL	101		RA		58							58
E10	ALL	101		RA		9							9
E10	201	71	1	RA	60	1	0	1644	180	.91	7	47	55
E12	6	101	1	RA	27	1	0	2160	180	.91	10	15	26
E13	100	101	1	RA	27.1	1	0	0	180	.91	0	23	24
F08	ALL	101		RA		2							2
F11	ALL	101		RA		1							1
F11	ALL	130		RA		2							2
F11	4	130	1	RA	36.6	0	0	1082	180	.91	5	28	33
F12	ALL	101		RA		2							2
Totals					**363.99**	**262**	**0**				**51**	**269**	**582**

TABLE 4. SUDBURY ZONE II BUILDOUT
ZONE II C

Map	Lot	Use Code		Zoning	# Acres	# Existing Dwelling Units	# Grand-Fathered Vacant Lots	Frontage	Minimum Frontage	Minimum Lot Size	# Potential ANR Lots	# Potential Subdiv. Lots	Total Developable Lots (G+O+Q)
E06	ALL	101		RA		17							17
E06	4	101	1	RA	8.1	1	0	350	180	.91	0	7	8
E06	525	101	1	RA	2.37	1	0	307	180	.91	0	2	3
E07	ALL	101		RA		3							3
F04	ALL	101		RA		1							1
F04	302	903		RA		1							1
F05	ALL	101		RA		80							80
F05	ALL	130		RA		3							3
F05	219	903		RA		1							1
F05	7	101	1	RA	4.86	1	0	236	180	.91	0	4	5
F06	ALL	101		RA		99							99
F06	3/400	100/78	1	RA	52.65	1	0	744	180	.91	2	44	47
F07	ALL	101		RA		31							31
F07	19	101	1	RA	4.35	1	0	332	180	.91	0	3	4
F07	401	101	1	RA	2.08	1	0	490	180	.91	1	1	3
G05	ALL	101		RA		43							43
G06	ALL	101		RA		112							112
G06	ALL	130		RA		2							2
G07	ALL	101		RA		87							87
G07	401	101	1	RA	3	1	0	870	180	.91	3	0	4
G08	ALL	101		RA		8							8
H05	ALL	101		RA		26							26
H06	ALL	101		RA		92							92
H06	ALL	130		RA		1							1
H07	310	101	1	RA	2.34	1	0	235	180	.91	0	2	3
Totals					79.75	598	0				6	63	667

TABLE 5. SUDBURY ZONE II BUILDOUT
ZONE II D

Map	Lot	Use Code		Zoning	# Acres	# Existing Dwelling Units	# Grand-Fathered Vacant Lots	Frontage	Minimum Frontage	Minimum Lot Size	# Potential ANR Lots	# Potential Subdiv. Lots	Total Developable Lots (G+O+Q)
J05	ALL	101		RA/RC		14							14
J06	ALL	101		RA/RC		85							85
J06	13	101	1	RA	2.5	1		360	180	.91	0	2	3
J06	23	404	1	RA	10.96	1		820	180	.91	3	7	11
J07	ALL	101		RA		20							20
J07	ALL	130		RA		2							2
J07	12	131	1	RA	15	0		0	180	.91	0	13	13
J08	4	71	1	RA	36.73	2		1379	180	.91	5	28	35
K05	ALL	101		RA		46							46
K05	107,108	101	1	RA	4.59	0		371	180	.91	1	3	4
K06	ALL	101		RA		74							74
K06	ALL	130		RA		1							1
K06	600	79	1	RA	59.87	1		2010	180	.91	9	45	55
K07	ALL	101		RA		15							15
K08	ALL	101		RA		19							19
K08	20	131	1	RA	28.76	0		232	180	.91	1	24	25
K08	38	391	1	ID	4.07	0		414	50	1.46	2	0	2
K09	ALL	101		RA		4							4
K09	74	101	1	RA	4.07	1		332	180	.91	0	3	4
L07	ALL	101		RA/RC		16							16
L07	4,5,6	71	1	RA	26.04	4		722	180	.91	0	22	26
L07	16	101	1	RA	4.5	1		430	180	.91	1	3	5
L07	17	101	1	RA	8.82	1		870	180	.91	3	5	9
L07	20	101	1	RA	2.65	1		240	180	.91	0	2	3
L07	21	101	1	RA	11.07	1		240	180	.91	0	9	10
L07	26	71	1	RC	69.28	1		4163	210	1.37	18	26	45
L07	30	101	1	RC	6.98	1		366	210	1.37	0	4	5
L07	35	81	1	RC	7	1		626	210	1.37	1	3	5
L07	200	71	1	RC	27.35	1		1007	210	1.37	3	13	17
L08	ALL	101		RA		8							8
L08	ALL	130		RA		1							1
L09	ALL	101		RA		6							6
M08	ALL	101		RA		68							68
M08	3	109	1	RA	4.4	2		321	180	.91	0	3	5
M08	4	130	1	RA	8.51	0		383	180	.91	1	6	7
M09	ALL	101		RA		78							78
M09	ALL	130		RA		1							1
M09	208	101	1	RA	2	1		594	180	.91	2	0	3
M09	500	105	1	RA	4.5	1		721	180	.91	2	2	5
M09	703	101	1	RA	5	0		545	180	.91	2	2	4
M09	704	101	1	RA	3.13	1		343	180	.91	0	2	3
Totals					**357.78**	**481**	**0**				**54**	**227**	**762**

TABLE 6 - CURRENT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
WELL 5

LAND USE DATA INPUT	VALUES
Total single family houses	100
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	7,145
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 6 - CURRENT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 5

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	898
Withdrawal Rate (mgd)	0.5
Percent of withdrawal from surface water	10
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	2,878
Lawns (lb/yr)	459
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	15
Precipitation (lb/yr)	65
Total nitrogen load (lb/yr)	3,417
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	0.50
Surface water recharge (mgd)	0.05
Recharge from septic/sew. (mgd)	0.02
Recharge from precipitation (mgd)	0.43
Recharge from precipitation (in/yr)	6.38
NITROGEN CONCENTRATION (mg/l)	2.25

TABLE 7 - CURRENT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
WELL 11 ADJUSTED FOR BEING CONCEPTUAL ZONE II

LAND USE DATA INPUT	VALUES
Total single family houses	262
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	1,587
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 7 - CURRENT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
WELL 11 ADJUSTED FOR BEING CONCEPTUAL ZONE II

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	1,443
Withdrawal Rate (mgd)	2
Percent of withdrawal from surface water	40
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	5,455
Lawns (lb/yr)	1,203
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	243
Precipitation (lb/yr)	176
Total nitrogen load (lb/yr)	7,077
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	2.00
Surface water recharge (mgd)	0.80
Recharge from septic/sew. (mgd)	0.04
Recharge from precipitation (mgd)	1.16
Recharge from precipitation (in/yr)	10.76
NITROGEN CONCENTRATION (mg/l)	1.16

TABLE 8 - CURRENT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
WELLS 3, 8 10

LAND USE DATA INPUT	VALUES
Total single family houses	598
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	7,937
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 8 - CURRENT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELLS 3, 8 10

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	1,091
Withdrawal Rate (mgd)	1.9
Percent of withdrawal from surface water	30
N-conc. in Surface water (mg/l)	3.85
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	12,976
Lawns (lb/yr)	2,746
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	6,678
Precipitation (lb/yr)	186
Total nitrogen load (lb/yr)	22,586
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	1.90
Surface water recharge (mgd)	0.57
Recharge from septic/sew. (mgd)	0.11
Recharge from precipitation (mgd)	1.22
Recharge from precipitation (in/yr)	15.07
NITROGEN CONCENTRATION (mg/l)	3.91

TABLE 9 - CURRENT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR RAYMOND ROAD WELLFIELD

LAND USE DATA INPUT	VALUES
Total single family houses	1,180
STP sewered single family houses	699
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	360
STP sewered multi-family units (persons)	360
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	100,950
Com./Ind. STP sewage flow (gal/d)	850
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	50,000
STP discharge N conc. (mg/l)	10
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	135,985

TABLE 9 - CURRENT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
RAYMOND ROAD WELLFIELD

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	2,581
Withdrawal Rate (mgd)	4.6
Percent of withdrawal from surface water	25
N-conc. in Surface water (mg/l)	2.5
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	28,034
Lawns (lb/yr)	5,418
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	2,690
Sewage disposal (lb/yr)	1,522
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	8,749
Precipitation (lb/yr)	490
Total nitrogen load (lb/yr)	46,902
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	4.60
Surface water recharge (mgd)	1.15
Recharge from septic/sew. (mgd)	0.23
Recharge from precipitation (mgd)	3.22
Recharge from precipitation (in/yr)	16.77
NITROGEN CONCENTRATION (mg/l)	3.35

TABLE 10 - BUILDOUT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
WELL 5

LAND USE DATA INPUT	VALUES
Total single family houses	245
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	15,045
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 10 - BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 5

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	898
Withdrawal Rate (mgd)	0.5
Percent of withdrawal from surface water	10
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	6,752
Lawns (lb/yr)	1,125
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	15
Precipitation (lb/yr)	60
Total nitrogen load (lb/yr)	7,952
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	0.50
Surface water recharge (mgd)	0.05
Recharge from septic/sew. (mgd)	0.06
Recharge from precipitation (mgd)	0.39
Recharge from precipitation (in/yr)	5.91
NITROGEN CONCENTRATION (mg/l)	5.23

TABLE 11 - BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 11 ADJUSTED FOR BEING CONCEPTUAL ZONE II

LAND USE DATA INPUT	VALUES
Total single family houses	582
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	1,587
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 11 - BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 11 ADJUSTED FOR BEING CONCEPTUAL ZONE II

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	1,443
Withdrawal Rate (mgd)	2
Percent of withdrawal from surface water	40
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	11,882
Lawns (lb/yr)	2,672
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	243
Precipitation (lb/yr)	168
Total nitrogen load (lb/yr)	14,965
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	2.00
Surface water recharge (mgd)	0.80
Recharge from septic/sew. (mgd)	0.10
Recharge from precipitation (mgd)	1.10
Recharge from precipitation (in/yr)	10.27
NITROGEN CONCENTRATION (mg/l)	2.46

TABLE 12 - BUILDOUT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
WELLS 3, 8 10

LAND USE DATA INPUT	VALUES
Total single family houses	667
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	7,937
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 12 - BUILDOUT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
WELLS 3, 8 10

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	1,091
Withdrawal Rate (mgd)	1.9
Percent of withdrawal from surface water	30
N-conc. in Surface water (mg/l)	3.85
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	14,362
Lawns (lb/yr)	3,062
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	6,678
Precipitation (lb/yr)	184
Total nitrogen load (lb/yr)	24,287
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	1.90
Surface water recharge (mgd)	0.57
Recharge from septic/sew. (mgd)	0.12
Recharge from precipitation (mgd)	1.21
Recharge from precipitation (in/yr)	14.93
NITROGEN CONCENTRATION (mg/l)	4.20

TABLE 13 - BUILDOUT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
RAYMOND ROAD WELLFIELD

LAND USE DATA INPUT	VALUES
Total single family houses	1,461
STP sewered single family houses	699
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	360
STP sewered multi-family units (persons)	360
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	100,950
Com./Ind. STP sewage flow (gal/d)	850
N-conc. in septic effluent (mg/l)	40
STP discharge in WHPA (gal/d)	50,000
STP discharge N conc. (mg/l)	10
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	135,985

TABLE 13 - BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR RAYMOND ROAD WELLFIELD

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	2,581
Withdrawal Rate (mgd)	4.6
Percent of withdrawal from surface water	25
N-conc. in Surface water (mg/l)	2.5
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	33,678
Lawns (lb/yr)	6,708
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	2,690
Sewage disposal (lb/yr)	1,522
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	8,749
Precipitation (lb/yr)	483
Total nitrogen load (lb/yr)	53,828
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	4.60
Surface water recharge (mgd)	1.15
Recharge from septic/sew. (mgd)	0.28
Recharge from precipitation (mgd)	3.17
Recharge from precipitation (in/yr)	16.53
NITROGEN CONCENTRATION (mg/l)	3.85

TABLE 14 - NITRATE CONCENTRATIONS FOR WELL WATER IN SUDBURY, MASSACHUSETTS

(Data from Sudbury Water Department and DEP, Boston)

ZONE II	WELL	No.	1977	1978	1979	1980	1991	1993	AVE.
A	Route 117	5		0.90	1.10	0.70		1.17	0.97
B		11						0.07	0.07
C	East Street	8					2.10	1.47	1.79
C	Pratts Mill Pond	3	2.80	2.60	2.60	2.00	5.52	2.62	3.63
D		9					0.49	0.07	0.28
D	Nobscot Road	7					1.41	1.88	1.65
D	Raymond Road	6					1.67	1.53	0.80
D	Warren Road	4		3.80	3.60	3.60	3.34	3.74	3.59
D	Raymond Street	2	0.10	0.00	0.00	0.00	0.19	0.13	0.08
C	3, 8 & 10							2.05	
D	2, 4, 6, 7 9							1.47	

TABLE 15 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 5

LAND USE DATA INPUT	VALUES
Total single family houses	245
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	15,045
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	26
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 15 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 5

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	898
Withdrawal Rate (mgd)	0.5
Percent of withdrawal from surface water	10
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	4,389
Lawns (lb/yr)	1,125
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	15
Precipitation (lb/yr)	60
Total nitrogen load (lb/yr)	5,589
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	0.50
Surface water recharge (mgd)	0.05
Recharge from septic/sew. (mgd)	0.06
Recharge from precipitation (mgd)	0.39
Recharge from precipitation (in/yr)	5.91
NITROGEN CONCENTRATION (mg/l)	3.67

TABLE 16 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 11 ADJUSTED FOR BEING CONCEPTUAL ZONE II

LAND USE DATA INPUT	VALUES
Total single family houses	582
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	1,587
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	25
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 16 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELL 11 ADJUSTED FOR BEING CONCEPTUAL ZONE II

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	1,443
Withdrawal Rate (mgd)	2
Percent of withdrawal from surface water	40
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	7,426
Lawns (lb/yr)	2,672
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	243
Precipitation (lb/yr)	168
Total nitrogen load (lb/yr)	10,510
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	2.00
Surface water recharge (mgd)	0.80
Recharge from septic/sew. (mgd)	0.10
Recharge from precipitation (mgd)	1.10
Recharge from precipitation (in/yr)	10.27
NITROGEN CONCENTRATION (mg/l)	1.73

TABLE 17 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELLS 3, 8 10

LAND USE DATA INPUT	VALUES
Total single family houses	667
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	7,937
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	25
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 17 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR WELLS 3, 8 10

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	1,091
Withdrawal Rate (mgd)	1.9
Percent of withdrawal from surface water	30
N-conc. in Surface water (mg/l)	3.85
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	8,976
Lawns (lb/yr)	3,062
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	6,678
Precipitation (lb/yr)	184
Total nitrogen load (lb/yr)	18,901
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	1.90
Surface water recharge (mgd)	0.57
Recharge from septic/sew. (mgd)	0.12
Recharge from precipitation (mgd)	1.21
Recharge from precipitation (in/yr)	14.93
NITROGEN CONCENTRATION (mg/l)	3.27

TABLE 18 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
RAYMOND ROAD WELLFIELD

LAND USE DATA INPUT	VALUES
Total single family houses	1,461
STP sewered single family houses	699
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	360
STP sewered multi-family units (persons)	360
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	100,950
Com./Ind. STP sewage flow (gal/d)	850
N-conc. in septic effluent (mg/l)	22
STP discharge in WHPA (gal/d)	50,000
STP discharge N conc. (mg/l)	10
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	135,985

TABLE 18 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR RAYMOND ROAD WELLFIELD

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	2,581
Withdrawal Rate (mgd)	4.6
Percent of withdrawal from surface water	25
N-conc. in Surface water (mg/l)	2.5
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	18,523
Lawns (lb/yr)	6,708
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	2,690
Sewage disposal (lb/yr)	1,522
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	8,749
Precipitation (lb/yr)	483
Total nitrogen load (lb/yr)	38,673
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	4.60
Surface water recharge (mgd)	1.15
Recharge from septic/sew. (mgd)	0.28
Recharge from precipitation (mgd)	3.17
Recharge from precipitation (in/yr)	16.53
NITROGEN CONCENTRATION (mg/l)	2.76

TABLE 19 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS WELLHEAD PROTECTION AREA FOR RAYMOND ROAD WELLFIELD

LAND USE DATA INPUT	VALUES
Total single family houses	1,461
STP sewered single family houses	699
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	360
STP sewered multi-family units (persons)	360
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	100,950
Com./Ind. STP sewage flow (gal/d)	850
N-conc. in septic effluent (mg/l)	22
STP discharge in WHPA (gal/d)	50,000
STP discharge N conc. (mg/l)	10
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	135,985

TABLE 19 - CALIBRATED BUILDOUT NITRATE LOADING ANALYSIS
WELLHEAD PROTECTION AREA FOR
RAYMOND ROAD WELLFIELD

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	2,581
Withdrawal Rate (mgd)	4.6
Percent of withdrawal from surface water	25
N-conc. in Surface water (mg/l)	2.5
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	18,523
Lawns (lb/yr)	6,708
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	2,690
Sewage disposal (lb/yr)	1,522
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	8,749
Precipitation (lb/yr)	483
Total nitrogen load (lb/yr)	38,673
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	4.60
Surface water recharge (mgd)	1.15
Recharge from septic/sew. (mgd)	0.28
Recharge from precipitation (mgd)	3.17
Recharge from precipitation (in/yr)	16.53
NITROGEN CONCENTRATION (mg/l)	2.76

TABLE 20 - ALTERNATIVE SCENARIO FOR WELL 5 WITH CONVERSION TO RESIDENTIAL (1,000 GALLONS PER ACRE FOR 25 ACRES)

LAND USE DATA INPUT	VALUES
Total single family houses	232
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	25,000
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	26
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 20 - ALTERNATIVE SCENARIO FOR WELL 5 WITH CONVERSION TO RESIDENTIAL (1,000 GALLONS PER ACRE FOR 25 ACRES)

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	898
Withdrawal Rate (mgd)	0.5
Percent of withdrawal from surface water	10
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	5,007
Lawns (lb/yr)	1,065
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	15
Precipitation (lb/yr)	59
Total nitrogen load (lb/yr)	6,146
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	0.50
Surface water recharge (mgd)	0.05
Recharge from septic/sew. (mgd)	0.06
Recharge from precipitation (mgd)	0.39
Recharge from precipitation (in/yr)	5.79
NITROGEN CONCENTRATION (mg/l)	4.04

TABLE 21 - ALTERNATIVE SCENARIO FOR WELL 5 WITH CONVERSION TO RESIDENTIAL (103.9 ACRES AT 1,000 GALLONS PER ACRE)

LAND USE DATA INPUT	VALUES
Total single family houses	219
STP sewered single family houses	0
Average number of persons per unit	3
Wastewater flow per person (gal/d)	55
Total multi-family units (persons)	0
STP sewered multi-family units (persons)	0
Commercial/Industrial land (acres)	0
Commercial/Industrial water use (gal/d)	103,900
Com./Ind. STP sewage flow (gal/d)	0
N-conc. in septic effluent (mg/l)	26
STP discharge in WHPA (gal/d)	0
STP discharge N conc. (mg/l)	55
Landfills (acres)	0
Lawn area per house (square feet)	5,000
Lawn leach rate (lbs/ac/yr)	40
Agricultural area A (acres)	0
Agricultural area A leach rate (lbs/ac/yr)	
Agricultural area B (acres)	0
Agricultural area B leach rate (lbs/ac/yr)	
Agricultural area C (acres)	0
Agricultural area C leach rate (lbs/ac/yr)	
Sewage collection system flows (gal/d)	0

TABLE 21 - ALTERNATIVE SCENARIO FOR WELL 5 WITH CONVERSION TO RESIDENTIAL (103.9 ACRES AT 1,000 GALLONS PER ACRE)

HYDROLOGIC DATA INPUT	
Total wellhead protection area (acres)	898
Withdrawal Rate (mgd)	0.5
Percent of withdrawal from surface water	10
N-conc. in Surface water (mg/l)	0.1
N-conc. in Precipitation (mg/l)	0.05
CALCULATIONS OF N-LOADS (lb/yr)	
Septic systems (lb/yr)	11,079
Lawns (lb/yr)	1,006
Agriculture A (lb/yr)	0
Agriculture B (lb/yr)	0
Agriculture C (lb/yr)	0
Sewage system leakage (lb/yr)	0
Sewage disposal (lb/yr)	0
Landfills (lb/yr)	0
Induced infiltration (lb/yr)	15
Precipitation (lb/yr)	47
Total nitrogen load (lb/yr)	12,147
CALCULATION OF WATER VOLUME	
Recharge equals withdrawal (mgd)	0.50
Surface water recharge (mgd)	0.05
Recharge from septic/sew. (mgd)	0.14
Recharge from precipitation (mgd)	0.31
Recharge from precipitation (in/yr)	4.64
NITROGEN CONCENTRATION (mg/l)	7.98

FIGURES

FIGURE 1. BUILDOUT SOURCES OF WATER FOR WELL 5

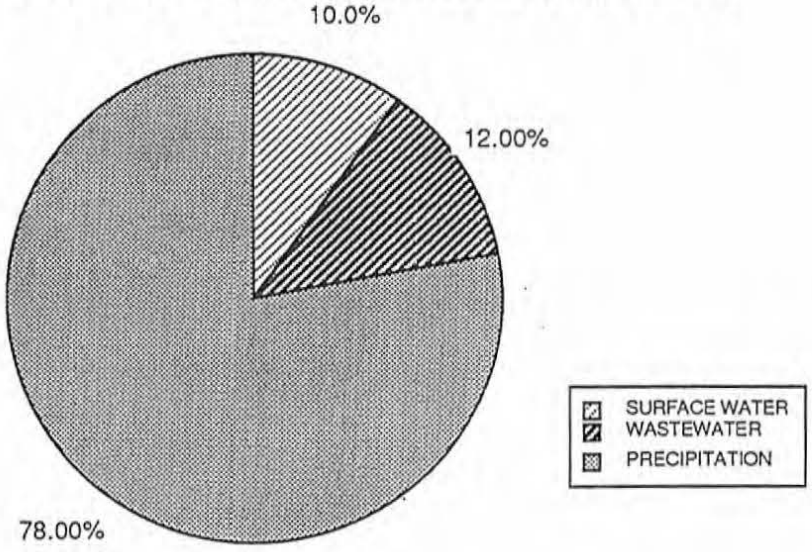


FIGURE 2. BUILDOUT SOURCES OF NITRATE FOR WELL 5

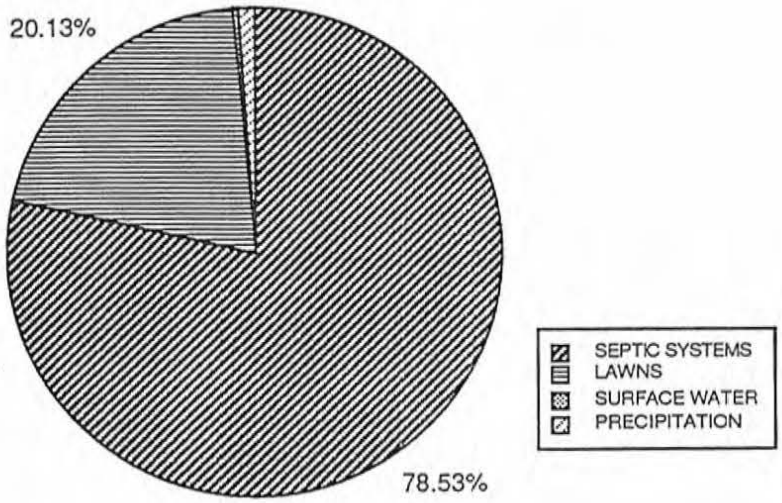


FIGURE 3. BUILDOUT SOURCES OF WATER FOR WELL 11

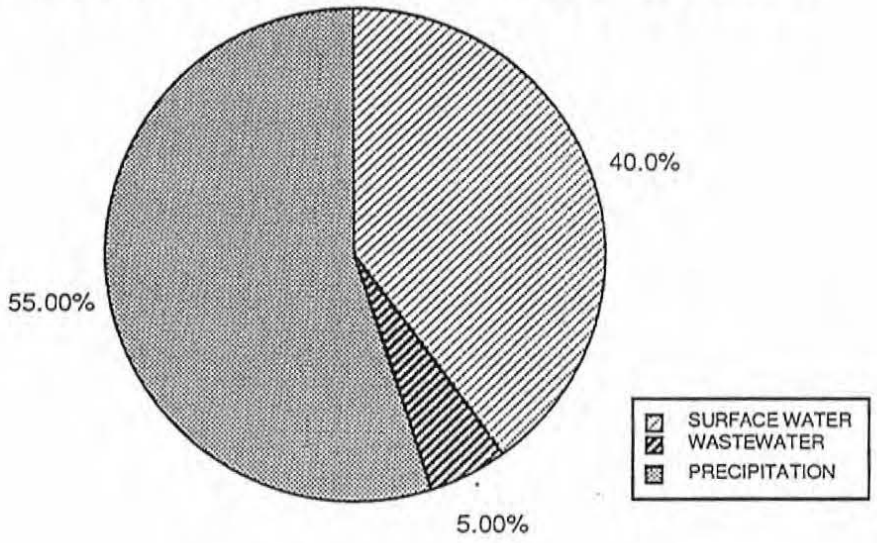


FIGURE 4. BUILDOUT SOURCES OF NITRATE FOR WELL 11

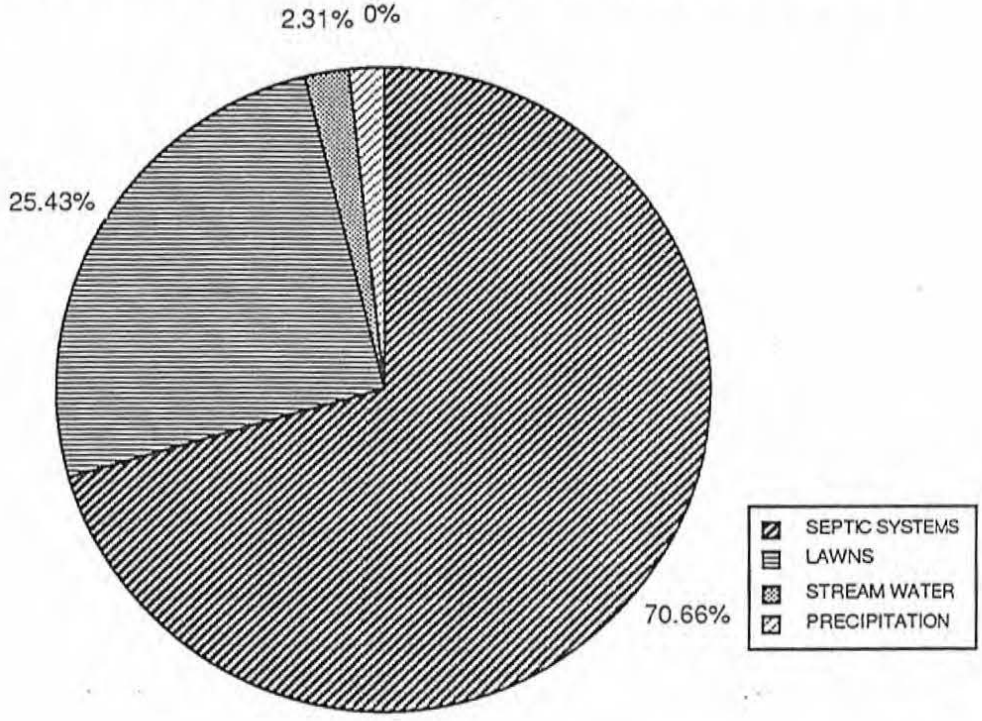


FIGURE 5. BUILDOUT SOURCES OF WATER
FOR WELLS 3, 8 & 10

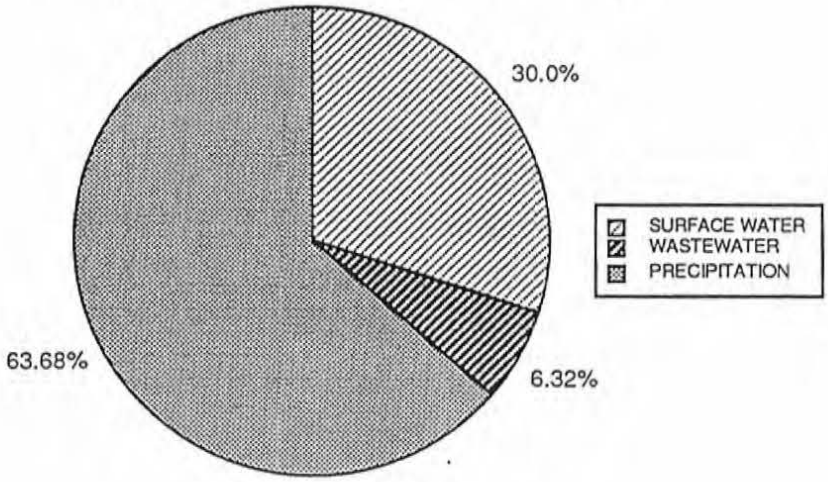


FIGURE 6. BUILDOUT SOURCES OF NITRATE
FOR WELLS 3, 8 AND 10

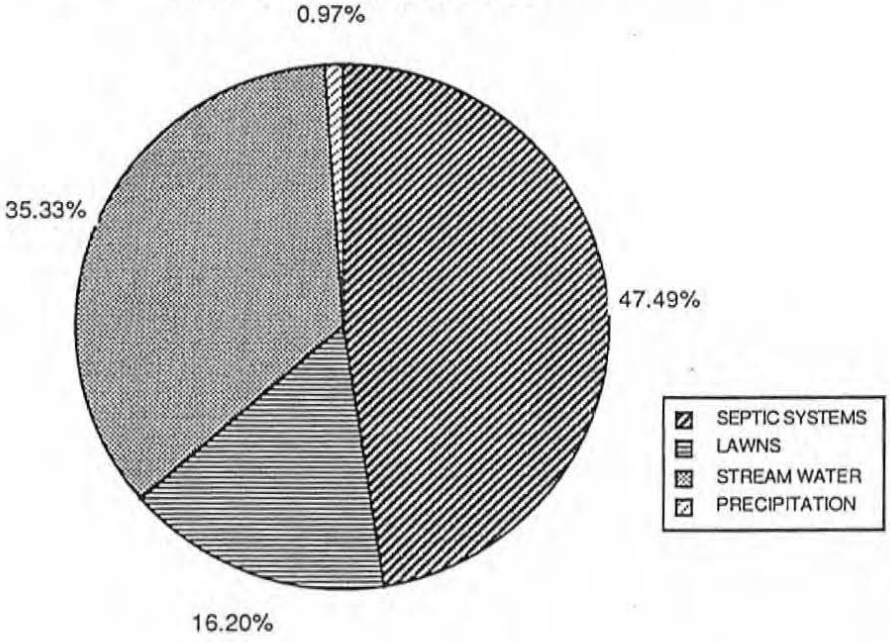


FIGURE 7. BUILDOUT SOURCES OF WATER FOR RAYMOND ROAD WELLFIELD

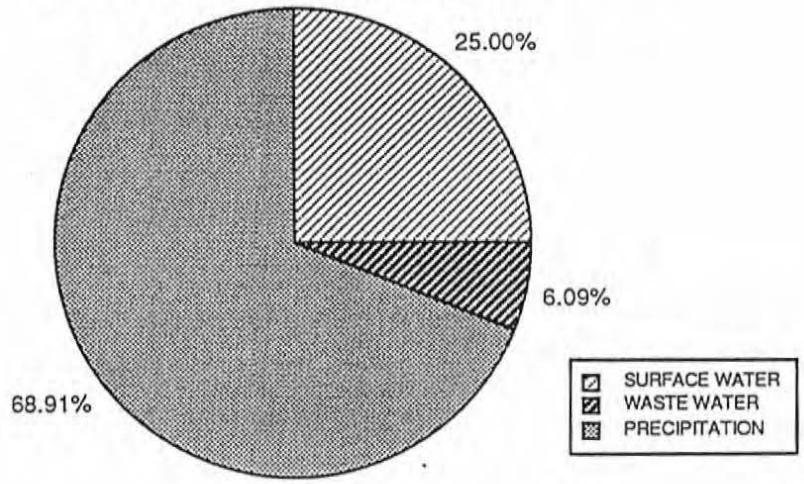
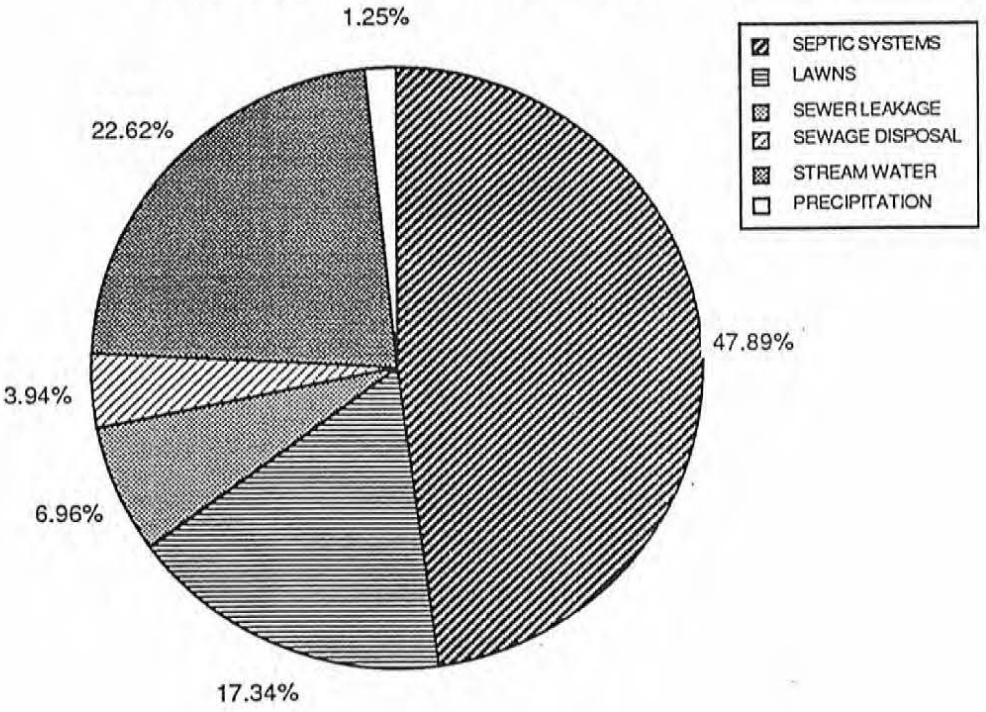


FIGURE 8. BUILDOUT SOURCES OF NITRATE
FOR RAYMOND ROAD WELL FIELD



APPENDIX C

ADDITIONAL NITROGEN LOADING ANALYSIS MODEL

(For 5 persons, 10,000 sf of lawn per future built house and 3 persons per existing house)

H_2O Engineering Consulting Associates, Inc.

水利工程顧問

6 Page Place Woburn, MA 01801
Telephone (617) 933-6961, 933-9369 Fax (617) 935-1877

March 24, 1994

Board of Water Commissioners
Sudbury Water District
199 Raymond Road
Sudbury, MA 01776

RE: Nitrate Loading Analysis

Gentlemen:

As requested, new sets of Nitrate Loading Analysis have been performed based on the five person per house and 10,000 square feet of lawn per new house.

For your convenience, the following are the tabulated results, along with detail tables of analysis enclosed:

NITRATE LOADING, in mg/l

	3 Person/House 5,000 sq. ft. Lawn Area		5 Person/House 10,000 sq. ft. Lawn Area	
Wellfield	Buildout	Calibrated	Buildout	Calibrated
Well 3, 8 & 10	4.2	3.27	4.6	3.5
Raymond Road	3.85	2.76	4.2	3.2

Should you have any questions, please call.

Very truly yours,

T. T Chiang

Edward T.T. Chiang, Ph.D., P.E.
President

Enclosure

Horsley & Witten, Inc.
Environmental Services
3179 Main St., Courthouse Square
Post Office Box 7
Barnstable, Massachusetts 02630
Telephone: 508.362.5570
Facsimile: 508.362.5335

3 March, 1994

Dr. Edward T.T. Chiang, P.E., President
H_2O Engineering Consulting Associates, Inc.
6 Page Place
Woburn, MA 01801

Dear Dr. Chiang:

Enclosed are new buildout calculations for the Raymond Road and East Street Wellfields. These were made with the change to 5 persons per house and 10,000 square feet of lawn per new house, as requested.

The resultant calculations do not approach the 5 mg/L recommended planning goal for nitrate concentration. Pie diagrams showing the sources of loading split between existing septic systems and the new larger septic systems and split between existing lawns and new larger lawns are included so that the impact of new housing characteristics could be easily differentiated from that caused by existing housing.

You will note that the spreadsheet model used to make these calculations has been expanded over the one used in the previous calculations in order to include a separate section for future development. Our time in revising the spreadsheets was not charged to this project. We revised the spreadsheet model rather than running the old models to provide the calculations because we anticipate that other communities and, perhaps, the DEP, Division of Water Supply will wish to make the same kinds of sensitivity analyses as Sudbury in the future.

Sincerely yours,

HORSLEY & WITTEN, INC.

Michael H. Frimpter, Ph.D., P.HG.

Enclosure

Barnstable, Massachusetts
Washington, District of Columbia
Seattle, Washington

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

LINE	LAND USE DATA INPUT	VALUES	COMMENTS
2	FUTURE DEVELOPMENT		
3	Total single family houses	281	Derived from land use regulations and assessors data
5	STP sewered single family houses	0	Derive from buildout and sewer service maps
7	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
9	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
11	Total multi-family units (persons)	0	Derive from census data and assessor's maps
13	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
15	Commercial/Industrial land (acres)	0	Derive from assessors data, includes schools and other municipal properties
17	Commercial/Industrial water use (gal/d)	0	Source: design capacity of septic systems or water bills; includes schools and municipal properties
19	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
21	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
23	CALIBRATION, %N remaining after attenuation	55	Adjustment developed from comparing existing N level in well with initially estimated N levels
25	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator
27	STP discharge N conc. (mg/l)	0.0	From Health Department or STP operator
29	Sewage collection system flows (gal/d)	0	Calculated
31	Lawn area per house (square feet)	10,000	From Planning Board
33	EXISTING DEVELOPMENT		
34	Total single family houses	1,180	Derived from land use regulations and assessors data
36	STP sewered single family houses	699	Derive from buildout and sewer service maps
38	Average number of persons per unit	3.0	Obtain from census data, Regional Planning Agency or CACI
40	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
42	Total multi-family units (persons)	360	Derive from census data and assessor's maps
44	STP sewered multi-family units (persons)	360	Derive from sewer service maps and assessor's maps
46	Commercial/Industrial land (acres)	0.0	Derive from assessors data, includes schools and other municipal properties
48	Commercial/Industrial water use (gal/d)	100,950	Source: design capacity of septic systems or water bills; includes schools and municipal properties
50	Com./Ind. STP sewage flow (gal/d)	850	Derive from above and sewer service maps
52	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
54	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
56	STP discharge in WHPA (gal/d)	50,000	From Health Department or STP operator

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

58	STP discharge N conc. (mg/l)	10	From Health Department or STP operator
59			
60	Sewage collection system flows (gal/d)	135,985	Calculated
61			
62	Landfills (acres)	0	From Health Department and/or maps and aerial photographs
63			
64	Lawn area per house (square feet)	5,000	New England 5,000 square feet, Planning Department may revise
65			
66	Lawn leach rate (lbs/ac/yr)	40	New England average is 40 lb/acre, Local planning or agricultural agencies may revise
67			
68	Agricultural crop A (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
69			
70	Agricultural crop A leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
71			
72	Agricultural crop B (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
73			
74	Agricultural crop B leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
75			
76	Pasture or range (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
77			
78	Pasture or range leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
79			
80	Herds (1,000 lbs of animals)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
81			
82	Herds (N production in lbs/1,000lbs/yr)		From local agricultural agencies or published references and records of application rates
83			
84	Fowl (1,000 birds)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
85			
86	Fowl (N production in lbs/1,000/yr)		From local agricultural agencies or published references and records of application rates
87			
88	Golf Course area (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
89			
90	Golf Course area leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
91			
92	**HYDROLOGIC DATA INPUT**		
93			
94	Total wellhead protection area (acres)	2,581	Planimeter from wellhead protection area map or GIS calculation
95			
96	Withdrawal Rate (mgd)	4.60	Use pumping rate that was used to delineate wellhead protection area (Zone II)
97			
98	Percent of withdrawal from surface water	25	Use same value that was used to delineate wellhead protection area (Zone II)
99			
100	N-conc. in Surface water (mg/l)	2.50	Average total N from chemical analyses of surface water recharge source(s)
101			
102	N-conc. in Precipitation (mg/l)	0.05	From National Atmospheric Data Project report
103			

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

104	NITROGEN LOADS		
105	FUTURE DEVELOPMENT		
106	Septic systems (lb/yr)	5,173	Calculated
107			
108	Lawns (lb/yr)	2,580	Calculated
109			
110	Sewage system leakage (lb/yr)	0	Calculated
111			
112	New total nitrogen load (lb/yr)	7,754	Calculated
113			
114	EXISTING DEVELOPMENT		
115	Septic systems (lb/yr)	15,362	Calculated
116			
117	Lawns (lb/yr)	5,418	Calculated
118			
119	Sewage system leakage (lb/yr)	2,690	Calculated
120			
121	Agriculture, crop A (lb/yr)	0	Calculated
122			
123	Agriculture, crop B (lb/yr)	0	Calculated
124			
125	Pasture and range (lb/yr)	0	Calculated
126			
127	Herds (lb/yr)	0	Calculated
128			
129	Fowl (lb/yr)	0	Calculated
130			
131	Golf courses (lb/yr)	0	Calculated
132			
133	Sewage disposal (lb/yr)	1,522	Calculated
134			
135	Landfills (lb/yr)	0	Calculated
136			
137	Surface water recharge (lb/yr)	8,749	Calculated
138			
139	Precipitation (lb/yr)	478	Calculated
140			
141	Existing total nitrogen load (lb/yr)	34,218	Computed sum
142			
143	WATER VOLUME		
144			
145	Recharge equals withdrawal (mgd)	4.60	Copied
146			
147	Surface water recharge (mgd)	1.15	Calculated
148			
149	Recharge from NEW wastewater (mgd)	0.08	Calculated
150			
151	Recharge from EXISTING wastewater (mgd)	0.23	Calculated
152			
153	Recharge from precipitation (mgd)	3.14	Calculated
154			
155	Recharge from precipitation (in/yr)	16.37	Compare to estimates by government agencies
156			
157			
158	NITROGEN CONCENTRATION (mg/l)	3.0	Compare to 10 mg/l Maximum Contaminant Level
159			

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

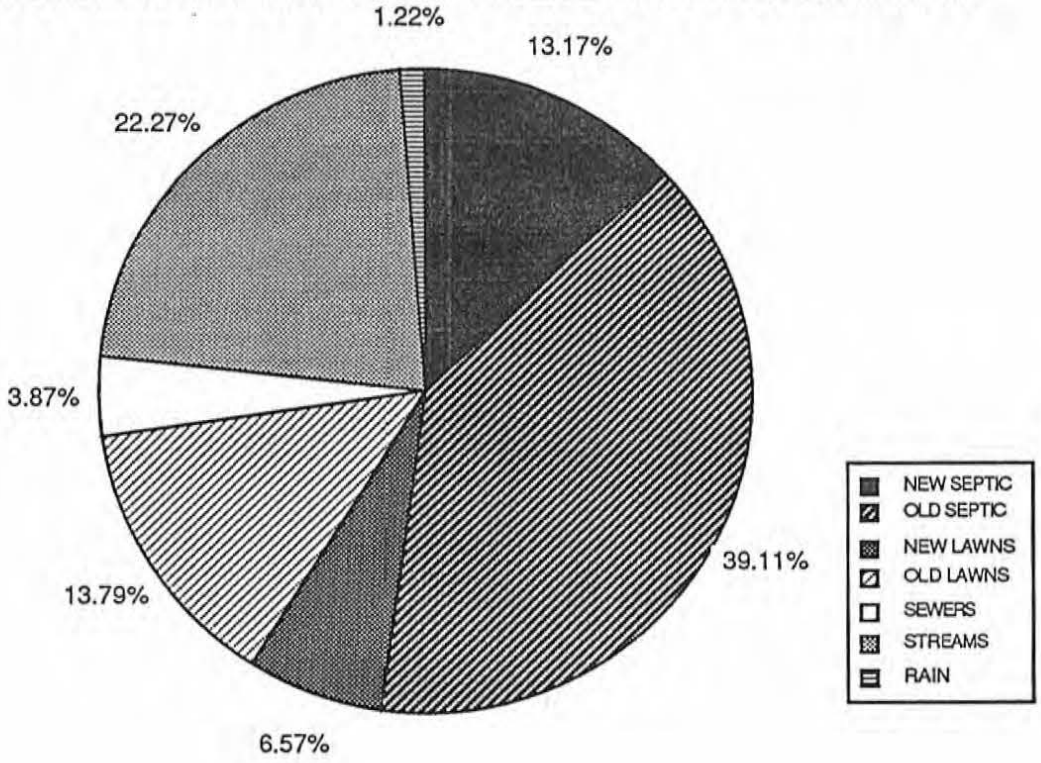
FOR WATER SOURCE PIE DIAGRAM

SURFACE WATER	1.15
WASTEWATER	0.31
PRECIPITATION	3.14

FOR NITROGEN SOURCE PIE DIAGRAM

NEW WASTEWATER	5,173.26
EXISTING WASTEWATER	15,361.80
NEW LAWNS	2,580.35
EXISTING LAWNS	5,417.81
AGRICULTURE	0.00
GOLF COURSES	0.00
SEWAGE COLLECTION AND TREATMENT	1,521.50
LANDFILLS	0.00
SURFACE WATER	8,748.64
PRECIPITATION	478.25

SOURCES OF NITRATE FOR RAYMOND ROAD WITH LARGER HOMES



NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

LINE	LAND USE DATA INPUT	VALUES	COMMENTS
2	FUTURE DEVELOPMENT		
3	Total single family houses	89	Derived from land use regulations and assessors data
5	STP sewered single family houses	0	Derive from buildout and sewer service maps
7	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
9	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
11	Total multi-family units (persons)	0	Derive from census data and assessor's maps
13	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
15	Commercial/Industrial land (acres)		Derive from assessors data, includes schools and other municipal properties
17	Commercial/Industrial water use (gal/d)	0	Source: design capacity of septic systems or water bills; includes schools and municipal properties
19	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
21	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
23	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
25	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator
27	STP discharge N conc. (mg/l)	0.0	From Health Department or STP operator
29	Sewage collection system flows (gal/d)	0	Calculated
31	Lawn area per house (square feet)	10,000	From Planning Board
33	EXISTING DEVELOPMENT		
34	Total single family houses	598	Derived from land use regulations and assessors data
36	STP sewered single family houses	0	Derive from buildout and sewer service maps
38	Average number of persons per unit	3.0	Obtain from census data, Regional Planning Agency or CACI
40	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
42	Total multi-family units (persons)	0	Derive from census data and assessor's maps
44	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
46	Commercial/Industrial land (acres)	0.0	Derive from assessors data, includes schools and other municipal properties
48	Commercial/Industrial water use (gal/d)	7,937	Source: design capacity of septic systems or water bills; includes schools and municipal properties
50	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
52	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
54	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
56	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator

NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

58	STP discharge N conc. (mg/l)	0	From Health Department or STP operator
59			
60	Sewage collection system flows (gal/d)	0	Calculated
61			
62	Landfills (acres)	0	From Health Department and/or maps and aerial photographs
63			
64	Lawn area per house (square feet)	5,000	New England 5,000 square feet, Planning Department may revise
65			
66	Lawn leach rate (lbs/ac/yr)	40	New England average is 40 lb/acre, Local planning or agricultural agencies may revise
67			
68	Agricultural crop A (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
69			
70	Agricultural crop A leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
71			
72	Agricultural crop B (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
73			
74	Agricultural crop B leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
75			
76	Pasture or range (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
77			
78	Pasture or range leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
79			
80	Herds (1,000 lbs of animals)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
81			
82	Herds (N production in lbs/1,000lbs/yr)		From local agricultural agencies or published references and records of application rates
83			
84	Fowl (1,000 birds)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
85			
86	Fowl (N production in lbs/1,000/yr)		From local agricultural agencies or published references and records of application rates
87			
88	Golf Course area (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
89			
90	Golf Course area leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
91			
92	**HYDROLOGIC DATA INPUT**		
93			
94	Total wellhead protection area (acres)	1,091	Planimeter from wellhead protection area map or GIS calculation
95			
96	Withdrawal Rate (mgd)	1.90	Use pumping rate that was used to delineate wellhead protection area (Zone II)
97			
98	Percent of withdrawal from surface water	30	Use same value that was used to delineate wellhead protection area (Zone II)
99			
100	N-conc. in Surface water (mg/l)	3.85	Average total N from chemical analyses of surface water recharge source(s)
101			
102	N-conc. in Precipitation (mg/l)	0.05	From National Atmospheric Data Project report
103			

NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

104	**NITROGEN LOADS**		
105	FUTURE DEVELOPMENT		
106	Septic systems (lb/yr)	1,862	Calculated
107			
108	Lawns (lb/yr)	817	Calculated
109			
110	Sewage system leakage (lb/yr)	0	Calculated
111			
112	New total nitrogen load (lb/yr)	2,679	Calculated
113			
114	EXISTING DEVELOPMENT		
115	Septic systems (lb/yr)	8,110	Calculated
116			
117	Lawns (lb/yr)	2,746	Calculated
118			
119	Sewage system leakage (lb/yr)	0	Calculated
120			
121	Agriculture, crop A (lb/yr)	0	Calculated
122			
123	Agriculture, crop B (lb/yr)	0	Calculated
124			
125	Pasture and range (lb/yr)	0	Calculated
126			
127	Herds (lb/yr)	0	Calculated
128			
129	Fowl (lb/yr)	0	Calculated
130			
131	Golf courses (lb/yr)	0	Calculated
132			
133	Sewage disposal (lb/yr)	0	Calculated
134			
135	Landfills (lb/yr)	0	Calculated
136			
137	Surface water recharge (lb/yr)	6,678	Calculated
138			
139	Precipitation (lb/yr)	182	Calculated
140			
141	Existing total nitrogen load (lb/yr)	17,716	Computed sum
142			
143	**WATER VOLUME**		
144			
145	Recharge equals withdrawal (mgd)	1.90	Copied
146			
147	Surface water recharge (mgd)	0.57	Calculated
148			
149	Recharge from NEW wastewater (mgd)	0.02	Calculated
150			
151	Recharge from EXISTING wastewater (mgd)	0.11	Calculated
152			
153	Recharge from precipitation (mgd)	1.20	Calculated
154			
155	Recharge from precipitation (in/yr)	14.77	Compare to estimates by government agencies
156			
157			
158	NITROGEN CONCENTRATION (mg/l)	3.5	Compare to 10 mg/l Maximum Contaminant Level
159			

NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

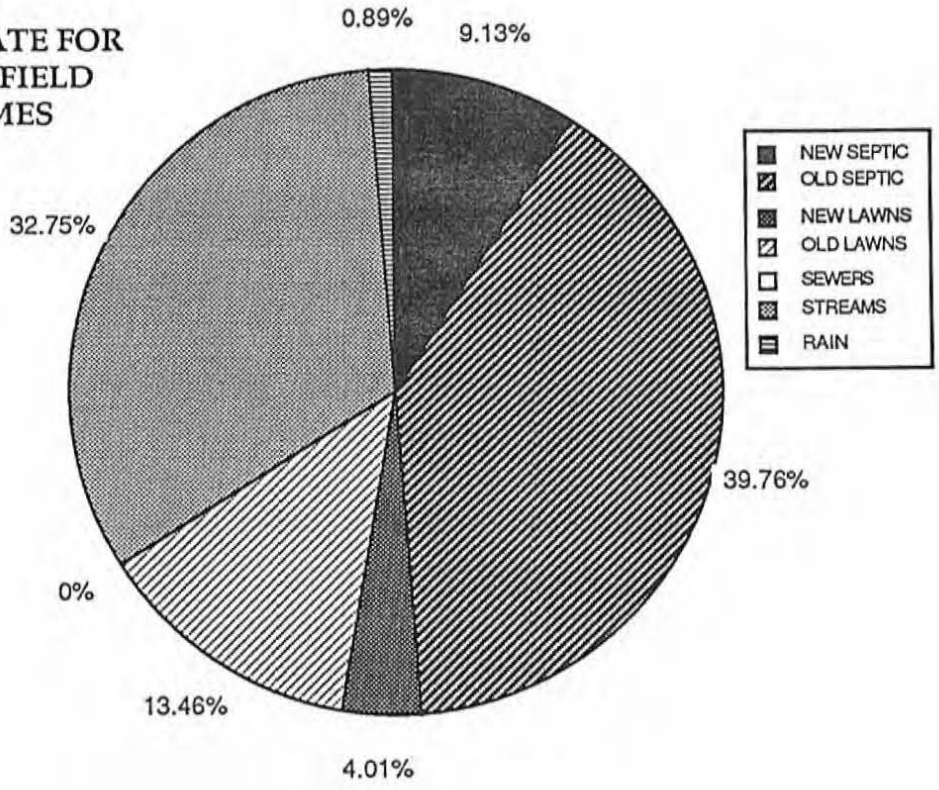
FOR WATER SOURCE PIE DIAGRAM

SURFACE WATER	0.57
WASTEWATER	0.13
PRECIPITATION	1.20

FOR NITROGEN SOURCE PIE DIAGRAM

NEW WASTEWATER	1,861.94
EXISTING WASTEWATER	8,110.15
NEW LAWNS	817.26
EXISTING LAWNS	2,745.64
AGRICULTURE	0.00
GOLF COURSES	0.00
SEWAGE COLLECTION AND TREATMENT	0.00
LANDFILLS	0.00
SURFACE WATER	6,677.88
PRECIPITATION	182.42

SOURCES OF NITRATE FOR EAST STREET WELLFIELD WITH LARGER HOMES



Horsley & Witten, Inc.
Environmental Services
3179 Main St., Courthouse Square
Post Office Box 7
Barnstable, Massachusetts 02630
Telephone: 508.362.5570
Facsimile: 508.362.5335

18 March, 1994

Dr. Edward T.T. Chiang, P.E., President
H_2O Engineering Consulting Associates, Inc.
6 Page Place
Woburn, MA 01801

Dear Dr. Chiang:

I have reviewed the model spreadsheets submitted on March 3 for the new buildout with larger lawns and greater occupancy rates for new homes and did find an input error in one of the calculations. On line 23 in the Raymond Road model the value 55 was entered instead of 63. This error resulted in an estimate of 3.0 mg/L rather than 3.2 mg/L, the correct estimate. A corrected and recalculated model run is enclosed to replace the one I sent on March 3. However, this does not address the problem perceived by the Sudbury Water District.

I think I have identified the source of the problem you and the District are having with these new calculations. It would seem that you were comparing the new calculations, that were made with the calibrated model, to calculations made before the model was calibrated. This is kind of like comparing apples to oranges. Because the new calculations were done with the calibrated model they should be compared to tables 18 and 19 that were made with the calibrated model our original report. The new nitrate concentrations are then 3.5 mg/L as compared to 3.27 mg/L for the East Street wells and 3.2 mg/L as compared to 2.76 mg/L for the Raymond Road wells.

In order to further explain these differences, I have recalculated and enclosed these new (bigger house and lawn) nitrate loadings *without* the calibration factor. These calculations of 4.6 mg/L for the East Street wells and 4.2 mg/L for the Raymond Road wells may be compared to the calculations for current conditions (3.91 mg/L and 3.35 mg/L) and buildout conditions (4.2 mg/L and 3.85 mg/L) before calibration. In every case the nitrate concentration increases under the new conditions of greater occupancy and larger lawns.

The calibrated model is adjusted for the difference between the measured nitrate concentrations from the well water and the initially modeled nitrate calculations. A part of this difference is attributed to renovation of the wastewater that occurs between the bottom of the septic leaching facility and the water table (the separation required by

Title 5). Because the renovation reduces the nitrate concentration of wastewater that becomes ground water, the estimates with the calibrated model should be compared only to other calculations with the calibrated model. The calibrated model is intended to be a more realistic representation of conditions in Sudbury.

If needed, I could meet with the District and explain the calibrated model in more detail, but it is described in our report. The good news is that even without calibration, the 5 mg/L planning goal for nitrate concentration is not exceeded.

Sincerely yours,

HORSLEY & WITTEN, INC.

Michael H. Frimpter, Ph.D., P.HG.

Enclosures

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

LINE	LAND USE DATA INPUT	VALUES	COMMENTS
2	**FUTURE DEVELOPMENT**		
3	Total single family houses	281	Derived from land use regulations and assessors data
5	STP sewered single family houses	0	Derive from buildout and sewer service maps
7	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
9	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
11	Total multi-family units (persons)	0	Derive from census data and assessor's maps
13	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
15	Commercial/Industrial land (acres)	0	Derive from assessors data, includes schools and other municipal properties
17	Commercial/Industrial water use (gal/d)	0	Source: design capacity of septic systems or water bills; includes schools and municipal properties
19	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
21	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
23	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
25	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator
27	STP discharge N conc. (mg/l)	0.0	From Health Department or STP operator
29	Sewage collection system flows (gal/d)	0	Calculated
31	Lawn area per house (square feet)	10,000	From Planning Board
33	**EXISTING DEVELOPMENT**		
34	Total single family houses	1,180	Derived from land use regulations and assessors data
36	STP sewered single family houses	699	Derive from buildout and sewer service maps
38	Average number of persons per unit	3.0	Obtain from census data, Regional Planning Agency or CACI
40	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
42	Total multi-family units (persons)	360	Derive from census data and assessor's maps
44	STP sewered multi-family units (persons)	360	Derive from sewer service maps and assessor's maps
46	Commercial/Industrial land (acres)	0.0	Derive from assessors data, includes schools and other municipal properties
48	Commercial/Industrial water use (gal/d)	100,950	Source: design capacity of septic systems or water bills; includes schools and municipal properties
50	Com./Ind. STP sewage flow (gal/d)	850	Derive from above and sewer service maps
52	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
54	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
56	STP discharge in WHPA (gal/d)	50,000	From Health Department or STP operator

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

58	STP discharge N conc. (mg/l)	10	From Health Department or STP operator
59			
60	Sewage collection system flows (gal/d)	135,985	Calculated
61			
62	Landfills (acres)	0	From Health Department and/or maps and aerial photographs
63			
64	Lawn area per house (square feet)	5,000	New England 5,000 square feet, Planning Department may revise
65			
66	Lawn leach rate (lbs/ac/yr)	40	New England average is 40 lb/acre, Local planning or agricultural agencies may revise
67			
68	Agricultural crop A (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
69			
70	Agricultural crop A leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
71			
72	Agricultural crop B (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
73			
74	Agricultural crop B leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
75			
76	Pasture or range (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
77			
78	Pasture or range leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
79			
80	Herds (1,000 lbs of animals)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
81			
82	Herds (N production in lbs/1,000lbs/yr)		From local agricultural agencies or published references and records of application rates
83			
84	Fowl (1,000 birds)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
85			
86	Fowl (N production in lbs/1,000/yr)		From local agricultural agencies or published references and records of application rates
87			
88	Golf Course area (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
89			
90	Golf Course area leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
91			
92	**HYDROLOGIC DATA INPUT**		
93			
94	Total wellhead protection area (acres)	2,581	Planimeter from wellhead protection area map or GIS calculation
95			
96	Withdrawal Rate (mgd)	4.60	Use pumping rate that was used to delineate wellhead protection area (Zone II)
97			
98	Percent of withdrawal from surface water	25	Use same value that was used to delineate wellhead protection area (Zone II)
99			
100	N-conc. in Surface water (mg/l)	2.50	Average total N from chemical analyses of surface water recharge source(s)
101			
102	N-conc. in Precipitation (mg/l)	0.05	From National Atmospheric Data Project report
103			

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

104	**NITROGEN LOADS**		
105	FUTURE DEVELOPMENT		
106	Septic systems (lb/yr)	5,926	Calculated
107			
108	Lawns (lb/yr)	2,580	Calculated
109			
110	Sewage system leakage (lb/yr)	0	Calculated
111			
112	New total nitrogen load (lb/yr)	8,506	Calculated
113			
114	EXISTING DEVELOPMENT		
115	Septic systems (lb/yr)	17,596	Calculated
116			
117	Lawns (lb/yr)	5,418	Calculated
118			
119	Sewage system leakage (lb/yr)	2,690	Calculated
120			
121	Agriculture, crop A (lb/yr)	0	Calculated
122			
123	Agriculture, crop B (lb/yr)	0	Calculated
124			
125	Pasture and range (lb/yr)	0	Calculated
126			
127	Herds (lb/yr)	0	Calculated
128			
129	Fowl (lb/yr)	0	Calculated
130			
131	Golf courses (lb/yr)	0	Calculated
132			
133	Sewage disposal (lb/yr)	1,522	Calculated
134			
135	Landfills (lb/yr)	0	Calculated
136			
137	Surface water recharge (lb/yr)	8,749	Calculated
138			
139	Precipitation (lb/yr)	478	Calculated
140			
141	Existing total nitrogen load (lb/yr)	36,452	Computed sum
142			
143	**WATER VOLUME**		
144			
145	Recharge equals withdrawal (mgd)	4.60	Copied
146			
147	Surface water recharge (mgd)	1.15	Calculated
148			
149	Recharge from NEW wastewater (mgd)	0.08	Calculated
150			
151	Recharge from EXISTING wastewater (mgd)	0.23	Calculated
152			
153	Recharge from precipitation (mgd)	3.14	Calculated
154			
155	Recharge from precipitation (in/yr)	16.37	Compare to estimates by government agencies
156			
157			
158	NITROGEN CONCENTRATION (mg/l)	3.2	Compare to 10 mg/l Maximum Contaminant Level
159			

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

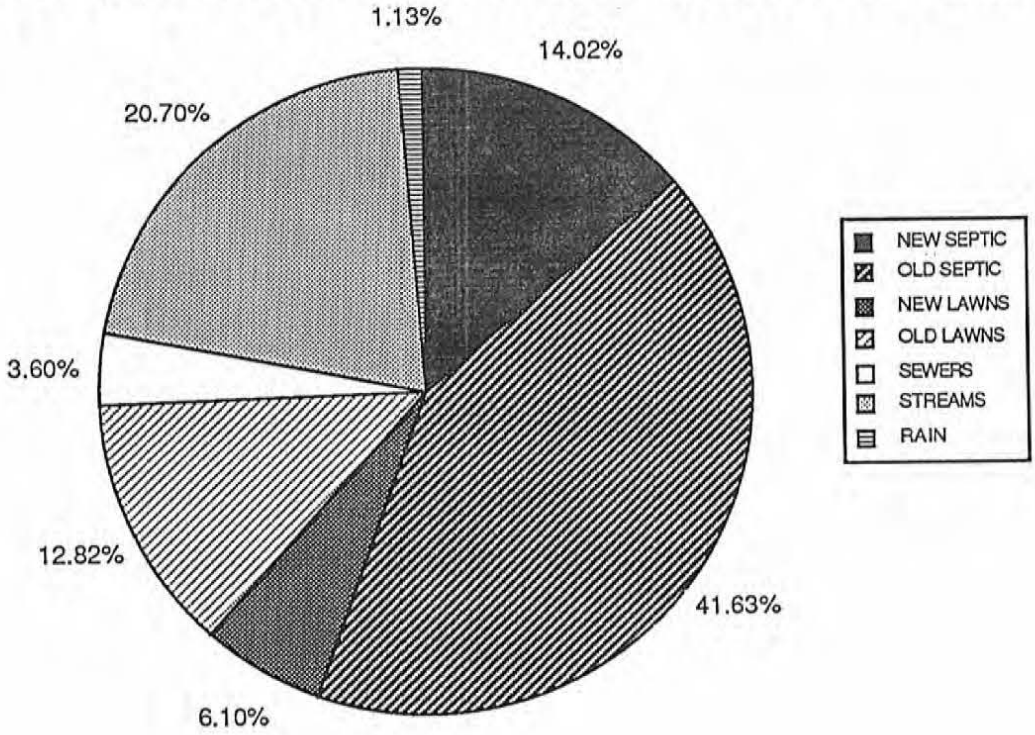
FOR WATER SOURCE PIE DIAGRAM

SURFACE WATER	1.15
WASTEWATER	0.31
PRECIPITATION	3.14

FOR NITROGEN SOURCE PIE DIAGRAM

NEW WASTEWATER	5,925.74
EXISTING WASTEWATER	17,596.24
NEW LAWNS	2,580.35
EXISTING LAWNS	5,417.81
AGRICULTURE	0.00
GOLF COURSES	0.00
SEWAGE COLLECTION AND TREATMENT	1,521.50
LANDFILLS	0.00
SURFACE WATER	8,748.64
PRECIPITATION	478.25

SOURCES OF NITRATE FOR RAYMOND ROAD WITH LARGER HOMES



NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

LINE	LAND USE DATA INPUT	VALUES	COMMENTS
2	FUTURE DEVELOPMENT		
3	Total single family houses	281	Derived from land use regulations and assessors data
4			
5	STP sewered single family houses	0	Derive from buildout and sewer service maps
6			
7	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
8			
9	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
10			
11	Total multi-family units (persons)	0	Derive from census data and assessor's maps
12			
13	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
14			
15	Commercial/Industrial land (acres)	0	Derive from assessors data, includes schools and other municipal properties
16			
17	Commercial/Industrial water use (gal/d)	0	Source: design capacity of septic systems or water bills; includes schools and municipal properties
18			
19	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
20			
21	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
22			
23	CALIBRATION, %N remaining after attenuation	100	Adjustment developed from comparing existing N level in well with initially estimated N levels
24			
25	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator
26			
27	STP discharge N conc. (mg/l)	0.0	From Health Department or STP operator
28			
29	Sewage collection system flows (gal/d)	0	Calculated
30			
31	Lawn area per house (square feet)	10,000	From Planning Board
32			
33	EXISTING DEVELOPMENT		
34	Total single family houses	1,180	Derived from land use regulations and assessors data
35			
36	STP sewered single family houses	699	Derive from buildout and sewer service maps
37			
38	Average number of persons per unit	3.0	Obtain from census data, Regional Planning Agency or CACI
39			
40	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
41			
42	Total multi-family units (persons)	360	Derive from census data and assessor's maps
43			
44	STP sewered multi-family units (persons)	360	Derive from sewer service maps and assessor's maps
45			
46	Commercial/Industrial land (acres)	0.0	Derive from assessors data, includes schools and other municipal properties
47			
48	Commercial/Industrial water use (gal/d)	100,950	Source: design capacity of septic systems or water bills; includes schools and municipal properties
49			
50	Com./Ind. STP sewage flow (gal/d)	850	Derive from above and sewer service maps
51			
52	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
53			
54	CALIBRATION, %N remaining after attenuation	100	Adjustment developed from comparing existing N level in well with initially estimated N levels
55			
56	STP discharge in WHPA (gal/d)	50,000	From Health Department or STP operator
57			

NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

58	STP discharge N conc. (mg/l)	10	From Health Department or STP operator
59			
60	Sewage collection system flows (gal/d)	135,985	Calculated
61			
62	Landfills (acres)	0	From Health Department and/or maps
63			and aerial photographs
64	Lawn area per house (square feet)	5,000	New England 5,000 square feet, Planning Depart-
65			ment may revise
66	Lawn leach rate (lbs/ac/yr)	40	New England average is 40 lb/acre, Local
67			planning or agricultural agencies may revise
68	Agricultural crop A (acres)	0.0	Derive from assessors data and aerial photos
69			and agricultural agencies, such as SCS
70	Agricultural crop A leach rate (lbs/ac/yr)		From local agricultural agencies or published
71			references and records of application rates
72	Agricultural crop B (acres)	0.0	Derive from assessors data and aerial photos
73			and agricultural agencies, such as SCS
74	Agricultural crop B leach rate (lbs/ac/yr)		From local agricultural agencies or published
75			references and records of application rates
76	Pasture or range (acres)	0.0	Derive from assessors data and aerial photos
77			and agricultural agencies, such as SCS
78	Pasture or range leach rate (lbs/ac/yr)		From local agricultural agencies or published
79			references and records of application rates
80	Herds (1,000 lbs of animals)	0.0	Derive from assessors data and aerial photos
81			and agricultural agencies, such as SCS
82	Herds (N production in lbs/1,000lbs/yr)		From local agricultural agencies or published
83			references and records of application rates
84	Fowl (1,000 birds)	0.0	Derive from assessors data and aerial photos
85			and agricultural agencies, such as SCS
86	Fowl (N production in lbs/1,000/yr)		From local agricultural agencies or published
87			references and records of application rates
88	Golf Course area (acres)	0.0	Derive from assessors data and aerial photos
89			and agricultural agencies, such as SCS
90	Golf Course area leach rate (lbs/ac/yr)		From local agricultural agencies or published
91			references and records of application rates
92	HYDROLOGIC DATA INPUT		
93			
94	Total wellhead protection area (acres)	2,581	Planimeter from wellhead protection area map
95			or GIS calculation
96	Withdrawal Rate (mgd)	4.60	Use pumping rate that was used to delineate
97			wellhead protection area (Zone II)
98	Percent of withdrawal from surface water	25	Use same value that was used to delineate
99			wellhead protection area (Zone II)
100	N-conc. in Surface water (mg/l)	2.50	Average total N from chemical analyses of
101			surface water recharge source(s)
102	N-conc. in Precipitation (mg/l)	0.05	From National Atmospheric Data Project report
103			

NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

104	**NITROGEN LOADS**		
105	FUTURE DEVELOPMENT		
106	Septic systems (lb/yr)	9,406	Calculated
107			
108	Lawns (lb/yr)	2,580	Calculated
109			
110	Sewage system leakage (lb/yr)	0	Calculated
111			
112	New total nitrogen load (lb/yr)	11,986	Calculated
113			
114	EXISTING DEVELOPMENT		
115	Septic systems (lb/yr)	27,931	Calculated
116			
117	Lawns (lb/yr)	5,418	Calculated
118			
119	Sewage system leakage (lb/yr)	2,690	Calculated
120			
121	Agriculture, crop A (lb/yr)	0	Calculated
122			
123	Agriculture, crop B (lb/yr)	0	Calculated
124			
125	Pasture and range (lb/yr)	0	Calculated
126			
127	Herds (lb/yr)	0	Calculated
128			
129	Fowl (lb/yr)	0	Calculated
130			
131	Golf courses (lb/yr)	0	Calculated
132			
133	Sewage disposal (lb/yr)	1,522	Calculated
134			
135	Landfills (lb/yr)	0	Calculated
136			
137	Surface water recharge (lb/yr)	8,749	Calculated
138			
139	Precipitation (lb/yr)	478	Calculated
140			
141	Existing total nitrogen load (lb/yr)	46,786	Computed sum
142			
143	**WATER VOLUME**		
144			
145	Recharge equals withdrawal (mgd)	4.60	Copied
146			
147	Surface water recharge (mgd)	1.15	Calculated
148			
149	Recharge from NEW wastewater (mgd)	0.08	Calculated
150			
151	Recharge from EXISTING wastewater (mgd)	0.23	Calculated
152			
153	Recharge from precipitation (mgd)	3.14	Calculated
154			
155	Recharge from precipitation (in/yr)	16.37	Compare to estimates by government agencies
156			
157			
158	**NITROGEN CONCENTRATION (mg/l)**	4.2	Compare to 10 mg/l Maximum Contaminant Level
159			

NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: RAYMOND ROAD WELLFIELD
with 5 persons and 10,000 sq. ft. lawn per new house

FOR WATER SOURCE PIE DIAGRAM

SURFACE WATER	1.15
WASTEWATER	0.31
PRECIPITATION	3.14

FOR NITROGEN SOURCE PIE DIAGRAM

NEW WASTEWATER	9,405.93
EXISTING WASTEWATER	27,930.54
NEW LAWNS	2,580.35
EXISTING LAWNS	5,417.81
AGRICULTURE	0.00
GOLF COURSES	0.00
SEWAGE COLLECTION AND TREATMENT	1,521.50
LANDFILLS	0.00
SURFACE WATER	8,748.64
PRECIPITATION	478.25

NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

LINE	LAND USE DATA INPUT	VALUES	COMMENTS
2	FUTURE DEVELOPMENT		
3	Total single family houses	89	Derived from land use regulations and assessors data
5	STP sewered single family houses	0	Derive from buildout and sewer service maps
7	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
9	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
11	Total multi-family units (persons)	0	Derive from census data and assessor's maps
13	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
15	Commercial/Industrial land (acres)		Derive from assessors data, includes schools and other municipal properties
17	Commercial/Industrial water use (gal/d)	0	Source: design capacity of septic systems or water bills; includes schools and municipal properties
19	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
21	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
23	CALIBRATION, %N remaining after attenuation	100	Adjustment developed from comparing existing N level in well with initially estimated N levels
25	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator
27	STP discharge N conc. (mg/l)	0.0	From Health Department or STP operator
29	Sewage collection system flows (gal/d)	0	Calculated
31	Lawn area per house (square feet)	10,000	From Planning Board
33	EXISTING DEVELOPMENT		
34	Total single family houses	598	Derived from land use regulations and assessors data
36	STP sewered single family houses	0	Derive from buildout and sewer service maps
38	Average number of persons per unit	3.0	Obtain from census data, Regional Planning Agency or CACI
40	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
42	Total multi-family units (persons)	0	Derive from census data and assessor's maps
44	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
46	Commercial/Industrial land (acres)	0.0	Derive from assessors data, includes schools and other municipal properties
48	Commercial/Industrial water use (gal/d)	7,937	Source: design capacity of septic systems or water bills; includes schools and municipal properties
50	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
52	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
54	CALIBRATION, %N remaining after attenuation	100	Adjustment developed from comparing existing N level in well with initially estimated N levels
56	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator

NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

58	STP discharge N conc. (mg/l)	0	From Health Department or STP operator
59			
60	Sewage collection system flows (gal/d)	0	Calculated
61			
62	Landfills (acres)	0	From Health Department and/or maps
63			and aerial photographs
64	Lawn area per house (square feet)	5,000	New England 5,000 square feet, Planning Depart-
65			ment may revise
66	Lawn leach rate (lbs/ac/yr)	40	New England average is 40 lb/acre, Local
67			planning or agricultural agencies may revise
68	Agricultural crop A (acres)	0.0	Derive from assessors data and aerial photos
69			and agricultural agencies, such as SCS
70	Agricultural crop A leach rate (lbs/ac/yr)		From local agricultural agencies or published
71			references and records of application rates
72	Agricultural crop B (acres)	0.0	Derive from assessors data and aerial photos
73			and agricultural agencies, such as SCS
74	Agricultural crop B leach rate (lbs/ac/yr)		From local agricultural agencies or published
75			references and records of application rates
76	Pasture or range (acres)	0.0	Derive from assessors data and aerial photos
77			and agricultural agencies, such as SCS
78	Pasture or range leach rate (lbs/ac/yr)		From local agricultural agencies or published
79			references and records of application rates
80	Herds (1,000 lbs of animals)	0.0	Derive from assessors data and aerial photos
81			and agricultural agencies, such as SCS
82	Herds (N production in lbs/1,000lbs/yr)		From local agricultural agencies or published
83			references and records of application rates
84	Fowl (1,000 birds)	0.0	Derive from assessors data and aerial photos
85			and agricultural agencies, such as SCS
86	Fowl (N production in lbs/1,000/yr)		From local agricultural agencies or published
87			references and records of application rates
88	Golf Course area (acres)	0.0	Derive from assessors data and aerial photos
89			and agricultural agencies, such as SCS
90	Golf Course area leach rate (lbs/ac/yr)		From local agricultural agencies or published
91			references and records of application rates
92	**HYDROLOGIC DATA INPUT**		
93			
94	Total wellhead protection area (acres)	1,091	Planimeter from wellhead protection area map
95			or GIS calculation
96	Withdrawal Rate (mgd)	1.90	Use pumping rate that was used to delineate
97			wellhead protection area (Zone II)
98	Percent of withdrawal from surface water	30	Use same value that was used to delineate
99			wellhead protection area (Zone II)
100	N-conc. in Surface water (mg/l)	3.85	Average total N from chemical analyses of
101			surface water recharge source(s)
102	N-conc. in Precipitation (mg/l)	0.05	From National Atmospheric Data Project report
103			

NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

104	**NITROGEN LOADS**		
105	FUTURE DEVELOPMENT		
106	Septic systems (lb/yr)	2,979	Calculated
107			
108	Lawns (lb/yr)	817	Calculated
109			
110	Sewage system leakage (lb/yr)	0	Calculated
111			
112	New total nitrogen load (lb/yr)	3,796	Calculated
113			
114	EXISTING DEVELOPMENT		
115	Septic systems (lb/yr)	12,976	Calculated
116			
117	Lawns (lb/yr)	2,746	Calculated
118			
119	Sewage system leakage (lb/yr)	0	Calculated
120			
121	Agriculture, crop A (lb/yr)	0	Calculated
122			
123	Agriculture, crop B (lb/yr)	0	Calculated
124			
125	Pasture and range (lb/yr)	0	Calculated
126			
127	Herds (lb/yr)	0	Calculated
128			
129	Fowl (lb/yr)	0	Calculated
130			
131	Golf courses (lb/yr)	0	Calculated
132			
133	Sewage disposal (lb/yr)	0	Calculated
134			
135	Landfills (lb/yr)	0	Calculated
136			
137	Surface water recharge (lb/yr)	6,678	Calculated
138			
139	Precipitation (lb/yr)	182	Calculated
140			
141	Existing total nitrogen load (lb/yr)	22,582	Computed sum
142			
143	**WATER VOLUME**		
144			
145	Recharge equals withdrawal (mgd)	1.90	Copied
146			
147	Surface water recharge (mgd)	0.57	Calculated
148			
149	Recharge from NEW wastewater (mgd)	0.02	Calculated
150			
151	Recharge from EXISTING wastewater (mgd)	0.11	Calculated
152			
153	Recharge from precipitation (mgd)	1.20	Calculated
154			
155	Recharge from precipitation (in/yr)	14.77	Compare to estimates by government agencies
156			
157			
158	NITROGEN CONCENTRATION (mg/l)	4.6	Compare to 10 mg/l Maximum Contaminant Level
159			

NITRATE LOADING IN ZONE II
WITHOUT CALIBRATION
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons and 10,000 sq. ft. per new house

FOR WATER SOURCE PIE DIAGRAM

SURFACE WATER	0.57
WASTEWATER	0.13
PRECIPITATION	1.20

FOR NITROGEN SOURCE PIE DIAGRAM

NEW WASTEWATER	2,979.10
EXISTING WASTEWATER	12,976.23
NEW LAWNS	817.26
EXISTING LAWNS	2,745.64
AGRICULTURE	0.00
GOLF COURSES	0.00
SEWAGE COLLECTION AND TREATMENT	0.00
LANDFILLS	0.00
SURFACE WATER	6,677.88
PRECIPITATION	182.42

APPENDIX D

ADDITIONAL NITROGEN LOADING ANALYSIS MODEL

(For 5 persons, 10,000 sf of lawn per house)

Horsley & Witten, Inc.
Environmental Services
3179 Main St., Courthouse Square
Post Office Box 7
Barnstable, Massachusetts 02630
Telephone: 508.362.5570
Facsimile: 508.362.5335

31 March, 1994

Dr. Edward T.T. Chiang, P.E., President
H_2O Engineering Consulting Associates, Inc.
6 Page Place
Woburn, MA 01801

Dear Dr. Chiang:

In response to the request of the Sudbury Water District (Bob Sheldon) for another set of model runs for the Raymond Road and East Street wellfields we have prepared the enclosed model spreadsheets and pie diagrams. Bob wanted the results as soon as possible and asked me to FAX the results to the District, which I have done.

These runs are prepared with the assumption that demographics change to the point that the average occupancy of homes in Sudbury increases to 5 in existing, as well as new homes. We did not make a similar change for homes in Framingham, but they are on the sewer system and the impact from such a change in Framingham would be relatively small.

Sincerely yours,

HORSLEY & WITTEN, INC.

Michael H. Frimpter, Ph.D., P.HG.

Enclosures

Barnstable, Massachusetts
Washington, District of Columbia
Seattle, Washington

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons per home in Sudbury, 3 per home in Framingham and 10,000 sq. ft. lawn per new house

LINE	LAND USE DATA INPUT	VALUES	COMMENTS
2	FUTURE DEVELOPMENT		
3	Total single family houses	281	Derived from land use regulations and assessors data
5	STP sewered single family houses	0	Derive from buildout and sewer service maps
7	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
9	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
11	Total multi-family units (persons)	0	Derive from census data and assessor's maps
13	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
15	Commercial/Industrial land (acres)	0	Derive from assessors data, includes schools and other municipal properties
17	Commercial/Industrial water use (gal/d)	0	Source: design capacity of septic systems or water bills; includes schools and municipal properties
19	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
21	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
23	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
25	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator
27	STP discharge N conc. (mg/l)	0.0	From Health Department or STP operator
29	Sewage collection system flows (gal/d)	0	Calculated
31	Lawn area per house (square feet)	10,000	From Planning Board
33	EXISTING DEVELOPMENT		
34	Total single family houses	1,180	Derived from land use regulations and assessors data
36	STP sewered single family houses	699	Derive from buildout and sewer service maps
38	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
40	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
42	Total multi-family units (persons)	360	Derive from census data and assessor's maps
44	STP sewered multi-family units (persons)	360	Derive from sewer service maps and assessor's maps
46	Commercial/Industrial land (acres)	0.0	Derive from assessors data, includes schools and other municipal properties
48	Commercial/Industrial water use (gal/d)	100,950	Source: design capacity of septic systems or water bills; includes schools and municipal properties
50	Com./Ind. STP sewage flow (gal/d)	850	Derive from above and sewer service maps
52	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
54	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
56	STP discharge in WHPA (gal/d)	50,000	From Health Department or STP operator

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons per home in Sudbury, 3 per home in Framingham and 10,000 sq. ft. lawn per new house

57			
58	STP discharge N conc. (mg/l)	10	From Health Department or STP operator
59			
60	Sewage collection system flows (gal/d)	135,985	Calculated w/ 3 persons per home (Framingham)
61			
62	Landfills (acres)	0	From Health Department and/or maps and aerial photographs
63			
64	Lawn area per house (square feet)	5,000	New England 5,000 square feet, Planning Department may revise
65			
66	Lawn leach rate (lbs/ac/yr)	40	New England average is 40 lb/acre, Local planning or agricultural agencies may revise
67			
68	Agricultural crop A (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
69			
70	Agricultural crop A leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
71			
72	Agricultural crop B (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
73			
74	Agricultural crop B leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
75			
76	Pasture or range (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
77			
78	Pasture or range leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
79			
80	Herds (1,000 lbs of animals)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
81			
82	Herds (N production in lbs/1,000lbs/yr)		From local agricultural agencies or published references and records of application rates
83			
84	Fowl (1,000 birds)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
85			
86	Fowl (N production in lbs/1,000/yr)		From local agricultural agencies or published references and records of application rates
87			
88	Golf Course area (acres)	0.0	Derive from assessors data and aerial photos and agricultural agencies, such as SCS
89			
90	Golf Course area leach rate (lbs/ac/yr)		From local agricultural agencies or published references and records of application rates
91			
92	**HYDROLOGIC DATA INPUT**		
93			
94	Total wellhead protection area (acres)	2,581	Planimeter from wellhead protection area map or GIS calculation
95			
96	Withdrawal Rate (mgd)	4.60	Use pumping rate that was used to delineate wellhead protection area (Zone II)
97			
98	Percent of withdrawal from surface water	25	Use same value that was used to delineate wellhead protection area (Zone II)
99			
100	N-conc. in Surface water (mg/l)	2.50	Average total N from chemical analyses of surface water recharge source(s)
101			
102	N-conc. in Precipitation (mg/l)	0.05	From National Atmospheric Data Project report
103			

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons per home in Sudbury, 3 per home in Framingham
and 10,000 sq. ft. lawn per new house

104	**NITROGEN LOADS**		
105	FUTURE DEVELOPMENT		
106	Septic systems (lb/yr)	5,926	Calculated
107			
108	Lawns (lb/yr)	2,580	Calculated
109			
110	Sewage system leakage (lb/yr)	0	Calculated
111			
112	New total nitrogen load (lb/yr)	8,506	Calculated
113			
114	EXISTING DEVELOPMENT		
115	Septic systems (lb/yr)	21,654	Calculated
116			
117	Lawns (lb/yr)	5,418	Calculated
118			
119	Sewage system leakage (lb/yr)	2,690	Calculated
120			
121	Agriculture, crop A (lb/yr)	0	Calculated
122			
123	Agriculture, crop B (lb/yr)	0	Calculated
124			
125	Pasture and range (lb/yr)	0	Calculated
126			
127	Herds (lb/yr)	0	Calculated
128			
129	Fowl (lb/yr)	0	Calculated
130			
131	Golf courses (lb/yr)	0	Calculated
132			
133	Sewage disposal (lb/yr)	1,522	Calculated
134			
135	Landfills (lb/yr)	0	Calculated
136			
137	Surface water recharge (lb/yr)	8,749	Calculated
138			
139	Precipitation (lb/yr)	470	Calculated
140			
141	Existing total nitrogen load (lb/yr)	40,501	Computed sum
142			
143	**WATER VOLUME**		
144			
145	Recharge equals withdrawal (mgd)	4.60	Copied
146			
147	Surface water recharge (mgd)	1.15	Calculated
148			
149	Recharge from NEW wastewater (mgd)	0.08	Calculated
150			
151	Recharge from EXISTING wastewater (mgd)	0.28	Calculated
152			
153	Recharge from precipitation (mgd)	3.09	Calculated
154			
155	Recharge from precipitation (in/yr)	16.10	Compare to estimates by government agencies
156			
157			
158	**NITROGEN CONCENTRATION (mg/l)**	3.5	Compare to 10 mg/l Maximum Contaminant Level
159			

NITRATE LOADING IN ZONE II
FOR: RAYMOND ROAD WELLFIELD
with 5 persons per home in Sudbury, 3 per home in Framingham
and 10,000 sq. ft. lawn per new house

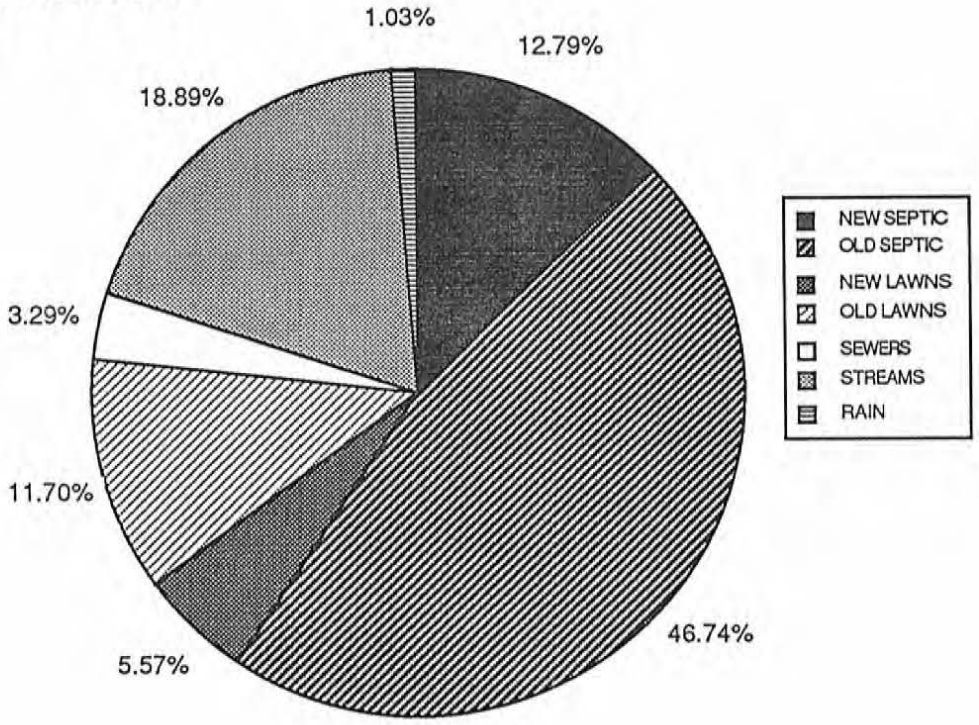
FOR WATER SOURCE PIE DIAGRAM

SURFACE WATER	1.15
WASTEWATER	0.36
PRECIPITATION	3.09

FOR NITROGEN SOURCE PIE DIAGRAM

NEW WASTEWATER	5,925.74
EXISTING WASTEWATER	21,653.58
NEW LAWNS	2,580.35
EXISTING LAWNS	5,417.81
AGRICULTURE	0.00
GOLF COURSES	0.00
SEWAGE COLLECTION AND TREATMENT	1,521.50
LANDFILLS	0.00
SURFACE WATER	8,748.64
PRECIPITATION	470.20

MODEL RUN #3 SOURCES OF NITRATE FOR
RAYMOND ROAD WELLFIELD



NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons per residence and 10,000 sq. ft. lawns per new house

LINE	LAND USE DATA INPUT	VALUES	COMMENTS
2	FUTURE DEVELOPMENT		
3	Total single family houses	89	Derived from land use regulations and assessors data
5	STP sewered single family houses	0	Derive from buildout and sewer service maps
7	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
9	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
11	Total multi-family units (persons)	0	Derive from census data and assessor's maps
13	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
15	Commercial/Industrial land (acres)		Derive from assessors data, includes schools and other municipal properties
17	Commercial/Industrial water use (gal/d)	0	Source: design capacity of septic systems or water bills; includes schools and municipal properties
19	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
21	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
23	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
25	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator
27	STP discharge N conc. (mg/l)	0.0	From Health Department or STP operator
29	Sewage collection system flows (gal/d)	0	Calculated
31	Lawn area per house (square feet)	10,000	From Planning Board
33	EXISTING DEVELOPMENT		
34	Total single family houses	598	Derived from land use regulations and assessors data
36	STP sewered single family houses	0	Derive from buildout and sewer service maps
38	Average number of persons per unit	5.0	Obtain from census data, Regional Planning Agency or CACI
40	Wastewater flow per person (gal/d)	55	About 55 gpd per person, derive from Water Dept. billing records
42	Total multi-family units (persons)	0	Derive from census data and assessor's maps
44	STP sewered multi-family units (persons)	0	Derive from sewer service maps and assessor's maps
46	Commercial/Industrial land (acres)	0.0	Derive from assessors data, includes schools and other municipal properties
48	Commercial/Industrial water use (gal/d)	7,937	Source: design capacity of septic systems or water bills; includes schools and municipal properties
50	Com./Ind. STP sewage flow (gal/d)	0	Derive from above and sewer service maps
52	N-conc. in septic effluent (mg/l)	40	About 40 mg/l, Health Department may revise
54	CALIBRATION, %N remaining after attenuation	63	Adjustment developed from comparing existing N level in well with initially estimated N levels
56	STP discharge in WHPA (gal/d)	0	From Health Department or STP operator

NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons per residence and 10,000 sq. ft. lawns per new house

57			
58	STP discharge N conc. (mg/l)	0	From Health Department or STP operator
59			
60	Sewage collection system flows (gal/d)	0	Calculated
61			
62	Landfills (acres)	0	From Health Department and/or maps
63			and aerial photographs
64	Lawn area per house (square feet)	5,000	New England 5,000 square feet, Planning Depart-
65			ment may revise
66	Lawn leach rate (lbs/ac/yr)	40	New England average is 40 lb/acre, Local
67			planning or agricultural agencies may revise
68	Agricultural crop A (acres)	0.0	Derive from assessors data and aerial photos
69			and agricultural agencies, such as SCS
70	Agricultural crop A leach rate (lbs/ac/yr)		From local agricultural agencies or published
71			references and records of application rates
72	Agricultural crop B (acres)	0.0	Derive from assessors data and aerial photos
73			and agricultural agencies, such as SCS
74	Agricultural crop B leach rate (lbs/ac/yr)		From local agricultural agencies or published
75			references and records of application rates
76	Pasture or range (acres)	0.0	Derive from assessors data and aerial photos
77			and agricultural agencies, such as SCS
78	Pasture or range leach rate (lbs/ac/yr)		From local agricultural agencies or published
79			references and records of application rates
80	Herds (1,000 lbs of animals)	0.0	Derive from assessors data and aerial photos
81			and agricultural agencies, such as SCS
82	Herds (N production in lbs/1,000lbs/yr)		From local agricultural agencies or published
83			references and records of application rates
84	Fowl (1,000 birds)	0.0	Derive from assessors data and aerial photos
85			and agricultural agencies, such as SCS
86	Fowl (N production in lbs/1,000/yr)		From local agricultural agencies or published
87			references and records of application rates
88	Golf Course area (acres)	0.0	Derive from assessors data and aerial photos
89			and agricultural agencies, such as SCS
90	Golf Course area leach rate (lbs/ac/yr)		From local agricultural agencies or published
91			references and records of application rates
92	HYDROLOGIC DATA INPUT		
93			
94	Total wellhead protection area (acres)	1,091	Planimeter from wellhead protection area map
95			or GIS calculation
96	Withdrawal Rate (mgd)	1.90	Use pumping rate that was used to delineate
97			wellhead protection area (Zone II)
98	Percent of withdrawal from surface water	30	Use same value that was used to delineate
99			wellhead protection area (Zone II)
100	N-conc. in Surface water (mg/l)	3.85	Average total N from chemical analyses of
101			surface water recharge source(s)
102	N-conc. in Precipitation (mg/l)	0.05	From National Atmospheric Data Project report
103			

NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons per residence and 10,000 sq. ft. lawns per new house

104	**NITROGEN LOADS**		
105	FUTURE DEVELOPMENT		
106	Septic systems (lb/yr)	1,862	Calculated
107			
108	Lawns (lb/yr)	817	Calculated
109			
110	Sewage system leakage (lb/yr)	0	Calculated
111			
112	New total nitrogen load (lb/yr)	2,679	Calculated
113			
114	EXISTING DEVELOPMENT		
115	Septic systems (lb/yr)	13,114	Calculated
116			
117	Lawns (lb/yr)	2,746	Calculated
118			
119	Sewage system leakage (lb/yr)	0	Calculated
120			
121	Agriculture, crop A (lb/yr)	0	Calculated
122			
123	Agriculture, crop B (lb/yr)	0	Calculated
124			
125	Pasture and range (lb/yr)	0	Calculated
126			
127	Herds (lb/yr)	0	Calculated
128			
129	Fowl (lb/yr)	0	Calculated
130			
131	Golf courses (lb/yr)	0	Calculated
132			
133	Sewage disposal (lb/yr)	0	Calculated
134			
135	Landfills (lb/yr)	0	Calculated
136			
137	Surface water recharge (lb/yr)	6,678	Calculated
138			
139	Precipitation (lb/yr)	172	Calculated
140			
141	Existing total nitrogen load (lb/yr)	22,710	Computed sum
142			
143	**WATER VOLUME**		
144			
145	Recharge equals withdrawal (mgd)	1.90	Copied
146			
147	Surface water recharge (mgd)	0.57	Calculated
148			
149	Recharge from NEW wastewater (mgd)	0.02	Calculated
150			
151	Recharge from EXISTING wastewater (mgd)	0.17	Calculated
152			
153	Recharge from precipitation (mgd)	1.13	Calculated
154			
155	Recharge from precipitation (in/yr)	13.96	Compare to estimates by government agencies
156			
157			
158	NITROGEN CONCENTRATION (mg/l)	4.4	Compare to 10 mg/l Maximum Contaminant Level
159			

NITRATE LOADING IN ZONE II
FOR: East Street/Hop Brook Wellfield, wells 3, 8 and 10
with 5 persons per residence and 10,000 sq. ft. lawns per new house

FOR WATER SOURCE PIE DIAGRAM

SURFACE WATER	0.57
WASTEWATER	0.20
PRECIPITATION	1.13

FOR NITROGEN SOURCE PIE DIAGRAM

NEW WASTEWATER	1,861.94
EXISTING WASTEWATER	13,114.37
NEW LAWNS	817.26
EXISTING LAWNS	2,745.64
AGRICULTURE	0.00
GOLF COURSES	0.00
SEWAGE COLLECTION AND TREATMENT	0.00
LANDFILLS	0.00
SURFACE WATER	6,677.88
PRECIPITATION	172.41

MODEL RUN #3 SOURCES OF NITRATE
EAST STREET WELLFIELD