TOWN OF BETHLEHEM, NEW HAMPSHIRE

NATURAL RESOURCES INVENTORY
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Commissioned and funded by the Bethlehem Conservation Commission

DEDICATION

This Natural Resource Inventory is dedicated to the residents of Bethlehem, New Hampshire.

BETHLEHEM CONSERVATION COMMISSION

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Cover Photo: Wetland along Blaney Road, Bethlehem, NH

Photo on current page: Scenic View off Prospect Street looking towards the Presidential Range of the White Mountains.

Unless otherwise stated, all photos were taken by Elise Lawson / Watershed to Wildlife during field work for this NRI.

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SUMMARY AND HOW TO USE THIS REPORT

In New Hampshire conservation commissions are tasked with many responsibilities, including environmental education, land protection, wetland evaluation and more. Although some of these are optional, creating inventories of natural resources is a statutory requirement (RSA 36-A:2). A Natural Resource Inventory (NRI) provides a clear picture of where a town's natural resources are located, which of them are significant, and why.

Examples of how an NRI can be used include:

- Guiding the conservation commission's goals and projects
- Advising the Planning Board and other government entities involved in making land use decisions
- Informing the town's Master Plan process and recommendation of Zoning Ordinances
- Assisting in the evaluation of wetland permit applications
- Creating a foundation for a Conservation Plan
- Providing background for public forums on natural resources and environmental topics
- Integrating information into environmental education curricula in schools

The application of the NRI to land use planning is perhaps its most critical purpose. Land use planning must constantly seek to balance future growth and development with protection of natural resources. The Bethlehem Conservation Commission (BCC) completed this report to give Bethlehem data on these resources, so the town can make informed and balanced decisions. This NRI provides Bethlehem with a foundation for proactive planning, rather than the all-too-common reactive approach.

Goals of the Natural Resources Inventory

In 2023 the BCC hired natural resources consultant and biologist Elise Lawson, owner of Watershed to Wildlife, to prepare this NRI. The following goals guided its development, and resulted in the maps, data and narrative.

1. Promote conservation of water, forested land, wildlife habitat, wetlands and unique co-existing natural resource features throughout the town.
2. Create a document that can be incorporated into future updates of Bethlehem's Master Plan
3. Identify areas for future conservation efforts, and areas of contiguous open space and wildlife corridors

4. Maintain inventories of natural and scenic resources, including aquifers, open water, steep slopes and hilltops
5. Provide the Town of Bethlehem with new accurate, standardized coverages that can be integrated into the existing GIS database
6. Increase awareness of the values of the characteristics of Bethlehem including forest and water resources, scenic view areas, recreation areas, riparian buffer habitat, and wetlands with associated wildlife habitat through public presentations and discussions.

Based on the results of this study, Elise Lawson of Watershed to Wildlife and the Bethlehem Conservation Commission offer the following observations and recommendations:

1. **Surface Water Protection** – **230.23 miles of streams/rivers – 228.75 acres of open water** Bethlehem's water bodies, including rivers, streams, lakes and ponds, provide recreational opportunities such as swimming, fishing and boating. Some are also critical sources of drinking water for our residents and neighboring communities. The Bethlehem Reservoir, for example, is part of the South Branch Gale River and an important water supply for Bethlehem. **Maintaining good water quality is one of the highest priorities of the Bethlehem Conservation Commission.** Currently, water quality is in relatively good condition, with Mercury levels being the biggest concern for fish consumption (NH Department of Environmental Services, 2024). We should continue to maintain a high standard not only in the Ammonoosuc River, but also in smaller rivers, streams, and headwater brooks that feed the Ammonoosuc River in Bethlehem, as well as the Connecticut and Pemigewasset Rivers outside of Town. Recent challenges in achieving this include new knowledge of the threat and extent of PFAS contamination and the increasing occurrence of cyanobacteria, both of which are toxic to humans and animals.

2. **Climate Change** – One of the most significant threats to the existing natural resources in Bethlehem is climate change. The predictions of impacts as described in the 2021 NH Climate Assessment Report should be considered by all town departments and committees in planning for Bethlehem's future. It is recommended that land use planning incorporate actions to minimize, mitigate and adapt to climate change impacts. The Town's Energy Commission can work with the Conservation Commission to help reduce municipal and residential activities that create greenhouse gases.

3. **Aquifer Protection** – **3,370.54 acres – 5.8% of town -** Future water supplies are a vital natural resource for Bethlehem and the abutting municipalities as demonstrated by the drinking water systems already in use. Most Bethlehem residents depend on drilled or

dug wells that draw from the groundwater and aquifers below. Land use planning should include consideration of what is built and disposed of on the land surface of this important underground resource. Maps #4 and #5 show the location of aquifers in Bethlehem.

4. **Importance of Forested lands – 89% Forested in Bethlehem including the WMNF**

    a. **Dense Softwood Protection**- **6,903.17 acres – 11.86% of Town -** Dense softwood stands (not including white pine stands) are beneficial to wildlife for cover particularly in the winter. Maintaining existing stands for the benefit of the deer, moose and other wildlife populations is very important. This type of habitat could be negatively impacted by climate change particularly the Lowland Spruce-Fir plant communities.

    a. **Carbon Sequestration** – Recent research indicates that forests and natural vegetation provide up to 37% of the emission reductions needed to keep global temperature increases under 2 degrees Celsius. Older trees and woody debris hold carbon in their structure, while the rapid growth of younger trees can sequester carbon at a faster rate. Thus, there is recognition of the carbon sequestering value of forests. Furthermore, sustainable forestry practices can enhance this function. There are opportunities to generate income from carbon offset programs, and revenue from the sale of these offsets can be used to purchase additional forested land for conservation. Funds can also be used to help private landowners put forested properties into conservation easements.

5. **Continued Wetland Conservation – 2,186.28 acres wetlands – 3.75% of town** - The Bethlehem Conservation Commission recognizes the many functions and values of wetlands including: excellent fish and wildlife habitats, higher water quality, flood storage, shoreline erosion protection, and recreation/observation/education opportunities (US EPA, 2023). This NRI report recommends that the Town continue to pursue ways to further conserve the functionality and diversity of these wetlands. An overall wetland study would help Bethlehem to work with willing landowners to conserve some of these valuable wetland resources. Bethlehem has Floodplain and Aquifer Ordinances ordinance with the intent to prevent the development of structures and land uses along river floodplains and above aquifers. This will help protect these resources. Currently there is no wetland ordinance. A link to the existing ordinances is found here:

    chrome-https://bethlehemnh.org/wp-content/uploads/2024/03/Zoning-Ordinance-2024.pdf

6. **<u>Land Conservation</u> – 34,377.57 acres of conserved land (30,360.22 WMNF, 3,719.12 privately-owned property, 120.59 State-owned land, 147.28 town-owned properties) -** As Bethlehem faces increasing development pressure, this NRI recommends strengthening efforts to secure for future generations the open spaces that help define the character and quality of life that residents have repeatedly listed as priorities for our town. Over 50% of town is conserved by the US Forest Service and contains the White Mountain National Forest. This NRI highlighted three areas to be considered for further land conservation. These areas warrant concern for water quality and wildlife travel, and include:
    a. Black Brook, associated wetlands and undeveloped upland areas in the North-east part of Bethlehem
    b. Areas near Ammonoosuc River and Alder Brook
    c. Indian and Baker Brook Areas east of the Rocks Estate

7. **<u>Hillside and Viewshed Protection</u>** – Bethlehem is one of the hilliest towns in the area. Its hilly topography is directly related to the town's tourism industry, scenic beauty, and diversity of natural resources - from alpine zones at the top of mountains to the beaver ponds, streams, and floodplain river habitat in the lower valleys. This NRI recommends research and consideration towards evaluating and updating the Zoning Ordinance in Bethlehem to conserve viewsheds that are basic to the rural character of the town.

8. **<u>Continued Cooperation</u>** - Ecosystems, watersheds and wildlife habitats often transcend municipal boundaries. The health of our natural resources is often dependent on actions taken by neighboring towns. The Franconia Conservation Commission has expressed interest in working with Bethlehem, particularly areas along and surrounding the Gale River. Bethlehem has been and will continue working with government agencies, regional planning commissions, land trusts including Ammonoosuc Conservation Trust, and natural resource organizations to enhance the protection of our shared natural resources.

Painted turtle photo by Watershed to Wildlife during 2006 Natural Resource Inventory in Bethlehem.

INTRODUCTION

Human relationship with natural resources in Bethlehem stretches back more than 13,000 years of habitation by Indigenous Peoples, who called their homeland N'dakinna. The White Mountains was home to the Abenaki tribes for thousands of years before the European settlers arrived at the "New World." Bethlehem was first settled in 1774 and originally called Lloyd Hills until 1799, when it was incorporated as the Town of Bethlehem. Initially, Bethlehem depended heavily on its abundant natural resources for its economic base and development occurred along the rivers. In 1798 there were 40 settlers, and by 1880, the population had grown to 1,400. The population was as high as 6,804 people in 1931, and the latest census in 2020 counted a total population of 2,484. With the arrival of the passenger railroad in the late 1800's Bethlehem became a popular summer vacation destination and experienced the rise of several grand hotels (Town of Bethlehem, 2004). The Bethlehem Historical Society has an excellent documentation of the town's history beginning with Native Americans (https://bethlehemhistoricalnh.org).

Today, the Town of Bethlehem, New Hampshire is rural and mostly forested containing 90.95 square miles (58,205.89 acres) of land including 228.75 acres of ponds and open water, and 230.23 miles of rivers and perennial streams. The White Mountain National Forest is prominent, with 47.4 square miles, located in the eastern half of town. Bethlehem's geography is quite diverse, ranging from flat floodplain areas along the Ammonoosuc, Gale and Zealand Rivers to rugged hilly areas with steep slopes throughout the White Mountain National Forest. There are several mountains over 4,000 feet including Mount Field (4,323 feet), North Twin (4,293 feet), Mount Willey (4,285 feet), Mount Tom (4,053 feet), and Mount Hale (4,050 feet). Nearly 90% of Bethlehem is forested.

Bethlehem contains a wide range of ecological habitats including rivers, ponds, and headwater streams. The latest Master Plan in Bethlehem was initiated in 2014 and completed in 2016. The first vision statement says: "Bethlehem takes pride in its past and present – its history, schools, parks, recreation and scenic beauty are all treasured by citizens both young and old. The small town qualities of Bethlehem are a hallmark of its existence and the reason why people live, work and play in the Community."

The Natural Resources Chapter of the 2016 Master Plan lists three goals.

1. Protect aquifer and open bodies of water
2. Maintain inventories for natural and scenic resources
3. Address growth and development through zoning

GOALS OF THE NATURAL RESOURCES INVENTORY

This project provides a Natural Resources Inventory (NRI) that, with the addition of data to the existing Bethlehem GIS database, can be integrated with past and future studies. One of the goals of this project is to provide an inventory and future recommendations, as well as educational and planning tools, for the Town of Bethlehem. It consists of a written report with maps, as well as an extensive GIS database that can be added as an overlay to existing maps in the town's database. It promotes conservation of water, unfragmented forested land, riparian habitat, wetlands, and unique co-existing natural resource features throughout the town.

Specific goals for this NRI include the following:

1. Promote conservation of water, unfragmented forested land, wildlife habitat, wetlands and unique co-existing natural resource features throughout the town.
2. Create a document that can be incorporated into future updates of Bethlehem's Master Plan
3. Prioritize areas for future conservation efforts, and areas of contiguous open space and wildlife corridors
4. Maintain an updated inventory of natural and scenic resources
5. Provide the Town of Bethlehem with new accurate, natural resource mapping features that can be integrated into the existing GIS database
6. Increase awareness of Bethlehem's natural resources – including forests, water resources, scenic views, recreation areas, riparian buffers, and associated wildlife habitat – along with the potential threats to these resources, through public presentations and discussions.

METHODOLOGY

Rachelle Lyons, member of the Bethlehem Conservation Commission, was the main contact for consultant Elise Lawson of Watershed to Wildlife. Elise has worked as a natural resource consultant for over 20 years. This town-wide Natural Resources Inventory uses a combination of existing mapping data, previous work, and current field work to produce an overall NRI for Bethlehem, NH.

Field Work

Elise completed four days of field work for this study (June 13, July 29, August 13, and August 23, 2024). The Bethlehem Conservation Commission reached out to landowners for permission to walk on their properties for this NRI. We respect the rights of landowners, and we did not trespass on private property; we ensured that we were granted permission. Field work was conducted to get an overall view of Bethlehem with a focus on previously identified

targeted areas. This work included inventories and assessments on several wetland complexes, riparian habitats, and upland habitats including higher elevation uplands. In most cases, Class VI roads and established trails were followed, while in other cases, compass-based orienteering and handheld GPS units were used. At points of interest, GPS locational data was taken, along with photographs and field notes. During field work sessions, any rare or endangered species found were noted and located on a map. Observed invasive plant species were also documented. Conservation Commission member, Rachelle Lyons joined on one of the days of field work. And town resident Leslie Dreier joined on the last day.

Spearheaded by Rachell Lyons, BCC set up an iNaturalist project for Bethlehem to gather species information throughout town. The project set up a date range from January 1, 2023 through March 31, 2025. Over 250 people recorded and reported on plant species, fungi, insects, wildlife. Data shown includes "research grade" identifications. "Observations become Research Grade when: the community agrees on species-level ID or lower, i.e. when more than 2/3 of identifiers agree on a taxon; or the community agrees on an ID between family and species and votes that the community taxon is as good as it can be" (iNaturalist, 2024).

Compiling Existing Data and Integrating into ArcGIS

Elise Lawson conducted GIS analyses. She gathered digital data from the Town of Bethlehem, GRANIT, Natural Resource Conservation Service (NRCS), and the US Fish and Wildlife Service and NH Fish and Game Department. These data include the following:

1. Aerial photography
2. Topographic maps
3. Hydrology (rivers, streams, lakes and ponds)
4. Roads and trails
5. Conservation lands
6. National Wetlands Inventory
7. Soil information (NRCS – Natural Resources Conservation Service)
8. Aquifers and subwatersheds
9. Bedrock geology
10. Federal Emergency Management Agency (flood area maps)
11. Maps created during the Wildlife Action Plans completed by the NH Fish and Game Department

Existing available maps were then integrated using ArcGIS Pro software. Using the USDA recent aerial photography, topographic maps, and soils maps, Elise digitized features, queried data, and overlaid them onto a base map. These include wetlands, farmland soils, forestry soil groups, steep slopes, permanent wildlife openings, dense softwood stands, subwatersheds and bedrock geology. Potentially significant wildlife habitat areas were noted.

Wetlands were reviewed and analyzed using the most recent aerial photos, National Wetland Inventory (NWI), Natural Resource Conservation Service (NRCS) soils maps (displaying hydric soil map units), and field work to confirm wetland locations where visited. New Hampshire state laws require that three parameters be met for classification as a jurisdictional wetland: the presence of hydric soil (very poorly and poorly drained soils); sufficient hydrology; and hydrophytic[1] vegetation. When soil maps alone are used, they could potentially overestimate the number of wetlands throughout the town. This is particularly true given that up to 35% of a soil classification can be inclusions (for example, upland areas within NRCS hydric soil units or wetland areas within NRCS upland units). On the other hand, examining the NWI data alone under-represents the number of wetlands, due to the U.S. Fish and Wildlife Service's method of using aerial photography to identify wetlands. Open water, emergent, and scrub-shrub wetlands can readily be identified using aerial photography alone, but forested wetlands are often missed. Official wetland delineations require extensive fieldwork beyond the scope of this project. Despite differences and potential errors, data provided from these sources are important tools and can be built-upon in future studies.

Farmland Soils – Prime farmland, farmland of statewide importance, and farmland of local importance throughout Bethlehem were determined using the NRCS soils map data. Data were displayed in ArcMap and queried so only those soils classified as important farmland were displayed in the Town.

Land utilized for pasture, forestry, recreation, or land uses other than urban, built or disturbed areas can still qualify as prime farmland, farmland of statewide importance, or farmland of local importance. The rationale for this approach is that land not already committed to irreversible (urban) uses is still available for cropping. Three categories of important farmlands have been described by the NRCS and they are:

1. Prime farmland soils, as defined by the U.S. Department of Agriculture, is the land that is best suited for food, feed, forage, fiber, and oilseed crops. It may be cultivated land, pasture, woodland, or other land, but it is not urban and built-up land or water areas. The soil qualities, growing season, and moisture supply are those needed for a well-managed soil to produce a sustained yield of crops in an economic manner. These soils are generally flat and relatively free of stones.
2. Farmland soils of statewide importance are lands, in addition to prime farmland, that are of statewide importance to produce food, fiber, forage and oilseed crops. Criteria used to define this agricultural land were determined by state and local

[1] Hydrophytic vegetation are plants that grow in water or on a substrate that is at least partially deficient in oxygen as a result of excess water; plants typically found in and adapted to wet habitats.

agencies in New Hampshire. The soils on the list are important to agriculture in New Hampshire, yet they exhibit some properties that exclude them from prime farmland. These soils can be farmed satisfactorily by greater inputs of fertilizer, soil amendments and erosion control practices than those necessary for prime agricultural farmland. They produce fair to good crop yields when managed properly.

3. Farmland of local importance is land, in addition to prime and statewide farmland, that is of local importance to produce food, fiber, forage and oilseed crops. It can include land that confines livestock. The criteria used to define this farmland were determined by local agencies in Grafton County.

Permanent openings (fields - areas dominated by grasses, forbs, brambles) were digitized from recent aerial photographs. The regions digitized include only those openings managed as permanent opening habitat. They do not include clear-cuts where the intent is for timber harvesting and regeneration for future logging. **Dense softwood** (or conifer excluding white and red pine) cover areas were also digitized from the aerial photographs. These areas are considered significant wildlife habitat and could be used by deer and moose for wintering areas.

Steep slopes were determined using the NRCS soils maps. Data was displayed in ArcGIS and queried so only those soils map units with 20% slope and greater were displayed. Similarly, **Forestry soils** were determined using the NRCS soils maps. Soils are grouped and ranked based on their capacity to grow valuable timber for harvest.

Maps are found at the end of this report with the features described above. All information gathered, compiled, and mapped for this report was delivered to the Bethlehem Conservation Commission in digital format. It is the property of the Town of Bethlehem, New Hampshire.

Public Presentation and Discussion

At the completion of this NRI, a public information meeting will be held to explain the results from this study. The goal of this meeting is to increase public awareness of the importance of the natural resource inventory including water resources, riparian habitat, forested land, and associated wildlife habitat. In addition, work from this project will be displayed on Bethlehem's town website for public access.

RESULTS

Forested Lands (Maps #1 and #2 at the end of report)

Bethlehem is nearly 90% forested, including all areas in the White Mountain National Forest. There are several different forest types, typical for this part of northern New Hampshire and the White Mountains including:

- Northern Hardwood-conifer – 26,933.16 ac = 46.3%
- High elevation spruce-fir – 12,038.11 ac = 20.7%
- Hemlock - Hardwood Pine – 7,537.2 ac = 13.0%
    - Dense softwood – 6,903.19 ac = 11.9% (some of this part of high elevation spruce-fir areas)
- Lowland Spruce-fir – 5,211.04 = 9.0%
- Floodplain Forest – 95.8 ac = 0.2 %

The list of forest types, acreages and percentages above are extrapolated from the NH Fish and Game's Wildlife Action Plan mapping of habitat types. Dense softwood stands were digitized from the most recent aerial photographs. The age of forests throughout Bethlehem is diverse, ranging from young regenerating forest to mature hardwood and softwood forests.

Carbon sequestration – Forests have always provided tremendous personal and public benefits, including clean water, wildlife habitat, recreational opportunities, and forest products. Moreover, forests are an essential natural solution for climate change. Carbon sequestration is the process where atmospheric carbon dioxide is taken up by trees, saplings, and other plants through photosynthesis and stored as carbon in biomass (trunks, branches, foliage, and roots) and soils. The sink of carbon sequestration in forests and wood products helps to offset sources of carbon dioxide put into the atmosphere through deforestation, forest fires, and fossil fuel emissions. Sustainable forestry practices can increase the ability of forests to sequester atmospheric carbon while maintaining or enhancing soil stabilization and water quality.

Fungi within these forests also play a vital role in carbon sequestration as well through their interactions with plants, their own metabolism, and contributions to soil structure (Clemmensen, et al, 2013).

1. Mycorrhizal Relationships with Plants: Many fungi, particularly mycorrhizal fungi, form symbiotic relationships with plant roots. They help plants absorb nutrients like phosphorus and nitrogen, and in return, plants provide fungi with carbon-rich sugars produced through photosynthesis. This process effectively captures atmospheric CO_2 in plant biomass, and some of this carbon is transferred to the fungi and stored in soil.
2. Soil Carbon Stabilization: Fungi contribute to soil structure, helping to form aggregates that trap organic matter. The carbon in these aggregates can become stable and remain

in the soil for extended periods, effectively sequestering carbon. Fungal hyphae (thread-like structures) are crucial in binding soil particles together, protecting organic matter from decomposition.

3. Decomposition and Humus Formation: Saprotrophic fungi (decomposers) break down organic material like fallen leaves, dead wood, and animal remains. While some CO_2 is released during decomposition, fungi also transform organic material into stable compounds like humus. Humus holds carbon in the soil for long periods and helps create a carbon reservoir.
4. Mycelial Biomass: Fungal networks themselves store carbon. Mycelium (the mass of fungal hyphae) is carbon-rich, and as fungi grow and die, this biomass can become a significant part of soil organic carbon.
5. Lignin Decomposition: Fungi, especially white-rot fungi, are among the few organisms capable of breaking down lignin, a tough component of wood. In decomposing lignin, they release some carbon, but they also help incorporate lignin breakdown products into the soil, where it can become stable and part of long-term soil carbon stores.

Bethlehem contains a variety of forest types. This hardwood stand in Bretzfelder Park is near a beaver-impacted wetland and associated softwood stand. Photo taken on July 28, 2024.

Forests are an essential and natural solution for climate change.

Dense Softwood – 6,903.17 acres (11.9%) of Bethlehem's forested land contains dense softwood stands, primarily eastern hemlock, balsam fir, and/or spruce. They do not include stands of white or red pine. These softwood stands range in size from just over 1 acre to over

859 acres. Some of the larger softwood stands are found in the White Mountain National Forest (WMNF). Many dense softwood stands are found along rivers, streams, ponds, and wetland complexes offering proximity to good cover for wildlife and a diversity of habitat types. Bethlehem is fortunate to have over 10% dense softwood cover throughout town. During the 2006 NRI, we noted 7.9% of the town contained dense softwood cover. Differences here are likely due to improved aerial photographs for digitizing for the current NRI.

A corridor of dense softwood forest can be seen along Indian Brook and associated wetland complex at the Rocks Estate. These softwood stands are used as travel corridors for many wildlife species. Photo taken June 13, 2024.

Dense softwood stands are an important habitat type to many wildlife species. They provide important cover and foraging habitat during harsh winter conditions by reducing snow accumulations and wind speeds. Therefore, animals such as red squirrels, snowshoe hare, ruffed grouse, white-tailed deer, and moose are often found utilizing them during the winter months. White-tailed deer are not well adapted for traveling in and dealing with deep snow conditions and require dense softwood stands to survive New Hampshire's harsher winters. When they congregate in these stands, they are referred to as deer yards or deer wintering areas. For the stand to be considered a deer yard two basic elements must be met: (1) A core area is identified by concentrations of dense softwoods, and (2) Mixed hardwood and softwoods adjacent to, or within the core area will provide accessible forage.

Dense softwood stands cover only about 3% of the land base in New Hampshire, so their identification and management are an important part of conserving the entire State's natural resources.

Standing in a dense softwood stand with balsam fir and red spruce. This stand is at the edge of a wetland and contains a network of wildlife trails. Photo taken June 13, 2024.

Mast Trees - Mast are the fruits produced by woody stemmed plants and can be either hard (seeds and nuts) or soft (fruits and berries). Wildlife species from nuthatches, chickadees, squirrels, and eastern chipmunks to white-tailed deer, black bears, turkeys, and wood ducks rely heavily on mast as a source of feed. Bethlehem has several species of trees that are considered important because of their mast production. These include red oak, beech, maple, hophornbeam, hemlock, black cherry, white ash, apple, and pine. Hard mast produced by red oak, beech, and some shrubs such as beaked hazelnut, is considered extremely important because it can persist for longer than soft mast and therefore is accessible to wildlife during times of the year when other food sources are limited. American beech trees face several diseases that can significantly impact their nut production, health and survival. The most common one today is Beech Bark disease which is a combination of infestation by an insect and fungus. Another emerging and concerning disease is Beech Leaf Disease caused by a nematode. It leads to dark, banded discoloration on leaves and reduces photosynthesis, which in turn weakens the leaves. It is more common in southern NH and MA but spreading northward. Beech canker is a third stressor to these important mast-producing trees and is caused by fungal cankers. Although this latter is not as fatal, it does weaken the trees, making them more vulnerable to other stresses and infections (UNH Extension, 2010).

Left: Mature acorn-producing red oak tree at the Rocks Estate. Trees such as this one are important fall food sources for many wildlife species.

Below: Young oak tree near the Ammonoosuc River.

Photos taken 6-13 and 8-23-24

Early Successional Habitat – Early successional habitat includes an area with grasses, forbs, shrubs, and young trees (aspen, white birch, and white pine are common in New Hampshire). It provides excellent food and cover for wildlife but needs some sort of disturbance to be maintained. Early successional habitats have been declining throughout the Northeast for decades, as have the wildlife species associated with them. For example, American woodcock have declined by 40% over the past 30 years, and New England cottontails occur in only 20% of their historic range. In Bethlehem, two examples of areas with early successional habitat are log landings and inactive gravel pits. In gravel pits especially, the topsoil has been removed so there is little organic matter. In these early successional habitats, the soil is sandy with very little topsoil. As a result, there were areas where birds had dusted themselves with the sand. Dust baths are part of a bird's preening and plumage maintenance. The dust is worked into the bird's feathers and absorbs excess oil to help keep the feathers from becoming greasy or matted. It also helps smother or minimize lice, feather mites and other parasites.

This type of habitat is also important for turtles. The proximity of a sandy area to open water gives turtle hatchlings a better chance of making it to water. Examples of early successional habitats in Bethlehem include abandoned/reclaimed gravel pits, log landings from

timber harvesting, transmission lines, old railway beds, and, in rare cases, in areas that experienced wildfires or prescribed burns.

Permanent Wildlife Openings[2] (Map #1 at the end of report)

Permanent wildlife openings are dominated by grasses, forbs, wildflowers, brambles and fruiting shrubs. These include hay fields, pastureland, cropland, brush-hogged fields, and mechanically maintained transmission lines. It is estimated that they provide required habitat for about 22% of New England's wildlife species and are seasonally important for nearly 70% of species. White-tailed deer, black bear, rodents, such as deer mice, meadow voles, shrews, and woodchucks, commonly feed on the vegetation present in these habitats, and carnivores from weasels and hawks to coyotes in turn feed on these species. Permanent wildlife openings are heavily used by bird species as feeding and nesting sites, specifically by the eastern bluebird, Bobolink, and northern harrier, which are species of concern in New Hampshire. They also create important edge habitats. Wherever an open area meets the forest, the area of transition will attract the largest diversity of species, both plant and animal. Generally, there will be species adapted to permanent wildlife openings, those adapted to forested habitat, and those that specialize in transition zone areas and will frequent these edge habitats. For example, many bird species that feed in openings are known to nest within the edge habitat because there is typically more structural diversity and cover.

Currently, Bethlehem has 1,347.79 acres maintained as permanent wildlife openings which make up 2.32% of the town's area. The New Hampshire state average is 10% permanent wildlife openings. Elise digitized a total of 228 different openings from aerial photos during this project ranging in size from 0.2 acres to approximately over 66.5 acres. Of note, in Bethlehem's 2006 NRI, we documented 1,369 acres of permanent openings, noting a small decrease over the past 18 years. These openings are scattered throughout town, but primarily in areas of town outside of the WMNF. They generally are found along roads and river floodplains - often associated with a private residence or working farms. Varying sizes of permanent openings are preferred by different species. For example, northern harriers – a predatory bird or raptor - prefer larger openings while feeding, yet snowshoe hare are more likely to feed in smaller openings where cover is more readily available. Lawns near homes and seeded woods roads were not mapped as they were so small or close to human structures. Even small openings, especially those in more isolated parts of the town, are still important habitat and help maintain Bethlehem's plant and wildlife diversity.

[2] Permanent wildlife openings are those that are and will continue to be maintained as herbaceous openings (grass and legumes). They are valuable for many wildlife species in a landscape dominated by forested areas.

As the percentage of permanent openings in New Hampshire has decreased significantly over the past 50+ years, the state is encouraging landowners to create or maintain permanent openings as important wildlife habitat.

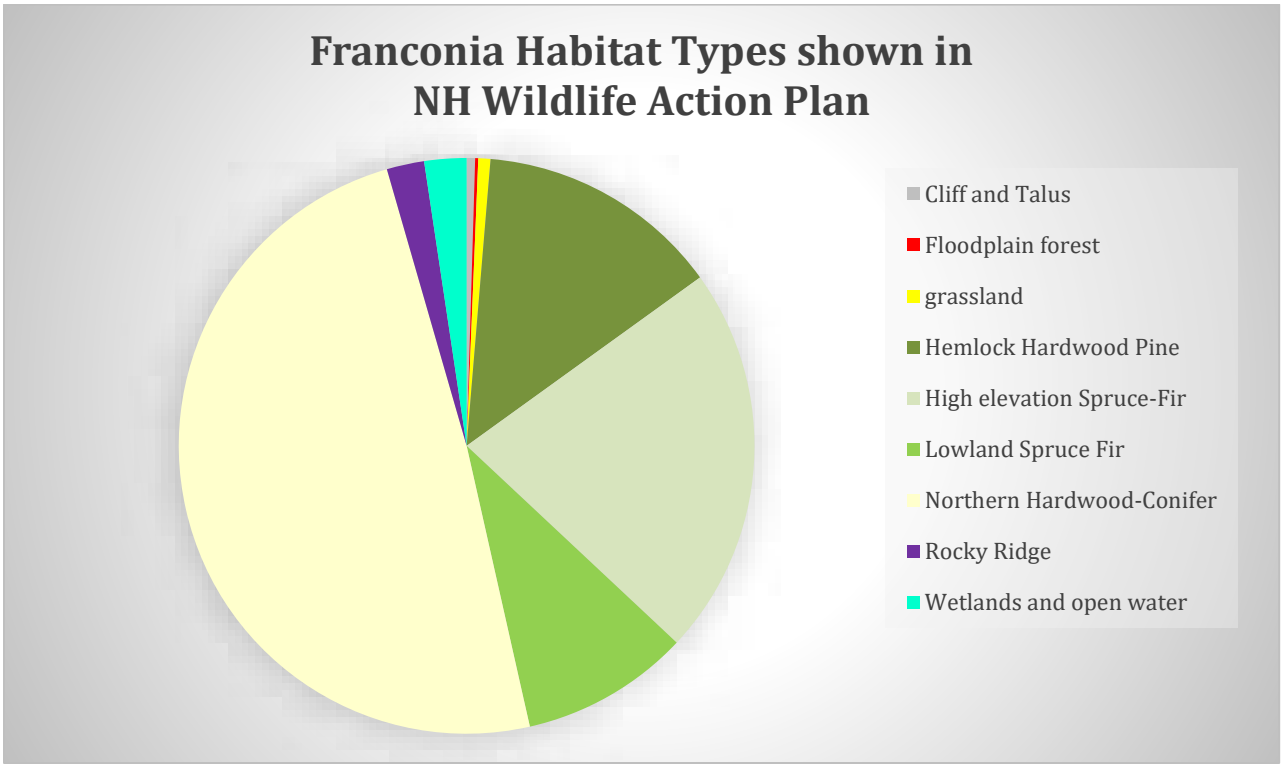
Open field along Prospect Street. The combination of fields, forested areas and proximity to wetlands and Barrett Brook, makes this area excellent wildlife habitat. Photo taken on 7-29-2024 facing southeast.

Permanent openings are excellent not only for wildlife, but also for scenic and expansive views. This photo was taken looking across Mid Acre Farm towards The Presidential Range of the White Mountains. Photo taken 7-29-2024.

Permanent Wildlife Openings

Retain, and possibly increase, permanent wildlife openings to increase the diversity of wildlife and plant community types throughout Bethlehem.

When possible, it is a good practice to remove non-functioning fencing, such as barbed wire and woven sheep fence.



Conservation Land (Maps #3 and #9 at the end of report)

Over 34,377 acres equaling 59.1% of Bethlehem is land conserved by conservation easements, State-owned land, town-owned properties, and the White Mountain National Forest. Land conservation has been a successful goal for Bethlehem, with the town proactively conserving special areas that contribute to the protection of wildlife and natural resources while also providing recreational opportunities. Some of the larger conserved or otherwise undeveloped areas are listed below.

1. 30,360.22 acres (52.2% of Town) are part of the White Mountain National Forest
2. 3,719.12 acres (6.4% of Town) make up Conservation Easements
3. 147.28 acres are owned by the Town of Bethlehem including a town forest.
4. 120.59 acres include State-owned lands including Strawberry Hill and Cushman State Forests

View at the Rocks Estate looking across the property towards Littleton and Whitefield. The Rocks Estate is owned by the Society for the Protection of NH Forests and contains over 1,300 acres. Photo taken 6-13-2024.

Beautiful open hardwood stand in the middle of Bethlehem's Town Forest. This area contains stonewalls and farmland soils, indicative of past farming activities. Photo taken 7-29-2024.

Wetland along a rail trail and snow machine trail in the White Mountain National Forest looking towards the White Mountains. Photo taken 7-29-2024.

There are several ways to conserve land. Many lands are owned by federal, state, and local governments (national forests, state parks, and state/town forests, for example). A conservation easement on private land is another means to protect property. It creates a legally enforceable land preservation agreement between a landowner and a municipality or a qualified land protection organization or trust. It restricts real estate development, commercial and industrial uses, and certain other activities on a property to a mutually agreed upon level. The decision to place a conservation easement on a property is strictly a voluntary one where the easement is sold or donated. The restrictions, once set in place, are binding for all future landowners. The restrictions are spelled out in a legal document that is recorded in the local land records, and the easement becomes a part of the chain of title for the property. The landowner who gives up these development rights continues to privately own and manage the land and may receive significant state and federal tax advantages with their land for future generations. The easement holder has a responsibility to monitor future uses of the land to ensure compliance with the terms of the easement and to enforce the terms if a violation occurs.

Three areas were highlighted for priority conservation efforts in the futures. They are described in the Discussion – Future Opportunities section, and also shown on Map #8 at the end of this report. The Conservation Commission has a Conservation Fund which is funded from a portion of the Current Use Tax.

Trail Easements – In addition to land conservation, another consideration are trail easements. They are legally binding agreements that allow public or private trails to cross privately owned land. These easements are generally permanent, securing the right for trail access over the long term. Easements on trails benefit conservation efforts, outdoor recreation, and community connectivity. Similar to land conservation easements, the landowners maintain ownership and control over their property under an easement, but they agree to allow access for trail use. They are negotiated with trail associations, land trusts, municipalities or conservation organizations. Trail easements serve as a tool for expanding and protecting recreational opportunities while balancing the rights of private landowners.

Rivers, Streams, Lakes, and Ponds (Maps #3 and #4 at end of report)

There are 230.23 miles of perennial streams and rivers that flow through Bethlehem. Of these, 79.4 miles include 25 named rivers and streams and 150.8 miles of unnamed streams, many of which are important headwaters streams. The largest River in Bethlehem is the Ammonoosuc River. It begins in Sargent's Purchase on the west side of Mount Washington. With the addition of several headwaters streams, the Ammonoosuc River is a third order stream before leaving Sargent's Purchase. It becomes a 4th order river in Crawfords Purchase with the addition of Abenaki, Mount Pleasant, Halfway and Dartmouth Brooks. It then flows through Carroll and into Bethlehem along Route 302. It flows through Bethlehem for 12.24 miles before entering Littleton, Lisbon, Landaff, Bath, eventually entering the Connecticut River in Woodsville. Total length of the Ammonoosuc River from near the top of Mt. Washington to Woodsville is approximately 60 miles. It is protected by the Shoreland Protection Act and in 2008 was officially classified as a Designated River by the State of NH and enrolled into the Rivers Management and Protection Program (RMPP). The Ammonoosuc River Local Advisory Committee represents seven river corridor towns: Haverhill, Bath, Landaff, Lisbon, Littleton, Bethlehem, and Carroll. This committee helps protect the Ammonoosuc River ecologically and culturally.

The other 4th order stream in Bethlehem is the Gale River. It forms with the confluence of the North Branch Gale River and South Branch Gale River near by Route 3 and Trudeau Road. It is further fed by Beaver Brook and flows for a total of 3.24 miles before entering Franconia.

The Zealand River is the second longest River in Bethlehem at 6.22 miles. It begins as a headwaters stream and flows north across the western part of town. It is fed by Whitewall Brook, Mount Field Brook, Havie Brook, Mount Tom Brook, Hale Brook, and several unnamed headwaters streams before leaving Bethlehem and entering the Ammonoosuc River in Carroll. The Zealand River Valley is a popular hiking and back country skiing area in the White Mountains, containing flatter topography and several unique wetlands which are fed by the Zealand River.

The third longest stream is Little River, which begins as a headwater stream in Franconia on the north slope of South Twin Mountain. It flows northwest through Bethlehem being fed by several unnamed perennial streams, before entering Carroll and the Ammonoosuc River just east of the Bethlehem/Carroll Townline along Route 302.

Ammonoosuc River flowing under Route 302 near Trudeau Road. Photo taken 7-29-2024.

Barrett Brook starts on the north side of Mt. Agassiz, flows through Bethlehem's Town Forest, Bretzfelder Park, and directly into the Ammonoosuc River in town (just over 4 miles total length). Photo taken on 7-29-2024.

The Zealand River in Bethlehem. It is a well buffered, cold-water stream. Photo taken for the 2006 NRI.

Many perennial streams in Bethlehem not only have a variety of upland forest types, but they also have several wetland types associated with them. Beaver activities along streams are dynamic and ongoing. Beavers enhance the diversity of wildlife habitat and make these rivers and streams some of the most diverse river/wetland complex systems throughout town. There are many unnamed streams located throughout Bethlehem with high value habitat and excellent vegetative buffers. These areas provide excellent wildlife habitat and connectivity to forests and wetlands.

Indian Brook flows through this beaver-impacted wetland south into Franconia and is a tributary to the Gale River. There were no active beaver ponds at the time of this photo. Photo 6-13-2024

Table1: List of Named Rivers and Streams in Bethlehem

River/Stream	Length in Bethlehem (miles)	Direction of flow	Watershed Area in Bethlehem (HUC 12)	Stream Order 4th order River System
Ammonoosuc River	12.24	West and Northwest	Middle Ammonoosuc and Lower Ammonoosuc River	4th Ammonoosuc
Gale River	4.6	West	Meadow Brook-Middle Tributaries	4th Gale
Baker Brook	4.28	Northwest	Lower Ammonoosuc River	1st, 2nd, 3rd Ammonoosuc
Barrett Brook	4.02	Northwest	Lower Ammonoosuc River	1st, 2nd, 3rd Ammonoosuc
Beaver Brook	3.24	West	North Branch Gale River	1st, 2nd, 3rd Gale
Black Brook	5.08	North	Lower Ammonoosuc River	1st and 2nd Ammonoosuc
Bog Brook	0.78	North	Forest Lake-Bog Brook	1st Johns River
Crawford Brook	1.49	East	Upper Ammonoosuc River	1st Ammonoosuc
Fowler Brook	0.09	South	Lower Ammonoosuc River	2nd Ammonoosuc
Hale Brook	1.29	North	Middle Ammonoosuc River	1st, 2nd Ammonoosuc
Havie Brook	1.59	Northeast	Middle Ammonoosuc River	1st Ammonoosuc
Haystack Brook	3.07	North	Middle Ammonoosuc River	1st Ammonoosuc
Indian Brook	3.07	Southwest	Lower Tributaries	1st, 2nd Gale
Little River	5.02	North	Middle Ammonoosuc River	2nd, 3rd Ammonoosuc

River/Stream	Length in Bethlehem (miles)	Direction of flow	Watershed Area in Bethlehem (HUC 12)	Stream Order 4th order River System
Mount Field Brook	1.77	Northwest	Middle Ammonoosuc River	1st, 2nd
Mount Tom Brook	1.96	Northwest	Middle Ammonoosuc River	1st Ammonoosuc
North Branch Gale River	3.65	Northwest	North Branch Gale River	2nd, 3rd Gale
North Fork East Branch	1.58	South	North Fork	1st, 2nd Pemigewasset
Scarface Brook	0.71	Northeast	North Branch Gale River	1st Gale
South Branch Gale	1.70	North	North Branch Gale River	2nd, 3rd Gale
Thompson Brook	0.03	Northwest	North Branch Gale River	2nd Gale
Tuttle Brook	1.98	Northwest	Middle Ammonoosuc River	1st, 2nd Ammonoosuc
Whitewall Brook	1.83	Northeast and Southeast	North Fork	1st Pemigewasset
Willey Brook	0.12	East	Headwaters Saco River	1st Saco
Wiseman Brook	2.35	South	Meadow Brook-Middle Tributaries	1st, 2nd Gale

Ammonoosuc and Gale Rivers

The Ammonoosuc and Gale Rivers are the largest in Bethlehem. Both rivers are classified as 4th Order Streams, and thus afforded more protection by the State of NH through the NHDES Shoreland Protection Act. These two are particularly vulnerable to runoff, erosion, and pollution, as they flow right through residential and commercial areas in Bethlehem, Franconia, and Littleton. Wherever possible:

- Minimize impervious surfaces adjacent to the river
- Maintain and enhance native vegetative buffers particularly wetlands
- Continue to test the water quality throughout the year

Lakes/Ponds – Due to its mountainous and hilly topography, Bethlehem has relatively fewer areas of open water compared to many other municipalities in New Hampshire. There are 228.75 acres of lakes, ponds and open water making up 0.4% of the town's area. Miller Pond is the largest body of open water at 17.92 acres. It is a shallow pond right beside Route 302. It has excellent and diverse wildlife habitat, and you can often see great blue herons, painted turtles and beaver.

Ethan Pond is the next largest body of open water at 5.27 acres. It is located in the WMNF in the southeast corner of Bethlehem. It is part of an unnamed headwaters stream which eventually feeds the Pemigewasset River. The size of this pond is likely variable depending on beaver activities. Zealand Pond is also in the WMNF. The GIS maps indicate that it is 2.09 acres, but recent aerial photos show that beaver activities have made it much larger. Zealand Pond is fed by Whitewall Brook and Zealand River. A popular hiking trails runs right beside the pond offering excellent views of the pond and associated wetlands.

Miller Pond viewed from Route 302 in Bethlehem. The pond is very shallow and contains abundant aquatic vegetation. Photo taken 7-29-2024

Unnamed pond viewed from Wing Road. It is part of a beaver-impacted stream which flows into the Ammonoosuc River. Photo taken 6-13-2024.

Table 2: Description of Named Ponds in Bethlehem, New Hampshire

Lake/Pond Name	Acres	Location
Miller Pond	17.92	Western Bethlehem, along Route 302 just east of Interstate 93.
Ethan Pond	5.27	Southeastern Bethlehem in the WMNF. Part of a headwaters stream which eventually feeds into the Pemigewasset River.
Zealand Pond	2.09	Southeastern Bethlehem in the WMNF. Fed by Whitewall Brook, just below Zealand Falls. It can be easily viewed while hiking along Zealand Trail.
Bethlehem Reservoir	0.38	In the WMNF and part of the North Branch of the Gale River. It is a water source for the Town of Bethlehem.
Twin Mountain Reservoir	0.22	In the WMNF north-central region of Bethlehem. It is part of the Little River and a water source for Bethlehem.

There are several smaller unnamed ponds found in Bethlehem, most of which are dependent on beaver activities. These ponds can be any size from no open water to a ponded area of several acres. The size generally varies year to year.

All rivers and water bodies offer wildlife and recreational value for Bethlehem and the entire region. Swimming, kayaking, canoeing, birdwatching, hiking, skiing, mountain biking, fishing and hunting are all common activities in Bethlehem. Tourism accounts for a large portion of income for New Hampshire and lakes and rivers are significant contributors.

Sub-Watersheds (Map #5 at end of report)

The ability to view the landscape from a watershed or sub-watershed perspective helps to understand drainages, flows, and associated habitat throughout the town. Sub-watersheds do not stop at municipal boundaries. All things downstream are affected by land management upstream, particularly in the headwaters. The State of NH breaks down the watershed to the HUC 12 level, and most towns and cities contain more than one subwatershed determined by topography and ridgelines.

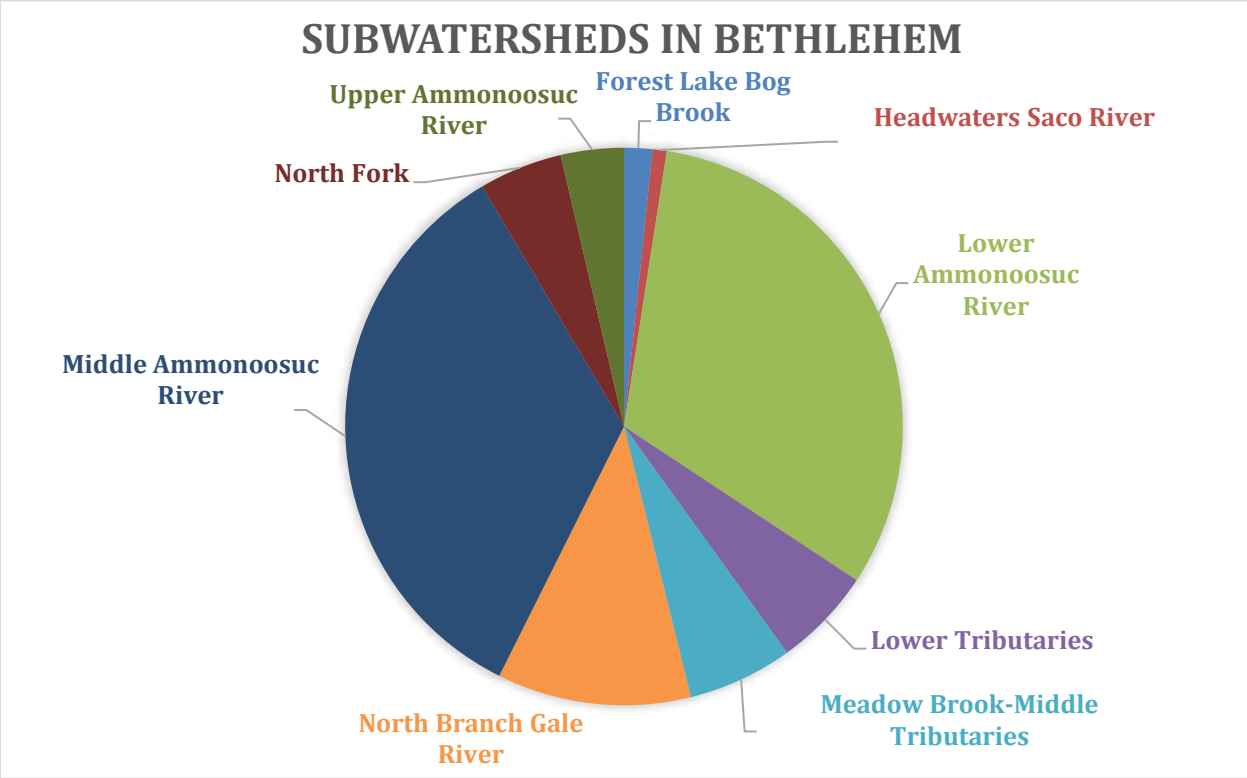
Bethlehem contains portions of 9 sub-watersheds when broken down to the level 12 hydrologic unit code (HUC) listings. The largest subwatershed in Bethlehem is Middle Ammonoosuc River Subwatershed which covers a large area in eastern Bethlehem within the WMNF. It is 19,864.32 acres, and includes several headwaters streams which feed the Ammonoosuc River. The Lower Ammonoosuc River subwatershed is the next largest in Bethlehem covering 18,530.27 acres and covers a large area in the western and northwestern part of town. This subwatershed includes the Ammonoosuc River along with Barrett, Baker, and Black Brooks. The North Branch Gale is the third largest subwatershed at 6,544.21 acres. The North Branch Gale encompasses south and central area, and it flows into the Gale River.

All 9 of the subwatersheds in Bethlehem are part of three larger watershed areas called the Upper Connecticut River and the Saco River, and the Merrimack River Watersheds. A list of the subwatersheds in Bethlehem are shown and described in the following chart and table.

Maintaining good water quality in Bethlehem's rivers, streams, lakes and ponds is important for ecological protection and recreational opportunities for residents and visitors.

Table 3: List of Sub-watersheds in Bethlehem, NH

HUC 12 Name - Subwatershed	Acres in Bethlehem Of HUC 12	General Location Description	HUC 6 Name – Larger Watershed Area	Acres in Bethlehem Of HUC 6
Middle Ammonoosuc River	19,864.32	East part of Bethlehem	Upper Connecticut River	14,969.8
Lower Ammonoosuc River	18,530.27	Western part of Bethlehem		
North Branch Gale River	6,544.21	South central Bethlehem		
Meadow Brook – Middle Tributaries	3,540.60	East of South-central Bethlehem		
Lower Tributaries	3,356.73	Southwestern corner of Bethlehem		
Upper Ammonoosuc River	2,125.47	Northeast corner of Bethlehem		
Forest Lake / Bog Brook	955.08	North part of Bethlehem near the Carroll and Whitefield Townline		
North Fork	2,815.61	Southeast area of Bethlehem	Merrimack River	2,815.61
Headwaters Saco River	473.59	Southeast corner of Bethlehem	Saco River	473.59



Riparian Zones and Floodplains

A riparian zone or riparian area is the interface between land and a stream or river. Riparian zones are important habitats because of their role in soil conservation, their biodiversity, and the influence they have on aquatic ecosystems. Riparian habitats occur in many forms including grassland, woodland, wetland, floodplains, or a combination of features. They are important travel corridors for many wildlife species as well as valuable habitat for frogs, turtles, snakes, minks, otters, and birds. Riparian habitats moderate stream flow, stabilize riverbanks, and provide shade to stabilize soil and water temperatures. A floodplain is flat or nearly level land adjacent to a stream or river that experiences occasional, seasonal, or periodic flooding. Floodplains are a category of riparian zones and often support rich, diverse ecosystems. Bethlehem contains a diverse amount of riparian and floodplain areas.

The Federal Emergency Management Agency (FEMA) maps floodplain areas throughout the country. Bethlehem has 1,168.26 acres (2%) of flood-prone areas located primarily along the Ammonoosuc River. Other flood zones are found around the Gale River, Black Brook, Baker Brook (including Miller Pond), and Barrett Brook. Floodplains are very fertile agricultural areas, especially along larger rivers. Some of the floodplains along the Ammonoosuc River contain fertile areas for farming. There are also floodplain areas along the Gale River in Bethlehem as well as some of the smaller streams/ponds including Black Brook, Barrett Brook, Baker Brook and Miller Pond. Floods carry nutrient-rich sediment and distribute it across a wide area.

Although some portions of Bethlehem's riparian areas and floodplains have been impacted by development, most areas have not, and there are a few opportunities for maintenance of adjacent riparian habitat and creation of additional buffers.

The Ammonoosuc River is the largest river in Bethlehem. There are forested floodplain areas along most of the river as it flows through town. Photo taken on 8-23-2024 facing downstream.

Small floodplain, riparian area with a mixedwood forest along Barrett Brook in the Bethlehem Town Forest. Smaller floodplain, riparian areas shown here moderate stream flow, stabilize riverbanks, and provide shade/cover to keep water temperatures cooler. Riparian areas are especially valuable habitat for many wildlife species including frogs, turtles, snakes, minks, otters, and birds. Riparian areas also function as travel corridors for animals moving from one habitat to another. Photo taken on 7-23-2024.

Timber Harvest in Riparian Habitat

Logging forested riparian areas is generally not recommended due to proximity to the rivers and wetlands. If timber is harvested in these areas, it should occur during the winter months when the ground is completely frozen.

Floodplains and riparian areas are home to a diversity of wildlife. The rich soil creates excellent insect and amphibian breeding habitats, and these species in turn become prey for birds such as woodcock and barred owl, for mammals such as mink and raccoon, and for reptiles such as smooth green snake and wood turtle. These corridors allow wildlife to move from one habitat to another. Intact riparian areas are essential for creating and maintaining a healthy aquatic system. Overhanging vegetation such as shrubs and trees provide important shade to aquatic habitats allowing them to maintain cooler water temperatures and adequate amounts of dissolved oxygen. This is particularly important for trout and other salmonid species. The root systems of the riparian vegetation are also important for reducing the amount of erosion and subsequent sediment accumulation that the constant moving water and flooding situations can cause. Riparian habitats also slow and hold floodwaters reducing shoreline damage and can work as a filtration system removing nutrients and toxins from the water and assisting in maintenance of water quality. Riparian vegetation can also provide habitat structure to aquatic systems through dead or broken limbs and whole trees that fall into the water.

Wetlands and Hydric Soils (Maps #4 at end of report)

Wetlands are an essential habitat type for most plant and animal species in New Hampshire. Wetlands are extremely diverse depending on the hydrology, soils, topography, and climate of an area. In addition to the rivers, lakes, and ponds, there are four general types of Palustrine[3] wetlands: forested, scrub shrub, emergent (wet meadow), and open water, with additional subtypes within each of these categories. This diversity extends into each individual wetland where a variety of plant/wildlife species, soil textures, and water regimes co-exist. In addition, the edge habitats within and around wetlands are frequently used by many wildlife species. ***It is estimated that riparian areas and wetlands are used by over 90% of the region's wildlife species and provide preferred habitat for 50% of local species.*** For these reasons wetlands provide plentiful wildlife habitat, viewing and hunting opportunities.

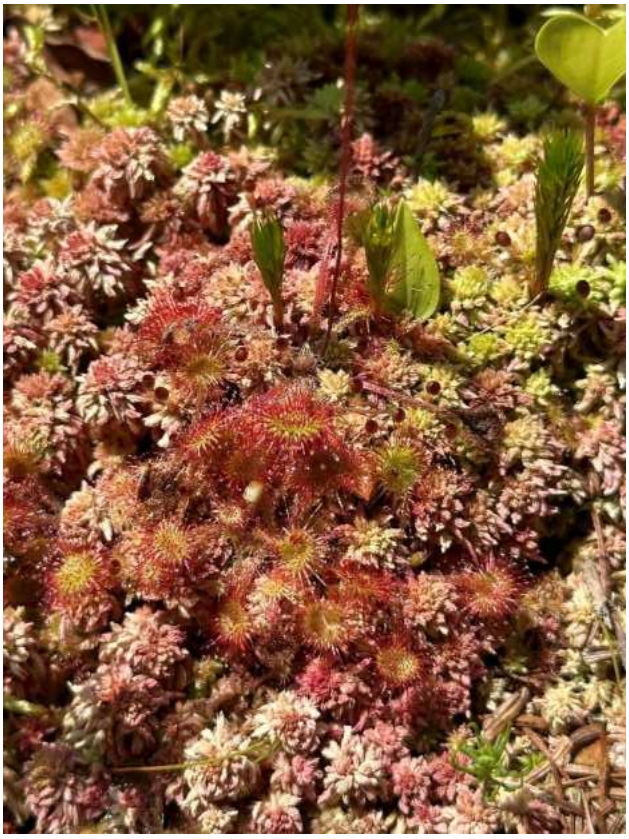
[3] Palustrine wetlands are a group of vegetated wetlands traditionally called marshes, swamps, bogs, fens. They also include the small, shallow, permanent or intermittent water bodies often called ponds.

This wetland complex can be viewed in Bretzfelder Memorial Park. The amount of water is heavily influenced by the presence of beaver. The wetland and area around it are conserved by SPNHF, and excellent wildlife habitat with a diversity of wetland and upland areas. Photo taken on 7-23-2024.

Wetland along Blaney Road. It is fed by an unnamed tributary to Baker Brook and is a scenic, diverse wetland. Photo taken on 8-13-2024.

The outlet to the pond shown in the previous photo has been enhanced by fresh beaver. With the proximity to Blaney Road, beaver activities often flood and damage town roads. At the time of the photo, there is evidence of an ongoing battle between the beaver and humans.

This remote wetland is fed by Black Brook, which flows under Cherry Valley Road, through this wetland, across the transmission line ROW, and directly into the Ammonoosuc River. The brook and wetland offer excellent habitat for many wildlife species including wood turtles. There is a diversity of wetland and upland habitat types. Photo taken on 8-13-2024.



Round-leaved sundew (*Drosera rotundifolia*) is a carnivorous plant often found in bogs, marshes and fens. Hair-like tendrils on each reddish leaf are tipped with glistening droplets that attract passing insects. But this 'dew' is very sticky, trapping the insect; the sundew's tendrils detect the presence of its stuck prey and curl inwards to engulf it. Eventually, the whole leaf wraps around the insect which is digested. The acidic habitats the round-leaved sundew lives in don't provide enough nutrients, so it has evolved this carnivorous way of life to supplement its diet. Photo taken 7-29-2024 in a wetland off of Trudeau Road.

Along with providing important plant, wildlife, and fish habitat, wetlands are also an important protector of water sources. Because they often contain hydrophytic vegetation (plants adapted to living in water and/or wet conditions) and poorly drained soils, wetlands store significant amounts of flood and/or run-off water, minimizing serious damage in times of high water. Wetlands are important contributors to groundwater recharge. This ability to retain water allows wetlands to act as filters. As moving water is slowed and stored in wetlands, suspended sediments and particles settle to the mucky substrate, giving plant roots a chance to absorb excess nutrients, toxins, pollutants, and contaminants. ***These functions make wetlands an important source for maintaining the health of aquatic systems.***

Wetland areas are dynamic and constantly changing. The general trend (without severe weather or other outside influences) is for wetlands to slowly fill in over time. The process begins with open water, and over time, submerged plants appear. Floating-leafed plants, such as water lilies, eventually follow. Then emergent plants such as reeds, sedges, and wetland grasses begin to flourish. Shrubs such as high bush cranberry (*Viburnum trilobum*), sweet gale (*Myrica gale*), mountain holly (*Ilex mucronate*), and bog rosemary (*Andromeda glaucophylla*) begin to appear and heaths such as leatherleaf (*Chamaedaphne calyculata*) and labrador tea (*Ledum groenlandicum*) surface among the shrubs. Trees including red maple (*Acer rubrum*),

Wetland Protection Recommendations

- Continue to prioritize good water quality, working to conserve and maintain all types of wetlands throughout the town. Emphasis should be placed on wetlands outside of conserved lands that are important linkages for wildlife.
- Consider additional protective buffers to all wetlands in town as well as ability to enforce impingements on these important areas.

gray birch (*Betula populifolia*), and larch (*Larix laricina*) subsequently emerge. This natural successional process is often referred to as lakefill.

On the other hand, there are several environmental and human-induced reasons for wetlands to increase in size. Some examples of these include:

- Human development, including damming or excavation such as the mining of gravel and sand could increase wetland sizes and often create new wetlands.
- Severe weather changes – an increase in rain will increase the wetland area, whereas a drought may diminish the area.
- The cyclic movements of beavers as hardwood saplings regenerate in early succession. In Bethlehem there is fresh sign of beaver activities in most of the wetland complexes throughout the town.
- Human activities such as logging and landscape alteration can dredge out wetland areas or increase the amount of runoff into wetlands.

Bethlehem contains 2,183.28 acres of wetlands (3.8% of town). They range in size from less than an acre to over 30 acres, and contain a variety of wetland habitats including forested, scrub shrub, emergent, riverine, and open water wetlands. Most wetlands mapped in Bethlehem have been obtained from the U.S. Fish and Wildlife Service's National Wetland Inventory. Based on field work and examining recent aerial photographs, Elise digitized an additional 13.36 acres of wetland areas for this study. There are relatively fewer wetlands in Bethlehem because of the hilly and mountainous topography. However, each wetland serves an important role for wildlife and maintaining good water quality.

Of the hydric soils mapped throughout Bethlehem, 2,521.91 acres are classified as poorly drained, and 1,080.21 acres are very poorly drained – for a total of 3,602.12 (12.9%) hydric soils throughout Bethlehem. Hydric soil data excludes all White Mountain National Forest land owned by the US Forest Service. The USDA Natural Resources Conservation Service (NRCS) does not map soils within the White Mountain National Forest.

Poorly drained soils are defined as soils where water is removed from the soil so slowly that the soil is saturated periodically during the growing season or remains wet for long periods. With very poorly drained soils, water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season. Hydric soils are scattered throughout the Town with some of the larger areas listed below. As true with NWI data, there are fewer hydric soils in the hilly or mountainous parts of town (particularly the WMNF). On the other hand, in flatter sections near rivers, streams, and open water, there are larger areas of very poorly drained soil. Wetlands are evenly scattered primarily throughout the western half of Bethlehem outside of the WMNF. The river/stream valleys are wider and flatter topography compared to the headwater's streams coming out of the White Mountains. They allow for a diversity of wetlands associated and directly connected to them.

Pickerel Frog found in a wet meadow in Bethlehem. They are common in New Hampshire and found in several types of wetlands, often preferring dense vegetation adjacent to aquatic environments for cover.

Photo taken 6-13-2024.

This wetland is on the Bethlehem Town Forest just north of the former landfill. Soils here are classified as Peacham and Ossipee Soils. The Peacham/Ossipee series consists of very deep, very poorly drained soils that formed in organic material over loamy lodgment till in glaciated uplands and lowlands. They are shallow to a dense substratum and very deep to bedrock. Photo taken on 7-29-2024.

The wetland complex along Black Brook has Greenwood Mucky Peat soil type. The Greenwood series consists of very deep, very poorly drained soils formed in organic deposits more than 51 inches thick on outwash plains, till floored lake plains, or lake plains. Photo taken on 8-13-2024.

Vernal Pools – Over the last several years, 18 vernal pools were documented in Bethlehem. Undoubtedly there are many more throughout town. ***We recommend continuing to build upon this database as new vernal pools are discovered in town***. Vernal pools are unique, often isolated and important wetland types. Vernal pools provide essential breeding habitat for certain amphibians and invertebrates such as wood frogs (*Rana sylvatica*), spring peepers (*Pseudacris crucifer*), yellow spotted salamanders (*Ambystoma maculatum*), and fairy shrimp (*Branchinecta lynchi*). These creatures depend on vernal pools as breeding sites because they are only temporary water bodies preventing fish and other aquatic predators from taking up residency. Reptiles such as painted turtles (*Chrysemys picta*) and wood turtles (*Glyptemys inculpta*) also rely on vernal pools as important feeding areas in early spring. Vernal pools fill annually from precipitation, runoff, and rising groundwater in the fall and spring. By mid-summer, however, these wetlands are typically dry, making them a dynamic system inhabitable to many species except for specifically adapted plant and wildlife species. For this reason, many unique, rare, threatened, and endangered species are linked to this wetland type. The State of New Hampshire (Fish and Game Department and Wetlands Bureau) recognizes their value as important habitat and gives them special attention. Refer to Map #4 –*Water Resources* - at the end of the report for locations of known vernal pools throughout Bethlehem. A description of vernal pools documented during this study is shown in the table below.

Vernal pool created by ruts and soil compaction along a private forested road. It is part of a forested wetland not too far from where Black Brook crosses the transmission lines. Photo taken 8-13-2024.

Vernal pool is on the way up to the top of Mt. Agassiz on a flat shelf. The pool was much smaller at the time of this photo (8-13-2024), but well buffered.

Vernal Pool Number	Location/Description	Probable or Confirmed	Date
VP01	Pine Knob Conservation Area	Confirmed	2006
VP02	Pine Knob Conservation Area	Confirmed	2006
VP03	Pine Knob Conservation area	Confirmed	2006
VP04	Off Blaney Road – other side of road from the pond	Confirmed	2006
VP05	Woods road ponded on private property	Probable	8-13-2024
VP06	Part of Black Brook wetland complex	Probable	11-2015
VP07	Bretzfelder park – adjacent to the Pond	Confirmed	2006/2024
VP08	Bethlehem Town Forest	Confirmed	2006/2024
VP09	Adjacent to snow machine trail on private property	Confirmed	2006/2013
VP10	Pond on private road	Confirmed	2006/2024
VP11	Pond on former White Mountain School property with VP species	Confirmed	2006/2013
VP11	Seven Springs Forest Conservation Land	Confirmed	2006/2013
VP12	Former White Mountain School Conservation Easement	Confirmed	2006
VP13	The Rocks Estate near Indian Brook and wetland	Confirmed	2006/2024
VP14	Johnson Clark Nature Preserve	Confirmed	2006
VP15	Flat shelf on the side of Mt. Agassiz	Probable	2006/2024

Vernal Pool Number	Location/Description	Probable or Confirmed	Date
VP16	WMNF near Trudeau Road	Confirmed	2006/2024
VP17	WMNF near Trudeau Road	Confirmed	2006
VP18	The Rocks Estate – cement pond which supports VP species	Confirmed	2006/2024

Geology (Map #6 at the end of this report)

Geologic events that occurred thousands and millions of years ago still influence the management of forests today. Parent bedrock material provides the nutrients for vegetation today and, to some extent, determines which species will grow where in the forest.

Bedrock lies below the glacial deposits and sediments that dominate our valley floor. Most of the deep wells serving the community drill into this bedrock. Bedrock is also a source of radon that can be a risk to homeowners if not monitored and mitigated.

In Bethlehem, the majority of the bedrock type is plutonic. There are a few areas with metamorphic rock and three small sections of volcanic rock. These last two types are found in the White Mountain National Forest. Plutonic rocks are igneous rocks. They formed deep underground from the slow cooling and solidification of magma. As a result of the slow cooling process, they have coarse-grained crystals. Common rocks are granite and diorite. Metamorphic rocks are formed from the alteration and recrystallization of existing rocks (igneous, sedimentary or other metamorphic rocks) under heat and pressure. They occur deep within the Earth but without melting the rock. Examples include schist, slate, gneiss, quartzite. Volcanic rocks are igneous rocks which are formed at or near the Earth's surface from the rapid cooling of lava. They are fine-grained or glassy due to quick cooling. Examples include basalt, rhyolite and obsidian.

In Bethlehem, there are several areas where the type of bedrock naturally buffers the soil, helping to maintain a higher pH—an uncommon characteristic for the region. One notable example is The Rocks Estate, extending northward along Brook Road and surrounding area. This region is underlain by biotite granodiorite, a rock type that contributes to localized higher pH and enhanced nutrient availability. During fieldwork for the NRI, Elise documented species such as mature and young American basswood, blue cohosh, orchids, and maidenhair fern, all of which are indicative of more alkaline soils. The weathering of biotite in the granodiorite releases magnesium, iron, and potassium, enriching the soil and buffering acidity. Additionally,

feldspar in the rock contributes calcium and potassium, which further raise soil pH and improve structure.

Other areas within the White Mountain National Forest (WMNF) also contain alkaline-rich rocks. Notable examples include a section on either side of Route 3 near the Town of Carroll and a broad vein encompassing Haystack Mountain, Sugarloaf Mountain, and the slopes of Mount Tom. Understanding the bedrock geology of the region provides valuable insight into areas where soils are more likely to maintain a higher pH. These conditions support rare plant communities and species, highlighting the importance of geological knowledge in conservation efforts.

Left photo is a young American Basswood and the right photo is maidenhair fern. Both of these species along with blue cohosh, and oak fern were documented on a private property between Baker Brook and the Rocks Estate. Several mature basswood trees were noted in this area. These plant species indicate soil with a higher pH and the possibility of rare plants and plant community types. Photo taken 7-29-2024.

Soils

Along with bedrock geology, the nature of soil has a profound effect on plant growth. Whether it is rich with organic material, very poorly drained, or sandy, these characteristics will affect the type of vegetation adapted to grow in those conditions, thus affecting the type of wildlife in the area. Scientists can learn much about the soil type by examining the vegetation. At the same time, examining the soil will predict the types of vegetation that the area will

support. Understanding soil conditions and characteristics can help in identifying critical areas such as wetlands, agricultural lands, forestlands, and wildlife habitat. In descriptions of soil types, the NRCS evaluates soils according to their capacity for agriculture, sand and gravel production, woodland, community development, recreation, and wildlife habitat. Certain soils are better suited for certain land uses such as agriculture or residential development. For example, residential development should be located away from areas with unstable soil conditions such as high-water tables, and slow percolation rates, due to constraints for building foundations and septic system placement.

Farmland Soils (Map #7 at the end of report)

As is true with many New England towns and cities, Bethlehem had family farms in the 1800's and early 1900s. Overall, New Hampshire has experienced a loss of working farms. Many of the former, larger-scale farms have been replaced with smaller farms offering a wide range of products throughout Town, including beef, dairy, vegetable, berry, and tree farms. Working farms in Bethlehem including:

- Meadowstone Farm on Brook Road– a small, diverse farm offering a diversity of fruit and vegetables, pork, eggs, chicken, goat cheese, and seedlings. The property was originally homesteaded by the Cole family in the mid-1800's, remaining in their family as a cow dairy farm until the early 1950's.
- Bent Fork Farm on Maple Street – A small farm growing produce and cut flowers
- The Rocks Estate off Route 302 – A tree farm and northern headquarters for the Society for the Protection of New Hampshire Forests. It includes sustainable managed forestland, a Christmas tree farm and the NH Maple Experience.
- Mountain Roots Farm on Route 302 – A flower farm and floral design.

As stated in the methodology section, prime farmland, as defined by the U.S. Department of Agriculture, is the land that is best suited to food, feed, forage, fiber, and oilseed crops. It is land that still has the potential to serve agricultural uses and can be cultivated land, pasture, or woodland. It either is used for food or fiber crops or is available for those crops. The soil qualities, growing season, and moisture supply are those needed for a well-managed soil to produce the highest sustainable yields with minimal inputs of resources while at the same time generating the least possible damage to the environment. Farmlands that hold state and local importance may not be as ideal for producing the highest possible sustainable yield as prime farmlands, but these soil types have been determined to be of agricultural importance on a more localized scale.

Out of the 27,845.67 acres of land within Bethlehem and excluding the White Mountain National Forest, the NRCS has classified 12,110.02 acres (43.5%) as farmland with 818.30 acres

(2.9%) of land classified as USDA prime farmland soils, 1,014.05 acres (3.6%) classified as farmland soils of statewide importance, and 10,277.67 acres (36.9%) classified as farmland soils of local importance. Although farmland soils are found throughout town, the majority of prime farmland is found throughout the downtown area of Bethlehem, and also follows portions of the Ammonoosuc River floodplain. Generally, where there are steeper slopes (hills and mountains in town), there is less agricultural soil.

Most of the Maplewood Golf course is on Prime agricultural soil (Marlow and Peru fine sandy loams). Photo source (Town of Bethlehem – bethlehemnh.org).

The field shown here off Prospect Street contains farmland soil of statewide importance. Maintaining these fields creates permanent openings beneficial to wildlife, stunning views towards the White Mountains, and hay for livestock. Photo taken 7-29-2024.

Forestry Soil Groups (Map #8 at the end of report)

Similar to farmland and hydric soils, the Natural Resources Conservation Service (NRCS) has also organized the soils into Important Forest Soil Groups. The objective is to offer a simplified tool to aid natural resource professionals and landowners. These groupings allow managers to evaluate the relative productivity of soils and to better understand patterns of plant succession and how soil and site interactions influence management decisions. All soils have been grouped into one of six categories, as described below (UNH Extension, 2023). Map #8 at the end of the report displays the forest soil classifications.

Group IA consists of the deeper, loamy, moderately well-drained and well-drained soils. Generally, these soils are more fertile and have the most favorable soil-moisture conditions. Successional trends are toward climax stands of shade-tolerant hardwoods such as sugar maple and beech. Early successional stands frequently contain a variety of hardwoods such as sugar maple, beech, red maple, birch (yellow, gray, and white), aspen, white ash and northern red oak in varying combinations with red and white spruce, balsam fir, hemlock, and white pine. The soils in this group are well-suited for growing high-quality hardwood veneer and sawtimber, especially sugar maple, white ash, yellow birch, and northern red oak. Softwoods are usually less abundant and are best managed as a minor component of predominantly hardwood stands. Hardwood competition is severe on these soils. Successful natural regeneration of softwoods and the establishment of softwood plantations requires intensive management.

Group IB generally consists of soils that are moderately well-drained and well-drained, sandy or loamy-over-sandy, and slightly less fertile than those in group 1A. Soil moisture is adequate for good tree growth but may not be quite as abundant as in group 1A. Successional trends and the trees common in early successional stands are similar to those in group IA; however, beech is usually more abundant in group IB and is the dominant species in climax stands. Group IB soils are well-suited for growing less-nutrient-and-moisture-demanding hardwoods such as white birch and northern red oak. Softwoods generally are scarce to moderately abundant and managed in groups or as part of a mixed stand. Hardwood competition is moderate to severe on these soils. Successful regeneration of softwoods and the establishment of softwood plantations are dependent upon intensive management. The deeper, coarser-textured and better-drained soils in this group are generally suitable for conversion to intensive softwood production.

Group IC soils are derived from glacial outwash sand and gravel. The soils are coarse-textured. Soil moisture and fertility are adequate for good softwood growth but are limiting for hardwoods. Successional trends on these soils are toward stands of shade-tolerant softwoods, such as hemlock. White pine, northern red oak, red maple, aspen, gray birch, and paper birch are common in early successional stands. These soils are well-suited for high quality softwood sawtimber, especially white pine, in nearly pure stands. Less site-demanding hardwoods such as

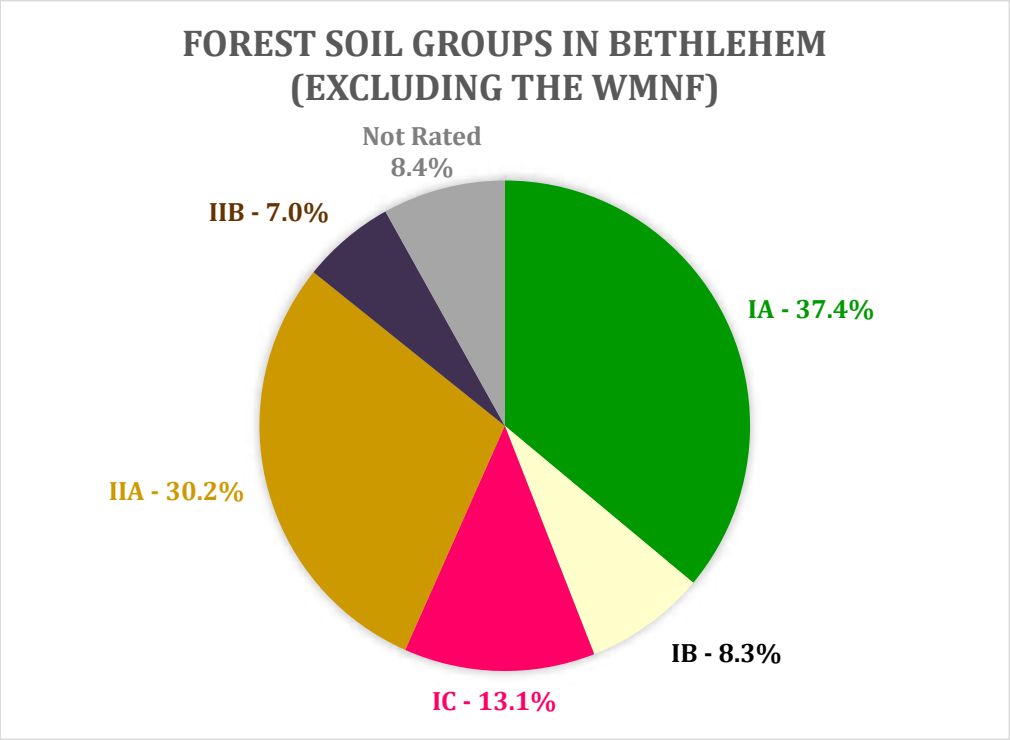
northern red oak and white birch have fair to good growth on sites where soil moisture is more abundant. Hardwood competition is moderate to slight. With modest levels of management, white pine can be maintained and reproduced. Although chemical control of woody and herbaceous vegetation may be desirable in some situations, softwood production is possible without it.

Group IIA consists of diverse soils and includes many of the soils that are in groups IA and IB. The soils in IIA, however, have limitations such as steep slopes, bedrock outcrops, erodibility, surface boulders, and extreme stoniness. Productivity of these soils isn't greatly affected by those limitations, but management activities such as tree planting, thinning, and harvesting are more difficult and more costly.

Group IIB soils are poorly drained. The seasonal high-water table is generally at a depth of 12 inches or less. Productivity is lower than in IA, IB, or IC. Fertility is adequate for softwoods but is limited for hardwoods. Successional trends are toward climax stands of shade-tolerant softwoods, such as hemlock. Early successional stands frequently contain a variety of hardwoods such as red maple, birch (yellow, gray, and paper), aspen, and white and black ash in varying mixtures with red spruce, hemlock, balsam fir, and white pine. Advanced regeneration is usually adequate to fully stock a stand. Hardwood competition isn't usually a major limitation, but intensive management by chemical control of competing woody and herbaceous vegetation may be desirable.

Not Rated Several mapping units in New Hampshire are either so variable or have such a limited potential for commercial production of forest products that they haven't been placed in a group. Examples are very poorly drained soils and soils at high elevations.

Soil type in this area is classified as Group 1A from a forestry soil group classification. This area has been logged, but there is a robust regeneration of diverse forest type thanks to the excellent quality and drainage of the soil below. This soil is a Monadnock Herman series which is well drained, very deep loamy and sandy soil. Excellent for forestry production. Photo taken on August 23, 2024.



Stratified-Drift Aquifers (Map #4 at the end of report)

An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, silt, or clay) from which groundwater can be pumped for drinking. Groundwater is a critical natural resource for the state of New Hampshire. Approximately 98% of public water systems rely on groundwater. There are three types of groundwater aquifers: stratified drift, till, and bedrock. Stratified drift and till aquifers are composed of unconsolidated glacial deposits (loose earth materials), while bedrock aquifers are fractured rock. In stratified drift aquifers, the materials are sorted sand and gravel. In till aquifers, the material is a gravel, sand, silt, and clay mixture. In bedrock aquifers, the material is rock with fractures. Areas of more porous sand and gravel will allow infiltration, and are known as "recharge zones," signifying their importance in replenishing groundwater reservoirs.

Stratified-drift aquifers are an important source of groundwater for commercial, industrial, domestic, and public-water supplies in the state. They typically are the most productive sources of groundwater; therefore, the highest yielding public water supply wells tap these aquifers. Stratified-drift or overburden aquifers are most directly influenced by surface waters and land-use activities. They are, therefore, perhaps most susceptible to contamination. Approximately 14% of land surface in New Hampshire is underlain with stratified-drift aquifers.

Approximately 3,370.5 acres (5.8%) of Bethlehem has Stratified Drift Aquifers, the majority lying along the Ammonoosuc River and Trudeau, River, Wing, and Whitefield Roads. Of the aquifers, 3,155.5 acres have a transmissivity of less than 2,000 ft^2/day, 141.9 acres have a transmissivity of 2,000-4,000 ft^2/day, and 73.2 acres have a transmissivity of over 4,000 ft^2/day. The U.S. Geological Survey (USGS) defines aquifer transmissivity as the volume of water that flows through an aquifer's cross-sectional area in a given amount of time. Transmissivity is calculated by multiplying the aquifer's thickness by its hydraulic conductivity. It describes an aquifer's overall ability to transmit water. This is lower than the 6,175.7 acres of aquifers noted in the 2006 NRI. The paragraph below describes the process for this update and is described in the UNH Granit website :

Aquifers

The largest contiguous aquifer is in the western half of Bethlehem along the Ammonoosuc River and surrounding area.

Aquifers provide many residents with drinking water and are important water sources for use in the future. It is recommended that these aquifers be protected from contamination from impervious surfaces, point and non-point source pollution sources, and development to ensure their future water quality and availability for the town.

Multiple studies were conducted by the U.S. Geological Survey, in cooperation with the New Hampshire Department of Environmental Services, Water Resources Division, to describe the geohydrology and water quality of stratified-drift aquifers river basins throughout New Hampshire. These studies were published between 1989 and 1998. The aquifer shapefile was created by the NH Department of Environmental Services by merging the transmissivity datasets from all the drainage basin study areas. Polygons with no transmissivity values were removed. In areas where study areas overlap, numerous sliver polygons may occur. In these areas, use of the study area-level datasets may provide more consistent data. Aquifer transmissivity is defined as the rate at which water can be transmitted through a unit width of aquifer under a unit hydraulic gradient (Heath, 1983). Transmissivity is equal to saturated thickness multiplied by horizontal hydraulic conductivity and is expressed in feet squared per day (ft /d). Data sets available from the 13 studies may include aquifer boundary lines and polygons, transmissivity, saturated thickness, water table, wells, low flow sites, and seismic lines.

Wells used by communities and private landowners draw groundwater from aquifers. The stratified-drift aquifers represent the greatest potential groundwater source for the Town of Bethlehem. These aquifers represent potential usable water sources for municipal purposes and should be protected to ensure their future quality and availability.

The aquifer under the Ammonoosuc River and surrounding valley is the largest in Bethlehem. Maintaining good surface water quality is critical to protecting our aquifers below. Photo taken on 8-23-2024.

Slope (Map #7 at the end of this report)

Slope is an important component of an area's landform and influences the plants and animals living there. Soils tend to be shallower on steeper slopes, the volume and amount of surface water runoff is higher, and the erosion potential is greater compared to flatter areas. These conditions create a unique habitat where, in some cases, plants and wildlife have special adaptations for dealing with the limitations associated with steep slopes.

Steep slopes provide opportunities for panoramic views and, for this reason, tend to be sought for residential development. However, there are significant problems associated with development on steep slopes. Slope has several limitations for building such as structural problems and a greater chance of erosion. The consequences of erosion are loss of soil resulting in sedimentation of surface waters, loss of the productive capability of the land, and in severe cases, visual scars that can be seen from far away. Slope is traditionally expressed as a percent and represents the amount of rise or fall in feet for a given horizontal distance. For example, a 15% slope means that for a 100-foot horizontal distance, the rise or fall in height is 15 feet. As slope becomes steeper, the expenses associated with building increase. In general, slopes between 15% and 25% are considered areas where development would be restrictive and slopes greater than 25% are considered too steep to provide adequate sites for structures such as roads, homes, and septic systems.

NRCS soil data was used to determine areas in Bethlehem with slopes equal to and greater than 20%. Using NRCS data, 9,139.54 acres or 32.8% of the land in Bethlehem contains slopes that are 20% and over. This is nearly one third of the area outside of the White Mountain National Forest. Steep slopes are further broken down as follows:

- 6,383.02 acres = 22.9% contain slopes between 20% and 30%
- 1,202.25 acres = 4.3% contain slopes between 30% and 40%
- 1,554.27 acres = 5.6% contain slopes over 40%

Excluding the White Mountain National Forest, some of the steepest slopes include the sides of Mount Agassiz, Cleveland Mountain, and Garnet Mountain. As stated previously this data does not include the WMNF as the NRCS did not create maps on US Forest Service property.

The slope climbing up Mount Agassiz is steep. Steep slopes generally have less soil depth to bedrock. The exposed bedrock shown here, with a few mosses and grasses is an example of very shallow to none soil layer. Photo taken 8-13-2024.

Steep slopes often offer excellent views. The view here is from the top of Mount Agassiz looking across Bethlehem and into Franconia Notch. Photo taken on 8-13-2024.

Climate Change and the Effects on Natural Resources

The New Hampshire Fish and Game department as part of their Wildlife Action Plan has a chapter on Wildlife Risk Assessment: Climate change. The major impacts of climate change on wildlife and our forests include the following risks:

1. Extreme storms and flooding – Scientists predict annual average precipitation will increase 14-20%. Storms will be less frequent, more severe with longer dry periods between storms.
2. Shifting habitat – As temperatures rise, the plant communities that make up habitat for wildlife will also change. In turn, wildlife may shift their habitat range.
3. Phenology – The timing of biological events throughout the year such as leaf out in the spring, emergence from hibernation, the arrival of migrating birds and the appearance of adult insects. Climate change is causing a mismatch – what wildlife species needs in their habitat versus availability at critical times for their survival. One example is winter ticks and their negative effects on moose caused by shorter winters and less snow.
4. Winter seasonal changes – Warmer temperatures affect winter conditions including less accumulating snow and earlier arrival of spring-like weather. Winter months now include more precipitation in the form of rain or ice, and less as snow, resulting in reduced snowpack.

5. Rising temperatures – Warmer temperatures affect cold-water fish species such as brook trout and salmon. They will be replaced by warmer species including yellow perch and smallmouth bass. Moose, who are already at the southern limit of their range, will experience more heat stress and need to seek shade and cooler areas at the cost of foraging.
6. Invasive species – Many invasive species will further expand into NH because of warmer temperatures. They may replace native plant species and therefore impact wildlife habitats.

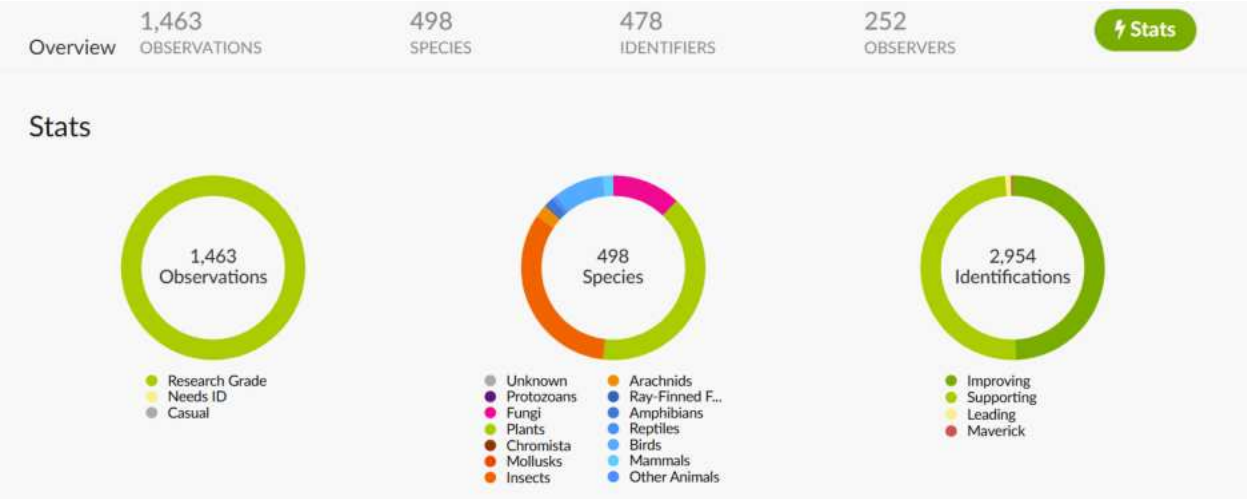
Animals and plants are constantly adapting to their changing ecosystems. The rapidly changing levels of greenhouse gases in the atmosphere, however, are leading to much faster and greater ecosystem pressures. The rapid rate of change observed in our climate is already affecting plants and wildlife in New Hampshire. There is increased flooding, extreme fluctuations in precipitation (including rain, snow, and ice events), shifting habitats, and species struggling to adapt. Biologists are keeping a close eye on wildlife as these changes unfold. Some of these species include American pine marten, Canada lynx, moose, brook trout, White Mountain fritillary. However, predicting what wildlife population numbers and assemblages will be in the future is difficult. Wildlife species in New Hampshire most at risk from a shifting habitat directly rely on these habitats to get their basic needs and cannot adapt to changes as quickly.

Forests in northern New England will be affected by a changing climate and other stressors during this century. Balsam fir, for example, has been identified as a species that will be heavily impacted by climate change. Balsam fir is a common species found in Lowland Spruce-Fir habitats as well as High Elevation Spruce-Fir. Future management of these forests should work to shift the species composition over time to other species with better long-term viability. In addition to silvicultural systems and harvest practices, enrichment plantings may be part of forest management practices to encourage those conifer and hardwood species expected to be adapted to future conditions (red spruce, white pine, hemlock, red oak, and black birch). The NH Fish and Game Department is an excellent resource for what is happening to our forests and wildlife with climate change, as well as what is being done to monitor and adapt.

This stand of balsam fir is in the Bethlehem Town Forest. Lowland spruce-fir forests such as this one are likely to suffer the effects of climate change in Bethlehem. Photo taken on (7-29-2024).

Bioblitz Results

Spearheaded by Rachell Lyons, 252 observers, including Bethlehem residents, contributed local knowledge for this NRI via an iNaturalist project. Between January 1, 2023 and March 31, 2025, 498 species were recorded including plants, fungi, insects, and wildlife found throughout town. Details of this project can be found here. This project was queried so only those observations classified as "research grade" were included. The American marten (Martes americana) was documented 3 separate times in the White Mountain National Forest. They are classified as threatened in New Hampshire. A summary is shown in the figure below, which is a screen shot of the project site.



Rare Species and Exemplary Natural Communities

The Town of Bethlehem has documented occurrences of rare species and communities. They are listed by the NH Natural Heritage Bureau (NHB), the state agency that houses reported occurrences. New Hampshire is home to more than 500 species of vertebrate animals. Many of these animals live in Bethlehem and the surrounding towns. The number would be considerably larger if a complete list of invertebrates (insects, crustaceans, clams and snails) were included. About 75% are nongame wildlife species – not hunted, fished, or trapped. Thirty species are endangered and 21 are threatened in the state. The New Hampshire Fish and Game Department maintains lists of Endangered or Threatened animal species in New Hampshire (https://www.wildlife.nh.gov/wildlife-and-habitat/nongame-and-endangered-species/endangered-and-threatened-wildlife-nh). Minimal information is available relative to their occurrence in Bethlehem, but their habitats, when identified, should be protected.

Wood Turtle have been documented in Bethlehem. This one was documented by Elise and Alexandra Lawson in 2007 near Baker Brook. Wood Turtles are classified as a species of special concern and a species in greatest need of conservation by NH Fish and Game Department. They are found in slow-moving streams and channels with sandy bottoms. During the summer they can be found in floodplains, meadows, woodlands, and wetlands. Threats to their survival include road mortality, habitat loss and fragmentation, stream alteration, and human collection.

Bethlehem has large tracts of land that are unfragmented, with many areas being conserved. These contain a diversity of habitat types and, thus, Bethlehem has the potential for containing many rare and endangered plant and wildlife species, beyond those currently recorded in the town.

NH Natural Heritage Bureau Listing for Bethlehem

NH Natural Heritage Bureau

Town Flag	Species or Community Name	Listed? US	Listed? NH	~ reports last 20 yrs Town	~ reports last 20 yrs State
Bethlehem					
	Natural Communities - Terrestrial				
~	*- Birch - mountain maple wooded talus*	--	--	Historical	6
***	*- High-elevation spruce - fir forest system*	--	--	1	10
~	*- Lowland spruce - fir forest*	--	--	Historical	6
~	*- Montane - subalpine acidic cliff*	--	--	Historical	6
~	*- Montane black spruce - red spruce forest*	--	--	Historical	2
~	*- Montane lichen talus barren*	--	--	Historical	3
~	*- Red spruce - heath - cinquefoil rocky ridge*	--	--	Historical	12
~	*- Sugar maple - beech - yellow birch forest*	--	--	Historical	17
	Natural Communities - Palustrine				
**	*- Black spruce swamp*	--	--	1	11
***	*- Montane heath woodland*	--	--	1	6
***	*- Montane sloping fen system*	--	--	1	4
~	*- Northern hardwood - black ash - conifer swamp*	--	--	Historical	15
**	*- Poor level fen/bog system*	--	--	1	29
~	*- Red spruce swamp*	--	--	Historical	10
~	*- Sedge meadow marsh*	--	--	Historical	4
	Plants				
**	American ginseng - *Panax quinquefolius*	--	T	1	82
***	broad-leaved twayblade - *Neottia convallarioides*	--	T	1	24
~	Jack pine - *Pinus banksiana*	--	T	Historical	8
~	Lindley's american-aster - *Symphyotrichum ciliolatum*	--	T	Historical	12
~	Loesel's wide-lipped orchid - *Liparis loeselii*	--	T	Historical	27
**	meager sedge - *Carex exilis*	--	E	1	8
*	northern adder's-tongue fern - *Ophioglossum pusillum*	--	E	1	7
~	northern bog violet - *Viola nephrophylla*	--	E	Historical	8
~	northern neglected reed grass - *Calamagrostis stricta* ssp. *inexpansa*	--	T	Historical	16
**	northern sweet-coltsfoot - *Petasites frigidus* var. *palmatus*	--	E	1	9
~	parasol sedge - *Carex umbellata*	--	E	Historical	12
~	peat moss - *Sphagnum andersonianum*	--	T	Historical	1
~	peat moss - *Sphagnum angermanicum*	--	E	Historical	1
~	peat moss - *Sphagnum contortum*	--	T	Historical	10
~	peat moss - *Sphagnum majus* ssp. *norvegicum*	--	T	Historical	1
~	peat moss - *Sphagnum pylaesii*	--	T	Historical	2
~	smooth cliff fern - *Woodsia glabella*	--	E	Historical	5
~	stiff dwarf-gentian - *Gentianella quinquefolia* ssp. *quinquefolia*	--	E	Historical	7
~	thin-leaved sedge - *Carex cephaloidea*	--	T	Historical	6
***	White Mountain avens - *Geum peckii*	--	T	2	18
***	Wiegand's sedge - *Carex wiegandii*	--	E	2	8
~	wild hound's-tongue - *Andersonglossum boreale*	--	E	Historical	8
	Vertebrates - Mammals				
**	American Marten - *Martes americana*	--	SC	2	143
~	Canada Lynx - *Lynx canadensis*	T	E	Historical	17

NH Natural Heritage Bureau Listing for Bethlehem continued

NH Natural Heritage Bureau

Town Flag	Species or Community Name	Listed? US	Listed? NH	~ reports last 20 yrs Town	~ reports last 20 yrs State
	Vertebrates - Birds				
~	American Three-toed Woodpecker - *Picoides dorsalis*	--	SC	Historical	7
**	Peregrine Falcon - *Falco peregrinus anatum*	--	T	1	25
**	Rusty Blackbird - *Euphagus carolinus*	--	SC	2	16
	Vertebrates - Reptiles				
~	Smooth Green Snake - *Opheodrys vernalis*	--	SC	Historical	85
**	Wood Turtle - *Glyptemys insculpta*	--	SC	1	281
	Invertebrates - Dragonflies & Damselflies				
**	Kennedy's Emerald - *Somatochlora kennedyi*	--	SC	1	5
**	Subarctic Darner - *Aeshna subarctica*	--	--	1	10

Listed? E = Endangered T = Threatened SC = Special concern

Flags
**** = Highest importance
*** = Extremely high importance
** = Very high importance
* = High importance
~ = Historical Record

These flags are based on a combination of (1) how rare the species or community is and (2) how large or healthy its examples are in that town. Please contact the Natural Heritage Bureau at (603) 271-2215 to learn more about approaches to setting priorities.

May 2022

To learn more about threatened or endangered species or unique communities, contact the New Hampshire Natural Heritage Bureau office of NH Division of Forest and Lands for plant species at 603-271-2214. Website: https://www.nh.gov/nhdfl/about-us/natural-heritage-bureau.htm.

Wildlife Action Plan (Maps #2 and #9)

The New Hampshire Fish and Game Department worked together with many partners in the conservation community to create New Hampshire's Wildlife Action Plan (WAP). The plan, which was mandated and funded by the federal government through the State Wildlife Grants Program, provides a base tool for restoring and maintaining critical habitats and populations of the state's species of concern and their habitat. New Hampshire Fish and Game states that the Wildlife Action Plan is a first step on a statewide scale to work towards helping keep species off the rare species lists. The NH Wildlife Action Plan was submitted to the U.S. Fish and Wildlife Service on October 1, 2005, and was approved in the spring of 2006. It was then revised in 2015. A team of biologists are currently working on an updated 2025 WAP.

NH WAP High Priority Areas

Bethlehem contains several areas classified as "Highest Ranked Habitat in NH" (Tier 1) as well as "Highest Ranked Habitat in the Biological Region" (Tier 2). Areas with both classifications include the following:

- The White Mountain National Forest in Bethlehem is largely Tier 1 and 2 throughout the whole area.
- Most of the Ammonoosuc River flowing through town
- Black Brook and associated wetland areas in the northern part of Bethlehem outside of the WMNF
- Ammonoosuc River and Alder Brook area in northwestern Bethlehem
- Wiseman Brook and Gale River riparian habitats
- Indian Brook and associated wetlands

In the GIS phase of the Wildlife Action Plan, biologists and GIS technicians conducted co-occurrence analyses using a variety of digitized natural resource features such as wetlands, riparian habitat, unique rock outcrops, dense softwood stands, alpine areas, etc. This analysis identified and ranked areas of conservation priorities throughout the state and at a statewide level.

Future work, including this NRI, can be shared with Fish and Game and incorporated into the Wildlife Action Plan to build upon and improve data and habitat analyses. For more details on the Wildlife Action Plan visit the NH Fish and Game's website at: https://www.wildlife.nh.gov/wildlife-and-habitat/nh-state-wildlife-action-plan. The plan and associated maps can be downloaded and viewed. Fish and Game keeps record of updates and describes how the WAP is being used and updated. A 2025 update will be coming out this year. There is an opportunity to sign up for regular WAP e-mails to receive updates.

Scenic Resources

With a hilly and mountainous topography, ponds, rivers, and wetlands, Bethlehem has many scenic views and viewsheds throughout the entire town. Most areas offer scenic views overlooking rivers, streams, lakes, ponds, and hillsides across valleys. Almost every road in Bethlehem is scenic. The following are some of Bethlehem's many scenic vista points.

- Hilltops of Mount Agassiz and Cleveland Mountain
- The grounds of the former White Mountain School
- The Rocks Estate
- The two golf courses in Bethlehem (Municipal and Maplewood)

- The White Mountain National Forest
- Ammonoosuc River corridor through the entire length of Town
- Swazey Lane (a Town designated Scenic Road)
- Gilmanton Hill Road (a Town Designated Scenic Road)
- Lewis Hill Road (a Town Designated Scenic Road)

One of the many scenic views from the Rock's Estate. Photo taken 6-18-2024 facing north.

View of the Presidential Range from Prospect Street. Many of the roads in Bethlehem offer excellent views of the mountains, hillsides, wetlands and ponds. Photo taken 7-29-2024 facing east.

In addition to views from mountain tops or across ponds, lakes and rivers, excellent views can be found across fields and permanent wildlife openings. People experience scenic views in all directions while driving, biking or walking along the roads in the town, particularly where fields and permanent wildlife openings are maintained. ***Continuing to maintain permanent wildlife openings will retain these outstanding views throughout Bethlehem.***

Development and population growth throughout the state and region have caused people to increase their appreciation of the natural scenery New Hampshire has to offer. As with many other towns and cities in NH, there are potential threats to viewsheds. Several communities are struggling with the concern of future development on the ridgelines and tops of hills. In many communities, there have been extensive debates over wind towers, cell towers, and houses built on ridgelines because of their detrimental effect on viewsheds.

Dark Skies and Responsible Outdoor Light at Night

Over the past 100+ years, a steady increase in artificial outdoor lighting has led to unprecedented levels of light when there should be dark. The World Atlas of Artificial Sky Brightness, published in 2016, estimated that 80% of the world's population and 99% of North Americans, live in light polluted places. And a 2023 Study comparing data from citizen science observations around the globe found that over the past decade, the average amount of artificial light in the night sky has increased by up to 10% per year (Falchi, et. al. 2016).

In Bethlehem, dark skies are a valuable natural resource, offering benefits that extend beyond the scenic beauty they provide. Preserving dark skies has become a priority for communities that recognize the ecological, cultural, and health implications of artificial light pollution. Below are several reasons why dark skies are vital to Bethlehem's natural landscape and the well-being of its residents.

Ecological Health - The disruption of natural light cycles can impact wildlife, particularly nocturnal species that rely on the darkness for survival behaviors like foraging and mating. Light pollution disrupts these patterns, leading to changes in predator-prey relationships, disorientation in migrating birds, and disrupted activity cycles in mammals, reptiles, and insects. Preserving dark skies helps protect these natural rhythms, maintaining a balanced ecosystem.

Local species of conservation interest (NH Wildlife Action Plan, 2015; NH Heritage Bureau,2020; Bethlehem NRI 2006) impacted by light pollution include, but are not limited to:

- Insects- Monarch Butterfly, White Mountain Fritillary Butterfly, Sub-Artic Darner Dragonfly, Kennedy's Emerald Dragonfly, Fireflies, Tiger beetle
- Reptiles- Eastern Box Turtle, Wood Turtle
- Amphibians- Fowler's Toad, Northern Leopard Frog, Blue Spotted Salamander
- Birds- Bicknell's Thrush, Golden Eagle, Peregrine Falcon, Cliff Swallow, Grasshopper Sparrow, Cerulean Warbler, Black-backed Woodpecker, American Three Toed Woodpecker

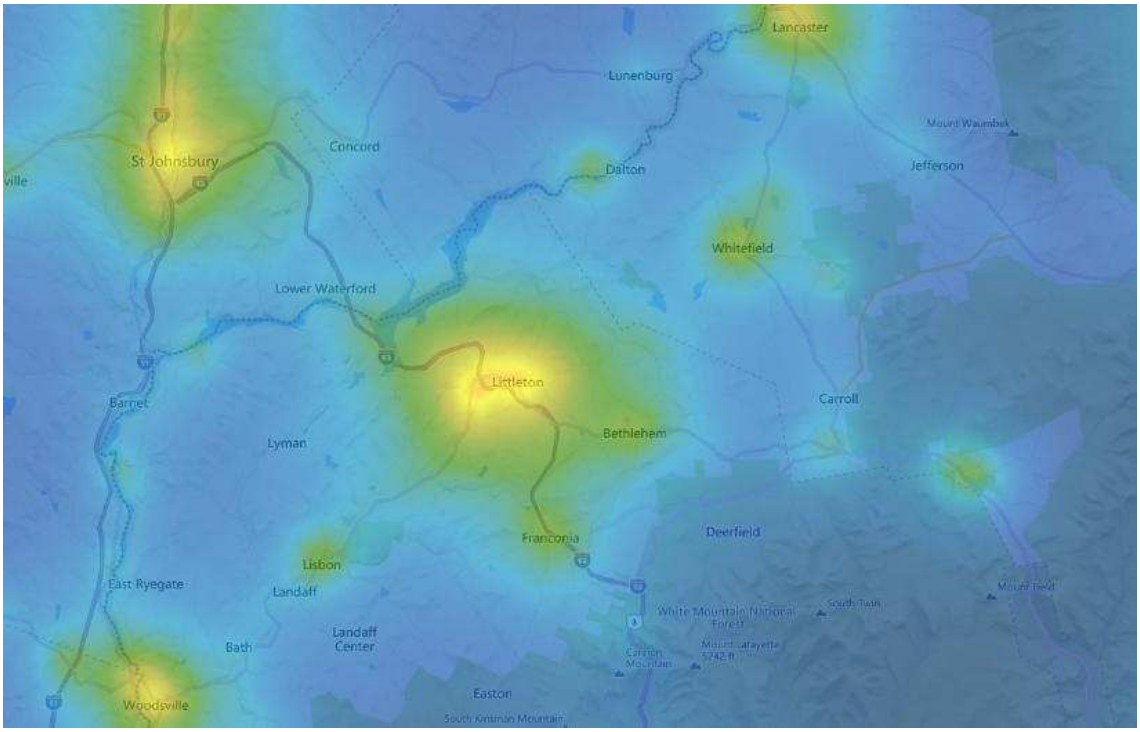
Human Health and Well-Being - Exposure to artificial light at night is associated with disruptions in human circadian rhythms, potentially leading to sleep disorders, mental health challenges, and other health issues. Dark skies provide a reprieve from urban lighting, allowing residents and visitors alike to experience the restorative effects of natural darkness. This is especially important for Bethlehem, where visitors seek the natural environment for health and recreation.

Recreational and Educational Value - Dark skies are a draw for stargazers, astrophotographers, and nature enthusiasts who seek unobstructed views of the night sky. This contributes to the town's tourism, as dark-sky activities like star gazing gatherings and night hikes become more popular. Clear, dark skies are essential for astronomical research and education. Dark-sky preservation allows for better viewing of celestial objects, providing educational opportunities for local schools and astronomy groups.

Climate and Energy Considerations - Reducing light pollution is also an environmentally friendly choice. Outdoor lighting requires energy, and excessive lighting contributes to greenhouse gas emissions. By promoting dark-sky initiatives and encouraging responsible lighting practices, Bethlehem can decrease its energy usage, reduce its carbon footprint, and support broader sustainability goals.

In general, outdoor lighting should follow the five guidelines laid out by DarkSky International.

1. **Useful** – Use light only if it is needed. All light should have a clear purpose. Consider how the use of light will impact the area, including wildlife and their habitats
2. **Targeted** – Direct light so it falls only where it is needed. Use shielding and careful aiming to target the direction of the light beam so that it points downward and does not spill beyond where it is needed.
3. **Low Level** – Light should be no brighter than necessary. Use the lowest light level required. Be mindful of surface conditions, as some surfaces may reflect more light into the night sky than intended.
4. **Controlled** – Use light only when needed. Use controls such as timers or motion detectors to ensure that light is available when it is needed. Dimmed when possible and turned off when not needed.
5. **Warm-colored** – Use warmer color lights where possible. Limit the amount of shorter wavelength (blue-violet) light to the least amount needed.



Screenshot from recent light pollution in our region. It is a worldwide issue and working with neighboring towns and regions will help reduce the effects of light pollution. Screen shot taken from light pollution map information on January 13, 2025.

The conservation commission updated the town's existing Sign and Lighting ordinances to better protect the town's night skies and rural character. Both warrant articles passed with a 3:1 ratio in support of these protections at the 2025 town meeting.

Cultural Resources

The Town of Bethlehem has an exceptionally rich history of land use changes and cultural features from when Indigenous people first lived with the land, to the first settlements, to current times. Many of these historic and cultural features can be seen at:

1. Downtown, Main Street Bethlehem
2. The Rocks Estate
3. Several town-owned and private cemeteries throughout town
4. Along trails on public and private properties
5. Snowmachine trails
6. Rural, Class VI roads

Along Main Street in Bethlehem, there are several historical buildings and homes. The Bethlehem Historical Society on Main Street offers a window into Bethlehem's history and a great resource.

Formal gardens at the Rocks Estate. The pond in the foreground also functions as a vernal pool with wood frog tadpoles and yellow spotted salamander egg masses at the time of the photo (6-18-2024).

The many stone walls in Bethlehem indicate farming occurred here. Fields were cleared of stones, and these walls were created as property boundaries as well as places to store stones removed from fields. Photo taken at the Rocks Estate on 6-18-2024.

Invasive Plant Species

There continues to be an increase in public awareness and concern about the rapid spread of invasive species in NH and throughout New England. Invasive species are plant and wildlife species that are not native to an area but take up residency and can out-compete native species. These species tend to be more common in wet areas such as lakes, wetlands, riparian habitats, and areas of recent disturbance including roadsides and old gravel pits. They can also be found at old farm sites where people have planted various fruit and ornamental plants for agricultural purposes.

Invasive species were documented during field work for this NRI. Those documented and links to eradication methods are shown in the table below.

Species	**Eradication Methods** **(sources: USDA Forest Service, 2007, UNH Cooperative Extension, 2018, NH Division of Forests and Lands, 2012, and NH Department Environmental Services, 2019)**
Japanese Knotweed (*Polygonum cuspidatum*) Located throughout town	• Repeated cutting several times (4-6) during growing season leaving cut plants onsite • Or cover with durable material for 3-5 years, checking regularly • Knotweed plants may be controlled by application of a systemic herbicide containing glyphosate or triclopyr to the actively growing plants. The injection method is recommended to reduce injury to desirable vegetation. Click here for more information
Japanese barberry (*Berberis thunbergii*) Observed in mixed forested areas throughout town (mostly isolated plants)	• Hand removal is the best option for eliminating small, isolated plants. Larger plants can be removed with a garden spade, hoe, or weed wrench. • Try to remove as much of the root system as possible because Japanese barberry can easily re-sprout from the remaining roots. • Large populations can be effectively controlled using recommended herbicides. Click here for more information
Purple Loosestrife (*Lythrum salicaria*) Documented throughout town, primarily near wetlands along roads	• Best time to manage is when it is flowering (late summer) • Small new infestations can be hand-pulled or removed with a shovel • Before digging remove flower heads to prevent seed spreading

Species	Eradication Methods **(sources: USDA Forest Service, 2007, UNH Cooperative Extension, 2018, NH Division of Forests and Lands, 2012, and NH Department Environmental Services, 2019)**
	• Plants can also be cut to the ground. This treatment only slows their spread • Dispose of all plant parts – do not put them on a compost pile • Can be controlled with an herbicide if in an upland area • Purple loosestrife is also being biologically controlled by two species of introduced leaf-eating beetles Click here for more information
Japanese and Tatarian honeysuckles (*Lonicera japonica*) (*Lonicera tatarica*)	• Use mechanical means first, such as digging out or pulling the vines by their roots. This method works best for small populations. • If mechanical control isn't possible or practical, such as with large infestations, Japanese and Tatarian honeysuckle can be managed with herbicides such as glyphosate or triclopyr. If applied as a foliar spray, these herbicides are best applied in fall or early spring while native vegetation is still dormant. These herbicides should be applied according to product label instructions. Click here for more information

Japanese Knotweed was documented throughout Bethlehem, and is shown here at the Rocks Estate. The Forest Society has been hard at work trying to eliminate this invasive species on the property. The photo on the right shows successful eradication for now. Photos taken on 6-18-2024.

This NRI is not an all-inclusive search and documentation of invasive species in Bethlehem. Undoubtedly, other species and locations where invasive species occur in Bethlehem have been or will be documented. The Town of Bethlehem should continue its efforts to help identify and eradicate these invasive species and may want to seek assistance from the Invasive Plant Atlas of New England (IPANE), New England Wildflower Society, UNH Cooperative Extension, and other organizations that have begun programs to control or eradicate invasive species. For further information on invasive species and an update of the list of these species, review the IPANE website https://www.eddmaps.org/ipane/. The Invasive Plant Atlas of New England's (IPANE) mission is to create a comprehensive web-accessible database of invasive and potentially invasive plants in New England that will be continually updated by a network of professionals and trained volunteers.

There are several other organizations with websites that help with identification and control of invasive species throughout New Hampshire and the northeastern US region. Here are a few with website links:

- University of New Hampshire: Invasive Academy Resources
- University of New Hampshire Extension: Invasive species resources
- Native Plant Trust: Controlling Invasives
- Penn State Cooperative Extension has several educational materials including publications, portable field guides and webinars/online materials. Click here.

Habitat Area Summary Table

The table below is a summary of different habitat areas in acres, square miles, and percentage of town land area.

Habitat Type	Acres	Square Miles	Percentage of Town Land Area
Town of Bethlehem	58,205.89	90.95	100%
Conservation Land Total	34,377.57	53.71	59.1%
Land Excluding WMNF	4,004.99	6.26	6.8%
Ponds and Open Water	228.75	0.36	0.4%
Wetland Complexes (from National Wetland Inventory data & field work)	2,183.28	3.41	3.8%
Hydric Soils – poorly and very poorly drained*	3,602.12	5.63	12.9%
Floodplain Zones (FEMA)	1,169.26	1.83	2.0%
Aquifers	3,370.54	5.27	5.8%
Northern Hardwood Conifer	26,933.16	42.08	46.3%
High Elevation Spruce-Fir	12,038.11	18.81	20.7%
Hemlock-Hardwood Pine	7,537.20	11.78	12.95%
Dense Softwood Cover	6,903.17	10.79	11.9%
Permanent Wildlife Openings	1,347.79	2.11	2.32%
Cliff, Talus and Alpine	259.11	0.40	0.5%
Farmland Soils – prime, statewide and local importance*	12,110.02	18.9	43.5%
Steep slopes – 20% and greater*	9,139.54	14.28	32.8%
Steep slopes – 30% and greater*	2,756.52	4.30	9.9%

* = Data extrapolated from NRCS soil data. This data does not include the WMNF so percentages based on area outside of WMNF

DISCUSSION – RECOMMENDATIONS FOR FUTURE ACTIONS AND OPPORTUNITIES

This project is an inventory of natural resources, including a written report, maps, and a digital database in GIS format. It is the property of the Town of Bethlehem and was funded by the Bethlehem Conservation Commission. The data from this project is compatible for integration with the existing Town GIS. Efforts from this project will aid in future work and inventories, as well as provide tools to guide future development and conservation decisions in Bethlehem.

We anticipate that the results from this study will help the Town of Bethlehem in various ways. Town-wide zones based on habitat and vegetation can be assessed and modified. Data gathered from this work will also assist the Conservation Commission, along with the Planning and Zoning Boards, in foreseeing possible conflicts with future development. Perhaps the most powerful advantage of this project is that future studies and work can be easily integrated to build upon this database indefinitely.

Based on results from this study, Elise Lawson and the Bethlehem Conservation Commission offer the following additional recommendations:

1. **Surface Water Protection** - Bethlehem's residents obtain drinking water from town-treated water as well as from personal drilled or dug wells. The Village District of Bethlehem uses water drawn from the Gale and Zealand Rivers in town. Maintaining good water quality is one of the highest priorities for the Bethlehem Conservation Commission.

   Currently, water quality in Bethlehem's streams and rivers is in very good to excellent condition. Water quality should continue to be addressed not only in large rivers like the Ammonoosuc, Gale, and Zealand Rivers, but also in the headwater streams and brooks that feed into these larger river systems.

   a. Where possible, work to maintain or enhance riparian habitat adjacent to headwater streams and brooks. Any wetland setback should also apply to all riparian habitat along perennial streams.

   b. Continue monitoring water quality in the Ammonoosuc River as well as some of the smaller feeder streams in town.

   c. The town should update any potential contamination source location inventory at least on an annual basis and ensure that compliance measures (secondary containment structures, and spill kits) are in place.

2. **Aquifer Protection** - Based on the locations of the underlying aquifers in Bethlehem, it is important to protect the quality of groundwater, brooks, streams, and aquifers in town. Future water supplies are an invaluable natural resource for Bethlehem and the abutting towns. Those areas with the highest water quality and quantity, whether zoned residential or industrial, should have the least impactful development. Correspondingly, where the least potential for aquifer recharge exists, the more desirable and suitable the area is for development, barring other development concerns.
    a. Implement Best Management Practices (BMPs) within aquifer areas.
    b. Monitor septic system plumes with a focus on parcels adjacent to rivers, wetlands, and aquifers.
    c. Monitor the placement of future septic systems keeping in mind the typically high permeability of many of Bethlehem's soils.
    d. Develop a deeper understanding of the movement of ground water and the recharge of aquifers to better understand water resources available to Bethlehem and the larger watershed as a whole. This knowledge can also serve as an important guide to policies related to sewage treatment, solid waste disposal, landfills and risks associated with existing ground water contamination.
        - This includes knowledge, education and caution to avoid disturbing contaminated soils from 19th and 20th century landfill operations.
    e. Develop town-wide ordinances to help protect aquifers, including restrictions on impervious surface development and dumping of waste on top of aquifers, particularly areas with high productivity and flow.
3. **Climate Change** – One of the most significant threats to the existing natural resources in Bethlehem is climate change. The predictions of impacts as described in the 2021 NH Climate Assessment Report should be considered by town departments and committees in planning for Bethlehem's future.
    a. Incorporate actions to minimize, mitigate and adapt to climate change impacts when making land use planning decisions. Examples include increasing culvert size for storm events, encouraging vegetation diversity on forested properties, and manage for tree species resilient to the effects of climate change in Bethlehem.
    b. Develop a town energy use plan to reduce municipal and residential activities that create greenhouse gases.

c. With the passage of two Dark Sky warrant articles in March 2025, work can begin to incorporate Dark Sky initiatives - creating energy efficient lighting and reducing lighting wherever possible.

4. **Dense Softwood Stand Protection** – Based on results from this project, there are areas that contain adequate acreage of dense softwood stands (excluding white pine stands) scattered throughout the town. These areas are beneficial to many wildlife species for cover as well as important wintering areas.

    a. Maintain existing softwood stands for the benefit of the deer, moose and other wildlife populations is very important. This type of habitat could be negatively impacted by climate change.

    b. Where possible, investigate maintaining or possibly extending some existing softwood areas and/or connecting patches of softwood stands to increase overall size. Willing landowners can be encouraged to do so, particularly those whose property abuts wetlands and riparian habitat.

5. **Continued Wetland Conservation**– The Bethlehem Conservation Commission recognizes the importance of wetland protection as an important means to maintaining good water quality. It is hoped that the town will continue to pursue ways to further conserve the functionality and diversity of these wetlands. An overall wetland study could help Bethlehem work with willing landowners to conserve some of these valuable wetland resources. This NRI recommends the following:

    a. Conduct an overall wetland study throughout Bethlehem to identify, assess and functionally rank wetlands in town.

    b. Revisit and update the Wetlands Conservation District Overlay to incorporate a protective buffer around wetlands in town to protect them from development pressures.

    c. Continue to inventory vernal pools throughout Bethlehem to enable the Conservation Commission, Planning Board, and Select Board to critique and adjust future subdivision proposals if vernal pools are likely to be impacted.

    d. Continue to monitor stormwater runoff and associated drainage immediately after storm events whenever possible. Treatment devices for stormwater structures should be installed and maintained, particularly within 150 feet of rivers and wetlands.

    e. Current development ordinances in Bethlehem, including lighting, aquifer protection, and floodplain protection, can be found at the following link. https://bethlehemnh.org/wp-content/uploads/2024/03/Zoning-Ordinance-2024.pdf

6. **Land Conservation** – Over 50% of Bethlehem is conserved, most of it being the White Mountain National Forest. The Town has a Town Forest, and there over 3,700 acres of land under private conservation easements. Results from this study identified additional higher priority areas for conservation. They are described below and shown on Map #9 at the end of this report.

    a. **Black Brook and Associated Wetlands and Upland Area** – In the north part of Bethlehem near the Townline with Whitefield is a large, unfragmented area containing a diversity of streams, wetlands, and upland habitat. The area abuts Pine Knob Conservation Land to the north, and includes large parcels of property owned by a timber company. Working to conserve this land would help protect wetlands, water quality and diverse wildlife habitat.

    b. **Ammonoosuc River / Alder Brook Area –** This area is in the northwestern part of Bethlehem adjacent to the Brebner Farm and Forest conservation land. It incorporates the Ammonoosuc River, Alder Brook, Barrett Brook, and several headwater streams.

    c. **Indian Brook / Baker Brook Area** –This area is east of The Rocks Estate and south of Route 302 in Bethlehem. It includes parts of the Indian and Baker Brooks, their associated wetlands, as well as a large area of undeveloped diverse habitat.

    There are several land trust organizations which the Bethlehem Conservation Commission can work with to help purchase land for conservation or work with willing landowners to put their land in a conservation easement. These include Ammonoosuc Conservation Trust, Society for the Protection of New Hampshire Forests, and Trust for Public Land.

7. **Hillside and Viewshed Protection** - Bethlehem's mountainous and hilly topography, wetlands, and rivers are directly related to the town's tourism industry, scenic beauty, and diversity of natural resources (wetlands, streams and rivers, wildlife, plants, soils, etc.). We recommend evaluating and updating the Zoning Ordinance in Bethlehem to conserve viewsheds as an important feature and tourist attraction to the area, while continuing to consider landowner rights.

    a. **Scenic View Conservation** - The potential for continued population increase throughout the town makes it wise to take a proactive approach in dealing with future development pressures and preserving the scenic vistas and beauty. Scenic easements are types of conservation easements that make protection of scenic resources possible.

b. **Ridgeline Development Criteria** - Several municipalities throughout the state have developed ridgeline ordinances to protect ridgeline views. Bethlehem may want to review some of these and explore the possibility of implementation.

c. **Steep Slope Development Criteria** – Develop town-wide ordinances to restrict future development and road construction at sites with over 25% slopes and limit development on slopes between 20% and 25%.

9. **Cooperation** – Ecosystems, watersheds and wildlife habitats often transcend municipal boundaries. The health of our natural resources is often dependent on actions taken by neighboring towns. Bethlehem should continue working with government agencies, regional planning commissions, neighboring municipalities, and natural resource organizations to enhance the protection of our shared natural resources on a larger watershed-wide level.

   a. Work with regional planning commissions who have developed several templates for town-wide ordinances in areas from wetland and shoreline setbacks to restrictions on steep slopes, to ridgeline development.

   b. The Franconia Conservation Commission is interested in partnering with Bethlehem to expand their "Tri-town" effort (Franconia, Sugar Hill and Easton).

   c. Continue ongoing partnerships with local land trusts, high schools and colleges to encourage young people to be involved.

8. **Carbon Sequestration** – Explore the possibility of securing funds for Bethlehem from carbon offset programs. A great resource is The Northeast Forest Carbon Program (website: https://www.northeastforestcarbon.org/). Funds from participating organizations can be used to incentivize landowners to protect their land from development for a period of time. Sustainable forestry is an important part of this process.

Furthermore, Bethlehem officials should consider requesting that all future development plans be delivered in digital format, which would build upon the existing database (including assisting in updating tax maps for assessment) at little cost to the town.

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MAPS

Map #1: Dense Softwoods and Permanent wildlife openings

Map Data Sources:

- Town Boundary, Roads, Open Water, and Streams obtained from GRANIT
- Dense Softwood Stands and Permanent wildlife openings digitized by Elise Lawson 2020 using the 2015 aerial photographs

Map #2: Wildlife Action Plan – Habitat Types

Map Data Source:

- New Hampshire Fish and Game Department – downloaded from GRANIT and queried so habitat types displayed

Map #3: Conservation Lands

Map Data Sources:

- Town Boundary, Roads, Open Water, Streams obtained from GRANIT
- National Wetlands Inventory wetlands obtained from U.S. Fish and Wildlife Service and GRANIT
- Additional Wetlands were field verified by Elise Lawson and or digitized using 2015 aerial photographs (obtained from GRANIT)
- Conservation Lands obtained from GRANIT and the Town of Bethlehem

Map #4: Water Resources – Wetlands, Hydric Soils, and Aquifers

Map Data Sources:

- Town Boundary, Roads, Aquifers, Open Water, Streams, obtained from GRANIT
- Vernal Pool locations taken using a Avenza Maps GPS during field work by Elise Lawson over four days of field work
- National Wetlands Inventory wetlands obtained from U.S. Fish and Wildlife Service and GRANIT
- Additional Wetlands were field verified by Elise Lawson and/or digitized using 2015 aerial photographs (obtained from GRANIT)
- Poorly and Very Poorly Drained Soils obtained from the Natural Resource Conservation Service

Map #5: Subwatersheds

Map Data Sources:

- Town Boundary, Roads, Open Water, Streams, Aquifers obtained from GRANIT
- Subwatershed Units (NH DES HUC 12 Names) obtained from GRANIT

Map #6: Bedrock Geology

Map Data Source:

- Town Boundary, Roads, Bedrock Geology downloaded from GRANIT

Map #7: Steep Slopes and Agricultural Land

Map Data Sources:

- Town Boundary, Roads, Open Water, Streams obtained from GRANIT
- Soil data obtained from Natural Resource Conservation Service and queried to display farmland soils and soils with steep slopes

Map #8: New Hampshire Forest Soil Groups

Map Data Sources:

- Town Boundary, Roads, Open Water, Streams obtained from GRANIT

- Soil data obtained from Natural Resource Conservation Service and queried to display NH Forest Soil Groups

Map #9: Priority Areas for Land Conservation with WAP Tiers and Existing Conservation Land

Map Data Source:

- Town Boundary, Roads, Open Water, Streams obtained from GRANIT
- National Wetlands Inventory wetlands obtained from U.S. Fish and Wildlife Service and GRANIT
- Additional Wetlands were field verified by Elise Lawson and/or digitized using 2015 aerial photographs (obtained from GRANIT)
- Conservation Lands obtained from GRANIT and the Town of Bethlehem
- Priorities Areas for Conservation obtained from New Hampshire Fish and Game Department – downloaded from GRANIT and queried so the highest rank and supporting areas displayed

Map #1
Town of Bethlehem, NH
Natural Resource Inventory
Dense Softwood and Permanent Openings
March 2025

N

Town Boundary
Roads
Dense Softwood
Permanent Openings
Perennial Streams
Ammonoosuc River
Open Water

Map Produced by:
Watershed to Wildlife / Elise Lawson
507 West Darling Hill Rd
West Burke, VT 05871
watershedtowildlife.net

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Map #2
Town of Bethlehem, NH
Natural Resource Inventory
Wildlife Action Plan Habitat Types
March 2025

N

Legend

- Bethlehem roads
- Town Boundary
- Perennial Streams

WAP Habitat Types

- Cliff and Talus
- Floodplain forest
- Grassland
- Hemlock-hardwood-pine
- High-elevation spruce-fir
- Lowland spruce-fir
- Northern hardwood-conifer
- Northern swamp
- Open water
- Peatland
- Rocky ridge
- Sand/Gravel
- Temperate swamp
- Wet meadow/shrub wetland

Bethlehem FEMA flood zones

FLD_ZONE

- A
- AE

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Map #3
Town of Bethlehem, NH
Natural Resource Inventory
Conserved Land
March 2025

N

Town Boundary
Roads
Perennial Streams
Ammonoosuc River
Open Water
Conservation Land
Town Owned
White Mountain National Forest
State Owned
Littleton Water and Light
Private Conservation Easement

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Map #4
Town of Bethlehem, NH
Natural Resource Inventory
Water Resources
March 2025

N

- Vernal Pools
- Town Boundary
- Roads
- Perennial Streams
- Ammonoosuc River
- Open Water
- WTW wetland additions
- NWI Wetlands

Aquifer Transmissivity
- Less than 2000 feet sq./day
- 2000 - 4000 feet sq./day
- Greater than 4000 feet sq./day
- <all other values>

Hydric Soils
- Poorly drained
- Very poorly drained

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Map #5
Town of Bethlehem, NH
Natural Resource Inventory
Subwatersheds
March 2025

Lower Ammonoosuc River

Forest Lake-Bog Brook

Lower Tributaries

Meadow Brook-Middle Tributaries

North Branch Gale River

Middle Ammonoosuc River

Upper Ammonoosuc River

Headwaters-Saco River

North Fork

N

- Roads
- Town Boundary
- Perennial Streams
- Ammonoosuc River
- Open Water

Aquifers with Tranmissivity

Transmissivity

- Less than 2000 feet sq./day
- 2000 - 4000 feet sq./day
- Greater than 4000 feet sq./day

Subwatersheds - HUC 12

- Forest Lake-Bog Brook - 955 ac
- Headwaters-Saco River - 474 ac
- Lower Ammonoosuc River - 18,530 ac
- Lower Tributaries - 3,356.73 ac
- Meadow Brook-Middle Tributaries - 3.540.60 ac
- Middle Ammonoosuc River - 19,864.32 ac
- North Branch Gale River - 6,544.21 ac
- North Fork - 2,815.61 ac
- Upper Ammonoosuc River - 2,125.47 ac

Bethlehem FEMA flood zones

FLD_ZONE

- A
- AE

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Map #6
Town of Bethlehem, NH
Natural Resource Inventory
Bedrock Geology
March 2025

N

Legend

- Roads
- Town Boundary
- Perennial Streams
- Ammonoosuc River
- Open Water

Bedrock Geology
FullName

- Ammonoosuc Volcanics, Bimodal volcanic rocks
- Bethlehem Granodiorite
- Biotite granite
- Biotite granodiorite
- Conway Granite
- Fitch Formation (Upper Silurian; Pridolian and Ludlovian)
- Granite porphyry
- Kinsman Granodiorite
- Littleton Formation, undivided
- Metavolcanic and metasedimentary rocks of the lower part of Ammonoosuc Volcanics, undivided
- Migmatitic rocks
- Moat Volcanics
- Pink equigranular biotite granite
- Porphyritic (alkalic feldspar) biotite granite
- Porphyritic hornblende or alkalic amphibole quartz syenite
- Rangeley Formation, undivided
- Two-mica granite of northern and southeastern New Hampshire

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Map #7
Town of Bethlehem, NH
Natural Resource Inventory
Agricultural Soils and Steep Slopes

N

Legend

- Town Boundary
- Bethlehem roads
- Bethlehem perennial streams
- Bethlehem Rivers
- Bethlehem Open Water

Bethlehem Soils

slopegradd

- 20
- 25
- 30
- 35
- 38
- 40
- 45
- 48

Bethlehem Soils

farmlndcl

- All areas are prime farmland
- Farmland of local importance
- Farmland of statewide importance

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Map #8
Town of Bethlehem, NH
Natural Resource Inventory
NH Forestry Soil Groups
March 2025

N

Legend

- Town Boundary
- Perennial Streams
- Open Water

Forestry Soil Classification

- Group IA
- Group IB
- Group IC
- Group IIA
- Group IIB

NH Forestry Soil Groups

IA = Deeper, loamy, moderately well-drained and well-drained soils. Generally these soils are more fertile and have the most favorable soil-moisture conditions.
IB = Moderately well-drained and well-drained, sandy or loamy-over-sandy, and slightly less fertile than those in group IA.
IC = Glacial outwash sand and gravel. The soils are coarse textured and are excessively drained and moderately well-drained. Soils moisture and fertility are adequate for good softwood growth, but are limiting for hardwoods.
IIA = Diverse soils and includes many of the soils that are in groups IA and IB. The soils in IIA however, have limitations such as steep slopes, bedrock outcrops, erodibility, surface boulders, and extreme stoniness.
IIB = Poorly drained soils. Productivity is lower than in IA, IB, or IC. Fertility is adequate for softwoods, but is a limitation for hardwoods.

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Alder Brook
Ammonoosuc
River Region

Black Brook and associated
wetland and upland area

Indian Brook /
Baker Brook

Map #9
Town of Bethlehem, NH
Natural Resource Inventory
Conservation Land, WAP Tiers
Priority Areas for Future Conservation
March 2025

N

- Roads
- Town Boundary
- Perennial Streams
- Open Water
- Conservation Land

Wildlife Action Plan Tiers
- 1
- 2
- 3

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