MAP UNITS OF HIGHLY ERODIBLE LAND

INTRODUCTION

Natural processes continually create new soil from the raw underlying parent material or from bedrock. For most soils in the State, these processes offset about 3 tons per acre of erosion each year. Erosion slower than the rate of replacement is considered "tolerable". Each soil is assigned a tolerance value based mainly on the thickness of the soil above bedrock or unaltered parent material.

Soil Conservation Service Soil Scientists and Soil Conservationists determine if a soil or map unit is highly erodible or potentially highly erodible due to sheet and rill erosion. This is done by using the Universal Soil Loss Equation (USLE). The USLE relates the effects of rainfall, soil characteristics, and length and steepness of slope to the soil's tolerable erosion rate by water.

DEFINITION OF HIGHLY ERODIBLE SOIL

A highly erodible soil/map unit is a soil with a maximum potential for erosion that equals or exceeds eight times the tolerable erosion rate. This can be represented by the formula - $RKLS/T \geq 8$. The formula does not consider crop management or conservation practices, which influence the actual erosion rate.

CRITERIA FOR HIGHLY ERODIBLE SOIL MAP UNITS

The procedure used to determine whether a given soil map unit qualifies as highly erodible land or potentially highly erodible land follows:

Step 1. For each soil map unit in the county soil legend, calculate the minimum LS value required for $RKLS/T \geq 8$ by solving for LS, ie. $LS = 8T/RK$.

Step 2. For the specific combinations of slope and steepness specified in Steps 3 and 4, obtain LS values from table 3 in the Appendices (from Agriculture Handbook 537, December, 1978).

Step 3. A soil map unit qualifies as highly erodible land if the LS value for the shortest length and minimum percent of slope expected for the unit equals or exceeds the minimum value calculated in Step 1, ie. $LS = 8T/RK$. See Appendices A-F.

Step 4. A soil map unit qualifies as potentially highly erodible land if --

a. The LS value for the shortest length and minimum percent of slope expected for the unit is less than 8T/RK and

b. The LS value for the longest length and maximum percent of slope expected for the unit exceeds 8T/RK.

See Apendices A-F.

This information is to be used in conjunction with published county soil surveys.

List of Map Units that Qualify as Potentially Highly Erodible Land

Middlesex County, Connecticut
(Correlated and Published, 1980)

AfB	Agawam fine sandy loam, 3 to 8 percent slopes
BoB	Branford silt loam, 3 to 8 percent slopes
CbB	Canton and Charlton fine sandy loams, 3 to 8 percent slopes
CsB	Cheshire silt loam, 3 to 8 percent slopes
HfB	Hartford sandy loam, 3 to 8 percent slopes
HkC	Hinckley gravelly sandy loam, 3 to 15 percent slopes
LpB	Ludlow silt loam, 3 to 8 percent slopes
MgC	Manchester gravelly sandy loam, 3 to 15 percent slopes
MyB	Merrimac sandy loam, 3 to 10 percent slopes
PbB	Paxton and Montauk fine sandy loams, 3 to 8 percent slopes
WkB	Wethersfield loam, 3 to 8 percent slopes
WxB	Woodbridge fine sandy loam, 3 to 8 percent slopes
YaB	Yalesville fine sandy loam, 3 to 8 percent slopes

List of Map Units that Qualify as Highly Erodible Land

Middlesex County, Connecticut
(Correlated and Published, 1980)

BoC	Branford silt loam, 8 to 15 percent slopes
CsC	Cheshire silt loam, 8 to 15 percent slopes
HME	Hinckley and Manchester soils, 15 to 45 percent slopes
PbC	Paxton and Montauk fine sandy loams, 8 to 15 percent slopes
PbD	Paxton and Montauk fine sandy loams, 15 to 25 percent slopes
WkC	Wethersfield loam, 8 to 15 percent slopes
WkD	Wethersfield loam, 15 to 35 percent slopes
YaC	Yalesville fine sandy loam, 8 to 15 percent slopes

LIST OF MAP UNITS THAT QUALIFY AS ADDITIONAL FARMLAND OF STATEWIDE IMPORTANCE

Yellow

Middlesex County, Connecticut - Correlated and Published, 1980

Map Unit	Description	Class
BoC	Branford silt loam, 8 to 15 percent slopes	III
CsC	Cheshire silt loam, 8 to 15 percent slopes	III
HkC	Hinckley gravelly sandy loam, 3 to 15 percent slopes	IV
MgA	Manchester gravelly sandy loam, 0 to 3 percent slopes	III
MgC	Manchester gravelly sandy loam, 3 to 15 percent slopes	IV
PbC	Paxton & Montauk fine sandy loams, 8 to 15 percent slopes	III
PnA	Penwood loamy sand, 0 to 3 percent slopes	III
PnB	Penwood loamy sand, 3 to 8 percent slopes	III
Rb	Raypol silt loam	III
Ru	Rumney fine sandy loam	III
Rv	Rumney Variant silt loam	III
St	Suncook loamy sand	III
Wd	Walpole sandy loam	III
WkC	Wethersfield loam, 8 to 15 percent slopes	III
Wr	Wilbraham silt loam	III
WvA	Windsor loamy sand, 0 to 3 percent slopes	III
WvB	Windsor loamy sand, 3 to 8 percent slopes	III
YaC	Yalesville fine sandy loam, 8 to 15 percent slopes	III

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TABLE 2–3. EXAMPLE WASTEWATER FLOW REDUCTION METHODS

- I. Elimination of nonfunctional water use
  - A. Improved water use habits
  - B. Improved plumbing and appliance maintenance
  - C. Nonexcessive water supply pressure
- II. Water saving devices, fixtures and appliances
  - A. Toilet
    - 1. Water carriage toilets
      - a. Toilet tank inserts
      - b. Dual-flush toilets
      - c. Water-saving toilets
      - d. Very low-volume flush toilets
        - i. Wash down flush
        - ii. Mechanically assisted
          - . Pressurized tank
          - . Compressed air
          - . Vacuum
          - . Grinder
    - 2. Non-water carriage toilets
      - a. Pit privies
      - b. Composting toilets
      - c. Incinerator toilets
      - d. Oil-carriage toilets
  - B. Bathing devices, fixtures, and appliances
    - 1. Shower flow controls
    - 2. Reduced-flow showerheads
    - 3. On/off showerhead valves
    - 4. Mixing valves
    - 5. Air-assisted low-flow shower system
  - C. Clotheswashing devices, fixtures, and appliances
    - 1. Front-loading washer
    - 2. Adjustable cycle settings
    - 3. Washwater cycle settings
  - D. Miscellaneous
    - 1. Faucet inserts
    - 2. Faucet aerators
    - 3. Reduced-flow faucet fixtures
    - 4. Mixing valves
    - 5. Hot water pipe insulation
    - 6. Pressure-reducing valves
- III. Wastewater recycle/reuse systems
  - A. Bath/laundry wastewater recycle for toilet flushing
  - B. Toilet wastewater recycle for toilet flushing
  - C. Combined wastewater recycle for toilet flushing
  - D. Combined wastewater recycle for several uses

From: Clements et al., 1980.

East Hampton Ad Hoc Lake Advisory Committee

Taxes and Water Quality

March 7, 1995

March 7, 1995

Taxes and Water Quality

Ad Hoc Lake Advisory Committee

One of the Ad Hoc Lake Advisory committee's charges is to conduct research and make recommendations to the Town Council to address algae blooms in Lake Pocotopaug. Part of these recommendations include a lake management plan. This report focuses on the effects of current property tax policy on the maintenance of watershed forest land, and its importance with respect to the water quality of Lake Pocotopaug.

Why is undeveloped land in the watershed important to the future of Lake Pocotopaug?

Lake water quality is largely dependent on the intensity of land use in its watershed. Most important is the delivery of nutrients to the lake, such as phosphorus, as a result of various land uses. Undeveloped forest land exports the least amount of phosphorus and other eutrophication causing materials to lakes (Worden 1993). As forest land is developed into residential, commercial and industrial uses, the export of phosphorus increases greatly (NYDEC 1992). If the watershed of Lake Pocotopaug was developed to the full extent of todays zoning using todays practices, the water clarity in the lake would likely decline substantially from what it is today. Figure 1 and Table 1 show past, present and future projections for Lake Pocotopaug based on a model derived from the inlet sampling program done in 1991 and 1992 and watershed mapping project (LAC 1993).

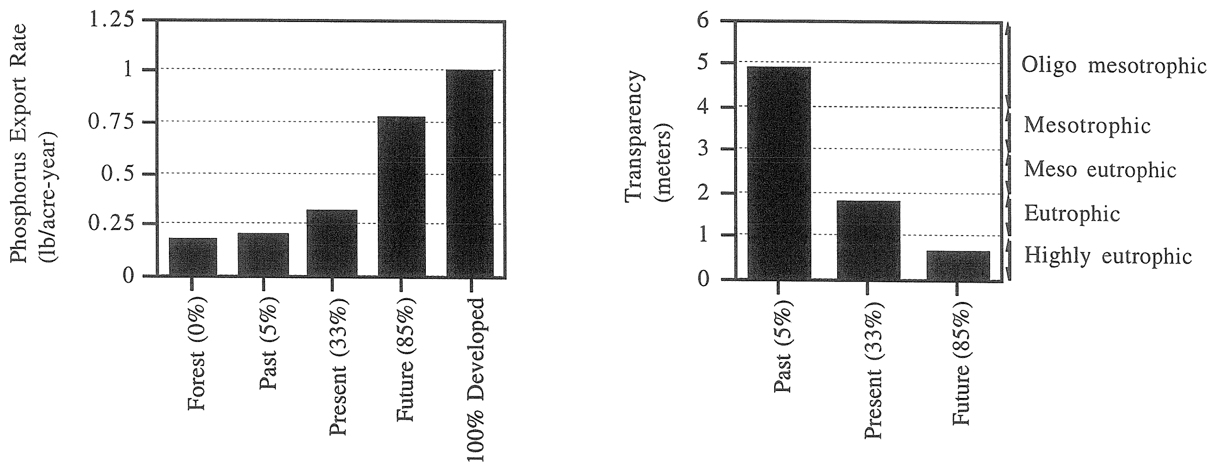

Figure 1: Phosphorus export rates and transparency for various intensities of development as predicted by the model.

Time	Developed Area	Phosphorus Export From Land Areas		Total P Input, (all sources)	Spring P Conc.	Spring Trans-parency	Trophic Classification*
	(%)	(lb/acre-year)	(lb/year)	(lb/year)	(ppb)	(meters)	
Past	5	.20	476	704	9	4.9	Oligotrophic
Present	33	.32	791	1,277	17	1.8	Eutrophic
Future	84	.76	1,817	2,303	31	.6	Highly Eutrophic
* Based on spring transparency. ("The Trophic Classification of Seventy Connecticut Lakes", CT DEP 1982)							

Table 1: Past, present and future conditions as predicted by the model.

Figure 1 and Table 2 shows that increasing development of the watershed is associated with decreasing transparency in the lake because of the increased nutrient export associated with increasing intensity of land use in the basin.

Today 67 percent of Lake Pocotopaug's watershed is undeveloped woodland. Although it would be best for the lake, it is unrealistic to try to prevent the development of all remaining woodland in the lake basin. However, not all woodland owners may wish to develop their land. Some may want to keep it the way it is, as woodland. However, today's method of taxation and high property values make it difficult for many landowners to afford to keep their land as undeveloped woodland. Often, the eventual result is the forced sale of land. Few people are in the position to buy land for the purpose of keeping it for conservation purposes. Usually it is purchased and subdivided as building lots. The result is added nutrients for Lake Pocotopaug.

There are two tax situations that may cause this to happen. 1) Ever increasing local property taxes cause ownership of open land to become prohibitive, thus forcing sale, and 2) state and federal estate (death) taxes can cause the forced sale of land within 9 months of the death of the owner to settle an estate when the land comprises most of the deceased total assets.

The following discussion focuses on the property tax issue, since it is something a town government can do something about.

How have rising taxes affected landowners?

The revaluation in 1991 demonstrates how rising land values and increasing tax rates have especially affected the owners of undeveloped land. The following example, showing before and after tax bills of four typical landowners in different situations, summarizes how landowners were affected:[1]

Landowner 1: Owns a home of average value on a 1 1/2 acre lot in a 1 1/2 acre zone, and has an average number of cars.

Landowner 2: Owns the same as landowner 1, except his lot is 15 acres.

Landowner 3: Owns a vacant 15 acre lot.

Landowner 4: Owns the same home and cars as landowners 1 and 2 except he has 5 acres of land that borders Lake Pocotopaug.

Landowner	Before	After	Change	%
1: House and 1 1/2 acres	$2152	$2127	-$25	-1.2%
2: House and 15 acres	$3013	$3550	$537	18%
3: Vacant 15 acres	$1206	$2073	$867	72%
4: House and 5 acre lake lot	$3790	$6867	$3077	81%

Table 2: Taxes for four landowners before and after revaluation.

The reason for the varied change in taxes in the four cases shown in Table 2 is because tax revenues from land went up dramatically as a result of the revaluation. Revenues from all other sources went down. (Figures 2 and 3). As can be seen in these examples, taxpayers with little excess land, like land owner 1, may have seen a decrease in tax, because land was a smaller proportion of their total assessed property. In contrast, taxpayers with excess and vacant land, such as landowners 2, 3 and 4, saw substantial increases, because the increases on their land far overshadowed any reductions on their dwellings and cars. The size of their net increase depended on how much land they owned, and where it was located. It should be noted that most landowners' need for town supplied services changed little in the course of a year; their additional tax buys them nothing extra.

[1]The tax information used in this report is from draft reports "The Fiscal Impact of Three Major Land Uses for the Town of East Hampton" and "The Fiscal Impact of Open Space" which were based on fiscal years 1990-1991 and 1991-1992.

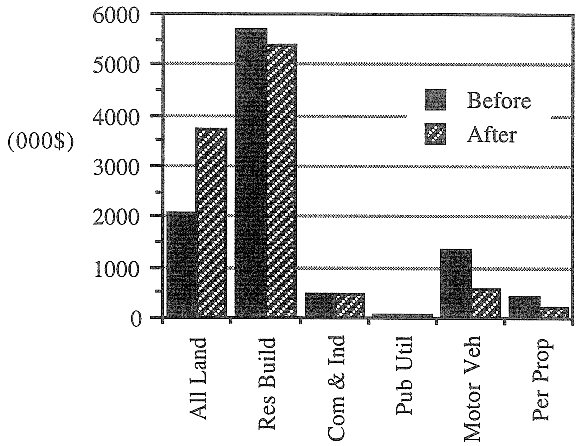

Figure 2: Revenues before and after revaluation

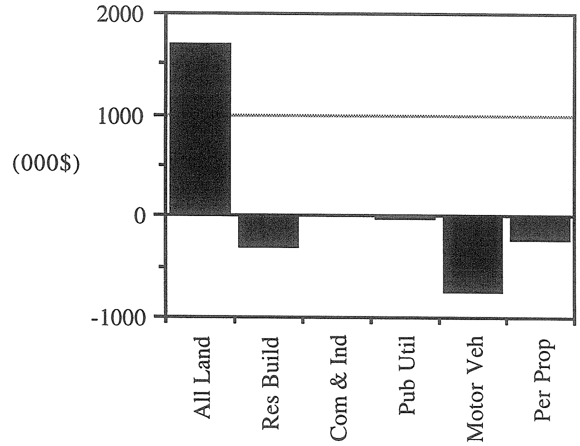

Figure 3: Revenue source change due to revaluation

What can be done about the heavy tax penalty for owning undeveloped land?

Fortunately, there is a program that allows tax reductions on undeveloped land. This allows an opportunity to reduce negative incentives that may force watershed landowners to sell their property into development.

Public Act 490

Public Act 490 (PA 490)[2] was enacted as a state statute by the 1963 Session of the General Assembly in response to concerns that local property taxation policies were adversely affecting crucial characteristics of our society and environment.

PA 490 provides that taxes be reduced for:

1) Farm tracts of any size.
2) Certified forest land aggregating more than 25 acres.
3) Other open space land as designated by the local planning commission[3] .

This reduction is based on what the land is actually used for (use value), such as pasture land, woodland. etc., and not on what it might bring on the market if sold for its highest use (fair market value). This is justified because open space land requires little if any support from local government revenues. Local property taxes largely support education with much of the balance for roads, and fire and police protection. Lower taxes on open space land recognizes a low utilization of town services and a high social value resulting from maintenance of open space land for environmental, conservation and recreational purposes. The East Hampton Plan of Development encourages the use of PA 490 tax incentives for the maintenance of agricultural and other open space lands (East Hampton 1989).

The Open Space Provision of PA 490

Most people are aware of the agriculture and forestry provisions of PA 490. Lower taxes are required on qualified agricultural and forest land by state statute. However, the open space provision is an *option* to towns. It is enacted by a vote of its legislative body, once a designation has been made in the Plan of Development. Open space land is defined in the statutes as any area of land, including forest land, not excluding farm land that if preserved would:

1. Promote orderly urban or suburban development.
2. Maintain and enhance natural or scenic resources.

[2] CGS 12-63, 12-107a through e, and 12-504a through h

[3] What is open space? Open space is a very broad term that means any undeveloped or open land, public or private, farmland, and lands traditionally used for active or passive recreation. Examples include state forest, Sears Park, ball fields, sportsman's club land, the wood lot next door, farms, abandoned fields, lakes, streams, ponds and wetlands, etc.

3. Protect streams or water supplies.
4. Promote conservation of soils, wetlands, beaches or tidal marshes.
5. Enhance public recreation opportunities.
6. Preserve historic sites.
7. Enhance the value to the public of neighboring or abutting parks, forests, wild life preserves, reservations, sanctuaries, or other open space.

Several of these qualities would be applicable to Lake Pocotopaug's watershed to enhance the lake's viability as a valuable natural and recreational resource.

Once the planning commission has designated open space lands in the Plan of Development, and the provision has been enacted, landowners may qualify for lower taxes if the land in question meets any of the above listed characteristics of open space, and has not been modified since the land was designated as open space in the Plan of Development. This is done through application to the local tax assessor.

To reduce the possibility of misuse of PA 490 status, the legislature has provided penalties in the form of an additional conveyance tax of up to 10% of the parcel's selling price for the sale or conversion of land to other uses within 10 years of it's acceptance as open space by the assessor.

Many towns in our area have enacted the open space provision in varying forms, including Clinton, Durham, East Haddam, Essex, Haddam, Hebron, Killingworth, Middlefield, Old Saybrook, Portland, Lyme, Old Lyme, and Willington.

How applicable is the open space provision to the watershed of Lake Pocotopaug? Would it make a difference?

No detailed study of woodland ownership specific to the watershed has been done, however some statistics for Connecticut woodlands are likely similar. (Figures 4 and 5).

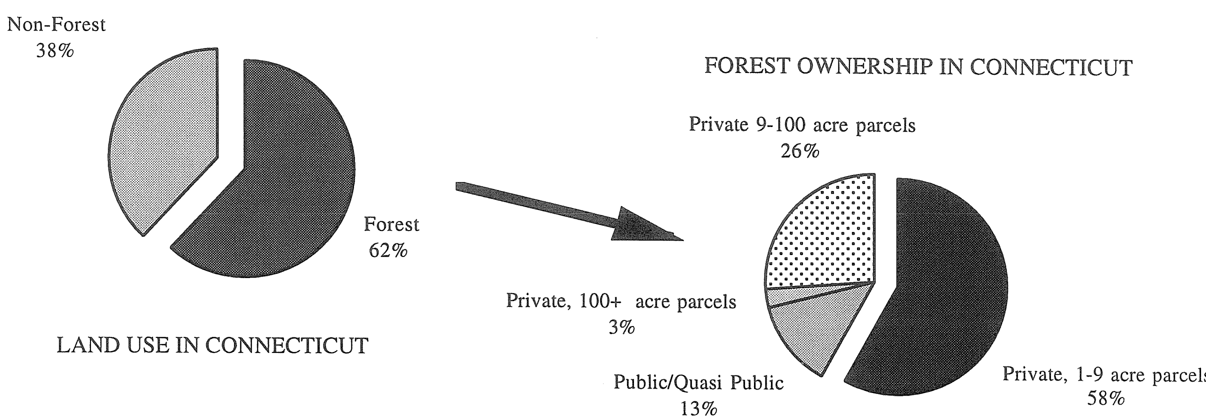

Figure 4: Land use and forest ownership in Connecticut. (Gibbons and Ricard)

What is interesting to note in Figure 4 is that most of the privately held woodland is in small parcels of less than 9 acres. Since forest land must aggregate over 25 acres to qualify for the PA 490 forestry program, most of privately held forest is subject to high taxes and the probability of forced sale, unless the PA 490 open space provision is enacted to include the smaller parcels.

The average age of Connecticut woodland owners is 61 years (Gibbons and Ricard). Most are at or near retirement and have limited incomes. The property they own was either inherited or bought years ago when land was cheap. Paying taxes on this property is often a burden.

The watershed of the lake is much like the state in terms of the proportion of forest land, and the proportion of that forest in private ownership (Figure 5). Forest land comprises 67 percent of the lake basin, and 83 percent of it is privately held. As a consequence, PA 490 tax reductions likely play an important role in reducing the forced sale of land into development. The open space provision could extend this important program to forest owners of smaller parcels, as a positive incentive to maintain their lands as open space, and provide subsequent benefits to the water quality of Lake Pocotopaug.

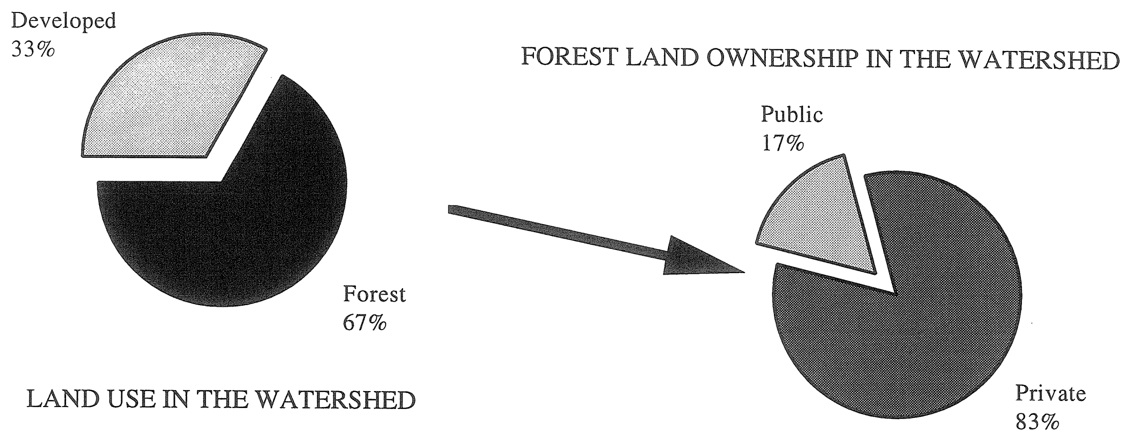

Figure 5: Land use and forest ownership in Lake Pocotopaug's watershed (LAC 1993).

PA 490 may be good for the open space owners in the watershed, but isn't development good to keep taxes down for everyone else because it increases the tax base?

At first glance it seems that development would have a beneficial effect to lower taxes. As land is subdivided and new houses and businesses are built, the Grand List goes up. With a larger tax base one would expect the mill rate to go down. This is true for commercial and industrial (or economic) development. However, the mill rate *will actually go up* as open space is converted to residential use to compensate for the increased need for town supplied services generated by residential land use.

It has been shown in several studies that commercial and industrial uses *bring in* more tax dollars than they *use* in services (American Farmland Trust 1986, Lincoln Institute of Land Policy 1992). This beneficial relationship is recognized in East Hampton and demonstrated by our commitment to encourage new business to locate here by providing a number of positive incentives through zoning and tax abatement programs. In contrast, residential land use has been shown to *use more* dollars in town provided services than it produces in tax revenues. What is less recognized is that these studies also show that like economic development, vacant lands *bring in* more revenue than they use in services.

Using a method similar to that used in a study conducted in Hebron in 1986 (American Farmland Trust 1986), the cost of services verses tax revenues for three types of land use in East Hampton are estimated as follows:

Land use type	Revenues	Expenditures	Difference
Residential	$15,491,400	$16,824,400	-$1,333,000
Commercial & Industrial	1,162,500	724,800	437,800
Private Open Space	954,700	59,400	895,300

Table 3: Revenues and Expenditures for Three Major Land Uses[4]

In terms of a ratio of revenues to expenditures, for each dollar of tax received, residential used $1.09 in services,

[4] From draft report "The Fiscal Impact of Three Major Land Uses for the Town of East Hampton" 1992.

commercial and industrial used $0.62, and open space used $0.06. (See Figures 6 and 7)

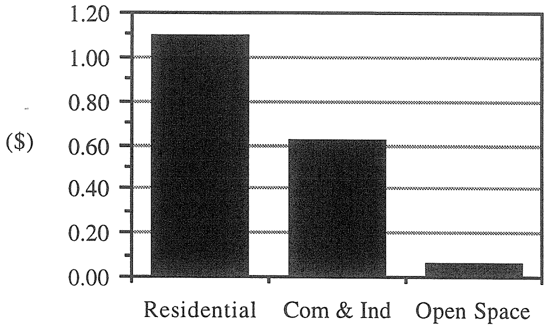

Figure 6: Cost of services per dollar of revenue received

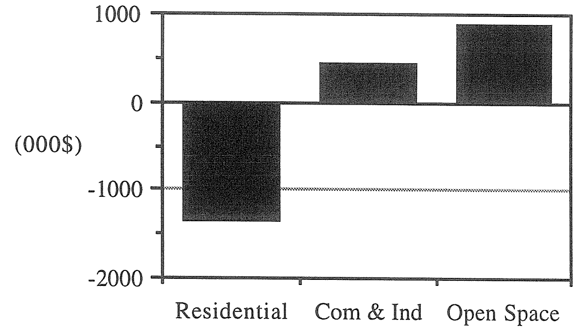

Figure 7: Surplus/shortfall

As shown in Table 3, each of the three land uses generates some revenue. However, as can be seen in Figures 6 and 7, it is not until the income from each is viewed in relation to the costs of town supplied services associated with them, that the net fiscal impact of the land use can be fully understood.

Because open space lands use so little in services when compared to the revenue they bring in, these lands effectively subsidize residential use. For fiscal year 1991-1992 this subsidy is nearly $900,000, almost double that contributed by commercial and industrial use. This makes sense; our biggest expenditures are for education, police and fire protection. Open space uses no education dollars, and very few in police and fire protection. However, unlike commercial and industrial land, open space rarely generates much income. Consequently, it provides this subsidy at a considerable burden to its owners.

What happens when open woodland is changed to residential use?

As a result of the above relationship, the conversion of vacant woodland, a net *producer* of revenue, into residential use, a net *user* of revenue, creates a fiscal deficit that can only be made up by raising the mill rate. This in turn makes it less affordable to keep open land, which forces its sale into development, and so on. The result is an ever increasing mill rate. The legislature enacted PA 490 to prevent this from happening.

Table 4 illustrates the fiscal impact of the conversion of open space to residential use using the 15 acre parcel of land in the previous example.

	Revenue	Cost of services	Revenue less services	Net change
Vacant 15 acre lot	$2,073	-$24	$2,098	-
Developed in R1 Zone (no sewers)	15,110	15,533	-423	-2,521
Developed in R1 zone (on sewers)	31,337	33,285	-1,948	-4,046

Table 4: The fiscal impact of land use change for a 15 acre parcel in the R1 zone.

It is interesting to note that a parcel of forest land that is given to a land trust, the state, or to the town, and is taken off the Grand List, causes a net change of -$2,098, which is less than if that same parcel were developed into house lots, because the residences would require more in services than the revenue they bring in with taxes.

Towns have the option of defining what land would be included for PA 490 open space. The following is a proposed open space designation for the watershed of Lake Pocotopaug. It is similar to those adopted by Durham, East Haddam, Essex, Haddam, Lyme, Old Lyme, and Willington. It has been designed to accomplish the following objectives:

1. To reduce the probability of forced sale of open space land into residential development due to property

taxes.

2. To promote the establishment of permanent open space dedications.
3. To designate only those areas that can be converted to residential use under the zoning regulations, so as to have the least initial impact to the Grand List while still accomplishing the objectives listed.
4. To not discourage the conversion of vacant industrial and commercial land into industrial and commercial uses in the watershed.

The following language is suggested for the proposed designation:

DESIGNATION:

1. That proportion of any lot or parcel of land, which portion is in excess of the minimum lot area for the zone in which it is located, provided that:

   a. The lot or parcel is wholly or partially within the watershed of Lake Pocotopaug.

   b. The open space to be preserved is itself not less than the minimum lot area for the zone in which it is located.

   c. The land is not in the C, I, DD, or CC zones.

   d. The land conforms with the essential character of "open space" as defined in the CT General Statutes.

2. Any parcel or part thereof that is permanently set aside as open space by a conservation easement or an open space exaction, providing that it is wholly or partially within the watershed of Lake Pocotopaug.

Doesn't lowering taxes for open space landowners make everyone else's taxes go up?

In the short term, yes. In the long term no. PA 490 was enacted to help *keep tax rates from going up* unnecessarily by reducing the forced sale of open lands into residential development, which changes a parcel from a net *producer* of revenue to a net *user* of revenue, and avoiding the necessary increase of the mill rate to make up for the increasing shortfall. In the short term, there would be a small one time increase in the mill rate to make up a small reduction in the Grand List as property landowners sign up.

How much would the short term one time increase be?

By examination of the Grand List, approximately 89 parcels totaling 241 acres (or 10 percent of the watershed) fall into the size range that might qualify as open space with the proposed designation. Assuming all these landowners apply for PA 490 open space status and are accepted, the increase would be approximately 0.4 percent , or about .08 mill. This is the worst case scenario. In reality not all this land will meet the statute's requirements, and not all landowners will apply. Some of the lots listed are small and landowners may feel the reduction is not worth the bother of applying. Other lots are being held for the purpose of sale, and it would make no sense for an owner to incur the conveyance tax penalties. Taking these factors into consideration, a more realistic estimate would be less than that stated above. These estimates also assume the use value set by the assessor is the minimum allowed by state statute. The assessor may assign a use value considerably higher than the minimum, depending on the property's current use, thus further reducing impact on the mill rate.

How does this affect taxpayers?

Using the previous examples and <u>assuming the maximum change in mill rate</u>, before and after enactment taxes are as follows:

Landowner	Before	After	Change	%
1: House and 1 1/2 acres	$2,127	$2,136	+$9	+.4%
2: House and 15 acres	3,550	2,246	-1,304	-37%
3: Vacant 15 acres	2,073	830	-1,243	-60%
4: House and 5 acre lake lot	6,867	3,876	-2,991	-44%

Table 5: Change in tax from enactment of proposed PA 490 open space Provision in the watershed of Lake Pocotopaug.

Enactment's net affect on the Grand List and taxpayers not able to take advantage of the open space provision is small because the maximum total reduction in assessed property is small in comparison to the entire Grand List. (0.4 percent).

Table 6 shows the distribution of lot sizes under 25 acres that might be eligible for the proposed PA 490 open space designation. It is interesting to note that most open land in this size range is in small lots under 5 acres. This distribution is similar to the state wide pattern shown in Figure 4[5] .

Size Range (acres)	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	Totals
Total acreage (%)	143 (59%)	69 (29%)	29 (12%)	0 (0%)	0 (0%)	241
Number of Lots (%)	77 (87%)	10 (11%)	2 (2%)	0 (0%)	0 (0%)	89

Table 6: Size distribution of open lots under 25 acres in Lake Pocotopaug's watershed.

A point that is sometimes raised is that, with reduction of taxes on open space land, a resident with a large lot or vacant land will not be paying his fair share of taxes, and that residents with a small lot will end up subsidizing the large lot owner. Since open land requires little in town services, it produces more revenue than it uses. In effect, residents with open land *have actually been subsidizing small lot owners*. In fiscal year 1991-1992 open space land provided nearly $900,000 more revenue than it used in services. Adoption of the open space provision will not eliminate this subsidy. It will reduce it somewhat, but watershed open space land will still be a net producer of revenue. In exchange for this reduction will be a reduced risk of forced sale of property that would rapidly move land onto the market into residential development, thereby becoming a net user of revenue, instead of a net producer. It should be noted that with the proposed open space designation vacant parcels will still be assessed for at least a building lot at about $50,000 ($150,000 when on the lake); not all acreage would be assessed at use value.

In Conclusion:

The maintenance of forested land in the watershed of Lake Pocotopaug is an important part of a lake management plan. Enactment of the proposed PA 490 open space provision for the watershed would provide a positive incentive for watershed landowners to keep their land in its natural state and reduce the probability of the forced sale of these lands into development because of the burden of local property taxes. Land in its natural state is the least likely to cause water quality impacts to Lake Pocotopaug. The proposed open space designation is designed to have minimal impact on the grand list while still providing a meaningful reduction in taxes on qualifying open lands. Participation in PA 490 is an option to landowners. Those who choose to develop their land are not affected. In the long term, enactment would not only benefit the town by reducing impacts on water quality, and increasing open space opportunities, but it would also benefit the town fiscally by reducing the conversion of open space into uses that cost the town more in services than the revenue they bring in.

[5] By inspection of the Grand List for 1990 and tax map.

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WELLS

East Hampton Ad Hoc Lake Advisory Committee

LAND USE AND PHOSPHORUS INPUT TO LAKE POCOTOPAUG

March 7, 1995

Summary

Since 1990 Lake Pocotopaug has experienced severe nuisance algae blooms resulting in transparencies to less than 0.5 meters. In response to this the Ad Hoc Lake Advisory Committee has adopted a goal to restore transparency to no less than 2 meters at any time in the future. Because lake water quality is largely dependent on the land surrounding a lake, a watershed management plan must be developed and implemented to accomplish the goal.

Internal loading of phosphorus from bottom sediments to overlying water has been identified as the event that leads to the late summer blooms. The predisposition of the lake to internal loading is ultimately related to phosphorus, oxidizable organic material, and turbidity entering the lake from external sources. Because phosphorus usually determines the potential growth of algae and resulting transparency, it is typically considered to be the most important when controlling algae blooms. By addressing sources of phosphorus, controllable sources of these other materials are also addressed. This report uses available information to develop a model to assess the overall input of phosphorus to Lake Pocotopaug. The model demonstrates that the information collected for Lake Pocotopaug is consistent with studies done on other lakes, and that lake water transparency is ultimately dependent on the intensity of land use in the watershed.

Present spring phosphorus concentrations in the lake cause transparencies to be about 2 meters before internal loading begins. The conditions that give rise to this transparency also predispose the lake to internal loading events that result in transparencies of less than .5 meters later in the season. For this reason, *current inputs of phosphorus must be reduced* in order to accomplish the 2 meter goal. Three major phosphorus sources have been identified. From the model, atmospheric fallout accounts for 35 percent of the total, waterfowl 4 percent, and the land area of the watershed, 61 percent. Seventy five percent of the input from land areas is from presently developed areas, which comprises only 33 percent of the land in the basin.

Although a few "hot spots" are identified, most of the excess phosphorus export from land areas is associated with typical land use. Forest has the lowest phosphorus export rate of any land use. Developed areas had substantially higher export rates. The highest were associated with runoff coming directly from impervious surfaces such as roads. Since source reduction is difficult in developed areas, reductions will rely heavily on retrofitting existing drainage systems with control technology. It is recommended that a study of the natural and manmade drainage systems of the watershed be undertaken to outline a cost effective program to reduce current phosphorus input to the lake.

In addition to addressing existing sources of phosphorus, future sources must also be considered, otherwise any reductions achieved today will be offset by increases from future development. Land use policies are a reasonable and cost effective way to achieve this goal. Because present sources are enough to cause lake problems, policies must be adopted to insure that *new development will not cause any increase in phosphorus export to Lake Pocotopaug*. In addition to source control, the single most important consideration is stormwater runoff because it is the vehicle that transports these materials to the lake. Efforts must be made to lessen the quantity of overland flow due to development, and to improve the quality of stormwater that eventually reaches the lake. Observations on present land use policies are offered along with general guidelines to accomplish the stated goals as part of a watershed management plan.

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I. INTRODUCTION

Since 1990 Lake Pocotopaug has experienced severe nuisance algae blooms resulting in transparencies to less than 0.5 meters. In response to this, the Ad Hoc Lake Advisory Committee has adopted a goal to restore transparency to no less than 2 meters at any time in the future. Because lake water quality is largely dependent on the land surrounding a lake, a watershed management plan must be developed and implemented to accomplish the goal.

The purpose of this report is to look at available information to assess the overall input of phosphorus to Lake Pocotopaug, and identify ways to reduce it as part of a watershed management plan. It also provides a rational for instituting policy changes for the purpose of watershed management. More specifically this report:

1. Summarizes information from the land use subcommittee's mapping project, information gathered from the inlet sampling program, and the subcommittee's estimates of seagull populations roosting on the lake.

2. Uses the above information to develop simple phosphorus loading and transparency models for Lake Pocotopaug to demonstrate the relationship between man's activities in the watershed and lake water transparency.

3. Looks at the past, and future of Lake Pocotopaug, using the model and present trends to lend a perspective as to where we are headed and what to expect for the future in terms of lake water quality.

4. Assesses the effectiveness of current land use policies in the lake basin.

5. Suggests general guidelines for developing land use policies and practices to reduce lake impacts due to land use in the watershed.

II. DISCUSSION

Algae, like all other living organisms, require many different nutrients to grow. Of particular interest are phosphorus and nitrogen because they are in the least supply relative to the growth needs of algae and other organisms in a lake. Because phosphorus usually determines the potential growth of algae and resulting transparency, it is typically the nutrient considered to be most important when controlling algae blooms (Frink et al. 1978, Reckhow et al. 1980, U.S. EPA 1988). Most Connecticut lakes such as Lake Pocotopaug are phosphorus limited, although some lakes may at times be nitrogen limited (Frink and Norvell 1984). The primary source of these nutrients is the watershed. Watershed sources of nitrogen are difficult to control (U.S. EPA 1988). In the case of Lake Pocotopaug, the algae species of concern, *anabaena,* has the ability to fix atmospheric nitrogen, and need not rely on watershed sources (Worden 1993). Having no common gaseous phase, phosphorus enters the lake from external sources which are more easily controlled (U.S. EPA 1988). Also, by addressing sources of phosphorus, controllable sources of nitrogen are also addressed. Efforts to control algae blooms can be undertaken either in the lake to reduce phosphorus and algae concentrations, or in the watershed, to reduce the export of eutrophication causing materials. However, in-lake efforts treat the symptoms of algae problems and are rarely long lasting unless the source of the problem, phosphorus input from the watershed, is addressed first. For these reasons, successful lake management efforts typically involve a watershed management plan that focuses on controlling external phosphorus sources that affect concentrations in the lake (U.S. EPA 1988).

Two major external sources of phosphorus to lakes are the land area of the watershed, and fallout from the atmosphere. Typically, because of a lake's relatively long hydraulic residency time, most of the phosphorus that enters it eventually sinks and is incorporated into bottom sediments. Little leaves by way of its outlet. Normally this phosphorus stays in the sediments. However, under conditions of low concentrations of oxygen, this phosphorus can be released into overlying water to again become available for algae growth in a process called internal loading. Although internal loading is an important part of Lake Pocotopaug's problem (Kortmann 1992, Rich 1992, Worden 1993), this paper focuses on the input of phosphorus into the lake, which is an important factor causing the internal loading process to occur (Rich 1992). Other factors are the input of turbidity and oxidizable organic material (E.H. Conservation Commission Meeting May 14, 1992). By addressing phosphorus sources, sources of turbidity and oxidizable organic material are also addressed, as they generally have similar sources as phosphorus (Worden, Ad Hoc Lake Advisory Committee Meeting May 18, 1993). The process of internal loading is complex and requires specialized field investigation. It is therefore beyond the scope of this report.

III. SUMMARY OF WATERSHED INFORMATION

Three significant external sources of phosphorus to Lake Pocotopaug have been identified; the land area of the watershed, atmospheric fallout, and waterfowl (Fredette, Kortmann, E.H. Conservation Commission meeting 1992). A number of studies have shown that phosphorus export from a watershed to a lake is dependent on the intensity of land uses present (Norvell et al. 1979, Reckhow et al. 1980, U.S. EPA 1988). A seven to ten fold increase in phosphorus export to surface waters can be expected with a change of land use from forest to low and medium density residential development (NY DEC 1992).

Phosphorus is transported into a lake by storm water falling in its drainage basin. This stormwater reaches the lake by overland flow, such as streams and drainage system outflows, or through groundwater infiltration. Groundwater typically contains much less phosphorus than overland flow. The water resources of the Lake Pocotopaug drainage basin are shown in Map 1 in Appendix 3. Atmospheric fallout, both wet and dry, contains significant amounts of phosphorus. Some falls directly on the surface of the lake. On vegetated land areas, most of this fallout is absorbed into the soil and taken up by root systems (Kortmann 1991, Rich 1992). Soil, which also contains significant amounts of phosphorus, is stabilized by root systems. Phosphorus adheres to soil particles, especially the finer ones, which are more easily transported by moving water (CT Council 1986, NY DEC 1992). Soil also contains organic material and causes turbidity. In developed areas, natural vegetation is removed and replaced with impervious surfaces such as roads and roof tops, which collect atmospheric fallout and erosion products. Lawns can also can be significant sources of phosphorus. These materials are then washed into drainage systems during rainstorms before they can be absorbed by vegetation. The amounts of phosphorus and other eutrophication causing materials reaching surface waters from storm drainage systems can be very significant. Studies have shown that pollutant loading rates for phosphorus and nitrogen during the first hour of a typical rainstorm far exceed the amount contained in raw sanitary sewage generated by the same urban area during the same time (NY DEC 1986). Small increases in phosphorus concentrations in lakes are sufficient to cause problems.

Watershed Developed Areas

The developed areas of the lake basin are well defined and cluster either near the shoreline, (within 1000 feet on the average,) or along existing main roads, such as Mott Hill and Clark Hill Roads, and Route 66. The only exception to this is development near the High School. Because of the clustering it is fairly simple to outline these developed areas. Map 2 overlays the developed areas of the watershed on the subbasins of the watershed.

Watershed Zoning

Zoning regulations define the allowable limits of future development in the basin. Map 3 shows present zoning in the basin. Map 4 overlays the presently developed areas on the zoning map (East Hampton 1989). Table 1 summarizes the uses, minimum lot size, and maximum impervious area (roads not included,) allowed in these zones.

Zone Designation	Principle Use	Minimum Lot Area (Without / with sewer)	Max Impervious Area (Without / with sewer)
R1	Lakeside and Village Residential	60,000 sf / 20,000 sf	10% / 20%
R3	Resource Residential	60,000 sf / 40,000 sf	10% / 10%
R4	Rural Residential	60,000 sf / 60,000 sf	10% / 10%
RL	Reserved Land	not applicable	not applicable
DD	Designed Development	Not allowed / 5 acres	Not allowed / 50%
I	Industrial	Not allowed / 40,000 sf	Not allowed / 50%
C	Commercial	Not allowed / 40,000 sf	Not allowed / 60%
(R1, C)	Congregate Housing (special permit)	Not allowed / 8,712 sf/unit	Not allowed / 25%
Undesignated	Scraggy Island	not applicable	not applicable

Table 1. Current watershed zoning requirements (East Hampton Zoning Regulations, 1992).

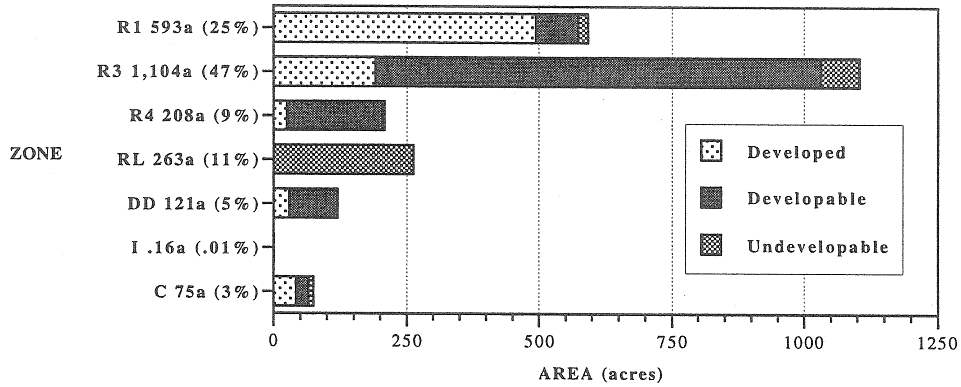
Table 2 shows the areas of the watershed in each zone, and the portion presently developed. It also shows the presently undeveloped area in each zone that could be developed at some time in the future. This was determined by subtracting areas that may reasonably be assumed to remain undisturbed in the future, such as state forest land, areas with easements that restrict development, and larger areas classified as wetlands.[1] These undevelopable areas amount to 364 acres or 15 percent of the land area of the basin.

Zone	Total Area		Area Presently Developed		Future Developable Area	
Designation	(acres)	(%)	(acres)	(%)	(acres)	(%)
R1	593	25	494	83	81	14
R3	1,104	47	191	17	841	76
R4	208	9	25	12	180	87
RL	263	11	0	0	0	0
DD	121	5	29	24	91	75
I	.16	.01	.16	100	0	0
C	75	3	42	56	24	32
Undesignated	.33	.01	0	0	0	0
Total	2,363	100	782	33	1,217	52

Table 2. Total, presently developed, and future developable area for each zone in the watershed of Lake Pocotopaug.

[1] The RL zone, which includes state forest land, is intended to allow for public uses of land. Though most of this land is forested today, there are no restrictions to any development that a local, state or federal government may chose to undertake in the future. Nor does it mean that the land cannot be sold for private development. (Town of East Hampton Zoning Regulations 1992). However, for the purpose of this report, RL land is assumed to be undevelopable.

For zoning purposes, wetlands may be included in the calculation of lot size. They therefore do not necessarily reduce density unless they are extensive.



Total, presently developed, and future developable area for each zone.

Watershed Sampling Program

In 1991 and 1992 various inlets to Lake Pocotopaug were sampled for total phosphorus and turbidity. Map 5 shows the locations where these samples were taken. Appendix 1a describes these locations and lists the lab data for each sampling period as well as the high, low and average phosphorus concentrations measured at each location. Appendices 1b through 1e show the total and per acre annual contribution of phosphorus for the same sampled areas, as well as their total and developed areas. Although each of these tables contain the same information, they are sorted by different columns to aid in identifying problem areas.[2] The areas associated with these contributions are shown in Map 6.

IV. PHOSPHORUS IMPORT AND TRANSPARENCY MODELS

The intent of the following modeling exercise is to demonstrate that the relationship expressed in the literature between the transparency of water in a lake and man's activities in the watershed holds true for Lake Pocotopaug.

Phosphorus Import Model

Watershed phosphorus export modeling is generally done to estimate total lake phosphorus loading using export rates from studies of other similar watersheds. These export rates are based on the land use present in a given area. In the case of Lake Pocotopaug, rates can be calculated from actual field data.

Samples collected during field work make use of available access points, and do not represent the entire watershed. To estimate the total phosphorus input to the lake from all land areas, a simple model using existing information can be developed. Sampled areas that are representative of typical export rates can be used to calculate phosphorus export as a function of developed area. The resulting model can then be applied to the rest of the watershed to estimate the total watershed export (Reckhow et al. 1980, U.S. EPA 1988, Windham RPA 1977).

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[2] See Appendix 4j for calculation of per acre export rates from concentrations found in streams. The first set of columns in Appendices 1b through 1e, labeled "Total Drained Area", represents calculated values for the entire area contributing water to that sampling point, essentially integrating all upstream areas. Where samples were taken at several points along a stream, it is possible to subtract out contributions from upstream sampled areas, from those of the downstream integrated sample. This results in contributions for just the downstream area, and gives better insight into where the measured phosphorus is originating. These values are represented in the second set of columns, labeled "Sub Drained Area".

The phosphorus import model for Lake Pocotopaug was derived by plotting the export rate per acre against the percent developed area for each point sampled in 1991 and 1992. (See Figure 1, 2 and 3). Water sampled at a particular point originates as rain falling on the land area draining to that point. These areas were determined from contours shown on USGS maps, and measured using a computer CAD program as part of the mapping project. (Maps 5 and 6 in Appendix 3). These areas were overlaid with the developed area shown on map 4 to determine each sampled areas' percentage of development. The phosphorus export rates were calculated from concentrations found in the samples, the annual runoff and the drained area. The model, or mathematical relationship between phosphorus export and developed area was derived using a computer curve fit program to find the best curve for the plotted data points as determined by regression analysis.

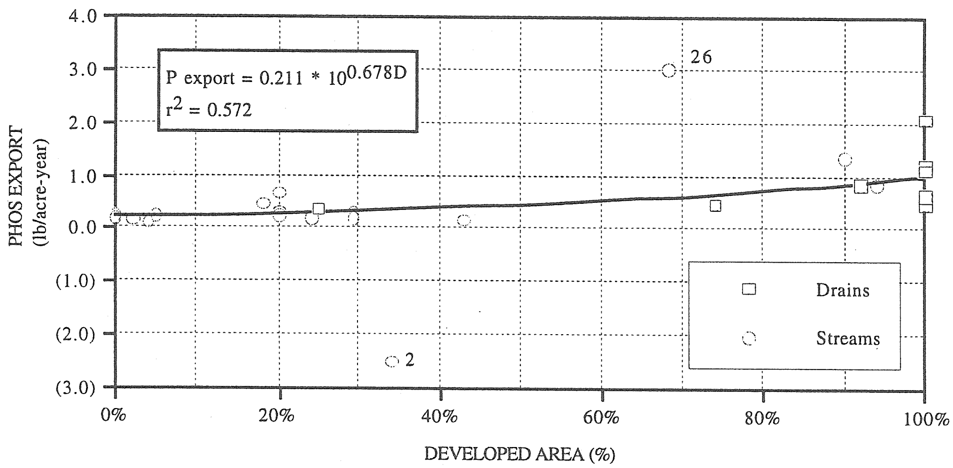


Figure 1. Phosphorus export verses percent developed area for all sampled stations.

Figure 1 plots all of the sampled points verses their percent developed area. As can be seen in Figure 1, several streams deviate significantly from the rest. These streams have identifiable reasons for their large deviation, and therefore were left out of the data set used to describe the model. (See Appendix 2). The resulting plot is shown in Figure 2.

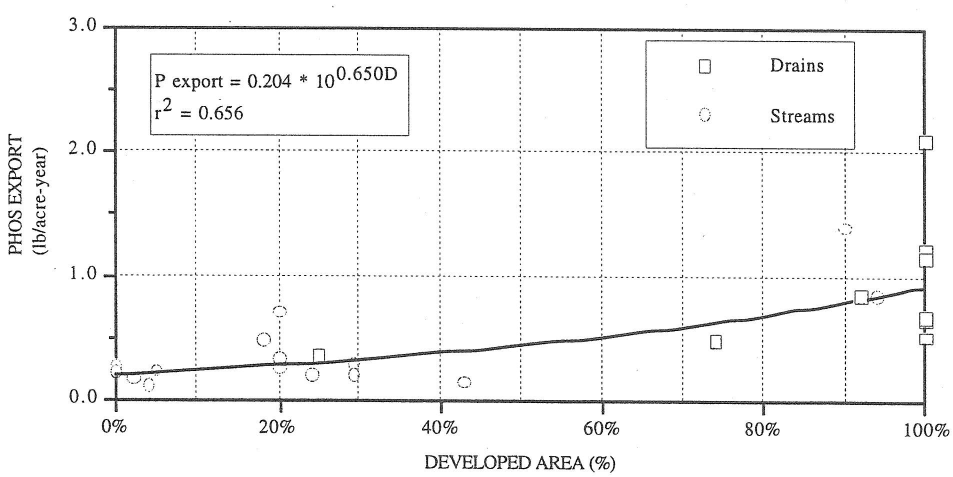


Figure 2. Phosphorus export verses percent developed area for sampled areas, less stations 2 and 26

Storm drains and road runoff (shown as squares,) are seldom representative of an area's phosphorus export since they often collect little groundwater. Since groundwater usually has lower phosphorus concentrations, it tends to dilute higher concentrations found in overland runoff. Natural streams with unmodified drainage patterns, however, are fed by both overland flows, and by groundwater discharging from wetlands and stream beds. Streams are therefore better indicators of a subbasin's true phosphorus export, and for this reason are used in the export model. Data from station 1, swamp near Wells Avenue was omitted for a similar reason. The sample was observed to represent a small fraction of the total outflow from this drainage area. Overland flow to the lake was non existent except during heavy prolonged downpours when groundwater is exceptionally high. Most of the runoff from this wetland area apparently entered the lake as groundwater seepage.

Figure 3 shows the remaining data points that were used in the model.

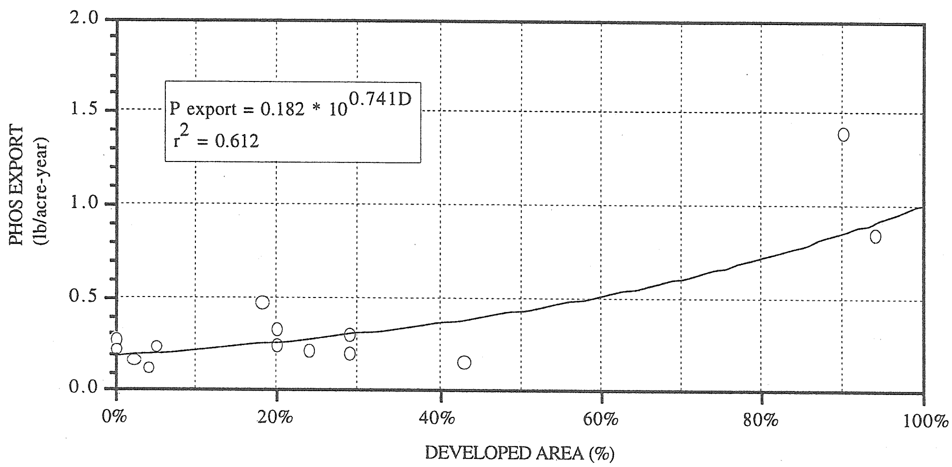


Figure 3. Phosphorus export model.

Figure 3 shows the best fit curve and equation describing the relationship between phosphorus export per acre and developed area. As shown in Table 3, the model values for forest and 100 percent developed area are in the range of other studies. The increase ratio is somewhat less than these studies.

Source	Forest	Developed	Increase
Norvell et al. 1979	.09	1.51	16.8:1
NY DEC 1992	.1	.8 - 1.1	8 - 11 :1
Reckow 1980	.24	1.9	8.1:1
Dennis 1986	.17	1.4	7.5:1
Model	.18	1.0	5.6:1

Table 3. Model results compared to various studies.

Present Phosphorus Loading

From Table 2, the overall percent developed area of the entire watershed is 33 percent. Using this value in the model yields an export rate of .33 lb/acre-year, for a total annual export of 791 lb/year for the entire watershed. Of this amount, approximately 73 percent is from presently developed areas, which comprise 33 percent of the total land area of the watershed. (See Appendix 4f for calculations)

There are several other phosphorus sources that must be considered; atmospheric loading directly on the lake surface, and droppings from waterfowl. Studies have shown that atmospheric loading averages about .89 lb/acre per year in our area (Kortmann 1991, Windham RPA 1977). The annual loading for Lake Pocotopaug's 512 acres would be 455 lb/year. (Appendix 4c). (A fraction of atmospheric phosphorus may be tied up in pollen grains in a form that is not readily available to lake algae.)

Phosphorus loading from waterfowl depends on the species, their numbers, and how long they stay on the lake. From observations, as many as 3,200 seagulls (mostly herring gulls) have been on the lake at one time to roost overnight during the late fall to early spring season. Using this information, it is estimated that they add about 43 lb of phosphorus to the lake on an annual basis. (Appendix 4d). Canada geese and ducks have also been observed on the lake in much smaller numbers, but their population and residency times have not been estimated.

The present total estimated phosphorus input from exterior sources is summarized in Table 4.

SOURCE	PHOSPHORUS INPUT (lb/year)	PERCENT OF TOTAL
Watershed Land	791	61%
Atmosphere (lake surface)	455	35%
Waterfowl	43	4%
Total	1,289	100%

Table 4. Present Lake Pocotopaug phosphorus loading from external sources, as predicted by the model.

It is interesting to note that before the above analysis was undertaken, waterfowl phosphorus input was suspected to be significant because of the numbers of seagulls present on the lake during the colder months. Subsequent observations of their numbers and their calculated contribution of phosphorus is relatively small, in the order of four percent of the total input to the lake. Their contribution of oxidizable organic material and its effect on oxygen depletion the the deeper waters of the lake during stratification could be more significant, but has not been assessed.

Table 4 includes external sources of phosphorus only. It does not include internal loading, which is considered to be a major source of phosphorus contributing to late summer algae blooms in Lake Pocotopaug. However external sources are significant because they take part in causing the internal process to occur (Rich 1992). External sources of phosphorus can be used to predict phosphorus concentrations in the lake at spring turnover when the water is well mixed from top to bottom, before oxygen depletion and the internal loading process begins (Windham RPA 1977).

In-Lake Phosphorus Concentrations

The Dillon-Rigler equation can be used to predict phosphorus concentrations in a lake at spring turnover by using the total annual phosphorus input from external sources and other physical characteristics of the lake and its watershed (Dillon and Rigler 1975, Reckhow et al. 1980). Using the loading from Table 4 yields 17.1 ppb.[3] (Appendix 4e and f). The actual average concentration in the lake during spring turnover in 1991 was 17.5 ppb, close to the calculated value. Spring concentrations were not measured in 1992 since necessary equipment was not available early enough in the season.

Transparency Model

Transparency measurements are the best indicator of the public's perception of water quality problems in lakes. They have been shown to be a good indicator of the amount of algae present in lakes (Dillon and Rigler 1975, Frink and Norvell 1984, U.S.EPA 1988). Since the amount of algae is related to phosphorus concentrations in the lake in the warmer months before senescence[4], a model relating transparency to phosphorus concentrations can be developed. Using the same method as was used for the phosphorus export model, transparency and total phosphorus concentration data from 1991 and 1992 for stations 1 and 2 was plotted and a best fit curve was determined by regression analysis. The plot and the resulting equation are shown in Figure 4. For 17.1 ppb the model yields 1.7 meters.[5]

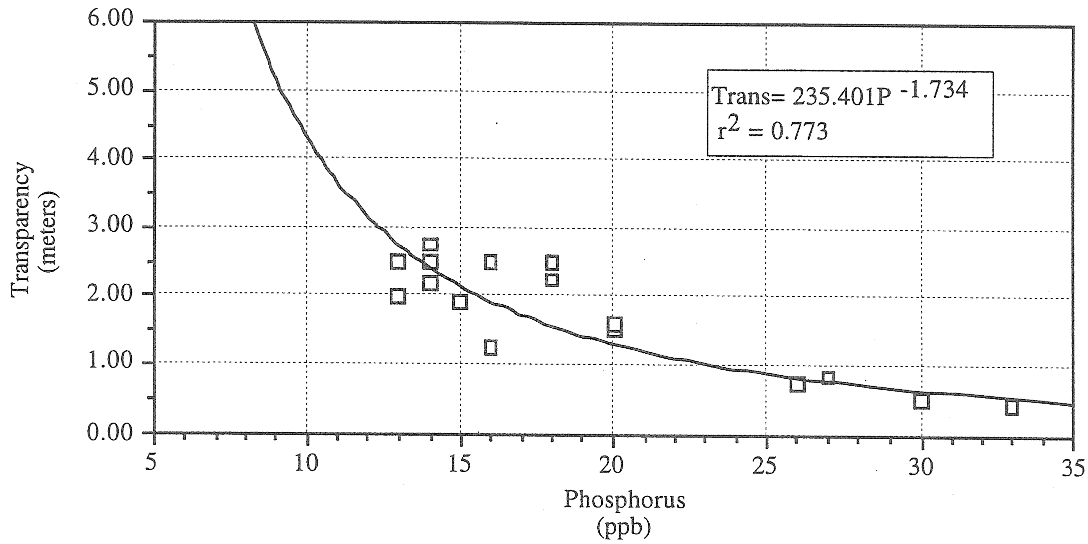


Figure 4. Transparency model.

[3] Although samples collected near the beginning of rainstorms are a good indicator of problem areas in the watershed, they may not accurately portray average phosphorus concentrations throughout the year. Rainstorms are highly variable. In some cases only two rain events were sampled at some locations. It is difficult to sample at the precise time the first flush of stormwater is passing a sampling point. Consequently, it is unlikely that the data represents the highest concentrations that may be present for a given storm. Also, true base flows may not represented in the data set for similar reasons. It would be more accurate if more samples were taken both before and after rainstorms, as well as during them, and information concerning flow volumes were taken simultaneously. In practice, actual samples represent values between the two extremes. Consequently, the model does result in loadings that are in the same range as those indicated in other studies.

[4] Senescence was determined to be when a marked increase in transparency occurred in September without a corresponding decrease in phosphorus.

[5] Resulting transparencies are lower than would be predicted by other models for algae alone. This may be caused by sources of turbidity other than algae, such as soil erosion, or motorboat or wind induced resuspension of sediments. It is most apparent at lower concentrations of phosphorus (higher transparencies) when concentrations of algae are lower.

The transparency model represented in Figure 4 demonstrates how sensitive lake transparency is to small changes in phosphorus concentrations. The difference between acceptable transparency (the two meter goal of the Ad Hoc Lake Advisory committee) and the worst measured thus far (.5 meters) is only 15 to 20 ppb.

Projections

Having phosphorus loading and transparency models for Lake Pocotopaug and its watershed, some projections can be made concerning past and future water quality.

Past Phosphorus Input

In precolonial times the watershed of Lake Pocotopaug was likely all forested, except for small areas used by native Americans for agriculture. Assuming that 5 percent of the basin was cleared for this purpose, and that the phosphorus export rate was the same as for presently developed areas, the model gives a phosphorus export rate of .2 lb/acre-year or a total annual input of 704 lb. Using the Dillon-Rigler equation spring turnover phosphorus concentrations would have been 9 ppb. Corresponding transparency would have been 4.9 meters. (Appendix 4g).

Future Phosphorus Input

Table 2 lists the undeveloped but developable area remaining in the watershed. If present development trends continue, this area will eventually become developed at some time in the future. What does this mean for the water quality of Lake Pocotopaug?

Referring to Table 2, when the watershed is "built out" to the limits allowed by present zoning, developed area will increase by 1,217 acres or 156 percent to 1,999 acres, or 84 percent of the land area comprising the watershed. The phosphorus loading model predicts that this will increase phosphorus import from 1,289 lb/year to 2,315 lb/year. This would result in a spring turnover phosphorus concentration of 31 ppb, and a transparency of .6 meters. 31 ppb is in the eutrophic range, and .62 meters is in the highly eutrophic range. These numbers do not include internal loading, which proceeds later in the season. However, since loading from external sources is an important factor causing internal loading, it is likely that this process will also intensify, resulting in much higher phosphorus concentrations in mid to late summer, depending on how early stratification occurs in the spring.

Table 5 summarizes past present and future phosphorus export, resulting spring turnover phosphorus concentrations, and transparencies projected with the model.

Time	Developed Area	Phosphorus Export From Land Areas		Total P Input, (all sources)	Spring P Conc.	Spring Trans-parency	Trophic Classification*
	(%)	(lb/acre-year)	(lb/year)	(lb/year)	(ppb)	(meters)	
Past	5	.20	476	704	9	4.9	Oligotrophic
Present	33	.32	791	1,289	17	1.7	Eutrophic
Future	84	.76	1,817	2,315	31	.6	Highly Eutrophic
* Based on spring transparency. ("The Trophic Classification of Seventy Connecticut Lakes", CT DEP 1982)							

Table 5. Past, present and future phosphorus export, spring phosphorus concentration, and transparency projections as predicted by the model. (Appendix 4f, g, h)

Another way to put this information into perspective is to compare the export rates for various land use intensities. (Table 6).

Source	Phosphorus Export Rate (lb/acre-year)	Increase Over Forest (%)
Forest, (0% Development)	.18	
Past Conditions, Average Watershed Export (5% Development)	.20	11%
Present Average Watershed Export (33% Development)	.32	78%
Future Average Watershed Export (85% Development)	.76	322%
100% Development	1.00	456%

Table 6. Phosphorus export rates predicted by the model for various land use intensities as compared to that of forests. (Appendix 4a, b)

Present average watershed export represents an 78 percent increase over that of entirely forested areas, and future export would be a 322 percent increase. It is interesting to note that atmospheric loading alone amounts to .89 lb/acre-year over land as well as the lake surface. This is equivalent to the export rate of an area with 92 percent development, and is 394 percent over that of forest. (Appendix 4c). This demonstrates a forest's ability to trap phosphorus, and gives insight into the importance of impervious surface when developing a watershed management plan.

The relationship between man's activities in the watershed and lake water quality is well established in the literature. The above analysis demonstrates that this relationship also holds true for Lake Pocotopaug and its watershed. However, the forgoing exercise is not a prerequisite to justify watershed management. Watershed management is advisable for any lake, with or without analytical study, whether or not they have problems.

Because of the simple approach used, some factors were not accounted for in the model.

The model recognizes areas to be either developed or not developed. It does not account for variations in the intensity of development within the developed areas. Studies have shown that phosphorus export increases with increasing density (Reckhow 1980, U.S. EPA 1988, Windham RPA 1977). For the most part, the sampled areas used in the derivation of the model have densities that average about one unit/acre, as measured from USGS maps. The projections do not account for the development of existing developable vacant lots, which when developed will increase the density and therefore the per acre export for these areas. The same is true for the C and DD zones which comprise 8 percent of the watershed land area, and are presently largely undeveloped or partially developed as residential. These zones allow 50 and 60 percent impervious surface respectively, a great deal more than the 10 percent allowed in most residential zones. Variances are often sought and granted by the zoning board of appeals to exceed these allowed percentages. Congregate housing is allowed by special permit in the R1 and C zones, which comprise 28 percent of the watershed. This use allows 25 percent impervious surface. If these zones are developed to the limits allowed by todays zoning standards, it is likely that they will export more phosphorus on a per acre basis than the model predicts.

V. ASSESSMENT OF CURRENT LAND USE POLICIES

The results of the inlet sampling done in 1991 and 1992 are consistent with the findings of other studies. Areas of Lake Pocotopaug's watershed that have a higher percentage of developed area export higher amounts of phosphorus. Lake Pocotopaug's natural trophic tendency is mesotrophic, almost oligotrophic (Taylor 1988). This suggests that the present algae blooms are due to cultural eutrophication, or man's activities in the watershed. If present land use trends continue, future increases in development in the watershed will result in higher phosphorus concentrations in the lake. This will result in lower transparency.

The Ad Hoc Lake Advisory committee has adopted a goal of no less than 2 meters transparency in the lake at any time in the future. To achieve this goal, a lake management plan must address reducing the current export of eutrophication causing material from the land areas of the watershed. These materials are organic material, turbidity, and most importantly, phosphorus. In addition to addressing existing sources, future sources must be considered to achieve a long lasting solution to restoring water clarity in Lake Pocotopaug. Otherwise, any success in remediation of todays existing sources will be offset by future increases as the remaining forest land in the basin is converted to more intense uses. In-lake measures are rarely successful in the long term unless steps are first taken to reduce inputs from external sources. Present spring phosphorus concentrations in the lake cause transparencies to be about 2 meters before internal loading begins. The conditions that give rise to this transparency also predispose the lake to internal loading events that result in transparencies of less than .5 meters later in the season. For this reason, any increase of phosphorus export from future development must be avoided. Land use policies must be adopted to insure that new development will not cause any increase in phosphorus export to Lake Pocotopaug. **The single most important consideration is stormwater runoff because it is the vehicle that transports these materials to the lake.** Efforts should be made to reduce stormwater generation to lessen the quantity of overland flow due to development, and to improve the quality of stormwater that eventually reaches the lake. A primary goal of stormwater management is to assure that the quantity and quality of stormwater runoff from any specific development is not substantially altered from predevelopment conditions (NY DEC 1992).

Current Phosphorus Input

Table 3 summarizes the three major sources of phosphorus to Lake Pocotopaug. To reduce current sources of phosphorus, each source must be examined to determine what options are available for control, and the feasibility of these options with respect to cost and social acceptability.

1. Direct atmospheric loading to the lake surface is significant, comprising 35 percent of the total loading of the lake. However, there are no options available to reduce this input, regardless of cost.

2. Phosphorus input from roosting seagulls during the colder months is estimated to be about four percent of the total loading of Lake Pocotopaug. Various options have been researched and discussed to discourage them from using the lake. However, because of their habits, the size of the lake and their protection under state statues as a species of concern, no practical method of control has been identified. Although their contribution of phosphorus is small, their contribution of oxidizable organic material and its effect on the internal loading process could be more significant, but has not been assessed. Methods of control should still be pursued.

3. The land area of the watershed is the most significant source of phosphorus to Lake Pocotopaug, comprising 61 percent of the total loading of the lake. The results of the inlet sampling, summarized in the tables in Appendix 1, gives guidance as to where significant watershed sources of phosphorus originate. Generally, phosphorus export from the watershed is dependent on the contributing area's size and its percent of developed area. The total amount of phosphorus entering the lake from a particular tributary (Appendix 1d) is less useful than the export per unit area (Appendix 1e) when identifying areas where efforts to reduce current export to the lake would be successful. For instance, although area 13, Hales Brook above Nelson's Campground, may have the second highest total export of the areas sampled, 52

lb/year, its per acre export is only .12 lb/acre-year, the lowest of all areas sampled. Because of this low rate, the likelihood of cost effectively reducing phosphorus export from this area is small. In contrast, area 26, Day Brook at Old Marlborough Road is shown to have been exporting 3.04 lb/acre (Appendix 1e), much higher than that which would be expected for the percent development present in this area. The excess export of 29.1 lb per year indicates that a special problem existed in this area during the time it was being sampled. One other area that was notably higher than expected was area 15, Brook near Candlewood Drive, at Lake Drive. With an export rate of 1.4 lb/acre-year, the total annual export was 6.4 lb/year higher than would be expected (Appendix 4i).

4. Other than the two "hot spots" mentioned above, the rest of the inlet data is consistent with what would be expected for a developed watershed. Storm water runoff coming directly from impervious surfaces such as roads tended to be very high in phosphorus. Higher export rates corresponded with a higher percentage of development in sampled areas. Drainage from forested areas is low in phosphorus. Presently developed areas account for about 73 percent of the current phosphorus input to the lake from land areas. Since efforts to reduce export from presently developed areas must depend heavily on treatment of stormwater rather than source reduction, solutions usually require the expenditure of public funds to retrofit existing natural and manmade drainage systems. To do this in a cost effective manner, a study of these existing systems should be conducted to map them, and explore the options available to retrofit these areas with control technology that specifically addresses the export of phosphorus, turbidity and organic material. Each subbasin of the watershed should be looked at separately to address its own unique features and patterns of development to determine what options are feasible. Guidelines for future development should be included. This study should also include the cost of each option, and a cost/benefit analysis to allow the town to make reasoned decisions as to how to accomplish goals.

Future Phosphorus Input

The following are several observations about current land use policies in the Town of East Hampton that may affect future phosphorus export:

1. The input of phosphorus as predicted by the model includes export from development after it is built. For the most part it does not include the one time inputs due to disturbances associated with construction activities. Eroded soil is considered to be the single most important non-point source pollutant (NY DEC 1992). Construction site erosion can be 20 to 200 times higher than the forest land it replaces (CT DEP 1991, Windham RPA 1977). Since 1985, the state has required that erosion and sedimentation control guidelines be used during construction. Though these guidelines do reduce soil erosion during construction, (providing they are properly specified, installed and maintained), they do not address the actual quality of the runoff when they are employed. Depending on site conditions, such as soil type and slope, unacceptable amounts of phosphorus, turbidity and organic material can be exported in spite of the proper use of these controls. Additionally, the guidelines do not have any provisions to address the quality or volume of runoff after the project is completed.

2. Zoning and inland wetland requirements have improved since most of the development has occurred in the watershed. However, changes have not been made that specifically address long term phosphorus export. Current land use policies have few requirements that effectively minimize removal of natural vegetation, promote infiltration, minimize impervious surfaces, or renovate the quality of water discharged by drainage systems. Storm water drainage practices, though well designed to safely remove water from developed areas and reduce peak flows in downstream areas, do not address the fact that they are also well designed (unintentionally) to

deliver phosphorus and other eutrophication causing materials directly into lakes. If frequently cleaned, typical catch basins retain heavier particles such as sand. Since phosphorus adheres to finer silt and clay particles, and organic material such as leaves and wood debris are light, they are easily transported by water. These basins remove little of this material (5-10 percent) because high flow velocities prevents it from settling out. Soluble phosphorus is not retained at all. (Doenges 1990, NY DEC 1992). In some cases, regulations require detention basins to be used to reduce peak flows to predevelopment levels. However, they have been used in less than 25 percent of the sizable subdivisions, (five lots or more,) in the past five years for various reasons, and not at all for smaller projects. Dry ponds are generally used as they satisfy current zoning requirements. Their ability to attenuate phosphorus export however, is low because of their short hydraulic residency time (NY DEC 1992).

3. The presence of a sanitary sewer system in the lake basin has had mixed success in reducing the probability of lake eutrophication. The installation was a result of a pollution abatement order issued by the DEP because of high coliform counts in the lake. The sewers appear to have been successful in minimizing impacts from phosphorus and nitrogen reaching the lake from subsurface septic systems, which appears to have been a significant factor causing algae blooms in Lake Pocotopaug prior to their installation in the early 1980's. However, increased nutrient input to lakes is largely dependent on the intensity of land use and the proportion of impervious surface in the watershed.

   Current zoning allows substantial increases in density and impervious surface when sewers are used. Commercial and designed development and its 60 and 50 percent maximum impervious surfaces are allowed only on sewers, as is congregate housing, which allows 25 percent impervious surface. Current regulations allow substantial increases in density in residential areas (66 percent in R1, and 31 percent in R3,) to give developers incentive to extend the serviced area. In addition, local ordinances can reduce costs to developers who extend sewers through a reimbursement program. Impervious surface may increase 168 percent in the R1 zone and 48 percent in the R3, or more with these density increases. In practice, the resulting density is increased more than the regulations would imply because it eliminates the difficulty of finding suitable soils for siting septic systems, which usually determines the number of lots allowed on a parcel when sewers are not available. Assuming that modern septic systems are properly sited, installed, operated and maintained, new development using sewers will likely increase phosphorus export over that without sewers, because of the increased impervious surface that results from the density bonus allowed by current zoning. The availability of sewers is not the only factor that needs to be considered when determining appropriate densities in given areas. The State Plan for Conservation and Development recommends that extending sewers into lightly developed areas be avoided except to address existing problem areas when no other alternatives exist. The purpose of this is to avoid unnecessary expense and the increase in non-point pollution due to increased density. This is emphasized for sensitive watershed areas (CT OPM 1991, Doenges 1993). Although many towns have adopted sewer avoidance plans, East Hampton currently maps all of the developable area of the watershed as "potential sewer area". (E.H. Plan of Development 1989). If this area is sewered, it will increase the serviced area of the watershed from 622 acres to 2000 acres, or 221 percent.

4. Sewers decrease the amount of groundwater reaching the lake by diverting it out of the watershed. Subsurface septic systems return well water to the ground to replenish ground storage. Groundwater generally contains much lower concentrations of phosphorus. It tends to dilute the higher concentrations reaching the lake from overland runoff. At this time approximately five percent of the annual water input to the lake is diverted away from the lake by sewers. (Appendix 4k) A municipal water system could reduce the amount of this diversion at considerable cost to citizens. However, this would be effective only if the source

of supply is outside of the lake watershed. A drawback of a water system could be increased growth and density, increasing impervious surface and the phosphorus export associated with it.

5. As can be seen on Map 8, 23% of the undeveloped area of the watershed has slopes of 15 percent or greater. Steep slopes pose special problems since soil erosion increases greatly with increasing slope. All else being equal, erosion on 15 percent slopes can be 5 times greater than on slopes of 5 percent, and on 25 percent slopes, 11 times greater. Overland runoff rates also increase with increasing slope. (CT Council on Soil and Water Conservation 1985). Map 9 overlays the steep slope areas on the presently developed area. 26 percent of the steep slope areas are presently developed. 56 percent are in undeveloped but developable areas. Current zoning in the watershed does not specifically address the presence of steep slopes. How these slopes are developed will be important to the future export of eutrophication causing materials to the lake both during construction and after these areas are stabilized.

VI. RECOMMENDATIONS: GENERAL WATERSHED LAND USE GUIDELINES

The following recommendations are general in nature and are meant to be a starting point from which more specific recommendations will be developed. They have been taken from the literature on lakes and water quality, and incorporate the information currently available for Lake Pocotopaug. These conceptual guidelines demonstrate the intent of future policy changes which are necessary to accomplish the Ad Hoc Lake Advisory committees goal of no less than two meter transparency at any time in the future, and are based on the rational presented earlier in this report.

Goals: For a long lasting solution to algae problems in Lake Pocotopaug, efforts must address both current and future inputs of eutrophication causing materials to the lake.

Goal 1. Develop land use policies that reduce the current export of phosphorus, turbidity and organic material to the lake.

Goal 2. Develop land use policies to insure that post development export of phosphorus, turbidity and organic material does not exceed that of predevelopment levels for all future development in the watershed.

The single most important consideration is stormwater runoff, because it is the vehicle that transports eutrophication causing materials to the lake. Policies must be adopted to:

Objective 1: Reduce the generation of overland flows due to stormwater.

Objective 2: Improve the quality of stormwater eventually reaching the lake

These goals can be accomplished through voluntary and regulatory actions and policies

Voluntary citizen actions:

1. Develop and disseminate educational and informational materials to landowners in the watershed to encourage property maintenance that minimizes lake impacts.

2. Identify problem areas in the watershed and approach landowners to make them aware and understand that their action or lack of action may affect the lake. Assist them with finding practical solutions through cooperative efforts.

3. Encourage the maintenance of forested land in the watershed by providing positive incentives to landowners to not develop their properties.

Regulatory actions:

1. Develop a regulatory framework to accomplish goals. Land use agencies such as the Planning and Zoning Commission, Inland Wetland and Watercourses Agency and Conservation Commission, and Zoning Board of Appeals are appropriate vehicles, as well as enactment of town ordinances.

2. Provide a basis by which land use applications can be judged (i.e., standards for performance).

3. Insure that applications are reviewed in accordance with the standards.

4. Establish policies and provide resources to insure adequate enforcement

5. Provide adequate training and access to expert technical and legal advisors to staff and agency members to insure informed decision making.

Governmental actions:

1. Perform an environmental engineering study to assess options for addressing watershed stormwater drainage to achieve goals.

2. Secure viable sources of funding to finance future engineering studies and watershed improvements necessary to accomplish goals.

3. Develop written town policies and procedures to further the goals of lake management for governmental agencies such as the Department of Public Works, and capital improvements committee.

4. Develop and implement town ordinances to achieve lake management goals.

5. Develop and implement policies that give landowners positive incentives to maintain their land as open space.

General items of consideration:

To reduce the quantity of stormwater runoff:

Reduce impervious surface
Promote infiltration of stormwater
Narrower roads
Shorter roads
Pervious types of pavement systems
Shorter driveways
Driveways that serve more than one dwelling
Open space (cluster) type subdivisions designed to lessen impervious surface
Smaller rooftops
Lower density zoning
Lower maximum allowable lot coverage requirements

Avoid steep slopes

To reduce erosion:

Avoid development on steep slopes
Use best management practices (BMP's) during construction
Design to minimize clearing of natural vegetation
Contract clearing limit lines
Paved roads and drives in lieu of gravel
Crushed stone roads and drives in lieu of gravel
Phasing - limit exposure time
Phasing - limit area exposed at any given time
Inspect tributaries and drainage swales for bed or bank erosion
Make landowners aware of problem areas on their property and encourage cooperative solutions

To improve stormwater quality:

Use wet ponds to promote retention and infiltration
Use detention and extended detention
Use multiple leak offs into vegetated areas from roads, drives and other impervious surfaces
Infiltration - drywells, infiltration ponds and trenches, pervious pavements
Use naturally vegetated buffer strips along shoreline and tributaries
Preserve wetland functions
Reduce lawn sizes
Created wetlands
Develop performance standards to renovate stormwater before discharge to off site areas
Improve street cleaning and maintenance practices
First-flush treatment
Grassed swales and filter strips

To minimize removal of natural vegetation:

Require contract clearing limit lines on all land use applications when appropriate
Clustering of units (Open space development)
Smaller lawns
The regulatory open space exaction process
Land acquisition
Avoid development - Positive incentives to retain open space, incentives to permanently dedicate open space
Land trusts and conservation easements
Avoid development - prohibit or restrict development in sensitive areas

To reduce the export of nutrients:

Proper design and siting of subsurface septic systems
Adequate maintenance of septic systems
Nutrient allocation program
Proper use of fertilizers and soaps
Proper disposal of gray water discharges
Proper lawn and garden debris disposal

		INLETS - LAKE POCOTOPAUG STUDY	4/21/91		8/9/91		9/5/91		9/25/91		6/5/92		7/15/92		8/9/92		Samp	Total Phosphorus			Turbidity		
Type	Map	Location	P	turb	P	turb	P	turb	P	turb	P	turb	P	turb	P	turb	Taken	High	Low	Ave	High	Low	Ave
	Loc		(ppb)	NTU	(ppb)	NTU	(ppb)	NTU	(ppb)	NTU	(ppb)	NTU	(ppb)	NTU	(ppb)	NTU		(ppb)			(NTU)		
Stream	1	Swamp near Wells Ave.							156	4.9	103	5			none	none	2	156	103	130	5	5	5
Stream	2	Christopher Brook at N Main	24	2.6	36	3.3	34		17	2	32	1.6	37	2.8	35	2.4	7	37	17	31	3	2	2
Drain	3	Christopher Brook, drain pipe at N Main											162	11	81	2.4	2	162	81	122	11	2	7
Stream	4	Christopher Brook, at entrance to Christopher Pond									32	1.6	28	3.7	69	19	3	69	28	43	19	2	8
Stream	5	Christopher Brook, North of Christopher Road									46	5.1	37	4.2	66	9	3	66	37	50	9	4	6
Road runoff	6	Christopher Brook, road runoff at N Main					260				143	18	260	12	242	7.3	4	260	143	226	18	7	12
Stream	7	Christopher Brook, north of Clark Hill Rd							45	9	33	3	22	0.8	50	1.7	4	50	22	38	9	1	4
Drain	8	Christopher Brook, storm drain at Clark Hill Rd							100	24	101	14	115	29	59	4.7	4	115	59	94	29	5	18
Drain	9	Drain at foot of Clark Hill Road	103	155	108	4.6	220		128	40	113	7.5	124	14	89	7.9	7	220	89	126	155	5	38
Drain	10	Drain at foot of Barbara Road									156	12	240	24	236	8	3	240	156	211	24	8	15
Stream	11	Hales Brook at Lake Drive (above pool)	26	15	7	0.8	82		55	11	34	0.5	17	1.7	62	2.5	7	82	7	40	15	1	5
Road runoff	12	Hales Brook, road runoff at Lake Drive					350				380	164	432	385	none	none	3	432	350	387	385	164	275
Stream	13	Hales Brook, above Nelson's Campground					18		33	5.9			13	0.4	21	1.8	4	33	13	21	6	0	3
Stream	14	Hales Brook, unnamed tributary above Mott Hill Rd									66	1.5			26	1	2	66	26	46	2	1	1
Stream	15	Brook at Candlewood Dr., at Lake Dr.	50	50	46	4.5	204		430	108	106	7.1	51	5.1	66	4.8	7	430	46	136	108	5	30
Stream	16	Brook at Candlewood Dr, above Candlewood Dr							83	11	130	2.3	66	2.5	70	5.3	4	130	66	87	11	2	5
Road runoff	17	Brook at Candlewood, road runoff at Candlewood									156	7.7			none	none	1	156	156	156	8	8	8
Stream	18	Brook Near Spellman's Pt., at Bay Rd	26	13	dry	dry	79		55	11	45	3.7	34	4.2	52	5.6	6	79	26	49	13	4	8
Stream	19	Brook near Spellman's Pt., above Lake Dr.			67	6	48		45	3.2	50	2.3	45	5.5	38	2.2	6	67	38	49	6	2	4
Drain	20	Brook at Spellman's Pt., drain at Lake Dr.			72	26	61		80	24	85	30	52	7.1	55	10	6	85	52	68	30	7	19
Stream	21	Hazen's Brook	41	49	37	0.9	51		59	4.4	54	1	11	1.5	22	0.9	7	59	11	39	49	1	10
Drain	22	Drain at foot of Mohigan Trail											125	15	121	10	2	125	121	123	15	10	13
Stream	23	O'Neill's Brook at Old Marlborogh Rd	33	29	89	11	122		100	36	90	10	26	12	73	10	7	122	26	76	36	10	18
Drain	24	O'Neill's Brook, at Route 66					189		135	55	29	2	21	4.5	67	2.3	5	189	21	88	55	2	16
Stream	25	O'Neill's Brook, unnamed tributary above Rt 66									32	1.8					1	32	32	32	2	2	2
Stream	26	Day's Brook at Old Marlborogh Rd	80	102	154	12	238		194	43	220	14	111	26	65	6.1	7	238	65	152	102	6	34
Stream	27	Day's Brook, above Route 66			81	7.9			27	1.3	27	71	37	4	32	1.4	5	81	27	41	71	1	17

APPENDIX 1a

INLET DATA BY LOCATION

		INLETS - LAKE POCOTOPAUG STUDY	Total Drained Area					Sub Drained Area				
Type	Map	Location	Total	Developed		Annual Phos Export		Total	Developed		Annual Phos Export	
	Loc		(acres)	(acres)	(%)	(lb)	(lb/acre)	(acres)	(acres)	(%)	(lb)	(lb/acre)
Stream	1	Swamp near Wells Ave.	4	1	20%	2.76	0.71	4	1	20%	2.76	0.71
Stream	2	Christopher Brook at N Main	478	173	36%	79.88	0.17	12	4	34%	-29.18	-2.47
Drain	3	Christopher Brook, drain pipe at N Main	6	6	100%	4.19	0.66	6	6	100%	4.19	0.66
Stream	4	Christopher Brook, at entrance to Christopher Pond	466	169	36%	109.07	0.23	160	69	43%	26.31	0.16
Stream	5	Christopher Brook, North of Christopher Road	306	100	33%	82.76	0.27	163	47	29%	48.88	0.30
Road runoff	6	Christopher Brook, road runoff at N Main	1	1	100%	0.80	1.23	1	1	100%	0.80	1.23
Stream	7	Christopher Brook, north of Clark Hill Rd	128	38	29%	26.08	0.20	128	38	29%	26.08	0.20
Drain	8	Christopher Brook, storm drain at Clark Hill Rd	15	15	100%	7.79	0.51	15	15	100%	7.79	0.51
Drain	9	Drain at foot of Clark Hill Road	18	18	100%	12.06	0.69	18	18	100%	12.06	0.69
Drain	10	Drain at foot of Barbara Road	4	4	100%	4.16	1.15	4	4	100%	4.16	1.15
Stream	11	Hales Brook at Lake Drive (above pool)	889	107	12%	195.79	0.22	409	82	20%	136.29	0.33
Road runoff	12	Hales Brook, road runoff at Lake Drive	6	6	100%	12.92	2.11	6	6	100%	12.92	2.11
Stream	13	Hales Brook, above Nelson's Campground	451	19	4%	52.25	0.12	451	19	4%	52.25	0.12
Stream	14	Hales Brook, unnamed tributary above Mott Hill Rd	29	6	20%	7.25	0.25	29	6	20%	7.25	0.25
Stream	15	Brook at Candlewood Dr., at Lake Dr.	41	16	39%	30.35	0.74	12	11	90%	16.50	1.40
Stream	16	Brook at Candlewood Dr, above Candlewood Dr	29	5	18%	13.85	0.48	29	5	18%	13.85	0.48
Road runoff	17	Brook at Candlewood, road runoff at Candlewood	1	1	92%	1.00	0.85	1	1	92%	1.00	0.85
Stream	18	Brook Near Spellman's Pt., at Bay Rd	156	4	3%	41.26	0.26	38	2	5%	8.87	0.24
Stream	19	Brook near Spellman's Pt., above Lake Dr.	110	0	0%	29.30	0.27	110	0	0%	29.30	0.27
Drain	20	Brook at Spellman's Pt., drain at Lake Dr.	8	2	25%	3.09	0.37	8	2	25%	3.09	0.37
Stream	21	Hazen's Brook	20	5	24%	4.38	0.21	20	5	24%	4.38	0.21
Drain	22	Drain at foot of Mohigan Trail	12	12	100%	7.73	0.67	12	12	100%	7.73	0.67
Stream	23	O'Neill's Brook at Old Marlborogh Rd	53	23	44%	21.94	0.41	11	11	94%	9.77	0.85
Drain	24	O'Neill's Brook, at Route 66	16	12	74%	7.77	0.48	16	12	74%	7.77	0.48
Stream	25	O'Neill's Brook, unnamed tributary above Rt 66	25	0	2%	4.40	0.17	25	0	2%	4.40	0.17
Stream	26	Day's Brook at Old Marlborogh Rd	55	8	15%	45.75	0.83	12	8	68%	36.09	3.04
Stream	27	Day's Brook, above Route 66	43	0	0%	9.66	0.22	43	0	0%	9.66	0.22

APPENDIX 1b

SAMPLED SUBBASINS BY LOCATION NUMBER

		INLETS - LAKE POCOTOPAUG STUDY	Total Drained Area					Sub Drained Area				
Type	Map	Location	Total	Developed		Annual Phos Export		Total	Developed		Annual Phos Export	
	Loc		(acres)	(acres)	(%)	(lb)	(lb/acre)	(acres)	(acres)	(%)	(lb)	(lb/acre)
Road runoff	12	Hales Brook, road runoff at Lake Drive	6	6	100%	12.92	2.11	6	6	100%	12.92	2.11
Road runoff	6	Christopher Brook, road runoff at N Main	1	1	100%	0.80	1.23	1	1	100%	0.80	1.23
Drain	10	Drain at foot of Barbara Road	4	4	100%	4.16	1.15	4	4	100%	4.16	1.15
Drain	9	Drain at foot of Clark Hill Road	18	18	100%	12.06	0.69	18	18	100%	12.06	0.69
Drain	22	Drain at foot of Mohigan Trail	12	12	100%	7.73	0.67	12	12	100%	7.73	0.67
Drain	3	Christopher Brook, drain pipe at N Main	6	6	100%	4.19	0.66	6	6	100%	4.19	0.66
Drain	8	Christopher Brook, storm drain at Clark Hill Rd	15	15	100%	7.79	0.51	15	15	100%	7.79	0.51
Stream	23	O'Neill's Brook at Old Marlborogh Rd	53	23	44%	21.94	0.41	11	11	94%	9.77	0.85
Road runoff	17	Brook at Candlewood, road runoff at Candlewood	1	1	92%	1.00	0.85	1	1	92%	1.00	0.85
Stream	15	Brook at Candlewood Dr., at Lake Dr.	41	16	39%	30.35	0.74	12	11	90%	16.50	1.40
Drain	24	O'Neill's Brook, at Route 66	16	12	74%	7.77	0.48	16	12	74%	7.77	0.48
Stream	26	Day's Brook at Old Marlborogh Rd	55	8	15%	45.75	0.83	12	8	68%	36.09	3.04
Stream	4	Christopher Brook, at entrance to Christopher Pond	466	169	36%	109.07	0.23	160	69	43%	26.31	0.16
Stream	2	Christopher Brook at N Main	478	173	36%	79.88	0.17	12	4	34%	-29.18	-2.47
Stream	7	Christopher Brook, north of Clark Hill Rd	128	38	29%	26.08	0.20	128	38	29%	26.08	0.20
Stream	5	Christopher Brook, North of Christopher Road	306	100	33%	82.76	0.27	163	47	29%	48.88	0.30
Drain	20	Brook at Spellman's Pt., drain at Lake Dr.	8	2	25%	3.09	0.37	8	2	25%	3.09	0.37
Stream	21	Hazen's Brook	20	5	24%	4.38	0.21	20	5	24%	4.38	0.21
Stream	11	Hales Brook at Lake Drive (above pool)	889	107	12%	195.79	0.22	409	82	20%	136.29	0.33
Stream	1	Swamp near Wells Ave.	4	1	20%	2.76	0.71	4	1	20%	2.76	0.71
Stream	14	Hales Brook, unnamed tributary above Mott Hill Rd	29	6	20%	7.25	0.25	29	6	20%	7.25	0.25
Stream	16	Brook at Candlewood Dr, above Candlewood Dr	29	5	18%	13.85	0.48	29	5	18%	13.85	0.48
Stream	18	Brook Near Spellman's Pt., at Bay Rd	156	4	3%	41.26	0.26	38	2	5%	8.87	0.24
Stream	13	Hales Brook, above Nelson's Campground	451	19	4%	52.25	0.12	451	19	4%	52.25	0.12
Stream	25	O'Neill's Brook, unnamed tributary above Rt 66	25	0	2%	4.40	0.17	25	0	2%	4.40	0.17
Stream	27	Day's Brook, above Route 66	43	0	0%	9.66	0.22	43	0	0%	9.66	0.22
Stream	19	Brook near Spellman's Pt., above Lake Dr.	110	0	0%	29.30	0.27	110	0	0%	29.30	0.27

APPENDIX 1c

SAMPLED SUBBASINS SORTED BY PERCENT DEVELOPED AREA

		INLETS - LAKE POCOTOPAUG STUDY	Total Drained Area					Sub Drained Area				
Type	Map	Location	Total	Developed		Annual Phos Export		Total	Developed		Annual Phos Export	
	Loc		(acres)	(acres)	(%)	(lb)	(lb/acre)	(acres)	(acres)	(%)	(lb)	(lb/acre)
Stream	11	Hales Brook at Lake Drive (above pool)	889	107	12%	195.79	0.22	409	82	20%	136.29	0.33
Stream	13	Hales Brook, above Nelson's Campground	451	19	4%	52.25	0.12	451	19	4%	52.25	0.12
Stream	5	Christopher Brook, North of Christopher Road	306	100	33%	82.76	0.27	163	47	29%	48.88	0.30
Stream	26	Day's Brook at Old Marlborogh Rd	55	8	15%	45.75	0.83	12	8	68%	36.09	3.04
Stream	19	Brook near Spellman's Pt., above Lake Dr.	110	0	0%	29.30	0.27	110	0	0%	29.30	0.27
Stream	4	Christopher Brook, at entrance to Christopher Pond	466	169	36%	109.07	0.23	160	69	43%	26.31	0.16
Stream	7	Christopher Brook, north of Clark Hill Rd	128	38	29%	26.08	0.20	128	38	29%	26.08	0.20
Stream	15	Brook at Candlewood Dr., at Lake Dr.	41	16	39%	30.35	0.74	12	11	90%	16.50	1.40
Stream	16	Brook at Candlewood Dr, above Candlewood Dr	29	5	18%	13.85	0.48	29	5	18%	13.85	0.48
Road runoff	12	Hales Brook, road runoff at Lake Drive	6	6	100%	12.92	2.11	6	6	100%	12.92	2.11
Drain	9	Drain at foot of Clark Hill Road	18	18	100%	12.06	0.69	18	18	100%	12.06	0.69
Stream	23	O'Neill's Brook at Old Marlborogh Rd	53	23	44%	21.94	0.41	11	11	94%	9.77	0.85
Stream	27	Day's Brook, above Route 66	43	0	0%	9.66	0.22	43	0	0%	9.66	0.22
Stream	18	Brook Near Spellman's Pt., at Bay Rd	156	4	3%	41.26	0.26	38	2	5%	8.87	0.24
Drain	8	Christopher Brook, storm drain at Clark Hill Rd	15	15	100%	7.79	0.51	15	15	100%	7.79	0.51
Drain	24	O'Neill's Brook, at Route 66	16	12	74%	7.77	0.48	16	12	74%	7.77	0.48
Drain	22	Drain at foot of Mohigan Trail	12	12	100%	7.73	0.67	12	12	100%	7.73	0.67
Stream	14	Hales Brook, unnamed tributary above Mott Hill Rd	29	6	20%	7.25	0.25	29	6	20%	7.25	0.25
Stream	25	O'Neill's Brook, unnamed tributary above Rt 66	25	0	2%	4.40	0.17	25	0	2%	4.40	0.17
Stream	21	Hazen's Brook	20	5	24%	4.38	0.21	20	5	24%	4.38	0.21
Drain	3	Christopher Brook, drain pipe at N Main	6	6	100%	4.19	0.66	6	6	100%	4.19	0.66
Drain	10	Drain at foot of Barbara Road	4	4	100%	4.16	1.15	4	4	100%	4.16	1.15
Drain	20	Brook at Spellman's Pt., drain at Lake Dr.	8	2	25%	3.09	0.37	8	2	25%	3.09	0.37
Stream	1	Swamp near Wells Ave.	4	1	20%	2.76	0.71	4	1	20%	2.76	0.71
Road runoff	17	Brook at Candlewood, road runoff at Candlewood	1	1	92%	1.00	0.85	1	1	92%	1.00	0.85
Road runoff	6	Christopher Brook, road runoff at N Main	1	1	100%	0.80	1.23	1	1	100%	0.80	1.23
Stream	2	Christopher Brook at N Main	478	173	36%	79.88	0.17	12	4	34%	-29.18	-2.47

APPENDIX 1d

SAMPLED SUBBASINS SORTED BY ANNUAL TOTAL PHOSPHORUS EXPORT

		INLETS - LAKE POCOTOPAUG STUDY	Total Drained Area					Sub Drained Area				
Type	Map	Location	Total	Developed		Annual Phos Export		Total	Developed		Annual Phos Export	
	Loc		(acres)	(acres)	(%)	(lb)	(lb/acre)	(acres)	(acres)	(%)	(lb)	(lb/acre)
Stream	26	Day's Brook at Old Marlborogh Rd	55	8	15%	45.75	0.83	12	8	68%	36.09	3.04
Road runoff	12	Hales Brook, road runoff at Lake Drive	6	6	100%	12.92	2.11	6	6	100%	12.92	2.11
Stream	15	Brook at Candlewood Dr., at Lake Dr.	41	16	39%	30.35	0.74	12	11	90%	16.50	1.40
Road runoff	6	Christopher Brook, road runoff at N Main	1	1	100%	0.80	1.23	1	1	100%	0.80	1.23
Drain	10	Drain at foot of Barbara Road	4	4	100%	4.16	1.15	4	4	100%	4.16	1.15
Stream	23	O'Neill's Brook at Old Marlborogh Rd	53	23	44%	21.94	0.41	11	11	94%	9.77	0.85
Road runoff	17	Brook at Candlewood, road runoff at Candlewood	1	1	92%	1.00	0.85	1	1	92%	1.00	0.85
Stream	1	Swamp near Wells Ave.	4	1	20%	2.76	0.71	4	1	20%	2.76	0.71
Drain	9	Drain at foot of Clark Hill Road	18	18	100%	12.06	0.69	18	18	100%	12.06	0.69
Drain	22	Drain at foot of Mohigan Trail	12	12	100%	7.73	0.67	12	12	100%	7.73	0.67
Drain	3	Christopher Brook, drain pipe at N Main	6	6	100%	4.19	0.66	6	6	100%	4.19	0.66
Drain	8	Christopher Brook, storm drain at Clark Hill Rd	15	15	100%	7.79	0.51	15	15	100%	7.79	0.51
Drain	24	O'Neill's Brook, at Route 66	16	12	74%	7.77	0.48	16	12	74%	7.77	0.48
Stream	16	Brook at Candlewood Dr, above Candlewood Dr	29	5	18%	13.85	0.48	29	5	18%	13.85	0.48
Drain	20	Brook at Spellman's Pt., drain at Lake Dr.	8	2	25%	3.09	0.37	8	2	25%	3.09	0.37
Stream	11	Hales Brook at Lake Drive (above pool)	889	107	12%	195.79	0.22	409	82	20%	136.29	0.33
Stream	5	Christopher Brook, North of Christopher Road	306	100	33%	82.76	0.27	163	47	29%	48.88	0.30
Stream	19	Brook near Spellman's Pt., above Lake Dr.	110	0	0%	29.30	0.27	110	0	0%	29.30	0.27
Stream	14	Hales Brook, unnamed tributary above Mott Hill Rd	29	6	20%	7.25	0.25	29	6	20%	7.25	0.25
Stream	18	Brook Near Spellman's Pt., at Bay Rd	156	4	3%	41.26	0.26	38	2	5%	8.87	0.24
Stream	27	Day's Brook, above Route 66	43	0	0%	9.66	0.22	43	0	0%	9.66	0.22
Stream	21	Hazen's Brook	20	5	24%	4.38	0.21	20	5	24%	4.38	0.21
Stream	7	Christopher Brook, north of Clark Hill Rd	128	38	29%	26.08	0.20	128	38	29%	26.08	0.20
Stream	25	O'Neill's Brook, unnamed tributary above Rt 66	25	0	2%	4.40	0.17	25	0	2%	4.40	0.17
Stream	4	Christopher Brook, at entrance to Christopher Pond	466	169	36%	109.07	0.23	160	69	43%	26.31	0.16
Stream	13	Hales Brook, above Nelson's Campground	451	19	4%	52.25	0.12	451	19	4%	52.25	0.12
Stream	2	Christopher Brook at N Main	478	173	36%	79.88	0.17	12	4	34%	-29.18	-2.47

APPENDIX 1e

SAMPLED SUBBASINS SORTED BY ANNUAL TOTAL PHOSPHORUS EXPORT PER ACRE

Appendix 2:

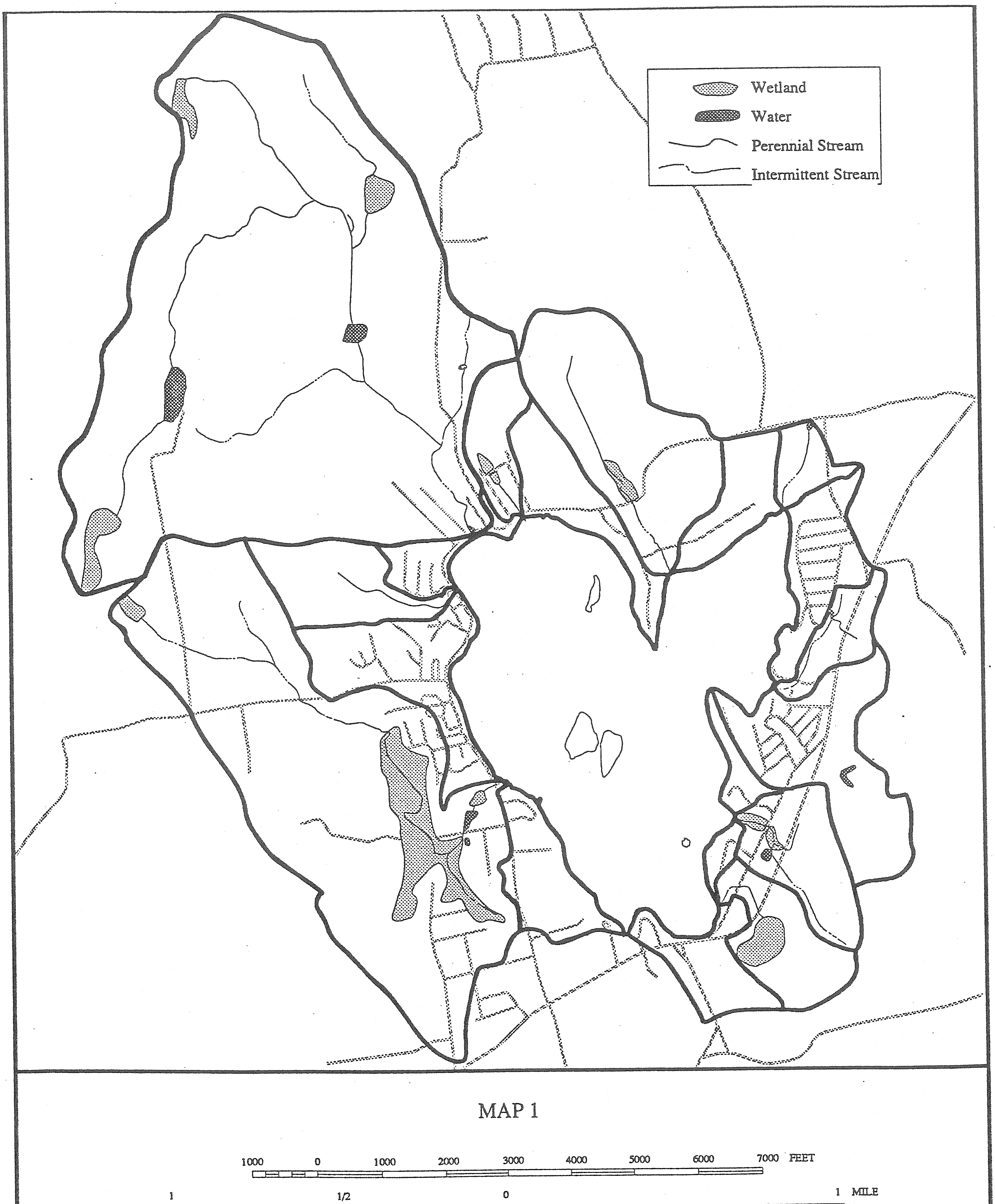
1. Data from sampled area 2, Christopher Brook at North Main, indicates that this area is a net sink for 29 lb/year of phosphorus. Between sampling point 2 and sampling point 4, the next upstream, is Christopher Pond. Water bodies are generally considered to be sinks for phosphorus because particulate material carrying phosphorus is sedimented out as the velocity of the entering water slows. Also, vegetation in a pond uses phosphorus in its growth process. The ability of a water body to store phosphorus is dependent on its flushing rate. Being a small pond with a relatively large watershed, Christopher's Pond's trapping ability is low, somewhere on the order of 10 percent or less (NYDEC 1992). Its effectiveness is likely overstated by the data for the following reason. Water in the pond at the beginning of the storm is comprised mostly of ground water which sustains stream flows between rain events. This relatively clean water must be displaced out of the pond by first-flush stormwater entering the pond from upstream, before the first-flush water can reach sampling point 2. Since both points are sampled within a few minutes of each other at the beginning of the storm, samples from point 2 likely consist mostly of the cleaner displaced water. To resolve the function of Christopher Pond in removing phosphorus from the stream a series of samples could be taken, starting before a storm event, continuing through until 24 hours after the storm ends.

2. Data from area 26, Day Brook at Old Marlborough Road, showed a total export of 36.1 lb/year, or 3.04 lb/acre-year. For a developed area of 68 percent, expected export would be .58 lb/acre-year, or a total of 7.0 lb/year. The difference, 29.1 lb/year, is likely due to a special problem in this sub drainage area, rather than typical development.

Appendix 3:

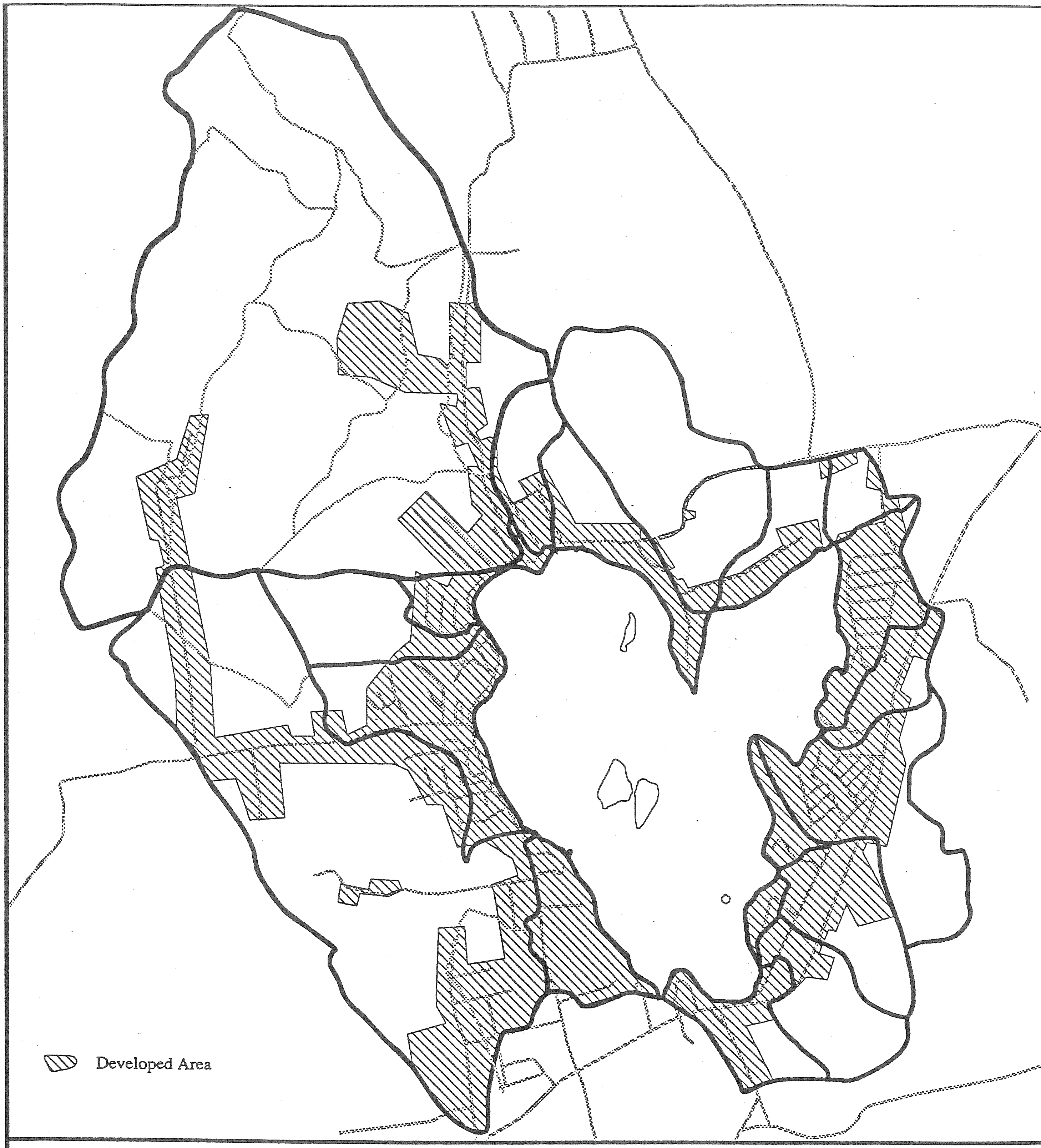
The watershed maps shown on the following pages were prepared by the land use subcommittee of the Ad Hoc Lake Advisory committee using a Macintosh computer and a MiniCad +4 CAD program. Sources of information include:

U.S.G.S. quadrangle maps
Connecticut DEP
East Hampton Zoning map
East Hampton Plan of Development
Midstate Regional Planning Agency
Field observations



MAP 1

WATER RESOURCES AND MAJOR SUBBASINS

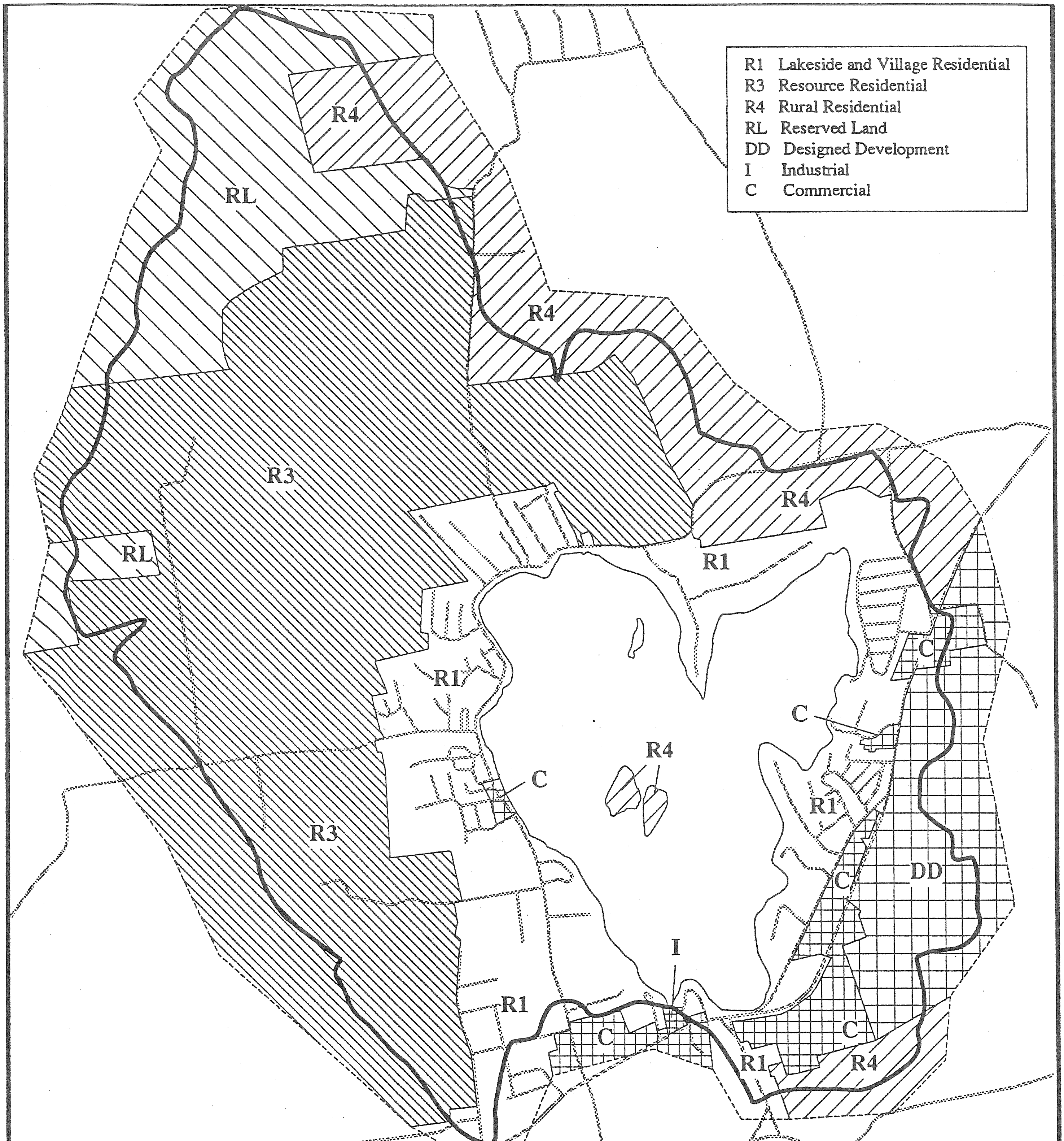


MAP 2

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 1/2 0 1 MILE

WATERSHED DEVELOPED AREA AND SUBBASINS

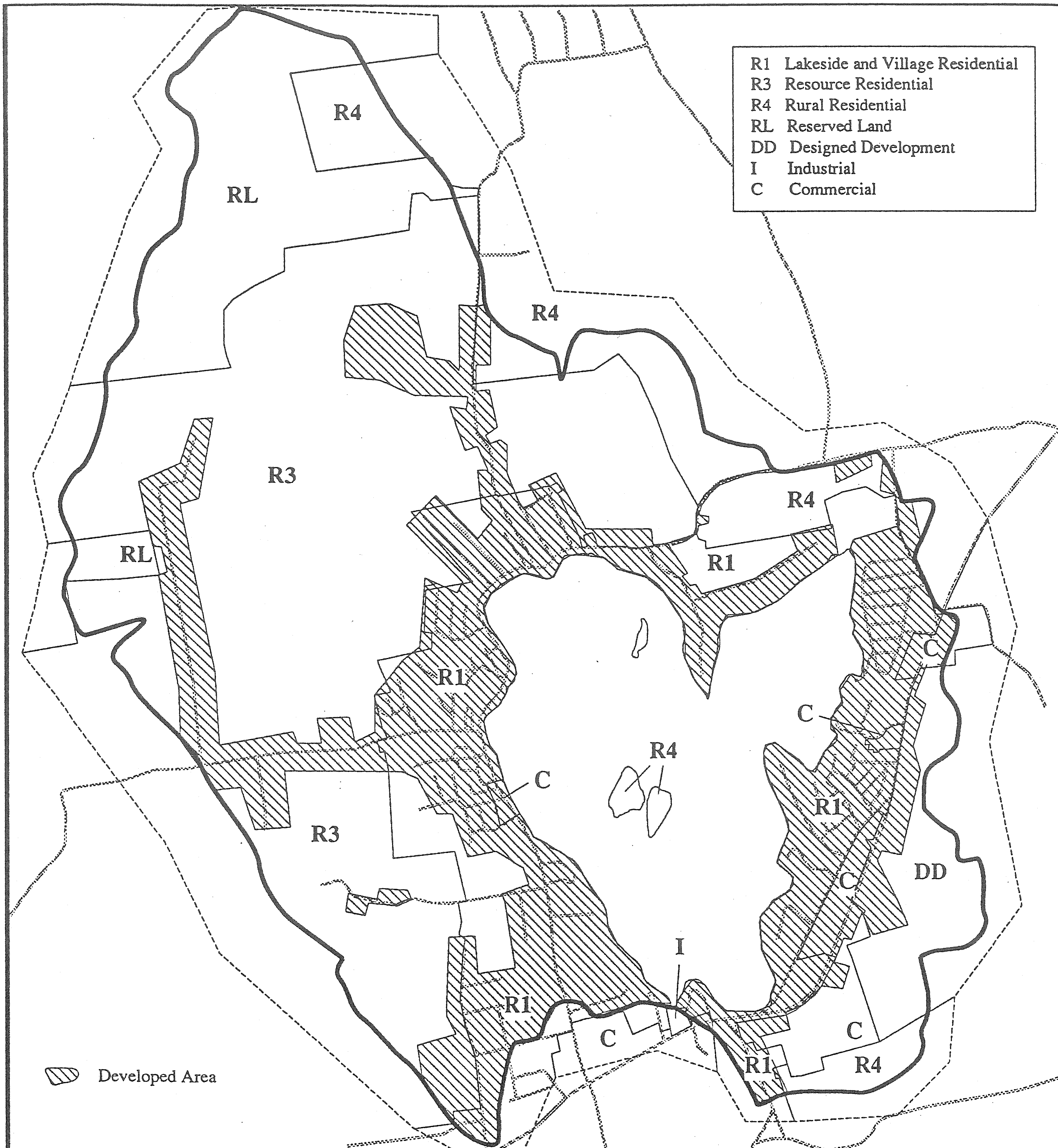


MAP 3

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 1/2 0 1 MILE

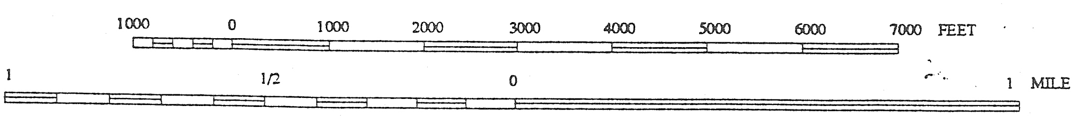
WATERSHED ZONING



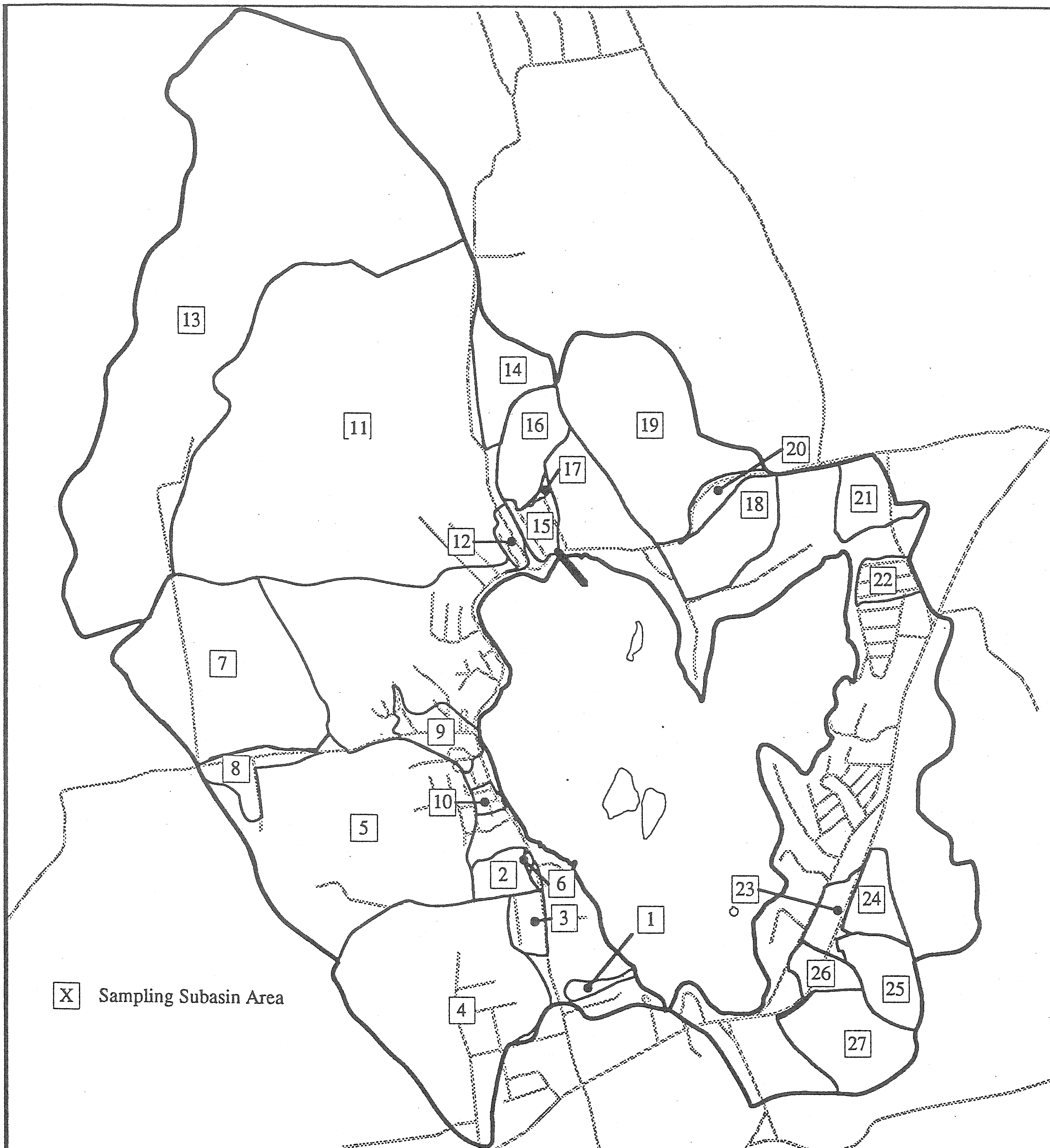
MAP 4

WATERSHED DEVELOPED AREA AND ZONING

MAP 5

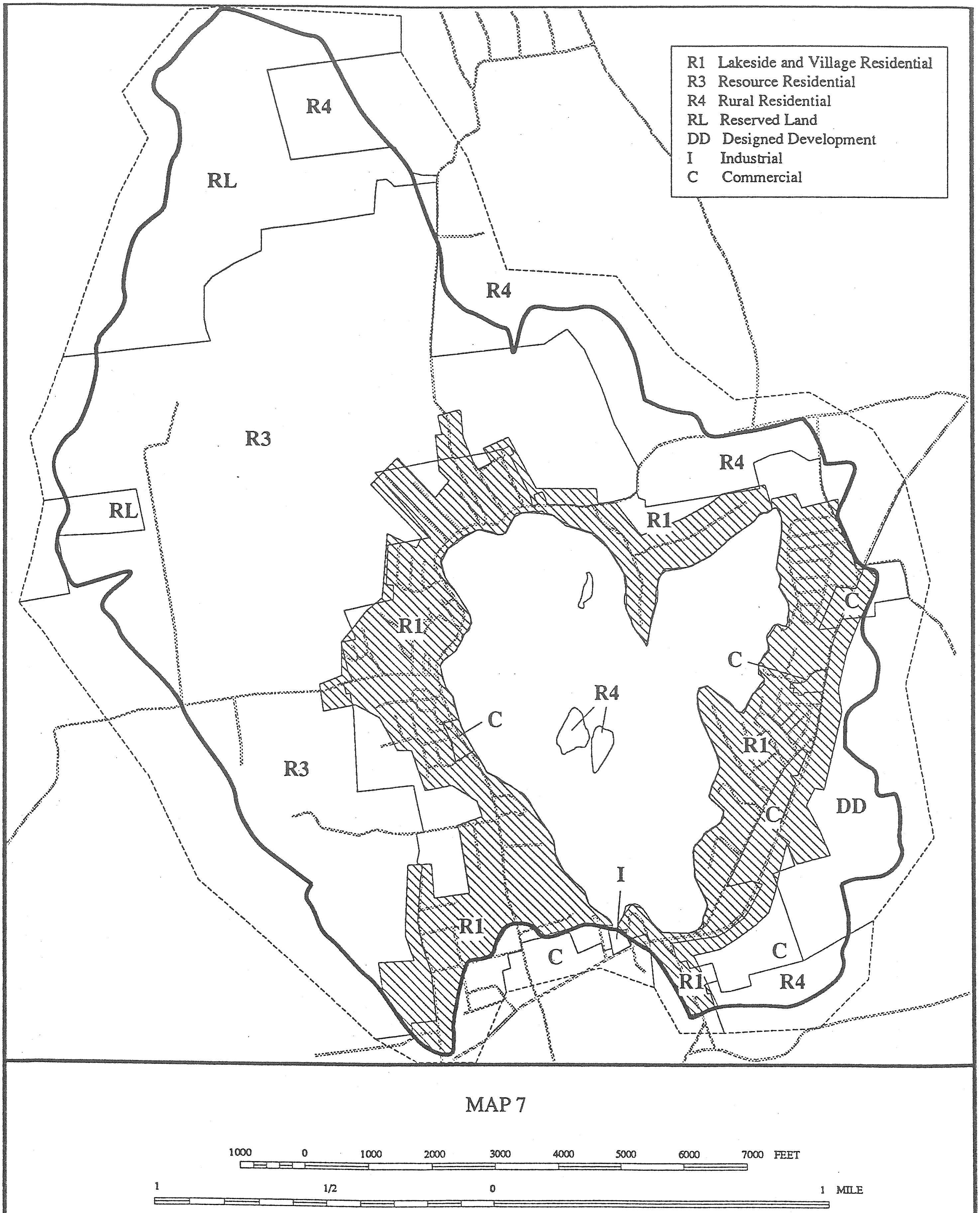


SAMPLING LOCATIONS



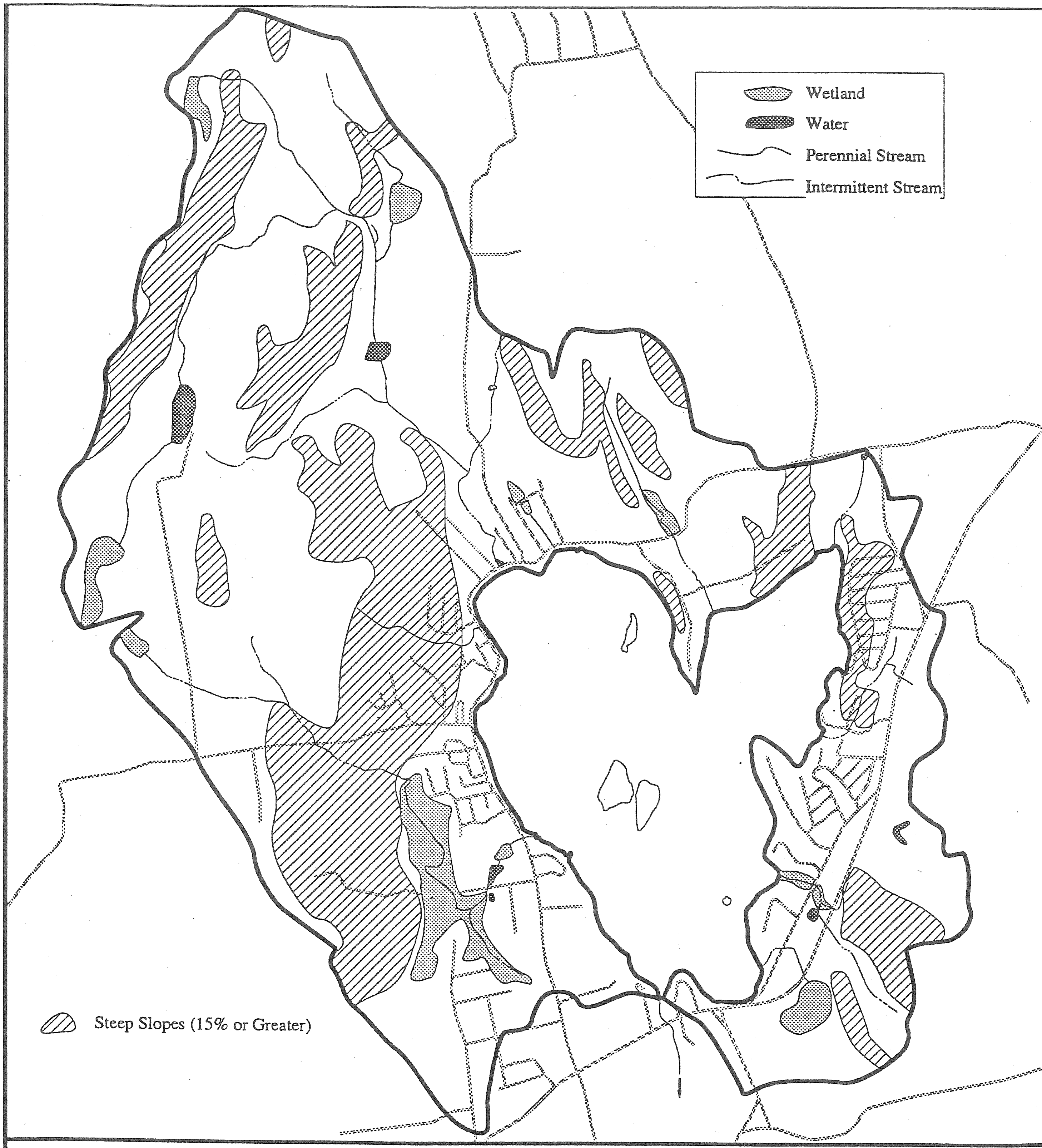
MAP 6

SAMPLED WATERSHEDS

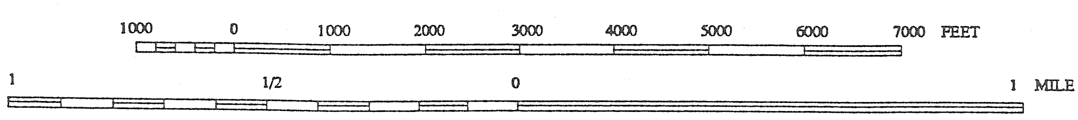


MAP 7

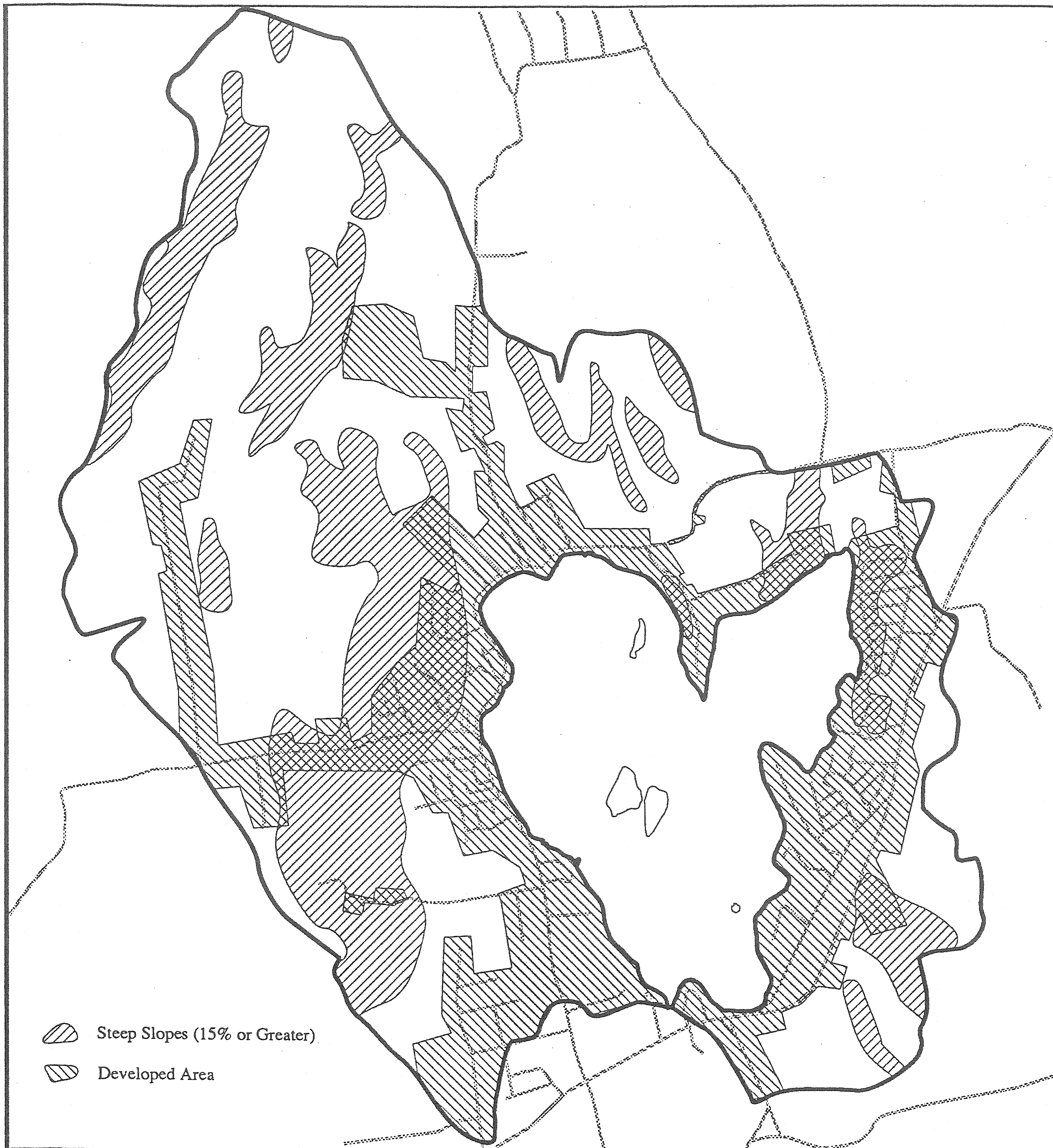
AREA SERVICED BY MUNICIPAL SEWERS AND ZONING



MAP 8



STEEP SLOPES AREAS AND WATER RESOURCES



MAP 9

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 1/2 0 1 MILE

STEEP SLOPES AND DEVELOPED AREA

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