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Forest Soil Site Selection Considerations for the Beneficial Application of Municipal Sludge and Wood Ash

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Introduction

Land application of clean municipal sludge (biosolids) offers potential benefits for some New Hampshire forest soils. These benefits may include: enhanced soil environment for tree growth; reduction in soil erosion especially in heavily disturbed sites; greater water holding and infiltration capacities and reduced overland flow. Sludge is the solid or semi-solid material produced by municipal wastewater treatment plants. It is a source of nitrogen, phosphorous and potassium.

In addition, treatment plants that use the lime stabilization process generate sludge with abundant calcium, an element of low supply in some forest soils. The metal content of sludge varies by municipality. The maximum amounts are regulated by federal law (Clean Water Act, 503 Regulation). The term biosolids is used in this paper for sludges that meet pathogen reduction, vector attraction reduction, and metal pollutant limits for land application.

Application of wood ash from wood-burning energy plants also offers potential benefits for some New Hampshire forest soils. These benefits may include provision of an effective method to neutralize the natural soil acidity and elevate levels of calcium and other plant nutrients in the soils.

Researchers report that the short-term effects of the proper use of municipal sludge and/or wood ash do not reduce environmental quality. Implicit in proper use is the need for best management practices, site management plans and environmental guidelines. More information is needed on the long-term environmental effects through monitoring activities on carefully managed forest land application sites.

The natural surface horizons occurring in forest soils are distinctive when compared to agricultural soils. Commonly, organic horizons overlie mineral horizons in the forest. On farmed fields all of this has been incorporated into a plow layer or Ap horizon. The role of the forest organic and mineral horizons has been and continues to be a focus for nutrient cycling research activities. Examples of research that studied the impact to the forest ecosystem from applying sludge or wood ash are presented below.

This paper includes a series of state-wide maps (Figures 1-5) that illustrate priority zones for the beneficial land application of biosolids and wood ash. This information is intended for general planning purposes. The forest land manager concerned with assessing site specific potentials on a woodlot should first use the figures and then focus on Table 1. Resource map information using Important Forest Soil Groups and the Habitats Classification are included in this table.

Research Results

Biosolids

Researchers at the U.S. Forest Service Hubbard Brook Experimental Forest, Thornton, New Hampshire looked at the effects of municipal sludge application on soil water and vegetation. Dewatered and limed sludge was spread at two rates on field plots in a northern hardwood stand. The light application was about 100 pounds total nitrogen (N) per acre and the heavy application rate was about 480 pounds total nitrogen (N) per acre. Loamy, acid glacial till soils with a hardpan layer (Marlow and Peru series) and a glacial outwash soil (Colton series) dominated the site. The light application caused only minor changes in soil water chemistry. The heavy application caused increases in most ions such as calcium, magnesium, chloride and nitrate at the eight-inch depth (B horizon). Ion concentrations were greatly reduced at 18 inch depth. The concentration of most ions returned to background levels within one year after sludge application. Researchers suggest that any elevated nutrient levels in stream chemistry would be short-lived. There were no significant differences in basal-area growth among control and treated plots for the first two growing seasons after sludge application. The dominant soils on this research study area are included in Zone 4 on Table 1 and Figure 4.

Barriers To Nutrient Leaching

Several studies at the University of New Hampshire (UNH) have focused on forest land utilization of municipal sludge. The key question is how much sludge can be applied to the forest so as not to upset the natural balance of the system.

Nitrate leaching through forest soils, for example, is often used as an indicator that an excessive amount of sludge has been applied. Elevated nitrate levels have implications for degradation of ground water and surface water quality. The goal is to apply sludge at loading rates that are not detrimental to the forest ecosystem. UNH researchers found that without tree uptake, a loamy glacial till soil (Charlton) leached nitrate-nitrogen in excess of EPA water quality standards of 10 mg/l. However, the second- growth northern hardwood forests formed an effective barrier to nitrate leaching even at high rates of application (about 680 pounds nitrogen per acre). This also suggests that loading rates of sludge on heavily disturbed forest soils should be less than for undisturbed soils. The Charlton soil is included in Zone 4 on Table 1 and Figure 4.

Variable Sludge Properties

Another UNH study looked at why different sludges with similar nitrogen-loading rates to forest soils have different quantities of nitrogen leaching. Vegetation was suppressed on all plots by continuous clipping. Apparently these differences were partially controlled by the C:N ratio of the sludge. For example, when using paper mill sludge with a characteristic high C:N ratio (130 in this study), the resident microbes utilize nearly all available nitrogen for their nutritional needs. This leaves little opportunity for nitrate leaching. Municipal sludge with lower C:N ratios presents a different scenario. Nitrogen in excess of the needs of microbes may result in nitrate leaching at similar nitrogen loading rates. Researchers have also found that when nitrate leaching occurs, base cations such as calcium, potassium and magnesium tend to be dragged down through the soil profile. This suggests less availability of those nutrients in the root zone for plant growth. Researchers report that the heavy metals, cadmium and zinc, also migrated downward in plots that received the highest application rates of municipal sludge. The increased soil acidity as a result of nitrification may have contributed to heavy metal solubility and migration.

Wood Ash Residuals

Large volumes of wood ash are produced by commercial power plants utilizing wood chips in the generation of electricity. Since 1987, some of this ash has been applied on New Hampshire farm land as a replacement for lime. The desired effect is to raise soil pH and thus enhance the soil environment for agronomic crop growth. Researchers at the Universities of Maine and New Hampshire have recently studied the effects of applying wood ash residuals to forested lands.

UNH researchers studied a white pine stand in Sandwich and a mixed hardwood stand in Twin Mountain with the objective of observing changes in soil chemistry and the soil water solution for one year after the wood ash application. The wood ash applied came from different power plants. The well drained Becket soils were identified at both sites. These acid glacial till soils have a hardpan layer in the substratum that restricts downward water movement. Commonly the seasonally wet Skerry soils occur in close association with the Becket.

The UNH study involved a very thorough analysis of the environmental effects of ash application. As expected, the ash did raise soil pH. The initial pH of the residual used at Sandwich was 10.6 and 10.8 at Twin Mountain. The application at Sandwich of 5 and 10 dry tons per acre as a wet slurry raised the upper organic horizon (Oe) pH from 3.0 to about 6.6. There was little effect on the mineral horizons. The 20 ton loading rate raised the pH for the upper organic horizons from 3.0 to 7.0. The effect on lower organic layer (Oa) and mineral A horizon was much less (3.0 to 5.3 and 4.4 respectively). Caking of the residuals on tree stems caused some stand damage. Elevated levels of calcium in soil water solution remained long after the ash was applied. Application of a dry granular residual at the Twin Mountain site had a different result. Calcium leached for only a short period after application. Most of the calcium was still present near the surface after one year. Magnesium and potassium were more mobile than calcium at both sites. Researchers concluded that while there may be important differences among ashes and differences in ash behavior with different site conditions, there was no threat to surface or ground water quality. Nor do they expect long term detrimental effects to site quality.

Priority Areas For Forest Land Application

Land application of sludge and wood ash on New Hampshire forest soils can improve soil fertility. Some forest soils are inherently lower in tree growth productivity than others. These soils could benefit from an enhanced soil environment for tree growth. Sludge has the potential to provide additions of organic matter, nitrogen and other plant nutrients. Lime-enriched sludge and wood ash provide additions of calcium. Researchers in northern New England have recently noted the importance of a favorable ratio of aluminum and calcium in the rate of wood formation in red spruce. Calcium uptake by fine roots of red spruce in the organic forest floor layers is impaired when aluminum dominates. Although researchers report no visible evidence of calcium deficiency in other tree species at this time, investigation continues as to how widespread this process may be and the impact on tree growth.

Heavily disturbed forest soils are also possible areas that can benefit from additions of organic matter and nutrients. Extensive areas of mineral soil (B and C horizons) may be exposed. The disturbance may be the result of human activity such as forest practices or natural events such as fire. Once the organic forest floor layer has been extensively disturbed, additions of organic matter and nutrients through biosolids application would help restore the health of the forest soil.

Four priority zones for beneficial land application of biosolids and residuals are illustrated in Figures 1 to 4. Areas not appropriate for land application are shown in Figure 5. These statewide maps utilize the State Soil Geographic Data Base (STATSGO) in identifying broad geographic areas with similar potential for tree growth as well as environmental concerns.

In New Hampshire STATSGO is maintained by the Durham office of the Natural Resources Conservation Service. Map units for STATSGO were digitized on U.S. Geological Survey (USGS) 1:250,000 scale, 1-by-2 degree quadrangle base maps. Maps unit composition for STATSGO was determined by transecting or sampling areas on more detailed soil maps and expanding the data statistically to characterize the whole map unit. STATSGO was designed to be used primarily for regional, multi-state, river basin, and state resource planning, management and monitoring. STATSGO data are not detailed enough to make interpretations at the county level.

<u>Zone 1- High Potential Benefit - Low Environmental Impact. Figure 1</u>
Soils developed on sandy, acid glacial till materials have the highest priority for land application. Typically, these soils have low levels of organic matter and basic plant nutrients. Since these soils do not overlie significant yielding aquifers, there is less concern for groundwater quality impacts. However, impacts to surface waters are a concern and it is important to adhere to all best management practices outlined in a management plan.

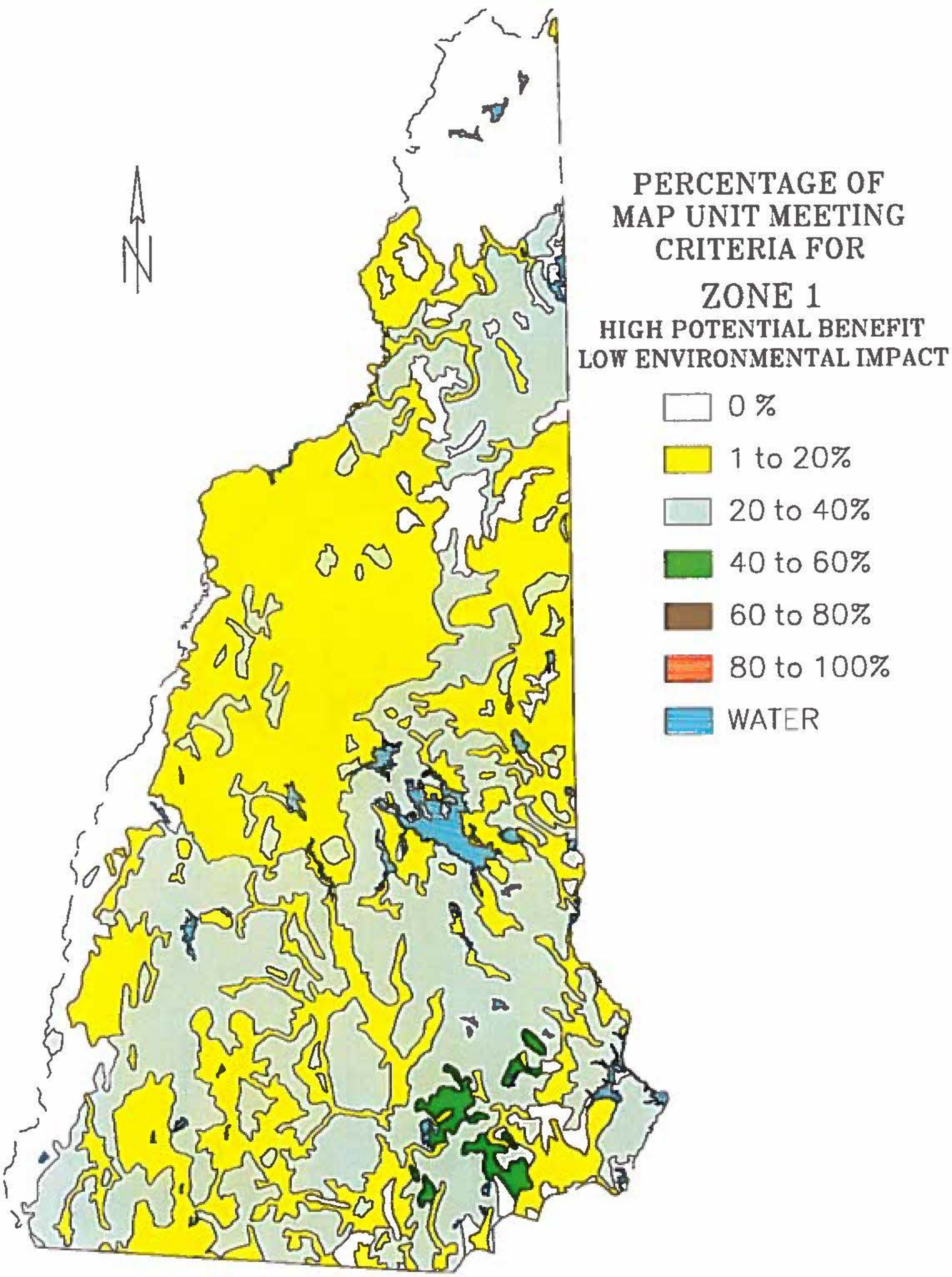
<u>Zone 2 - High Potential Benefit - Moderate Environmental Impact. Figure 2</u>
Soils developed on sandy and/or gravelly outwash materials in the south, central and northern areas of the state are included in this zone. Medium levels of organic matter and low levels of basic plant nutrients characterize these soils. These soils may overlie significant yielding aquifers. Adherence to loading rates and best management practices outlined in a management plan are important considerations for this environmentally sensitive zone.

<u>Zone 3 - High Potential Benefits - High Environmental Impact. Figure 3</u>
Soils developed on sandy and/or gravelly outwash materials in the southern areas of the state are included in this zone. Low levels of organic matter and basic plant nutrients along with a very low available water capacity are typical of these soils. Significant yielding aquifers may underlie these soils. Adherence to loading rates, number of applications and best management practices outlined in a management plan are important considerations for this environmentally sensitive zone.

<u>Zone 4 - Low Potential Benefits - Low Environmental Impact. Figure 4</u>
Soils developed in a variety of parent materials are included in this zone. Typically, these soils have medium levels of basic plant nutrients and some have medium levels of organic matter. Significant yielding aquifers generally do not underlie these soils. Priority areas within this zone include heavily disturbed sites. Depending on preferred species for the site, application of sludge with the added organic matter and nutrients may be beneficial.

<u>Zone 5 - No Land Application. Figure 5</u>
Soil conditions in those areas are not appropriate for land application. Included are high elevation areas, flood plains, slopes over 15%, wet soils and others. Table 1 provides specific examples.

FOREST LAND APPLICATION OF BIOSOLIDS AND WOOD ASH



10 0 10 20 STATUTE MILES

MAP SOURCE:

MAP PRODUCED BY THE NATURAL RESOURCES CONSERVATION SERVICE, 2 MADBURY ROAD,DURHAM, N.H. THE SOIL INFORMATION USED FOR THIS MAP WAS NATURAL RESOURCES CONSERVATION SERVICE 1992 STATSGO DATA. STATSGO WAS COMPILED AT 1:250000 AND DESIGNED TO BE USED PRIMARILY FOR REGIONAL, MULTISTATE, STATE, AND RIVER BASIN RESOURCE PLANNING, MANAGEMENT AND MONITORING.
INTERPRETED BY S.A.L. PILGRIM

FIGURE 1

MAY 11, 1994

FOREST LAND APPLICATION OF BIOSOLIDS AND WOOD ASH

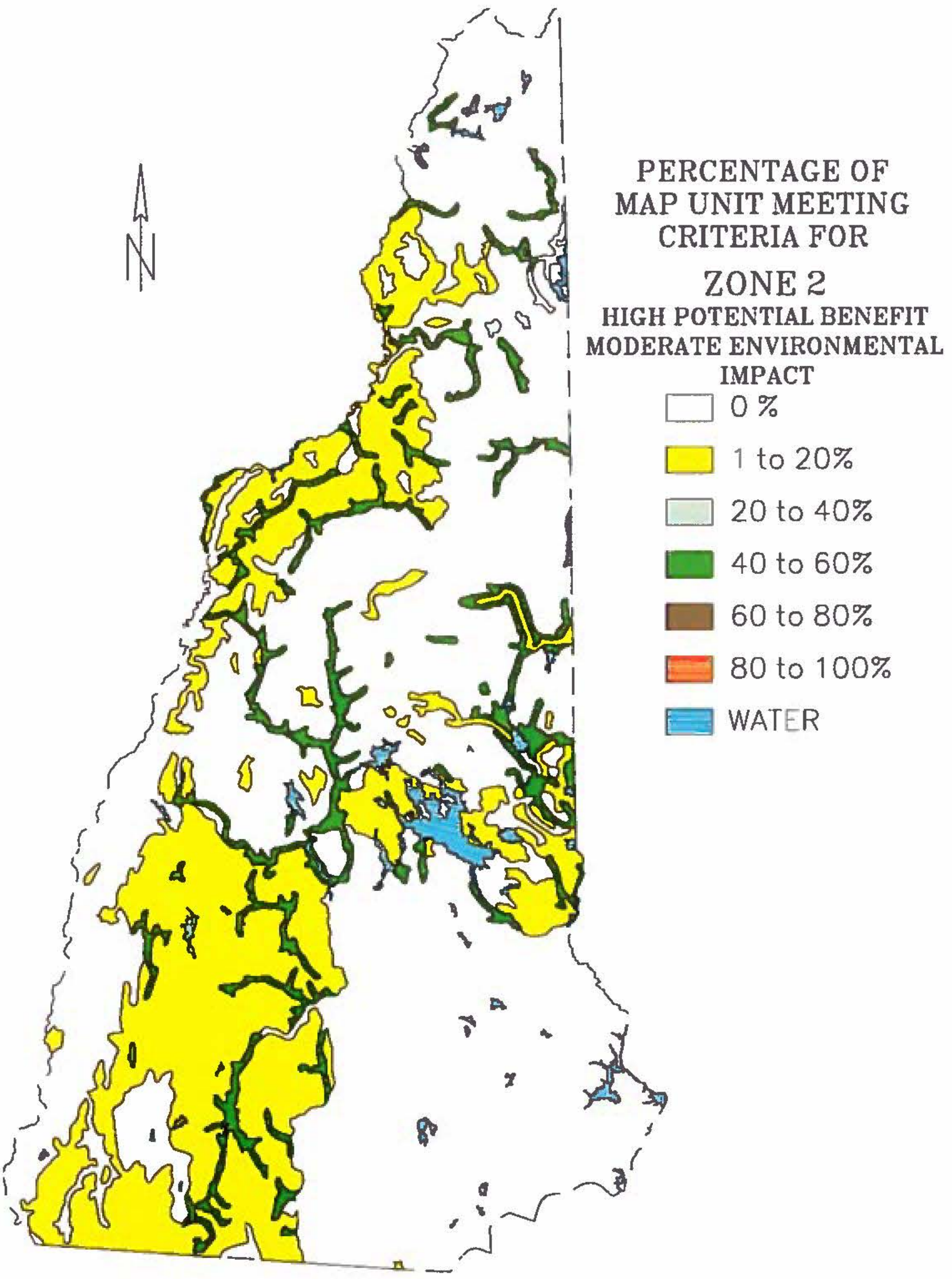


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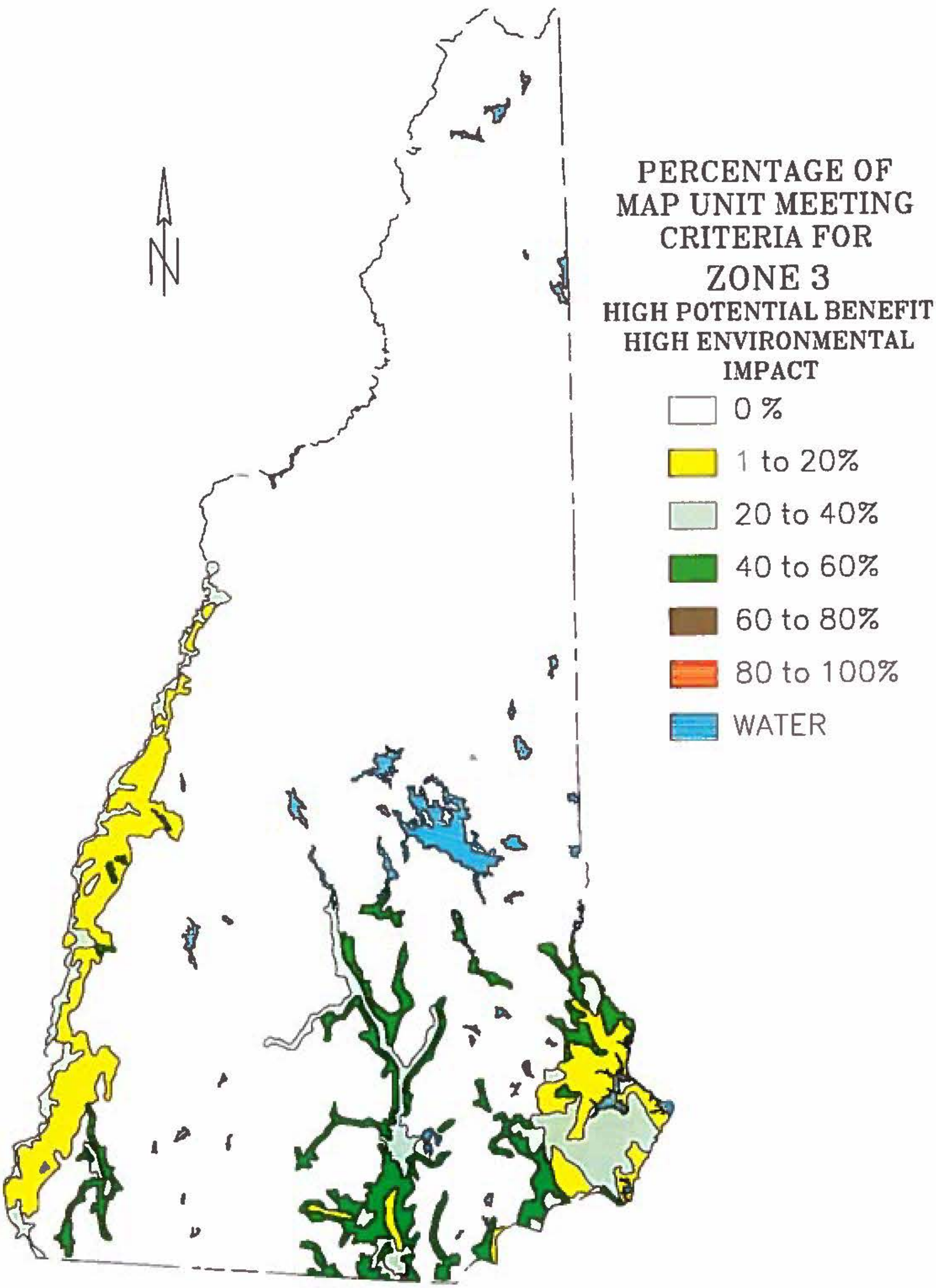
FIGURE 2

MAY 11, 1994

FOREST LAND APPLICATION OF BIOSOLIDS AND WOOD ASH



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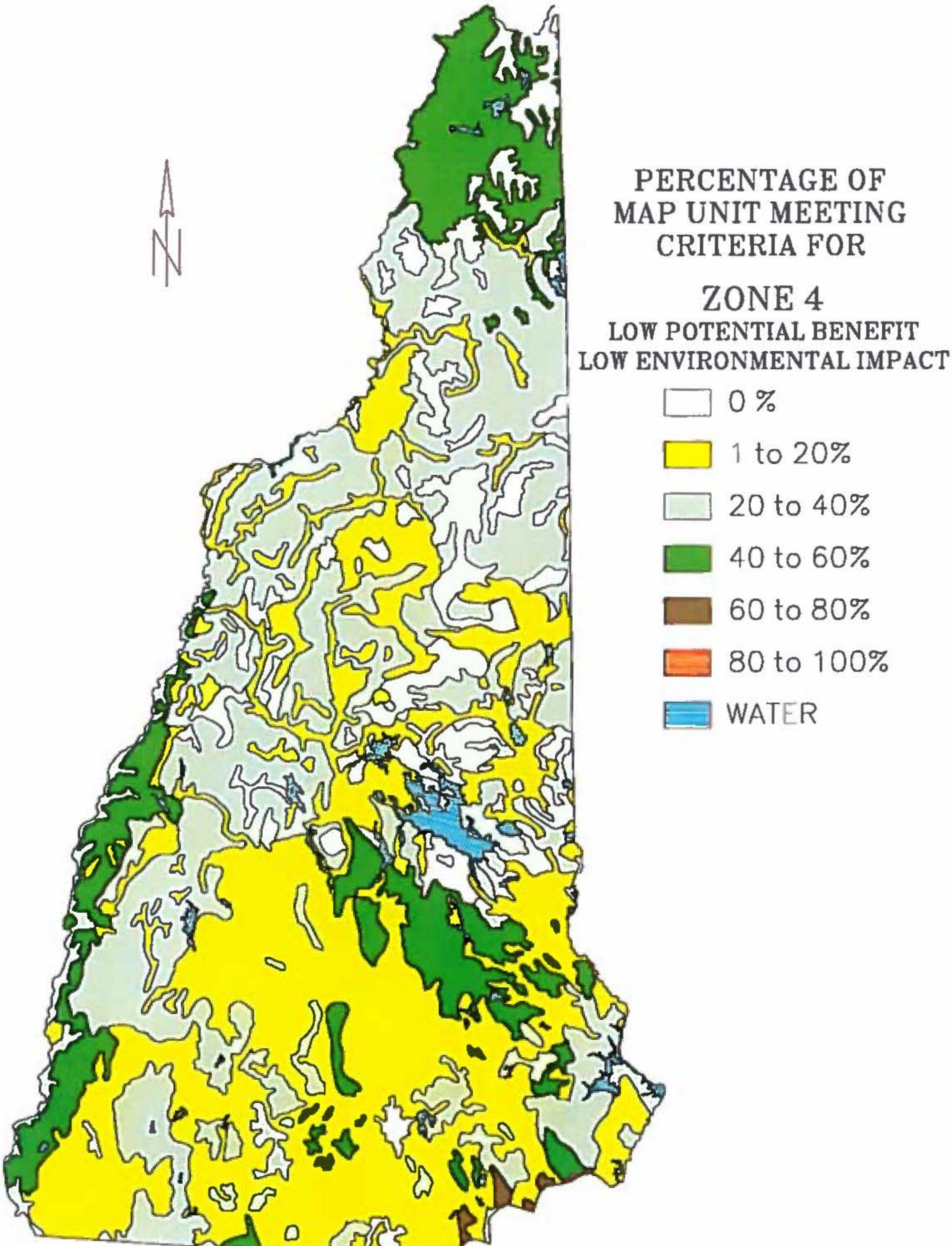
10 0 10 20 STATUTE MILES

FIGURE 3

MAY 11, 1994

FOREST LAND APPLICATION OF BIOSOLIDS AND WOOD ASH



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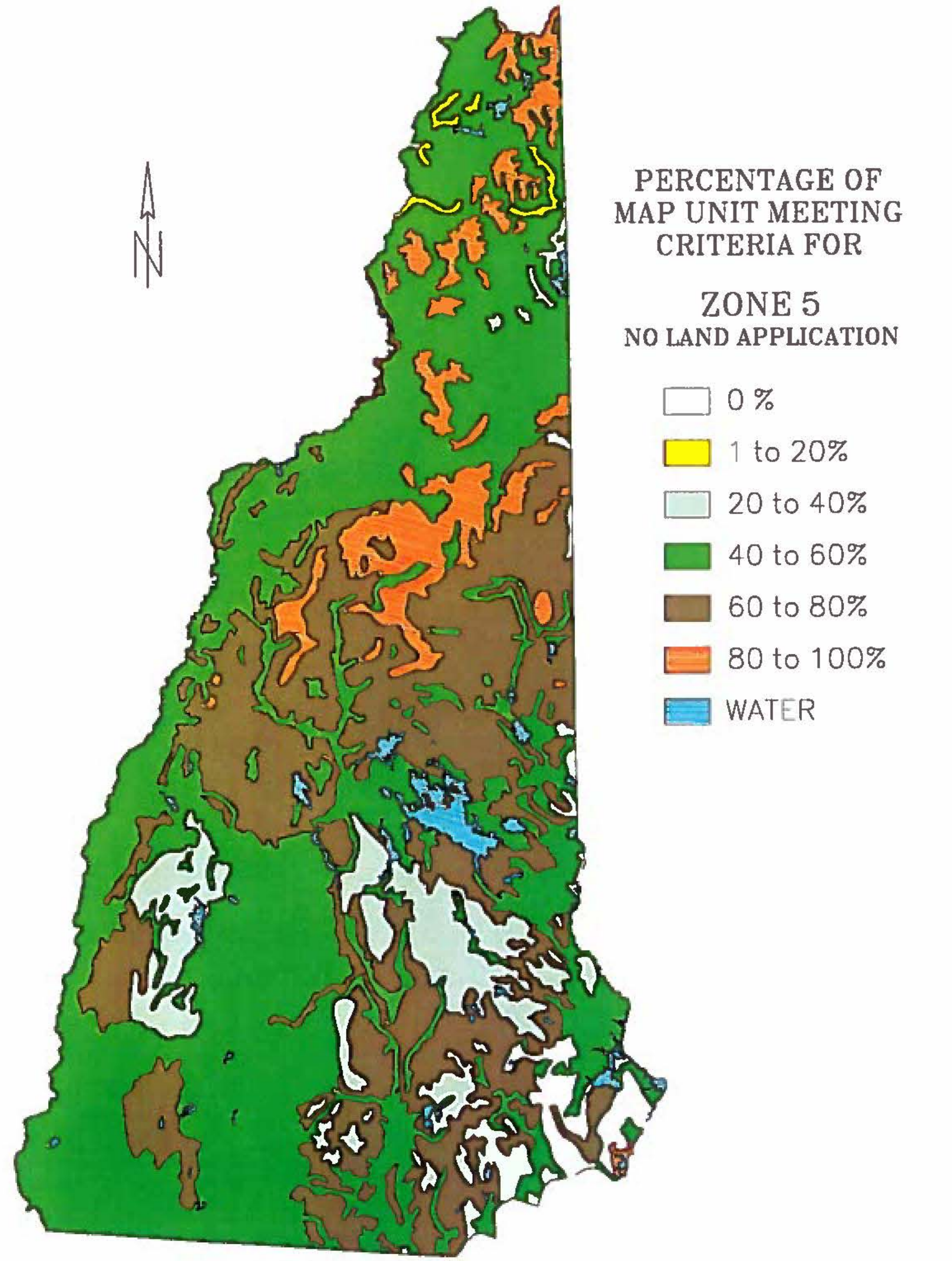
MAY 11, 1994

FIGURE 4

FOREST LAND APPLICATION OF BIOSOLIDS AND WOOD ASH



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10 0 10 20 STATUTE MILES

MAY 11, 1994

FIGURE 5

Application of Research Results to Field Operations

Soil Resource Maps

Experience in establishing research plots in the forest suggests it may be desirable to have a detailed soil map at scale of about one inch equals 400 ft. to clearly identify the various soil conditions. County soil maps are a starting point but often do not show the necessary detail. The forest land manager can identify soils using either the Important Forest Soil Groups System or the Habitat Classification System. Soil map units for both systems are presented in Table 1. Soils are arrayed from a grouping likely to have the most benefits of land application of biosolids and/or wood ash to soils likely to benefit the least (Zone 4). Heavily disturbed sites would likely benefit from biosolids or residual application regardless of the soil group. The exception is the final grouping for which there should be no land application. This includes soils occurring on flood plains, steep slopes, wetlands, high elevations, etc. Adverse environmental impacts, such as potential ground and surface water contamination, are also considered in Table 1.

Table 1

Using soil resource maps to further identify forest sites relative to environmental concerns and beneficial land application of municipal sludge (biosolids) and wood ash. *S.A.L. Pilgrim. 1994.*

Resource Maps for Forest Tract	Benefits of Land Application[e] High........			........Low	No Application
Zones	Zone 1	Zone 2 Sensitive areas Light application	Zone 3 Very sensitive area Very light application	Zone 4	Zone 5
Important Forest Soil Groups[a]	IB	IC	IC[c]	IA[d]	2A and 2 B slopes over 15% flood plain soil soils in cryic soil temperature regime
Habitats Classification[b]	coarse and fine washed till	outwash	outwash[c]	fine till silty sediments dry compact till sandy sediments[d]	poorly drained shallow bedrock enriched wet compact till flood plain and cryic soils slopes over 15%

Notes:

[a] This system uses NRCS county maps. A listing of all soils by group is available at the County Conservation District offices. More detailed mapping than NRCS maps may be appropriate for tracts with variable soil conditions (Spielman et al. 1984).

[b] Habitat Mapping and Interpretation in New England (W.B. Leak 1982).

[c] There is a possibility of ground water contamination when application rates of sludge constituents exceed plant uptake and soil binding capability. Sites occuring in Zone 2 frigid temperature zone have higher benefit than Zone 3 mesic zone.

[d] For heavily disturbed sites, ie., mineral soil (B or C horizons) is exposed, a higher benefit may result.

[e] Consider application to only portions of watershed to minimize increased nutrient levels in stream chemistry.

Management Plan

It is not the intent of this paper to outline the details of a plan, but rather to point out the need for one. Documentation of land application activities and long term monitoring of the site are important components of the management plan. EPA 503 regulations outline mandatory requirements on biosolid recordkeeping as well as setback distances to surface waters. Management plans which include pre-application soil testing and wood ash land application rates are required prior to receiving wood ash, in accordance with the **NH Solid Waste Rules and The Joint Policy Statement on the Use of Wood Ash on Agricultural Land between the Waste Management Division of the Department of Environmental Services and the Department of Agriculture.** Land application should be avoided when soils are wet, frozen or covered with snow to minimize surface runoff. On-site storage should consider set back requirements including dwellings and the possibility of an underlying aquifer. Land application equipment will depend on whether the biosolids and wood ash are in solid or in liquid form. Accurate rates of application are essential to a successful program.

■ Wildlife

Researchers emphasize the value of biosolid application to sites with poor soil quality as a means of improving wildlife habitat. The productivity of herbaceous vegetation in particular is increased. Levels of heavy metals such as cadmium need to be monitored in both biosolids and wood ash to protect the food chain.

Sampling Protocol for Soil Analyses

A complete soil sample analysis prior to biosolid application is not required under EPA 503 regulation, but is a recommended practice. Soil testing is required in New Hampshire prior to receiving wood ash for land application. Consideration should be given to sampling the forest floor and mineral soil separately. Nutrient availability and cycling implications suggest that this is important to management. The Oe and/or Oa horizons (exclude the loose leaf/needle litter of Oi) would comprise the forest floor sample. It is important to record the thickness of the organic horizons. The mineral soil sample should be taken in the upper six inches of mineral soil. Differences of one order of magnitude or more often characterize nutrient levels and other constituents in these distinct soil horizons. Detailed soil maps are useful in determining locations and number of soil samples.

Continuing Research Needs

Researchers are still investigating the rates of nitrogen transformation and how these transformations take place after biosolids are applied to the soil. This information will permit further refinements of the nitrogen loading rates on a site by site basis.

The potential negative effects of applying large amounts of calcium to agricultural soils concerns some researchers. Very high levels of calcium saturation may impact the availability of other cations as potassium and magnesium to plants. Is this a concern for a forest ecosystem? Maine researchers have identified several topics dealing with ash residuals. These include the effects residual materials have on competing vegetation, the application of residuals to partially cut stands, and the quantification and effects of heavy metals, particularly cadmium, in some ash materials.

Changes in the water infiltration and percolation characteristics of the upper part of the soil profile at a site where biosolids have been applied is the topic of an ongoing UNH investigation. This study is designed to gain a better understanding of how soil water movement is effected by the additional organic matter provided by the biosolids.

Researchers in western Canada report that fresh wood ash inhibits the germination and early survival of some conifers but this ameliorates with leaching. Water soluble components of ash that produce alkaline soil solutions above pH 12 have been identified as the inhibitors. Forty inches of precipitation were needed in this study to leach the wood ash sufficiently to allow jack pine establishment. This may be a research topic for appropriate conifer species in New England.

Regulations

Municipal sludge: A self implementing regulation by EPA covered by 40 CFR 503. This rule sets national standards for pathogens and 10 heavy metals and was developed in accordance with the 1987 Amendments to the Clean Water Act. N.H. Department of Environmental Services (DES), which regulates septage management in New Hampshire, has decided not to duplicate this rule and regulates only those aspects of sludge/septage management that are not covered by 40 CFR 503

Wood Ash: Ash from wood-burning energy plants is defined as solid waste under the provision of New Hampshire RSA 149-M. The disposal and utilization of wood ash is regulated by Department of Environmental Services, Waste Management Division. The ash generator must apply for and receive a Certificate of Direct Re-use in accordance with Part Env-Wm 318 of the **NH Solid Waste Rules.** DES requires the heavy metal content of the ash be analyzed on a regular basis and concentrations fall below established environmental standards. Wood ash is also analyzed regularly for nutrient content, pH and calcium carbonate equivalence, for the purpose of calculating application rates.

Endangered Species: EPA 503 regulations restrict the land application of biosolids where a threatened or endangered species listed under Section 4 of the Endangered Species Act or its designated critical habitat may be adversely effected.

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