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### 5.3 Runoff and Nutrient Loading Estimates

The runoff and nutrient loading estimates presented in this section are predictions developed using a standard “mass balance” approach to generate a simple average annual water budget and estimated nutrient sources to runoff and groundwater. These provide additional information on pollution sources and relative contribution from various sources. Phosphorus is used as an indicator of sediment-bound pollutants in runoff. Nitrogen is used as an indicator of other dissolved pollutants in surface runoff and in recharge entering groundwater.

#### Methods

Calculations are made using an Excel spreadsheet, which also generates statistics on the other watershed indicators described in the previous section. The input data sources are extracted from the RIGIS map database to include site-specific soils, land use types updated by trained volunteers, population estimates, and the estimated number of septic systems in each area studied. The analysis is run first for existing conditions using current land use map data. To evaluate future impacts the analysis is repeated using town zoning maps as the future land use scenario. As noted in the land use summary, this “build out” scenario assumes full development of all unprotected land other than wetlands and surface water buffers (200’). No timetable is estimated for this development to occur.

The model for the town of Jamestown used an average annual precipitation of 40 inches per year, with 18 inches per year lost to evaporation and plant use (U.S. Geological Survey, 1961). The proportion of remaining “available” precipitation (22 inches) that is converted to runoff is estimated using runoff coefficients based on the estimated impervious cover for each land use type and the underlying soil hydrologic group. This is adapted from standard methods (USDA NRCS, 1986). The remainder is assumed to seep into the ground to recharge either shallow or deep groundwater. Recharge to groundwater from septic systems is calculated separately based on average per capita water use and discharge to onsite systems of 50 gallons per person per year.

Nitrogen and phosphorus inputs to surface water from storm water runoff are estimated using generalized pollutant coefficients based on published literature values for 21 different land uses and direct atmospheric deposition on surface waters. Nitrate-nitrogen inputs to groundwater recharge are calculated separately, using results of URI field research on nitrogen losses to groundwater from specific sources, including septic systems, lawns, farmland and forest. Complete hydrologic and nutrient loading assumptions are provided in the appendix, *Technical Documentation, MANAGE GIS-Based Pollution Risk Assessment Method, Database Development, Hydrologic Budget and Nutri-*

#### Mass balance hydrologic models

*The mass balance concept uses a simplified water and nutrient "budget" to establish a quantitative relationship between pollutant inputs and outputs to a system. The nutrient loading component of MANAGE estimates pollutant outputs as nutrients (nitrogen and phosphorus) entering surface water runoff or infiltrating as recharge to groundwater. This standard mass balance method is similar to those widely used in comparable watershed assessment applications elsewhere. (Adamus, C. and M. Bergman 1993, Brown, K.W. and Associates 1980, Budd, L.F. and D.W. Meals 1994, Frimpter, M.H. et al. 1990, Fulton III, R.S. 1994, Nelson, K.L. et al. 1988, Reckhow, K.H. and S.C. Chapra 1983, Schuler, R.R. 1987, Weiskel, P.K. and B.L. Howes 1991, EPA, 1990).*

*ent Loading.* Additional information about the MANAGE assessment method is available at <http://www.edc.uri.edu/cewq/manage.html>.

### **Note on using models to evaluate land use impacts**

Field monitoring and modeling are two basic approaches, often used hand-in-hand to evaluate effects of land use activities on water quality. In order to assemble a reasonable picture of watershed or aquifer conditions, water quality models use available information about pollutant interactions and apply it to a particular study area. Modeling is frequently used to estimate the source of pollutants to supplement water quality monitoring, especially when field data is sparse or inconclusive. As an alternative to project-by-project impact review, modeling offers a “big-picture” perspective that is needed to evaluate cumulative impacts. Modeling is a valuable tool in testing relative effects of different land use options or pollution management decisions because even simple models can be used to explore what might happen if land is developed in a different way.

Models can range from the simplest “back of the envelope” calculation, to complex methods that require extensive field data to simulate physical, chemical, and biological responses. In this assessment we use a simple “mass balance” method similar to those widely used in comparable applications elsewhere, including Cape Cod and the New Jersey Pine Barrens. These methods calculate an annual water budget based on water inputs (precipitation) and outputs (evaporation and plant use, runoff, and groundwater recharge). Research results of nutrient losses from different land uses are then used to predict nutrient loads from similar land uses mapped in the study area. This incorporates accepted input values from published literature. Our estimates of nitrogen leaching to groundwater are strengthened by use of carefully selected input values derived from local research.

Typically, results of most mass balance models are generated as average annual estimates of runoff, infiltration, and nutrient loading (loading, or total amount is expressed here as lbs/ acre/year) for each study area. These estimates are useful in comparing relative differences in pollution risk among various land use scenarios or among sub-watersheds. The concentration of nitrogen (mg/L) entering groundwater can also be estimated based on dilution of inputs with infiltrating rainwater. However, concentration estimates may not necessarily represent the concentration at a well because it is difficult to account for nitrogen loss in wetlands or uneven mixing in deeper groundwater. There are times when a more sophisticated modeling approach is needed. Some examples include: situations when estimates must be compared with monitored water quality data; estimating pollutant loads in runoff or flowing waters on a storm event basis; or tracking movement of an effluent plume in groundwater. In order to generate reliable results however, complex

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models usually require extensive field monitoring information as necessary data inputs.

### **Selecting simple vs. sophisticated models**

When choosing a model it is important to be aware of limitations of both simple and complex models. For example:

- All models generate results that are only as good as the input values; results of both simple and sophisticated methods are estimates.
- Because output data from sophisticated models can easily appear to be more solid than it actually is, users must be careful to avoid generating false confidence in uncertain results.
- Complex models may not generate more useful data for management, especially when comparing relative differences may be adequate for choosing pollution controls.
- The cost of complex modeling with field data collection is typically orders of magnitude greater than screening level modeling and assessment approaches.

The decision on whether to use a simple vs. complex model should consider the costs and benefits of additional study vs. implementing pollution controls. Management decisions need to be based on good science with sound findings of fact. At the same time, given the uncertainty inherent in any model, land use decision makers need to carefully consider at what point limited funds might be better spent on adopting pollution controls using accepted management practices rather than devoting resources to additional study.

## **SURFACE RUNOFF**

Runoff is not a common natural occurrence. In forested watersheds with sandy soils, up to 97 percent of precipitation can be expected to seep into the ground (Simmons, D. and R. Reynolds 1982). In well-drained upland areas, this infiltrating water recharges deeper groundwater supplies. In areas where the groundwater table is near the surface, water seeping into the soil enters shallow groundwater and flows to nearby wetlands and streams. In critical periods without rain, groundwater discharges to streams as “base flow”— the primary source of water in streams.

Runoff is associated with declining water quality because it disrupts the natural cycle of infiltration and gradual discharge to streams. Land development compacts the soil and adds acres of pavement, dramatically increasing the rate and total volume of storm water runoff. The result is increased flooding, stream scouring with loss of aquatic habitat, and reduced groundwater recharge. In addition to these hydrologic impacts, storm water runoff washes off and delivers pollutants directly to the nearest surface waters. Street runoff is contaminated with oil and grease, metals, sediment, nitrogen from atmospheric sources, and other pollutants. Runoff from residential areas carries pesticides, fertilizers, and animal waste. Runoff may also be contaminated with wastewater effluent from failing septic systems, improper connections of sanitary wastes to storm drains, or leaking sewers.

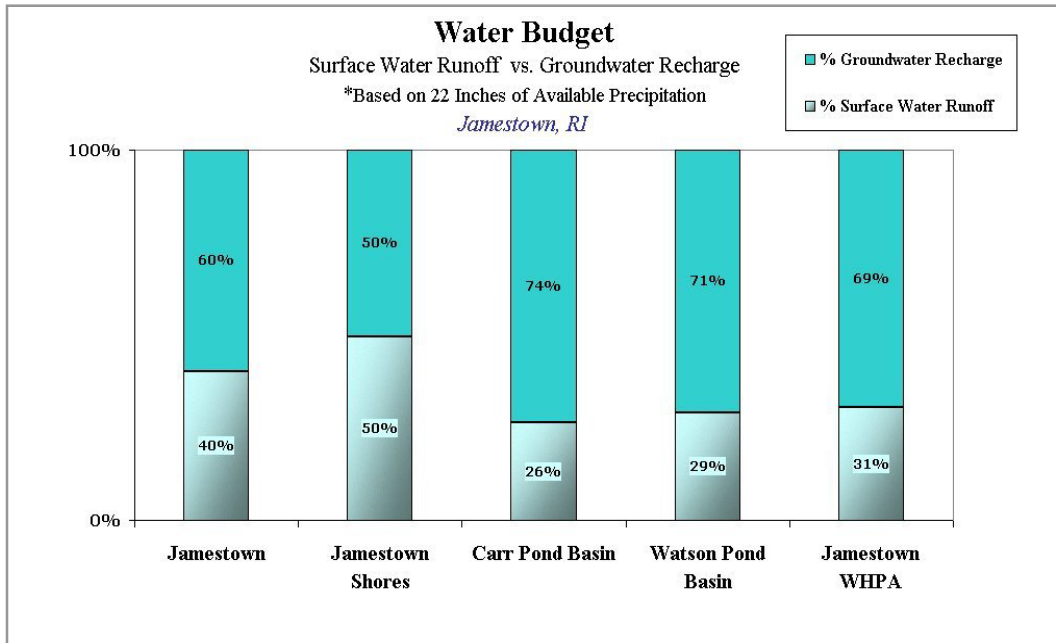
As a watershed health indicator, surface runoff levels signal potential pollution risks by identifying:

- High runoff zones where hydrologic impacts and runoff pollutants are likely to be greatest;
- Relative change in runoff between current and future conditions, and with use of storm water controls; and
- Water flow and pollutant movement pathways to support selection of management practices.

### **Interpreting runoff estimates**

Runoff calculations estimate the proportion of rainfall that is likely to runoff rather than infiltrate the ground surface. This runoff estimate includes rainfall running directly off the surface and shallow subsurface flow that may reach surface waters during or shortly after rain events. However, runoff estimates do not take into account temporary storage and infiltration that will affect the amount of runoff actually reaching a surface water body. Moreover, the effect of closed drainage systems with the potential to rapidly convey runoff to a surface water discharge point is not considered separately from a higher runoff coefficient for more urban impervious land.

**Figure 18. Water Budget – Surface water runoff vs. Groundwater recharge (Current Land Use)**

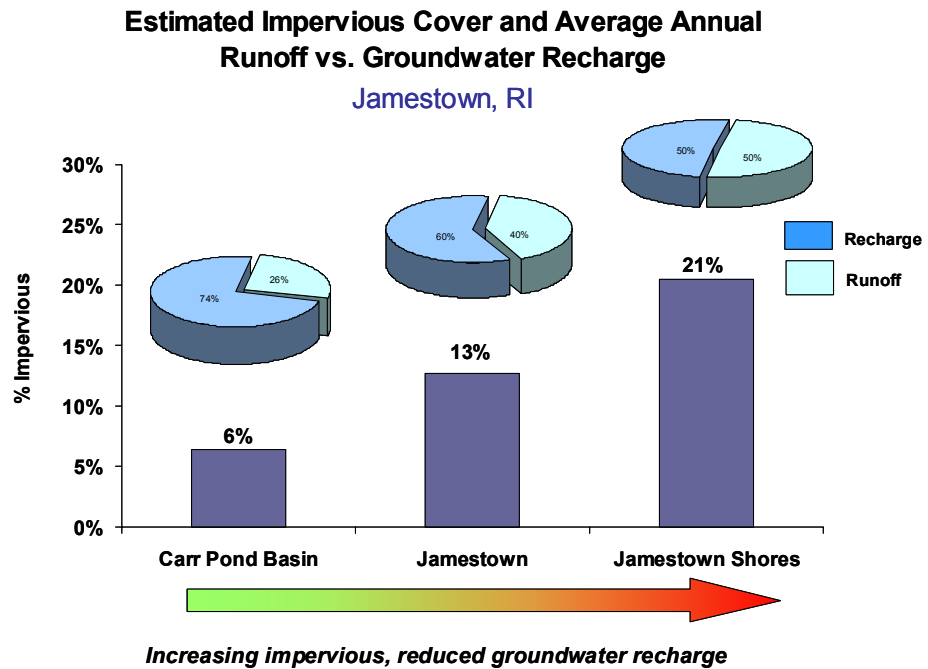


**Results: Surface Runoff**

- Groundwater is the primary pathway for water flow on Conanicut Island. In all of the study areas, 50 percent or more of available precipitation is estimated to infiltrate the ground.
- Due to much higher percentages of forested land, drinking water supply watersheds are estimated to have a healthy proportion of groundwater recharge, at about 70 percent of available precipitation.
- Due to low-density residential zoning, the proportion of runoff in drinking water supply areas is not expected to change significantly in coming years.

In the Watson Pond study area, Route 138 accounts for only 4 percent of land area, but contributes over 20 percent of surface runoff, highlighting the importance of minimizing impervious surface area. The highway drainage system has been specially designed to convey runoff out of the drinking water supply areas. Although this reduces risk of contamination from routine runoff and spills, this diversion is considered to be a source of additional low flow stress to Jamestown Brook (C.Carey, RIDEM Division of Water Resources, personal communication).

Figure 19



Applying the same water budget data in Figure 18 to selected study areas demonstrates how groundwater recharge decreases with land development as impervious cover and runoff increases. For example, only 50 percent of rainfall is estimated to infiltrate the ground in Jamestown Shores compared to 74 percent in the Carr Pond watershed.

- Based on the difference in modeled runoff estimates between current land use and natural forest conditions, the amount of groundwater recharge potentially lost to runoff in the Jamestown Shores area is estimated to be 162 million gallons each year. This is almost twice the entire safe yield of Carr Pond annually (82.13 Mgal/yr). The amount of groundwater recharge lost to runoff Island-wide is estimated to be 970 Mgal/yr – more than eight times the safe yield of both Carr and Watson reservoirs.
- Residential development accounts for over 80 percent of surface water runoff, indicating the importance of controlling runoff from these areas, as well as roads and commercial areas.
- Properly treated wastewater from septic systems can help replenish groundwater supplies and prevent saltwater intrusion. The value of recycled wastewater is greatest in densely developed areas such as Jamestown Shores where septic systems are estimated to contribute 16 percent of recharge to groundwater, compared to only 3 percent Island-wide. This is equivalent to 36 million gallons each year, roughly the average safe yield of the Watson Reservoir annually.

## NUTRIENT LOADING

### Nitrogen as a pollution indicator

The total amount, or “load,” of nutrients generated in the wellhead protection area or watershed is a widely used measure of pollution risk. Nitrogen loading estimates are most critical when assessing potential pollutant inputs to groundwater and coastal waters. Nitrogen is commonly used as an indicator of pollution from human activities for the following reasons:

- Nitrogen contaminates drinking water, interfering with oxygen absorption in infants and causing other health effects. The federal health standard for the nitrate form is 10 mg/l; the drinking water action level of 5 mg/l triggers increased monitoring. Some municipalities in Rhode Island are using 5 mg/l as regulatory limit.
- Nitrogen is associated with human inputs such as fertilizers and septic systems when groundwater nitrogen levels exceed 1 mg/l. The natural background level in Rhode Island groundwater is very low at 0.2 mg/l or less.
- Nitrogen moves easily in surface and groundwater, and can indicate the presence of other dissolved pollutants such as bacteria and viruses, road salt, and some toxic chemicals.
- Nitrogen over fertilizes coastal waters, leading to excessive growth of nuisance seaweed and algae, low dissolved oxygen, loss of eelgrass, and decline of shellfish beds. Healthy coastal waters generally have extremely low nitrogen concentrations, so even relatively small inputs above naturally occurring levels can cause a problem.

### Input values designed to match the local study area

Nutrient loading predictions in this report are modeled estimates based on site-specific land use and soil conditions in each study. This uses accepted values for nutrient inputs from various land uses based on: 1) field research on nitrogen losses to groundwater from septic systems, lawns, turf and corn fields, and forests conducted in southern Rhode Island by URI scientists; and 2) current published literature values for surface runoff. Because groundwater inputs are based on extensive and reliable local data, nitrogen-leaching estimates to groundwater are more accurate than nitrogen inputs to surface runoff.

Nutrient source estimates are derived from the number of homes and businesses in the study area and the total acreage of different land use types. For example the number of septic systems, an important input variable for groundwater nitrogen loading, is estimated from the number of homes and businesses in unsewered portions of each study area based on five residential land use categories, four nonresidential mapped land use types, and mapped sewer districts. To refine our estimate, we updated the RIGIS 1995 land use using corrections mapped by trained local volunteers and adjusted the residential units

Nitrogen Concentrations	
0.2 mg/l	Natural background level in Rhode Island groundwater
1 mg/l	A sign of human activities influencing groundwater.
5 mg/l	Planning action standard, indicator of degraded water quality
10 mg/l	Federal drinking water standard or Maximum Contaminant Level (MCL)
<i>Wastewater Effluent</i>	
40-60 mg/l	Effluent from standard septic system.
< 20 mg/l	Treated effluent from nitrogen-reducing septic system.
* In this report, monitored Nitrate-Nitrogen concentrations and estimated loading rates are referred to as nitrate concentrations.	

### Note on Nutrient Loading Estimates:

*The nutrient loading estimates used in this assessment assume the use of reasonable management practices. However, inputs may be much higher where lawns are over fertilized and over watered or where fertilizers are spilled or otherwise wash into storm drains. In addition, nutrients and bacteria inputs are likely to be comparatively higher where pet waste on curbs and sidewalks wash directly into storm drains and where bird and wildlife waste flow directly from roads, storm drains, and under bridges into surface waters. Commercial and Industrial activities vary widely in both the amount of effluent generated and its strength. For a more accurate estimate, these should be calculated individually to determine average flows, flow variability, and concentration of wastewater inputs.*

## **ASSUMPTIONS**

### **Nitrogen loading to groundwater recharge**

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#### **Septic systems**

2.41 persons/dwelling unit  
50 gal/person/day wastewater  
2.3 lbs P/person/yr (15.1 mg/l)  
7.0 lbs N/person/yr (46 mg/l)  
90% leaching to groundwater

*Commercial, Industrial and Institutional assumed equivalent to one dwelling unit /acre. Recreational land use assumed same but in use for 6 months annually.*

#### **Agricultural Fertilizers**

*Active cropland and orchard  
64.5 lbs N leached to groundwater based on 215 lbs N applied /acre/yr, 30% leaching.*

#### **Lawn Fertilizers**

*25 –50% residential area is lawn.  
75% of landowners fertilize.  
10.5 lbs N leached to groundwater based on 175 lbs (4 lbs N /1000 sq.ft.) N applied /acre/yr, 6% leaching.*

#### **Pets**

*0.41 lb N/person/yr. Leaches to groundwater from pet waste.*

#### **Background**

*1.2 lbs/acre/yr leaches from unfertilized lawns, pastures, forests and brush areas.*

to reflect the town parcel database. U.S. Census data was used to estimate occupancy per dwelling unit. Nutrient loading assumptions were also reviewed by assessment volunteers and revised as needed.

## **Types of outputs**

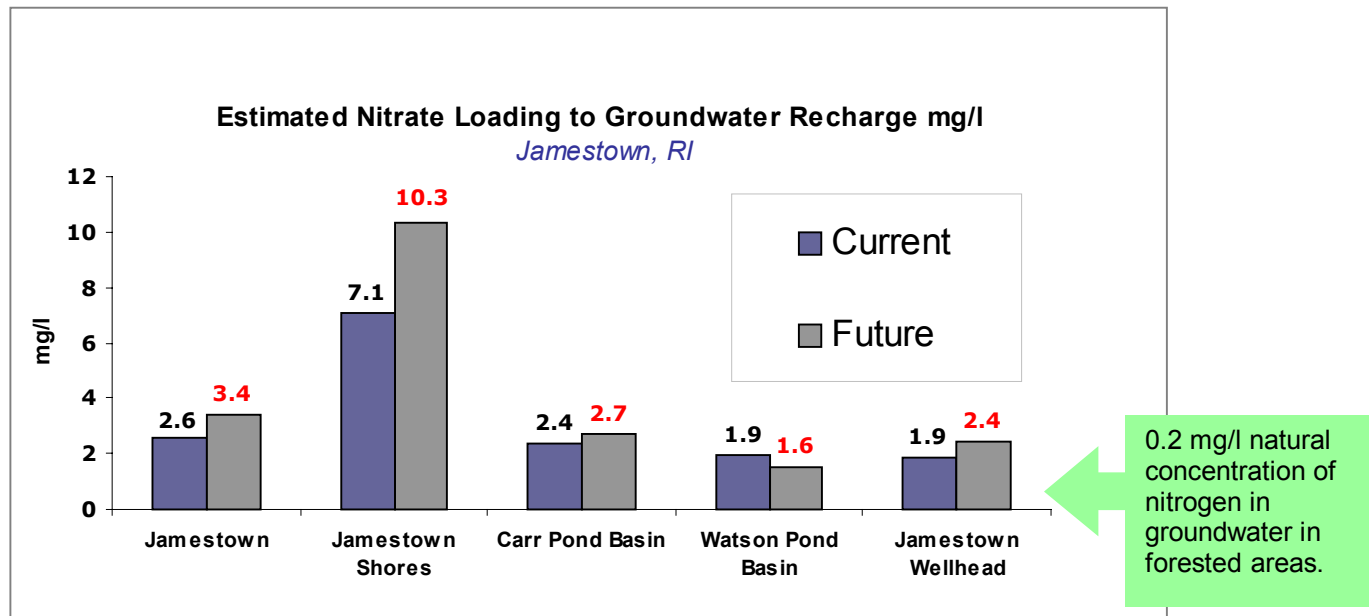
Nutrient inputs are estimated as the total average annual amount, or loading (pounds/acre/year) of nitrogen and phosphorus entering surface water runoff, and the total amount of nitrate-nitrogen entering groundwater recharge annually. These estimates represent nutrient sources at the point of origin, not the amount that might ultimately reach a groundwater aquifer, pumping well, wetland, or other surface water body. The nitrogen inputs to surface water represent the amount entering surface runoff at the point where runoff is generated; nitrogen inputs to groundwater represent the amount of nitrogen percolating into the groundwater with precipitation and septic system effluent. Nitrate loading to groundwater recharge is also estimated as a concentration by diluting the total load with the volume of infiltrating rainwater and septic system effluent. Due to uneven mixing in groundwater we don't assume this concentration will be the same at a pumping well.

## **Uncertainties in Mass Balance Models**

Since model estimates represent sources potentially generated, the actual amount that might ultimately reach a well or surface water body is likely to be less. The opportunity for nitrogen uptake is greater in large watersheds with abundant wetlands, where shoreline buffers have high nitrogen removal potential, and where pollution sources are further removed from sensitive receiving waters. The potential for nitrogen removal is lower in wellhead protection areas where nitrogen enters groundwater as recharge to a pumping well without treatment in wetlands. In these wellhead protection areas we assume that over time the quality of the underlying groundwater will begin to reflect the quality of recharge water entering the wellhead.

The estimates do not consider a number of factors such as: concentrated plumes of effluent where nitrogen levels may be much higher than average per acre loadings; the effect of storm events; other pollutants such as spills from underground storage tanks; and nitrogen uptake through natural processes. In addition, wastewater flow from nonresidential land uses are highly variable in both effluent strength and volume and should be calculated individually if a more accurate estimate is needed. As a result of uncertainties inherent in this mass balance approach, modeled nutrient estimates are most useful in comparing relative differences among land use types, among sub-watersheds, between current and future land use, and in comparing potential reductions in nutrient inputs with use of management practices.

**Figure 20. Estimated Nitrogen Loading to Groundwater Recharge**



**Results: Nitrogen Loading**

- Nitrogen loading to groundwater is estimated to be relatively low in all study areas except for the densely developed Jamestown Shores neighborhood where concentrations are estimated to be at least three times than other areas.
- Future development throughout the Island and in the drinking water supply areas is expected to result in only minor changes in nitrogen loading. This assumes however that wetlands will not be developed and 200’ buffers to streams and surface waters will be protected.
- The Jamestown Shores nitrogen loading estimates are based on a more accurate count of parcels, with the future scenario representing a worst case situation with full development of all lots. Since 46 percent of undeveloped lots have water tables at 18 inches or less and are not buildable, the future loading is likely to be less. However, any increase is a concern given current high inputs.

**Note:**

*Estimated nitrogen inputs represent sources, not the amount reaching a downstream water body or well. Actual nitrogen losses, especially in wetland buffers, will depend on fertilizer management practices, the design, condition and use of septic systems, and natural treatment by plants and soil microbes. In the less developed study areas, high infiltration rates helps to take advantage of natural pollution treatment capabilities in soil while also increasing the amount of recharge available to dilute pollutant loads.*

**Table 2. Estimated sources of nitrogen to groundwater, current and future land use.** With full development, the proportion of nitrogen entering groundwater recharge is either likely to remain about the same or shift from agricultural sources to septic system effluent Island wide.

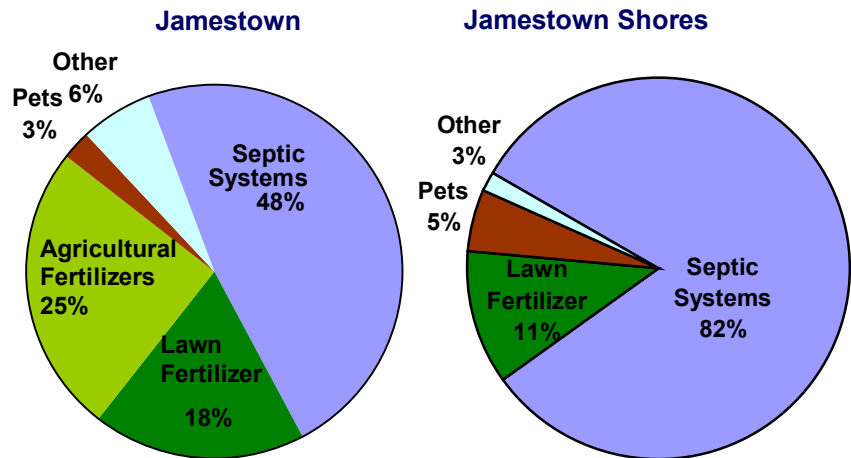
Although the total loading is expected to remain low, the increase in total number of septic systems represents a greater risk of localized impacts if any systems fail due to improper care, outdated design, or overuse. The town's inspection program is a major step forward in managing both new and existing systems.

<b>Based on Current Land Use</b>					
Sources of Nitrogen Entering Groundwater Recharge	Jamestown	Jamestown Shores	Carr Pond Basin	Watson Pond Basin	Jamestown wellhead
Septic Systems	47%	81%	75%	7%	74%
Lawn Fertilizer	18%	12%	12%	3%	12%
Agricultural Fertilizer	25%	0%	0%	79%	0%
Pet Waste	3%	5%	5%	0%	5%
Other	6%	2%	7%	10%	10%

<b>Based on Future Land Use</b>					
Sources of Nitrogen Entering Groundwater Recharge	Jamestown	Jamestown Shores	Carr Pond Basin	Watson Pond Basin	Jamestown wellhead
Septic Systems	62%	85%	75%	21%	74%
Lawn Fertilizer	16%	9%	16%	12%	16%
Agricultural Fertilizer	15%	0%	0%	58%	0%
Pet Waste	3%	6%	5%	1%	5%
Other	3%	1%	4%	8%	5%

**Figure 21. Sources of Nitrogen to Groundwater Recharge**

Under Current land use the contribution of nitrogen to groundwater is twice as much as the island as a whole. Combined with the very high total loadings, as shown in Figure 11, this is a very serious risk for both current and future land use.



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### How much of your drinking water is recycled effluent?

One way to look at nitrogen concentrations in groundwater is to consider the proportion of well water that may actually be recycled wastewater. Recycled wastewater is an important source of groundwater recharge but without adequate treatment, there are serious health risks with use of conventional systems in densely settled areas and high water table.

The proportion of effluent in drinking water can be calculated based on the concentration of nitrogen in a well water sample, and the estimated nitrogen contribution from wastewater effluent in the area. Table 3 lists the estimated proportion of recycled effluent in wellwater in the Jamestown Shores area where septic systems are estimated to contribute 82 percent of nitrate-N to groundwater. Groundwater nitrogen levels are naturally low, often at 0.05 mg/l. These estimates show that when nitrogen concentrations are slightly elevated, at 1 to 2 mg/l, the proportion of recycled effluent is also low, at about 2 to 3 percent.

The risk of wellwater contamination with improperly treated effluent increases as the concentration of nitrogen rises. For example, when wellwater nitrate concentrations reach 5 mg/l, about 9 percent of the water supply is likely to be recycled effluent. Groundwater studies by A. Veeger (1998) found up to 7 mg/l nitrate in Jamestown Shores wells, resulting in a relatively high percentage (12 percent) of recycled effluent in drinking water. Where only conventional treatment has been provided this is high enough to be a health concern, especially since viruses are known to travel further distances than bacteria. In the same groundwater study A. Veeger confirmed that high nitrate levels were associated with bacteria contamination, as wells with bacteria detects had an average nitrate concentration of 3.6 mg/l. At this level the amount of recycled effluent is expected to be just over 5 percent. In Jamestown Shores bacteria contamination of wells was correlated with nitrate concentrations. Small lots less than 1 acre in size were also found to be more susceptible to bacteria contamination, with nitrate levels in wells averaging 3.2 mg/l.

### Phosphorus as a pollution indicator

Phosphorus is the key nutrient responsible for over fertilizing freshwater lakes, ponds, and streams. Although phosphorus is essential for algal and aquatic plant productivity, even minute increases in the amount of phosphorus can trigger tremendous increases in growth. For example, the natural background concentration of phosphorus in Rhode Island waters is only 5 to 10 *parts per billion*, which is equivalent to .005 to .010 parts per million or mg/l. The RIDEM maximum average total phosphorus standard for freshwater lakes and reservoirs is 25 parts per billion.

**Table 3. Proportion of recycled effluent in Jamestown Shores Groundwater**

Well water nitrate concentration (mg/l)	Effluent in well water (percent)
1	2 %
2	3 %
3	5 %
5	9 %
7	12 %
10	18 %

*Based on 46 mg/l nitrate-N in effluent, less 0.05 mg/l nitrate natural background in ground water, and 82% nitrate-N from septic systems.*

**Trihalomethanes (THM)** are a group of four chemicals — chloroform, bromodichloromethane, dibromochloromethane, and bromoform — that are formed when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water.

Individual TTHMs have been classified as being potentially hazardous to human health. To reduce this health risk, EPA published the Stage 1 Disinfectants / Disinfection Byproducts Rule in December 1998. This requires water systems to use treatment methods to reduce the formation of disinfection byproducts and meet stricter regulatory standards.

This rule reduced the federal standard for Total Trihalomethanes (TTHM) from the 100 parts per billion maximum allowable annual average level to 80 parts per billion for all public supply systems beginning in December 2003.

For more information go to:  
[www.epa.gov/enviro/html/icr/dbp.html#regulatory](http://www.epa.gov/enviro/html/icr/dbp.html#regulatory)

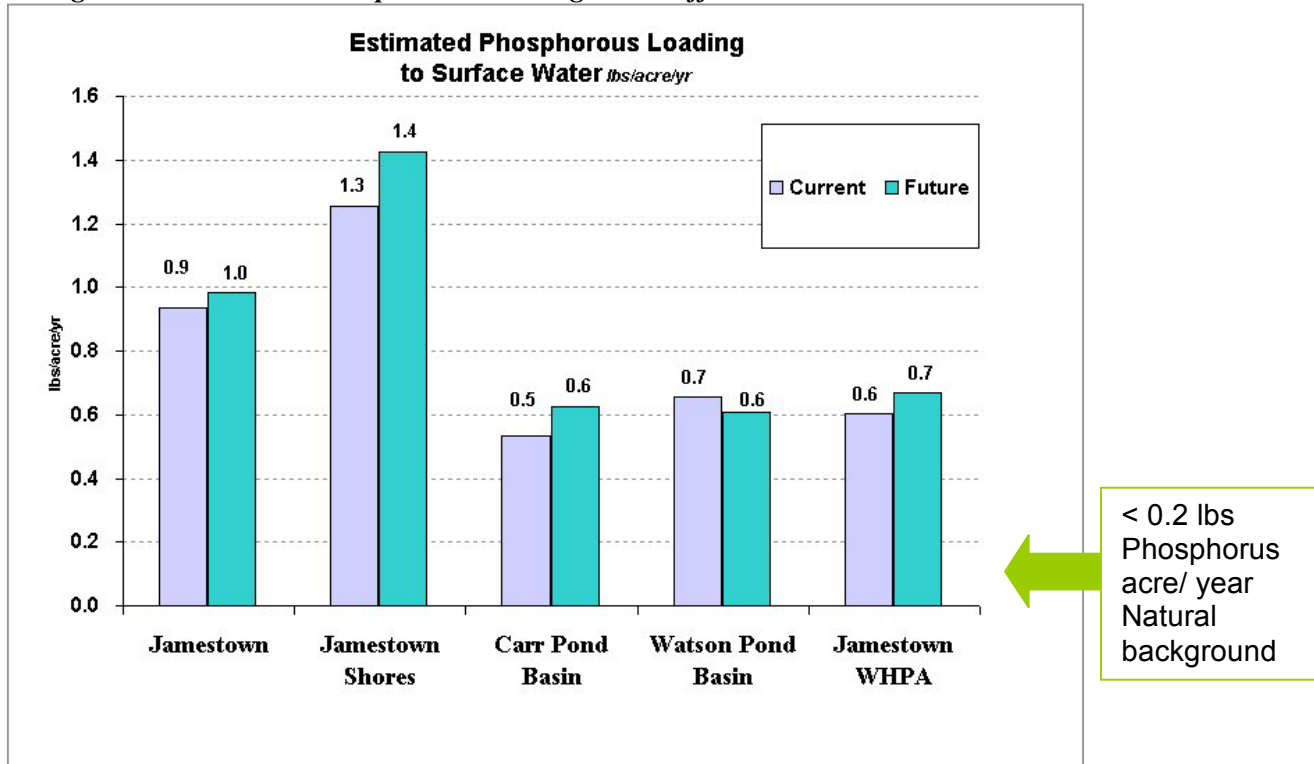
The degree of nutrient enrichment or “eutrophication” in a lake or pond is measured by the abundance of aquatic plants and algae, and phosphorus. Although eutrophication is a natural process whereby nutrients, sedimentation, and aquatic plant productivity increase as a lake or pond ages, phosphorus inputs from human activities can greatly accelerate this process. Managing phosphorus inputs to surface drinking water supplies is particularly important for man-made reservoirs as they tend to become eutrophic more rapidly than naturally formed lakes. There is a tendency for these reservoirs to revert back to their original state, usually a stream system or marsh (Addy and Green, 1996).

In drinking water reservoirs, nutrient enrichment is a problem because algae and accumulating sediment from runoff and decaying aquatic plants increases organic matter and suspended solids. These affect the taste and odor of drinking water. And while organic matter is not necessarily a health hazard, it reacts with chlorine in the disinfection process to create trihalomethanes. These byproducts are considered a health hazard and EPA has recently reduced that maximum allowable level from 100 to 80 ppb. One way to reduce disinfection byproducts is to reduce excessive organic matter in drinking water supplies by controlling nutrient inputs. Phosphorus’s tendency to attach itself to sediment means that the most effective phosphorus control measures are controlling erosion and sedimentation from farming and construction sites, controlling runoff from highways and other sources, and protecting shoreline buffers.

We use phosphorus loading estimates as a pollution indicator for the following reasons:

- Land use activities have significant, measurable impacts on phosphorus levels in surface water bodies.
- High phosphorus levels in freshwater bodies are often associated with the use of phosphate-based detergents, lawn and garden fertilizers, improperly sited and maintained septic systems, leaking sewers, agricultural drainage, pet waste, and urban storm water runoff.
- Phosphorus tends to be associated with sediment and is a good indicator of other runoff-borne pollutants such as metals and bacteria.

**Figure 22. Estimated Phosphorous Loading to Runoff**



**Results: Phosphorus Loading**

- Phosphorus concentrations entering runoff are estimated to be relatively low in all drinking water supply areas, although they are elevated compare to what we would expect in a completely forested watershed with similar soil characteristics.
- In the Carr Pond watershed and Jamestown wellhead area, residential development is estimated to contribute over 70 percent and 50 percent of the phosphorus, respectively. In the Watson Pond watershed agriculture and pastureland is thought to contribute over 60 percent of the phosphorus in runoff.
- Runoff from Route 138 is estimated to contribute about 20 percent of the phosphorus in the Jamestown and Watson watersheds. However, most of this may be diverted to coastal areas. As expected, estimated phosphorus concentrations are considerably higher in Jamestown Shores, at 10 times the natural background level, 90 percent of which is believed to come from residential land use.

## **ANALYSIS OF MANAGEMENT OPTIONS**

The hydrologic and nutrient loading component of the MANAGE assessment can be used to evaluate the relative effect of alternative development options. In addition to comparing the difference in runoff or nutrient loading with current and future land use, input values can be adjusted to reflect the expected change in nutrient loading with use of various land management practices. The management options that can be evaluated include:

- using creative development techniques to reduce the amount of impervious cover and preserve undisturbed forest,
- management of home or agricultural fertilizers to reduce nutrient losses to groundwater and surface runoff,
- treatment of stormwater runoff to reduce nutrient inputs to surface runoff, and
- use of nitrogen-reducing septic systems to minimize nitrogen loading to groundwater.

The input values for improved management practices are based on results of local research conducted by URI researchers on nitrogen losses to groundwater and other accepted literature sources. As with any of the indicators, the results are best used to compare relative differences among various scenarios, and should not be compared with monitored data.

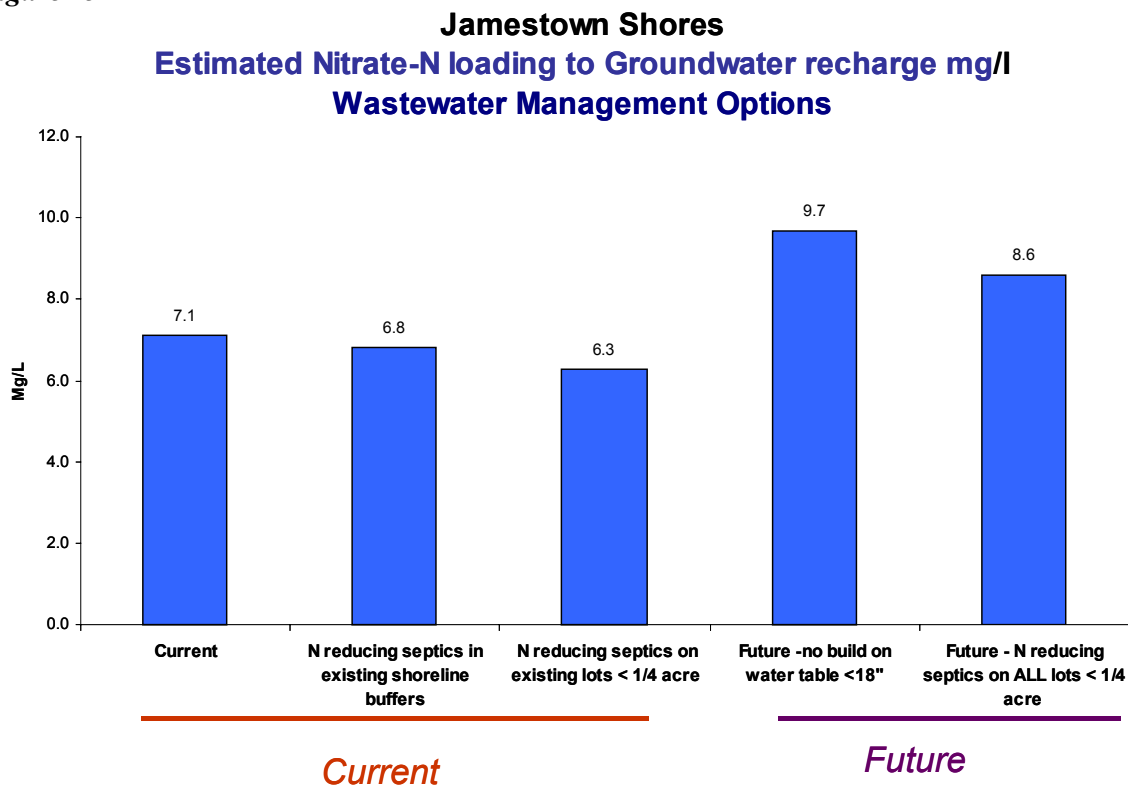
In evaluating results it is important to recognize that runoff and nutrient loading estimates represent only one type of pollution risk. Although nitrogen and phosphorus are used as indicators of other dissolved and sediment-borne pollutants, these estimates do not adequately represent all pollution risks, including likelihood of contamination from bacteria. For example, cesspools and other substandard septic systems, on densely clustered lots, and in areas where private wells are used are generally considered the most serious threats to water quality, especially where separation distances to wells are inadequate. Other high risk situations where systems are more likely to fail either due to improper treatment or hydraulic failure include high water tables, especially where subdrains are used to lower the water table. In addition, systems in wetland and surface water buffers have the potential to convey pollutants directly to a surface waters. Examining only the change in nitrogen loading with use of advanced wastewater treatment systems will not indicate the change in pollution risk under these various conditions. Because well-functioning septic systems are designed to leach nitrogen into groundwater some management practices, such as instituting wastewater management programs to eliminate failed septic systems will have little or no effect on nitrogen loading to groundwater and can't be modeled this way.

Management options evaluated in this assessment were selected to address key risks and concerns identified in the assessment process.

Because nutrient loading analysis has limited application and can't be used to evaluate all management options, recommendations are developed based on both modeling results and generally accepted management practices for preventing pollution from land use activities.

## Use of Nitrogen-Reducing Septic Systems

Figure 23



The modeled change in nitrogen loading to groundwater using nitrogen-reducing septic systems is shown in Figure 23. Current estimated nitrogen inputs, at 7.1 lbs/acre/yr are high enough to be a concern due to risk of elevated nitrogen concentrations in private wells and presence of other wastewater contaminants such as bacteria and viruses. Because septic systems are estimated to be the source of more than 80 percent of nitrogen inputs, bacteria from improperly treated effluent is a serious risk to private wells. Regular inspection, maintenance and repair of septic systems, including replacement of cesspools, are the most effective methods to ensure proper system function and reduce risk of bacteria contamination. Because the potential for movement of bacteria to wells or surface waters is greatest in high water table sites, densely concentrated lots and sites

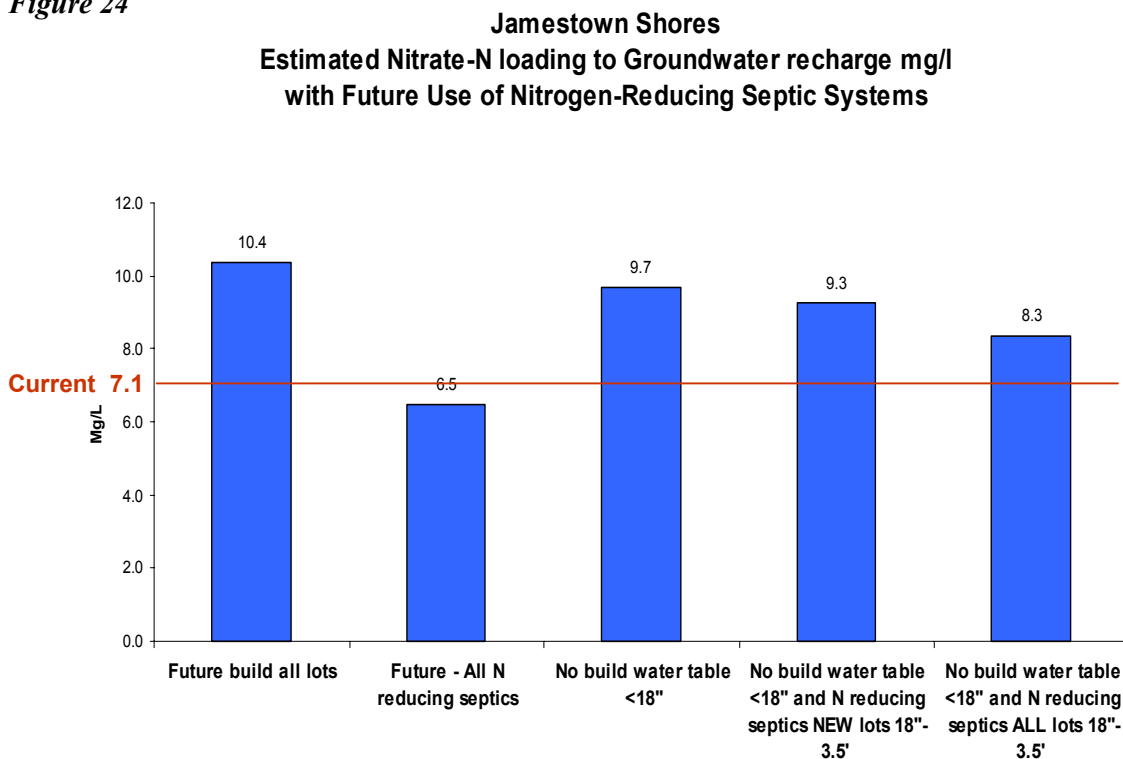
**NOTE:** Modeled nitrogen concentrations are estimates for the Jamestown Shores area as an average, based on calculated nitrogen sources to groundwater recharge. Concentrations are based on dilution of sources with available precipitation, after accounting for evapotranspiration and runoff. Actual concentrations in wells are likely to be lower.

close to surface waters and wetlands, this analysis focuses on use of advanced treatment systems in these high risk areas.

Nitrogen-reducing septic systems are those capable of reducing total nitrogen by 50 percent. These technologies also reduce bacteria counts by at least one to two orders of magnitude, however, advanced wastewater treatment systems can be specifically designed for bacteria treatment, especially where wells are located less than 100 feet from septic systems.

- Under current land use, using nitrogen-reducing septic systems in wetland buffers (to eventually replace failed or substandard septic systems already located in wetland buffers) would result in only a slight reduction in total loading, from 7.1 to 6.8 mg/l. However, improved treatment in critical wetland buffers would reduce potential for movement of improperly treated effluent to nearby wetlands.
- Replacing existing systems with advanced treatment systems located on lots less than ¼ acre size would result in a more significant decrease in total loading, with concentrations groundwater recharge declining to 6.3 mg/l. Improved treatment would protect private wells on small lots from increased nitrogen inputs and bacteria from improperly treated effluent. Since almost all lots are less than ¼ acre, this represents a best case scenario in terms of the maximum reduction in nitrogen inputs possible under current land use.
- With future development, building on all vacant, unprotected lots except those with water table within 18 inches or less would result in an increase in estimated nitrogen loading, with the groundwater nitrogen concentration in groundwater recharge rising to almost 10 mg/l with use of conventional septic systems. This is a serious concern given existing levels are already high and incidence of contaminated wells.
- Use of advanced wastewater treatment on all current and future lots ¼ acre in size and smaller would still result in an increase above current levels, but total loading would be closer to present levels, and risk of bacteria movement would be reduced. Nitrogen concentrations would also be diluted by keeping runoff at pre-development levels by retaining and recharging stormwater runoff onsite.

Figure 24



The advanced wastewater treatment options shown in Figure 24 explore the potential change in nitrogen inputs to groundwater recharge using nitrogen reducing septic systems in areas of high water table.

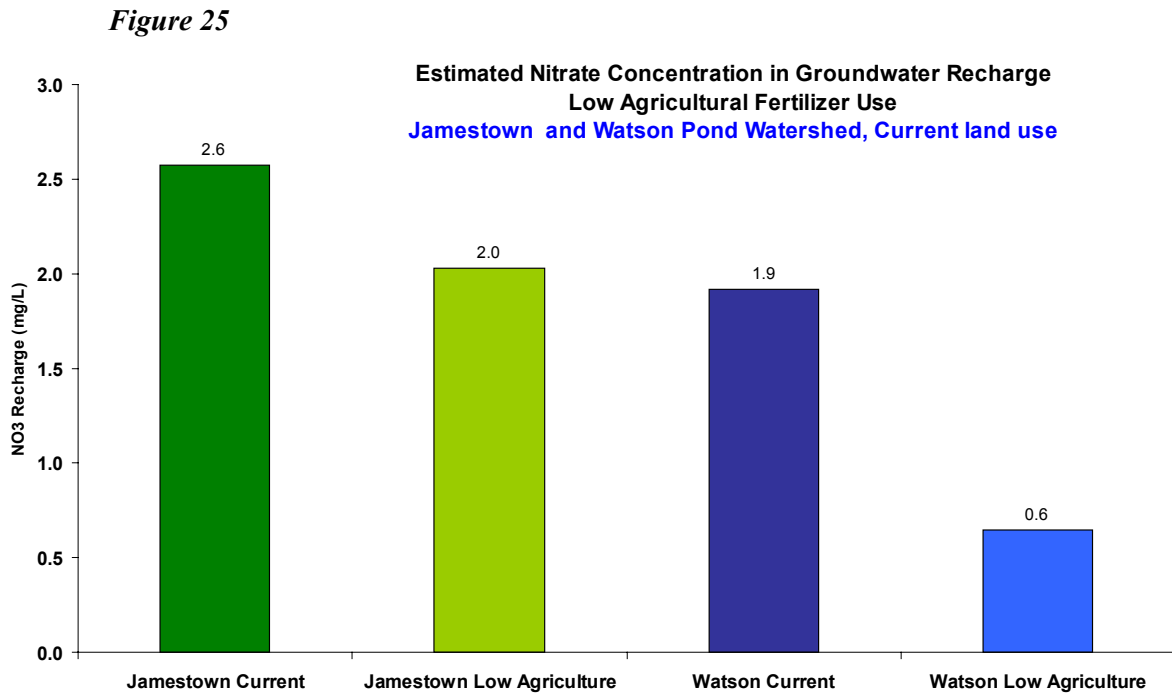
- The current estimated nitrogen concentration in groundwater recharge is 7.1 mg/l, represented by the red bar for comparison. The maximum worst case with future development of all vacant lots is 10.4 mg/l, which would include development of all lots, including those with water table less than 18 inches. For comparison, the future scenario with use of all nitrogen reducing systems on all existing and vacant lots is 6.5 mg/l. This includes vacant lots with high water table less than 18 inches which would probably not be considered developable.
- Future development excluding vacant lots with water table less than 18 inches would result in an estimated concentration of 9.7 mg/l nitrogen. This is probably the most realistic worst case future scenario as lots with water tables less than 18 inches are likely to be considered wetlands and are undevelopable.
- Use of nitrogen reducing systems with new development on lots with water table 18 inches to 3.5 feet would only result in a slight change in total nitrogen loading to 9.3 mg/l but under this scenario wetlands are more likely to be protected and risk of system failure would be reduced on marginal sites with use of

advanced treatment systems. It is important to remember however, that on marginal sites with water table less than 3.5 feet, groundwater is likely to rise at least 1 ½ feet higher than indicated by site evaluations and stay elevated for 10 percent of the year (Morgan and Stolt 2002). Ensuring adequate setbacks to wells and surface waters is especially critical on these marginal sites given that proper system function is very likely to be compromised when high water tables rise closer to the bottom of the leach field. In drinking water supply areas, especially in shoreline zones, more than 18 inches to high water table is justified to prevent improper treatment during periods of high water table.

- No new construction on water tables less than 18 inches and use of nitrogen-reducing septic systems on all developed and vacant lots with water tables between 18 inches and 3.5 feet would result in estimated nitrogen concentrations of 8.3 mg/l in groundwater recharge. Although this still represents an increase in nitrogen above present levels, risk of groundwater contamination would be substantially reduced with advanced treatment on all marginal lots. Because the area is already heavily developed, using advanced treatment systems only for new development will not substantially reduce pollution risks. Replacing failed and substandard systems is needed to protect groundwater quality, especially on small lots without adequate setbacks to wells and in areas with water table less than 3.5 feet. In these marginal areas advanced treatment systems will also minimize land disturbance and drainage alterations resulting from use of filled systems.

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## Agricultural Fertilizer Management



The modeled nitrogen loading estimates assume use of standard fertilizer application practices for tilled cropland. Fertilizer application rates for crops such as corn and potatoes are typically 4.9 lbs/1000 sq.ft. (215 lbs/acre), with 30 percent likely to leach to groundwater.

Estimates for Jamestown Current and Watson Current above, indicate average nitrogen inputs to groundwater for the Island as a whole and the Watson Reservoir watershed using these standard fertilizer application rates for areas mapped as tilled agriculture and orchards. Pasture was assumed to be unfertilized. Given that Jamestown agricultural lands may be farmed less intensively, we evaluated the change in loading likely with less intensive use, with only 6 percent leaching to groundwater (typical of well managed home lawns receiving smaller doses of fertilizer).

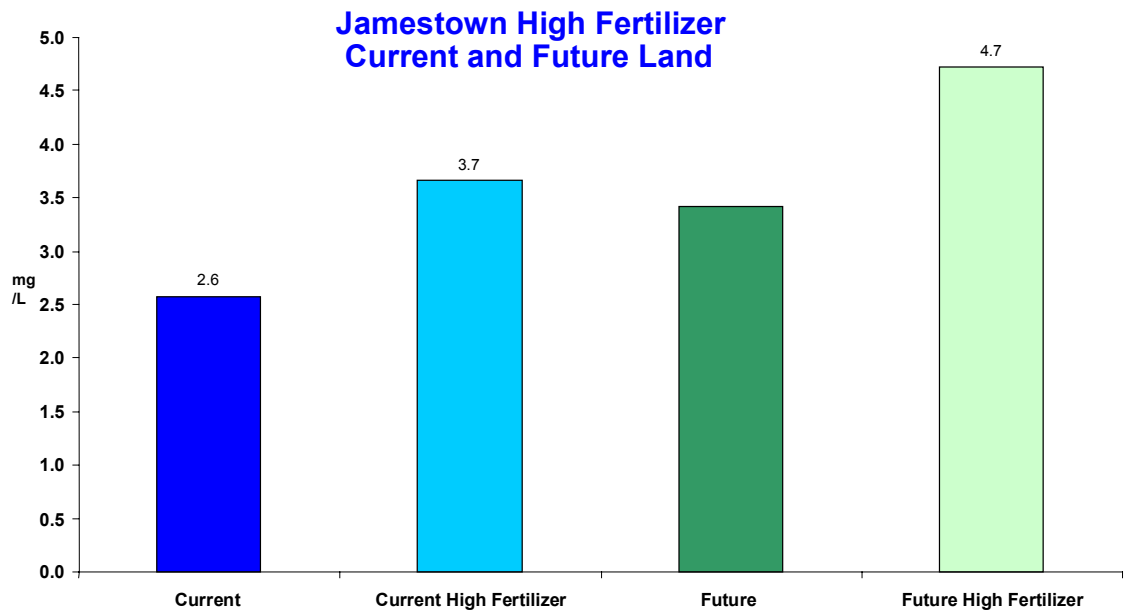
As shown above, the difference in nitrogen concentrations is slightly less for JAMEstown as a whole, but far less in the highly agricultural

Watson Farm watershed. This indicates that nutrient inputs of both nitrogen and phosphorus may be much lower for agricultural areas than estimated if fertilizer application rates and /or management practices result in reduced fertilizer losses to groundwater and surface runoff. Management practices might include, for example, reduced fertilizer application, use of slow release fertilizers, smaller doses, and irrigation management to prevent overwatering. This also shows that management practices can be highly effective in reducing nitrogen inputs to groundwater.

### Management of Home Lawns and Pets

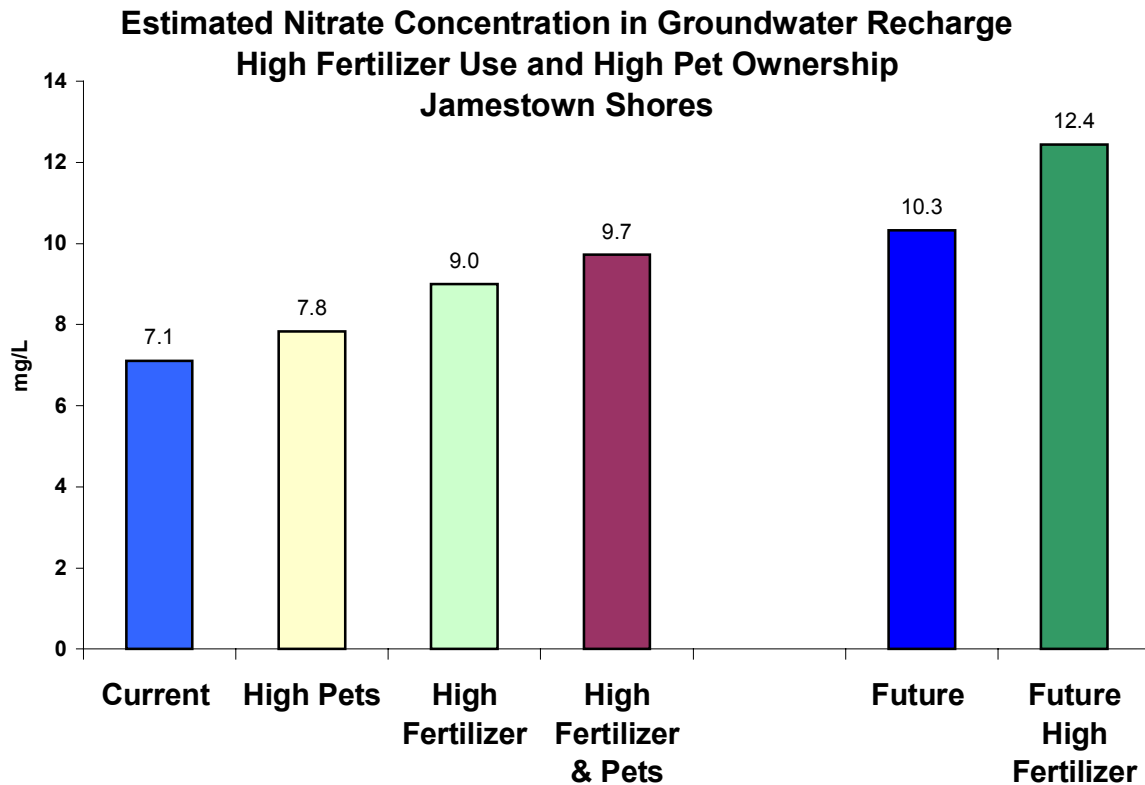
*Figure 26*

**Estimated Nitrate Concentration in Groundwater Recharge (mg/l)**



Nitrogen loading from home lawns assume that 75 percent of homeowners use lawn fertilizers at a rate of 4 lbs/1000 sq.ft./year. We also assume use of good management practices, without overfertilizing or overwatering, resulting in 6 percent leaching to groundwater recharge. With these assumptions, current loading to groundwater from all sources would be 2.6 mg/l, increasing to about 3.5 mg/l with future development. The high fertilizer scenarios shown above indicate nitrogen inputs expected under current and future land use with more intensive use, such as larger lawns, heavier fertilizer use or overwatering resulting in 30 percent leaching to groundwater. These estimates show that good lawn management is needed to avoid increased nitrogen concentrations in groundwater and also minimize risk of pesticides associated with home lawn care.

Figure 27



The impact of residential lawn care practices and pet ownership is magnified in densely developed areas. In Figure 27, the effect of high fertilizer use, with 30 percent leaching of nitrogen to groundwater is compared to current and future estimates. For example, with high fertilizer use the average concentration of nitrogen in groundwater recharge is expected to increase from about 7 to 9 mg/l.

In response to comments from the wastewater management commission that suggested Jamestown homeowners probably average one dog per home, we also recalculated nitrogen inputs from pet waste. These estimates show that residential practices such as fertilizer application can begin to offset gains made by using advanced wastewater treatment systems. Picking up after pets also makes sense in densely developed areas, especially where private wells are likely to receive overland runoff.

Lawn fertilizers may be controlled by public education and by setting limits of disturbance for new construction. In densely developed areas pet waste ordinances are commonly used.

