A Biosocial Analysis of the Pisgah Brook Watershed

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I. INTRODUCTION

This report presents a natural history of the Pisgah Brook watershed, a 2,750-acre (4.27 square miles) area in south-central Connecticut. As with other natural histories, it provides a story of how things are in the study area, how they came to be, how they interrelate, and how they are likely to be in the future (Burch 1996*a*). In so doing, this report concentrates on the **interconnections between humans and the environment** in the area. The work builds upon a long history of studies focused on various aspects of the Pisgah Brook watershed prepared by previous students at the Yale School of Forestry and Environmental Studies and others,[1] but represents the first major analysis of the area that we know of in the past 10 years. Given that hiatus and the fact that this natural history reflects a somewhat different perspective than the earlier works, we hope it will provide a first step for renewed attention by students of ecosystem management to better understand this important watershed system and to promote more effective management of it.

Overview of the Study Area

The Pisgah Brook watershed lies entirely in the New Haven County towns of North Branford and Branford (see Map 1). The brook is one of three major tributaries of the Branford River, entering the main stem approximately four miles upstream from the point where it flows into Branford Harbor and Long Island Sound. The overall Branford River watershed is recognized as an important component of the greater Long Island Sound ecosystem (see Map 2).

Pisgah Brook itself flows in a question-mark shaped pattern for about 5 miles from its source at Lidyhites Pond in the northwestern corner of the watershed to its confluence with the Branford River in the southeastern corner. Approximately 2 miles below Lidyhites Pond, a

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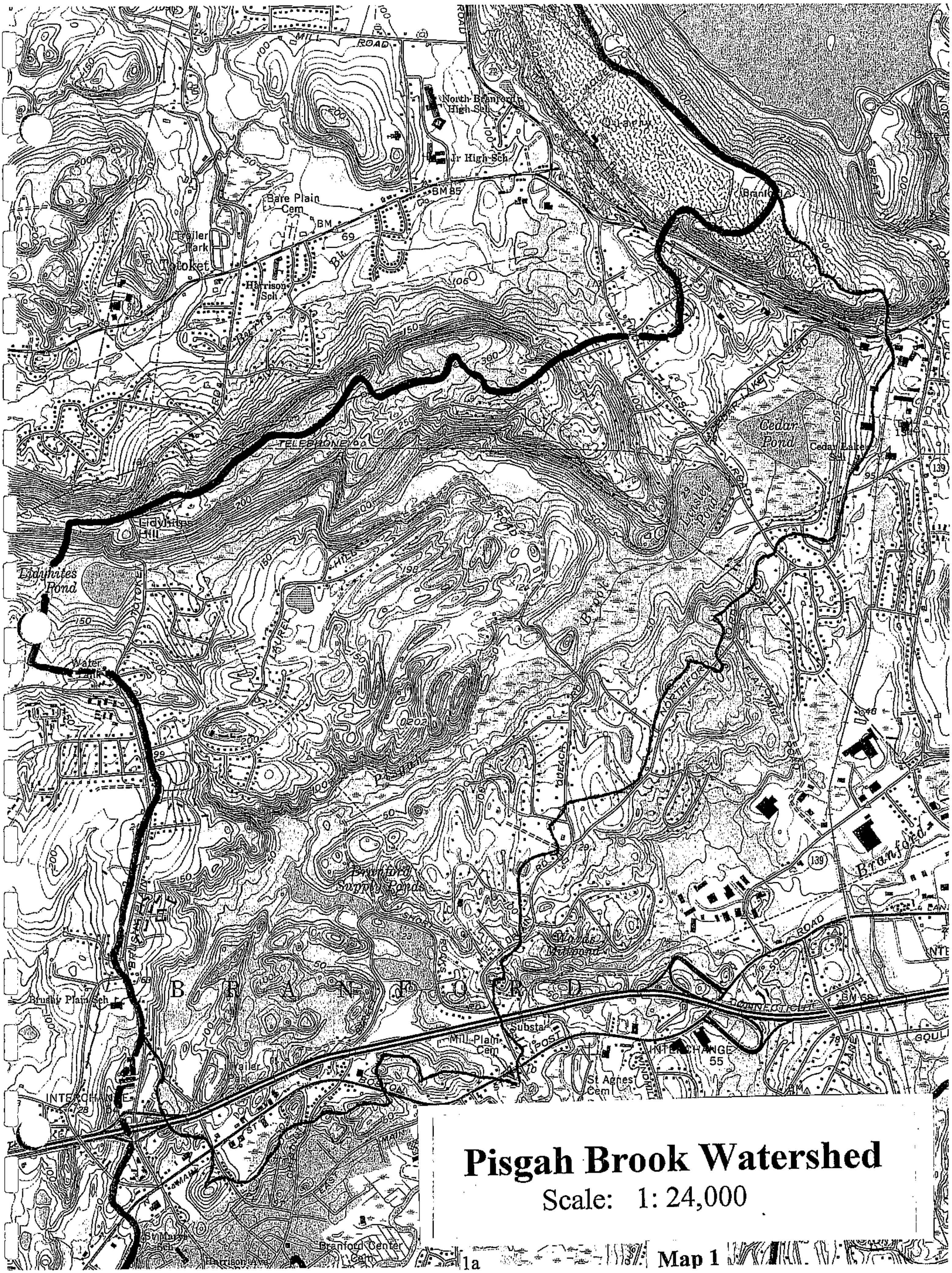
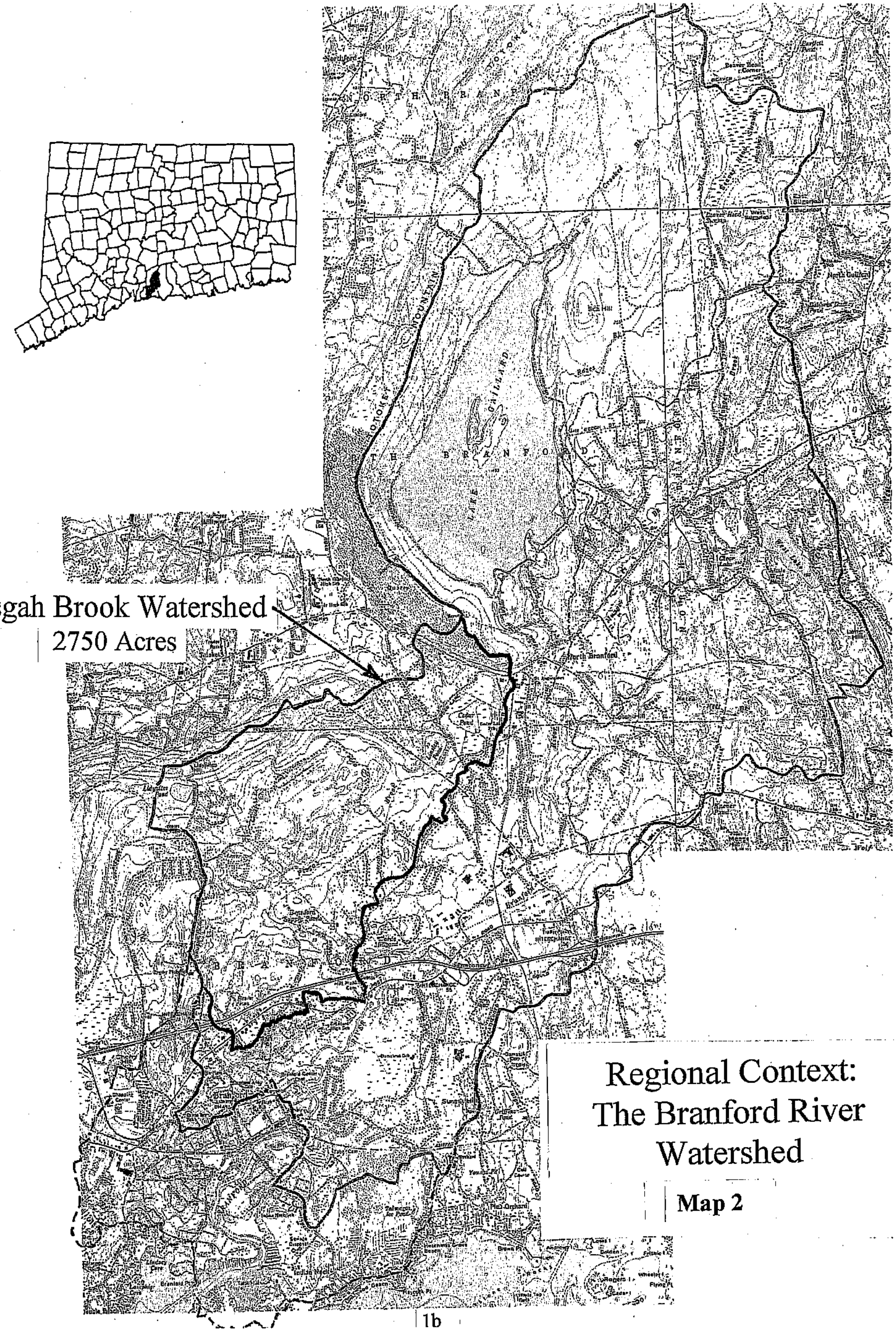
[1] Earlier reports related to the Pisgah Brook watershed include Cooper and Hotaling's (1970) *Ecology and Land Use of the Supply Ponds Natural Area, Branford, Connecticut*, Patton and Weissman's (1974) *Land Management Alternatives for the Lidyhites Natural Preserve*, Hasted and Hultman's (1975) *The Branford Supply Ponds Natural Area: A Study of Present and Potential Function, or "Trails and Tribulations"*, Ludwig's (1979) *The Branford Pisgah Brook Property*, and Culp and Naegel's (1986) *Management Alternatives for Pisgah Brook.*



Pisgah Brook Watershed

Scale: 1: 24,000

Map 1



Regional Context: The Branford River Watershed

Map 2

tributary draining Cedar Pond and Linsley Pond from the north enters the brook.[2] Approximately one mile upstream of the confluence with the Branford River, Pisgah Brook enters the Branford Supply Ponds, which were originally created to provide public water supply and are now a heavily used public recreation resource owned by the Town of Branford.

The watershed exhibits a distinct gradient of development and recent visible human impact on the land, ranging from extensive largely undeveloped ("natural") areas in a roughly linear corridor extending up to about one-half mile on either or both sides of Pisgah Brook, to a variety of types of residential development (i.e., densities, architectural styles, ages, etc.) located generally on the periphery of those natural areas (around the outer edges of the watershed), to a more intensively developed commercial and industrial area with an interstate highway (I-95) and major state highway (Route 1) along the southern edge of the watershed. The region has long been influenced by humans, including Native Americans, English settlers, and more recently, a diverse group of residents. As a result, even the relatively undeveloped areas in the watershed show clear evidence of the long-term interactions between humans and the land.

It is important to note at the outset of this natural history that a pending perturbation exists which could have significant implications for both the biophysical and the sociocultural components of the Pisgah Brook watershed system. A local developer has proposed the development of an 18-hole golf course and 105-home, single family residential complex on a 214-acre parcel that occupies most of a ridge surrounded on three sides by Pisgah Brook. The proposal, which is currently in the middle of the regulatory review process before the relevant town land use commissions, is the single most dominant current issue related to the watershed. Because of its immediacy and significance to the Pisgah Brook system, the proposed development was the focus (either directly or indirectly) of much of our attention in this project.

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[2] To avoid confusion, it is necessary to clarify to what "Pisgah Brook" refers. There is considerable inconsistency among various reports and individuals as to whether "Pisgah Brook" begins at Lidyhites Pond and encompasses the entire length of the watercourse extending from that pond downstream to the confluence with the Branford River (with the stream flowing from Cedar Pond/Linsley Pond being a tributary but not part of "Pisgah Brook" itself), or whether it begins at Cedar Pond/Linsley Pond and extends from there downstream to the confluence with the Branford River (with the stream flowing from Lidyhites Pond being a tributary rather than part of "Pisgah Brook"). We have chosen to use the former interpretation throughout this report.

Purposes of this Study

Our team approached the preparation of this natural history with two basic purposes in mind. The first was to take full advantage of an educational opportunity to develop and apply theoretical and conceptual frameworks for ecosystem management to a "real world" system. The second was to help foster and enlighten the public decision-making process that will affect the fate of the Pisgah Brook watershed. We have pursued the latter in two ways: first, by using our understanding of the system gained through the applied educational process as a foundation from which to develop management recommendations related to the pressing issues confronting the system; and second, by identifying and addressing several key questions to help decision-makers recognize and consider the full range of factors at stake in the public decision-making process about the Pisgah Brook natural area[3] (see Map 3). These questions include the following:

1) Is the Pisgah Brook natural area one of Branford's "crown jewels"?
2) Is the Pisgah Brook natural area recognized and managed as a "crown jewel"?
3) Can an enhanced vision of the Pisgah Brook natural area be articulated and implemented so that its full potential is realized?
4) Is the proposed Queach golf course and residential development compatible with an enhanced vision for the Pisgah Brook natural area?

The team's responses to these important questions and its management recommendations are presented in Section VI: The Meaning of the Story.

[3] We will use the phrase "Pisgah Brook natural area" throughout this report to refer to the undeveloped lands that surround the brook for up to one-half mile on either or both sides for virtually its entire length from Lidyhites Pond downstream to the Branford Supply Ponds, and including those lands owned by the town that surround the Supply Ponds. The term "natural area" is somewhat misleading in that it connotes a lack of human influence on the land. This certainly is not the case in the area around Pisgah Brook, given the long history of human presence and diverse land use that continues to this day. Nonetheless, we will use the term "natural area" because it has been used extensively for a long time in reference to the Supply Ponds and makes more sense in this suburban context than other possible terms (e.g., "wildlands").

The Branford Supply Ponds
One of the defining features of the Pisgah Brook Natural Area

Pisgah Brook, adjacent wetlands, and uplands
A diversity of topography and natural communities makes this area ecologically significant. Photo taken from foot bridge approximately 2000' downstream of Queach Road.

Hydrologic/Erosion Studies[5]

The hydrology of the Pisgah Brook watershed serves as a central theme for understanding both its biophysical and sociocultural elements. Not only does the flow of water provide the functional definition for our watershed boundaries, it is essential for supporting the abundance and diversity of plant and animal life, and serves a number of important functions for humans (e.g., water supply, aesthetics, recreation). The hydrologic characteristics of the area are also a vivid indicator of human presence and activity, providing an excellent example of the interactions between people and the landscape.

To gain a better understanding the biophysical and sociocultural aspects of the watershed's hydrology, we focused on a number of indicators and information sources. First, we were interested in defining the basic location, magnitude, direction, and extent of water flow and surface water bodies within the watershed. We transferred the watershed outline from the Connecticut Department of Environmental Protection's detailed 1:24,000 scale watershed delineation map onto the conventional topographic map at the same scale for the area. We then reviewed the topography described on the map and identified the connections between water bodies and direction of flow. Numerous site visits throughout the watershed were made to observe surface hydrologic characteristics, including the relative volumes and direction of flow, the relation of flow characteristics to topography, comparisons of flow to wetlands extent, and the interconnection of ponds and tributaries with the main stem. These field observations also showed us how the hydrology changes along the gradient from the headwaters at Lidyhites Pond downstream to the confluence with the Branford River.

In the search for covariation between components of the biophysical and sociocultural domains, we focused on certain observed instances of unnatural, pronounced erosion and sedimentation (i.e., water quality degradation) resulting from human decisions and actions. We also looked at patterns in the relationship between trash dumping and ravines that are created through hydrologic action.

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[5] We would like to make special note of the assistance, guidance, and inspiration we received from Yale Professor emeritus Herbert Bormann, who met and walked with us throughout much of the area on several occasions.

In using erosion and water quality as indicators, we correlated visual observation of relative levels of turbidity with 1) topography, 2) the degree of natural vs. disturbed conditions in the contributing upland area, and 3) the extent that wetlands provide buffers between upland sources and the Pisgah Brook main stem. Our primary study of erosion and sedimentation resulting from human activity was an extensive analysis of soil volumes lost from the Pine Gutter Brook drainage due to storm water discharges emanating from developments upstream. (Pine Gutter Brook is an important tributary of Pisgah Brook, entering the main stem just upstream of where it flows into the Supply Ponds.) Field measurements of soil loss were taken in and along Pine Gutter Brook from its confluence with Pisgah Brook upstream for about 1,745 feet to a major storm water outfall coming in from a steep south-facing slope. This outfall drains most of the Red Rock Road development[6] and is the largest of four such structures that enter Pine Gutter Brook.

By analyzing vegetation, soil substrate, and stream morphology (both of Pine Gutter Brook and a similar stream nearby), and by taking extensive cross-sectional measurements, we were able to make a relatively precise estimate of the volume of material that has been eroded from the brook. More specifically, we used exposed tree and shrub roots as approximate indicators of where soil was located prior to erosion. We also noted areas with clear evidence of recent soil disturbance. Next, by looking at the current stream bed, we were able to conservatively estimate the morphology of the former streambed prior to accelerated erosion. This was checked through comparison with the channel morphology of a somewhat smaller, undisturbed tributary of Pisgah Brook located just north of the power lines. Finally, we took cross-sectional measurements at each point along Pine Gutter Brook (from the confluence with Pisgah Brook upstream to the biggest storm water outfall) where the stream changed direction or the cross-sectional channel shape showed notable changes.

In an effort to quantify sociocultural causes of the extensive erosion in Pine Gutter Brook, we measured several characteristics of the drainage areas that contribute to Pine Gutter Brook. Specifically, we measured areas of impermeable surfaces (roads, sidewalks, roofs, and driveways),

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[6] The "Red Rock Road development" that drains into this major storm water outfall includes all of Pine Hollow Road and Bear Path, plus the section of Red Rock Road from the intersection with Pine Hollow Road northeastward to the crest of the hill before the power lines.

and estimated areas of low-permeability surfaces (i.e., lawns). Measurements of road area and sidewalk were taken with a 100' tape measure and car odometer; those for roofs and driveways were made with pacing and visual estimation. We also examined the directions of water flow in the network of storm drains and pipes to determine the underground discharge system. With this information, we were able to determine the connection between upland drainages and the inputs of storm water to the brook. We then used the topographic map to compute the total drainage area of the brook and the amount of that area that has been developed. Additional description of this methodology is presented in Appendix A.

In addition to the detailed measurements of the Pine Gutter Brook situation, we also monitored and photographed the results of a severe storm event on April 15-16, 1996. Furthermore, we closely examined and photographed a major newly eroded gully emanating from a small drainage area off Piscatello Drive, as well as an erosion problem affecting a road embankment in the Richill Road development.

We also analyzed hydrologic issues and erosion potential related to the proposed golf course and residential development, which represents the most significant pending perturbation in the entire watershed. Through examination of documents prepared by the developer, we were able to estimate areas of impermeability and low permeability and make qualitative comparisons with the Pine Gutter Brook situation.

Recreation User Survey

Surveys or questionnaires allow one to formulate theory and assumptions into questions whose responses may then be converted into empirical data for analysis. Because questions can be factual ("How many people are in your family?"), attitudinal ("How do you feel about the federal deficit?") or centered around specific events ("Do you support the Walmart development?"), surveys make it possible to access a wide variety of information that may not be otherwise available. Information can also be measured in levels. A survey developed for recreation users of the Pisgah Brook natural area used two levels: the nominal level, which simply distinguishes the categories that comprise a given variable (e.g., gender being either male or

The third category consists of well- to excessively well-drained soils that have been derived from Triassic parent material and vary in texture and slope. They are fast draining, have a low water table, and support upland vegetation. Because they are so well-drained and often free of bedrock exposure, stones, and steep slopes, they are better suited for intensive human use than the other soils found in watershed.

The fourth soil category is shallow to bedrock soils that are derived from Triassic or metamorphic parent material. These soils cover the largest area in the Pisgah Brook watershed. Moderately permeable, they are rocky to extremely rocky soils. They occur in locations throughout the watershed, from gentle to steep slopes, and all have a depth of less than two feet. Up to 50 percent of the areas have bedrock exposure. The thin soil limits vegetation growth, erodes easily, and prevents large trees from rooting deeply. The soil's lack of depth also makes it vulnerable to fire, due to its dryness and high organic content. Its rocky nature limits recreation by making camping, construction, or trail building difficult.

Outside of the natural areas, the soils are much the same. They include very poorly drained, moderately well-drained, excessively well-drained, and shallow-to-bedrock soils.

Erosion

Because water is such a dominant feature in the Pisgah Brook watershed, it is important to thoroughly examine the erosion potential in the Pisgah Brook watershed. Geology, topography, soils, climate, and vegetation define the erosional characteristics of the area. In particular, the frequency of steep to very steep slopes and poorly drained and shallow soils in the natural area make it naturally prone to erosion and susceptible to disturbances. However, vegetation, especially shrubs and forbs, provides a generally cohesive ground cover that reduces potential erosion. Changes in vegetation or ground cover will increase the likelihood of erosion.

Currently, rill and gully erosion are taking place in the Pisgah Brook watershed. Rill erosion results in the removal of soil from visible channels or streamlets due to concentrated overland flow. Gully erosion is indicated by the presence of bare soil on both sides of a channel or the enlargement of rills. These types of erosion have on-site and downstream effects. On-site, the loss of the organic material (O layer) can lead to a reduction in nutrients and water infiltration and holding capacity; this, in turn, can lower the water table. The resultant drying out of the soils will affect the vegetation cover, which may then die off, making the area prone to more aggressive erosion. The predominant result of such erosion is increased downstream sedimentation, which in turn can result in the silting up of wetlands and ponds at a faster than normal rate, damage to fish and their spawning habitats, and a reduction in the conveyance capacity of the watercourses. If wetlands are degraded, they may no longer provide a variety of important functions, including water storage capacity, groundwater recharge, and filtering of all pollutants. Conveyance reduction can lead to increased flooding and flood damage, two very costly things to remedy. A more detailed discussion of site-specific erosion issues in the Pisgah Brook watershed is presented below under "The Hydrologic Story."

Vegetation

The Pisgah Brook watershed consists of four major vegetation components: hardwoods, hemlocks, a hardwood-hemlock mixture, and wetlands/swamp. The hardwoods, hemlocks, and hardwood-hemlock mixture are included within the upland forest designation. There is also an array of smaller vegetative "patches" consisting of grass and shrubs areas, old evergreen plantations, and groupings of old field cedars. The patchiness of vegetation is reflective of both the natural patterns and processes like competition and succession, and past human land uses such as farming and logging.

Found most commonly on hilly terrain with rock outcroppings and shallow soils, the hardwood forest is the predominant vegetative community within the Pisgah Brook watershed. It has both a temporal and spatial scale, reflected in species diversity and composition. In the early stages of the hardwood forest there is a preponderance of species such as beech, sassafras, pignut hickory, gray birch, and flowering dogwood. The younger stands of hardwoods often have a shrub or herbaceous layer. Mountain laurel grows aggressively in the open areas and can be an indicator of disturbance, such as the area near the West Supply Pond that was logged by the New Haven Water Company in the 1940s. As the stand ages, understory vegetation is shaded out and oaks, maples, shagbark hickory, white ash, tulip poplar, basswood, and others dominate the canopy layer.

Of the total area involved in this project, approximately 75 acres would be directly affected by the golf course, and an additional 50 acres would be directly affected by houses and roads. According to the environmental consultant to the developer, the remaining area of approximately 90 acres would be "untouched" (Aniskovich 1995). The proposal calls for the creation of three permanent ponds (through the damming of existing wetlands) to provide irrigation water and aesthetic benefits for the golf course. The surface area of these ponds would cover a total of 6.9 acres (Delta Environmental Services 1996*a*). The proposal also calls for the construction of seven subsurface wastewater disposal systems to handle the sewage production of the residential development. These systems are to be located underneath seven of the fairways for the golf course, and are designed to accommodate a total daily flow of 50,400 gallons of wastewater per day (Delta Environmental Services 1996*a*).

There is an interesting aspect of the golf course proposal related to temporal scale. In their 1970 report *Ecology and Land Use of the Supply Ponds Natural Area*, Cooper and Hotaling wrote that "a golf course at the Supply Ponds Natural Area has been suggested by several citizens." The authors did not indicate that any specific location was being considered, so it is not clear whether what the "citizens" had in mind in 1970 coincides with the site of the current proposal. (Indeed, the current site is not within the boundary of the 359-acre Supply Ponds parcel owned by the Town that was the subject of Cooper and Hotaling's report.) Nonetheless, their concerns about the possibility of a golf course are directly relevant to the current situation on Laurel Hill:

> Because of the almost constant vegetation cover, hilly terrain, thin soils, rockiness, and bedrock exposures in the area, development of such a facility would be costly and destructive....Clearing land for a golf course would destroy large quantities of vegetation and wildlife habitat and would exchange all the possible uses of a large area for the single activity of golfing. All these factors indicate that the area has very low potential for a golf course. (Cooper & Hotaling 1970)

Woodland Wetland System
Wetlands in northeast portion of proposed golf course & residential development

The Johnson Farm
Watercourse draining upland of proposed golf course & residential development

drainages of Pine Gutter Brook. (The locations of these patches are shown in Map 7.) In terms of socioeconomic and density characteristics, these patches can be described as follows: the Crestwood Drive, Laurel Hill Road, and Red Rock Road neighborhoods contain middle-to-upper income single family homes; the Squire Hill Apartments and the Pine View Apartments consist of somewhat lower-income multi-family units; and the Richill Road development consists of large, upscale single-family residences.[10]

By looking at these patches and one other nearby cluster of dense apartments, we also noticed a correlation between the amount of trash dumped into the ravines adjacent to residential areas and the density and ownership of housing. What we generally found was more trash adjacent to the higher density and renter-occupied housing than the single family or owner-occupied housing. This pattern suggested a relationship between long-term investment in the area and the sense of having space that one could consider one's own to maintain and improve. Finally, examining patches of human development in the watershed alerted us to the potential for many more points of access from the neighborhoods on the perimeter to the core natural area.

The Hydrologic Story

Hydrology of the Pisgah Brook Watershed

Pisgah Brook and its associated tributaries and wetlands are the defining natural features of the Pisgah Brook watershed. They reflect the topographic patterns existing in the watershed, with fast running water in the steeper gradients and slower flows and wetlands in the flatter slopes. The large, complex web of wetlands and brooks are at the core of the watershed's ecosystem. They are the foundation for the watershed's ecological structure and function, and are at the heart of what people appreciate about this important recreational resource. As a watershed, the water running through this region connects all portions of the land together almost like a family tree connects the many descendants together. In this analogy, Pisgah Brook is the "trunk" as it is the collection of all drainage from the multitude of uplands that feed it.

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[10] The Pine View apartments and the Laurel Hill area contained insufficient sizes to be significant and were not included.

Lidyhites Pond to the Supply Ponds

From its origins at Lidyhites Pond, Pisgah Brook flows roughly 5 miles to its confluence with the main stem of the Branford River near the intersection of Route 1 and Mill Plain Road. From Lidyhites Pond to the confluence with the outlet from Linsley Pond (which also drains Cedar Pond) is a little over 2 miles long. Between Lidyhites Pond and the Linsley Pond outlet the stream drops in elevation from 100 feet above sea level to slightly below 30 feet. Through this reach, the brook flows quickly through a striking gorge and through extensive wetlands, particularly immediately below Lidyhites Pond and adjacent to the 90° turn in the unimproved portion of Laurel Hill Road. There is a tributary that enters a short distance downstream (after crossing the Johnson farm) that is not shown on the topographic map as perennial, but that had substantial flow during our springtime observations. The water quality in this wetland-fed tributary as well as the Pisgah Brook main stem in this section appears to be excellent, based on field observation. Even after storm events, the flow in both has remained clear. This undeveloped, "semi-wild" stretch is one of the visually stunning natural attributes of the watershed.

From the Linsley Pond confluence downstream to the inlet of the Supply Ponds is about 2 more miles. The brook's elevation remains between 30 feet and 20 feet all the way down to the outlet of the Supply Ponds, where it is approximately 20 feet. This relatively small drop in elevation results in a combination of deeper, slower flow and extensive wetlands that dominate a wide flood plain over the entire length of this segment. A different beauty is afforded here: an extensive diversity of wetland and upland plant life provides rich contrast, the brook's water volume is substantial, and the extensive floodplain provides a greater degree of openness. This permits a view across the varying topography of the overall area. The ridges that surround the brook and form the dominant topographic features of the basin boundary are typically at elevations in the range of 250 feet on the north, 100 - 200 feet on the west, and 100 feet on the east. The ridge running along the northern edge of the basin (roughly parallel to the Branford-North Branford town line) is about 320 feet high, among the highest elevations in the watershed. The highest point, at approximately 350 feet, is located in the northeastern-most portion of the watershed in North Branford, in what is now a traprock quarry.

The upper portion of the watershed includes Linsley Pond, the site of the famous limnological work done by G. Evelyn Hutchinson. Extensive wetland communities are located around and downstream of both Linsley and Cedar Ponds. Pine Gutter Brook, the one perennial tributary noted on the topographic map other than the outlets to Linsley Pond and Cedar Pond, enters the lower portion of Pisgah Brook just above its inlet into the Supply Ponds. There are also many topographic formations where intermittent streams flow into wetlands adjacent to Pisgah Brook, especially from the higher western slopes where elevations can reach over 200 feet.

Water quality is generally excellent through this segment, with an important exception at and downstream of Pine Gutter Brook. (This is described in detail later in this section.) We observed flows during "regular" flow periods and immediately following a major storm event. It is clear that, with the exception of Pine Gutter Brook, the hydrologic energy amassed in water running off the high, western slopes is dissipated by a combination of uncompacted soils, vegetatively stabilized soils and networks of small stream channels that fan out from the primary channels of incoming tributaries as they reach the floodplain and wetlands complex. The shallow slope and "roughness" of the wetlands further help to dissipate the energy and absorb sediments, so that the main stem above Pine Gutter Brook remains virtually clear, even during severe storm events.

Supply Ponds to the Branford River

From the inlet to the Supply Ponds to the confluence with the Branford River is about a mile. For most of this distance, Pisgah Brook is impounded in the ponds. There are wetlands along some of the shoreline of the ponds, although most of the areas are sufficiently steep to transition quickly into upland vegetation. The Supply Ponds are heavily used as a recreation area. Water quality has been impacted by the degradation upstream associated with Pine Gutter Brook. This is dramatically visible during and after storm events, when the ponds become brown with sediment.

The final portion of Pisgah Brook downstream of the Supply Ponds transitions from fast running water into a wide floodplain and tidal wetland, with a large volume of water in the stream channel at high tide. Although influenced by tides, the lower stretch of Pisgah Brook near the confluence with the Branford River has very low salinity, as evidenced by the dominant vegetation types. Much of the area is surrounded by houses and development along Route 1.

There are many other upland portions of the watershed that exhibit interesting hydrologic features and are part of the total hydrologic story. Description of these areas, however, is beyond the scope of this project.

Pine Gutter Brook Erosion Study

There is a serious erosion problem in Pine Gutter Brook. The original stream channel has been swept away by the huge force of storm water discharging from upper elevations of this sub-watershed. These extreme storm water volumes and energy are due to human developments and drainage systems. Not only does the undermining of the river corridor degrade the associated riverine habitat, take out upland vegetation and leave raw, unconsolidated soils exposed in many locations on huge embankments, but it contributes a continuous source of heavy sediment loading to both Pine Gutter and Pisgah Brooks, and therefore to the Branford Supply Ponds which are located immediately downstream. This sediment is highly damaging to ecosystem structure and function, as well as to the highly prized recreational and scenic values of Pisgah Brook and the Supply Ponds. Sediment loading clogs fish gills, destroys fish and aquatic organism habitat, interferes with the normal functioning of aquatic life (e.g., predators being able to see their prey), and disturbs the normal level of photosynthetic activity to which a balanced system is accustomed. Sediments also carry excessive nutrients into the water column, leading to additional water quality problems and accelerated eutrophication. (Noss & Cooperrider 1994) In addition, downstream wetlands and ponds may be physically inundated with sediment. In short, the ecological and recreational damage from erosion in the Pine Gutter Brook drainage is serious and has caused substantial degradation of the Pisgah Brook watershed's otherwise high quality. This damage is not likely to be restored for the foreseeable future because both the driving forces and vulnerable conditions remain. As we will see below, efforts have been made to solve the problem, but these have failed. The Pine Gutter Brook erosion problem represents a clear and measurable indicator of the connection between people and the biophysical system. It shows us the natural response of the ecosystem to human perturbation. It also reveals one of the ways humans have related and

Pine Gutter Brook Erosion

Pine Gutter Brook Erosion

Confluence of Pisgah Brook & Pine Gutter Brook
Note contrast of sediment laden water from Pine Gutter Brook entering relatively clear Pisgah Brook during April 15-16 storm.

Storm Impact to Supply Ponds
April 15-16 storm with visible sedimentation impacts from Pine Gutter Brook. An isolated cove shown in middle/right of photo escaped the flow of turbid water

Wetlands During April 15-16 Storm Event
Just upstream of Pine Gutter Brook showing the natural, undisturbed system's ability to maintain water quality - even during storm events

Sedimentation Sandbar, Mouth of Pisgah Brook & the Supply Ponds
An extensive sandbar formed during the Spring of 1996 at the confluence of Pisgah Brook and the Supply Ponds resulting from Pine Gutter Brook erosion and sedimentation

responded to both Pine Gutter and Pisgah Brooks. Furthermore, it can be used as a variable for examining the potential impacts associated with future development.

Volume of Erosion

In order to quantify the extent of the erosion problem, we measured and calculated the volumes of sediment that have been lost from the lower part of Pine Gutter Brook using the methods in Section IV and Appendix A. Although serious erosion was noted all along the brook to within a few hundred feet of Laurel Hill Road (near its headwaters), we were able to measure the vast majority of losses by measuring stream cross sections from the location of the major storm water outfall coming from Pine Hollow Road downstream about 1,745 feet to Pisgah Brook. (See Appendix A for calculations and associated diagrams.) Not only is this outfall the largest in size and flow volume, but below it are found the cumulative effects of all the concentrated storm water discharges from the entire upstream drainage. Consequently this is where the erosion is greatest.

Our calculations indicate that approximately 95,600 cubic feet of earth have been eroded and lost downstream. This is the equivalent of 3,540 cubic yards or 590 truck loads (using a standard 6-cubic yard, 6-wheeled dump truck). This is a huge figure for a brook that probably used to be on average about 8 feet wide from bank to bank and less than one foot deep in most places. Now, it is not uncommon to find the channel on the order of 25 feet wide and 5 feet or more deep. The volume of the original stream channel is estimated at 7,419 cubic feet—nearly 13 times less than the current one. (See Appendix A for further discussion.)

The total erosion figure represents the volume difference between the estimated size of the pre-development stream channel and the one that exists today. Consequently, we assume that this figure represents the cumulative erosion that has occurred since the problem first began, believed to be around 1970 with the development of the Red Rock Road neighborhood. It is possible, however, that this approach underestimates the actual erosion—in that the channel may not represent all of the material that has been lost. For example, road sand represents an additional source outside of the system, and fill lost during construction represents a huge source of erosion unaccounted for by the stream morphology. Furthermore, additional erosion has occurred

Undisturbed stream approximately 1200' north of Pine Gutter Brook
Adjacent to Pine Gutter Brook and of roughly comparable size, soils and topography, this shows what Pine Gutter Brook may have looked like prior to the erosion problems.

Pine Gutter Brook Erosion

upstream of the storm water discharge where we stopped our measurements and in tributary drainages to Pine Gutter Brook. (Indeed, Dr. Herbert Bormann has slides documenting the erosion problem in the early 1970s in the drainage that has now been filled with the massive storm water discharge project. The erosion was so severe at that time that the eroded stream channel is considerably deeper than the height of Bormann's subject—his colleague, Professor William R. Burch, Jr.)

Causes of the Erosion Problem

These results prompt several questions. Why is the erosion of Pisgah Gutter Brook so severe? Is it an anomaly? Are there factors related to the developed portion of the watershed that help to explain the level of erosion observed? Is there a correlation between the sociocultural system and the biophysical phenomenon we see here? From our observations, it is clear that this is not an anomaly, but rather a convergence of identifiable biophysical and sociocultural factors that makes this area and other adjacent areas highly vulnerable to erosion. In terms of biophysical factors, this vulnerability results from the area's steep topography and highly erodible soils made up of glacial till and underlain by easily weathered sedimentary bedrock. With respect to topography, the stream channels drop in elevation from approximately 165 feet elevation to 40 feet over a distance of only about 2,000 feet. The last stretch of Pine Gutter Brook is relatively flat, decreasing in elevation from about 40 feet to 25 feet over a distance of roughly 800 feet. However, during storm flows, water volumes are substantial at this point and carry tremendous kinetic energy, causing large soil losses in this area as well, in spite of its comparatively flat gradient.

The natural system of Pine Gutter Brook, as it was before human development, was capable of handling these conditions for reasons mentioned earlier in the description of natural characteristics. This capacity can be witnessed today in the undisturbed perennial and intermittent streams northeast of Pine Gutter Brook. With the residential developments of the Pine Gutter Brook drainage area, however, the volume of storm water has been increased dramatically because impervious surfaces do not allow for any retention or detention. Additionally, the concentrated network of storm drains dramatically accelerates the rate at which water is transported from the developed areas to the brook. These increased volumes and velocities create a large, powerful flow of water shooting continuously into the stream corridor during storm events.

Drainage Area Considerations

Given the biophysical significance of the erosion problem in Pine Gutter Brook, we decided to look more closely at the human-development aspects of the system. By looking at the total drainage area of the watershed, we determined what neighborhoods ("human patches") contribute flow to the brook and compared the amount of development with the amount of remaining undeveloped areas. Using the methods described in Section IV and Appendix A, we determined that the Pine Gutter Brook watershed is approximately 106 acres and the developed area is 46 acres. (The second figure refers to the footprint of human impact, and therefore includes structures, roads, and associated vegetation, such as grass. This area shows up as white areas on topographical maps.) In terms of the total area of the sub-watershed, the developed area is significant, covering 43 percent of the basin. It is comprised of six neighborhoods areas known (by their major street or apartment complex name) as Red Rock Road, Crestwood Road, Laurel Hill Road, Squire Hill Apartments, Pine View Apartments, and Richill Road. With the exception of a negligible portion of the Squire Hill area, all these developments were constructed after 1967. The most recent, the Richill Road neighborhood, was built since the last revision of the topographic map in 1984. (See Appendix A for more information). The Red Rock Road neighborhood is the largest, covering about 19.3 acres (840,000 square feet).

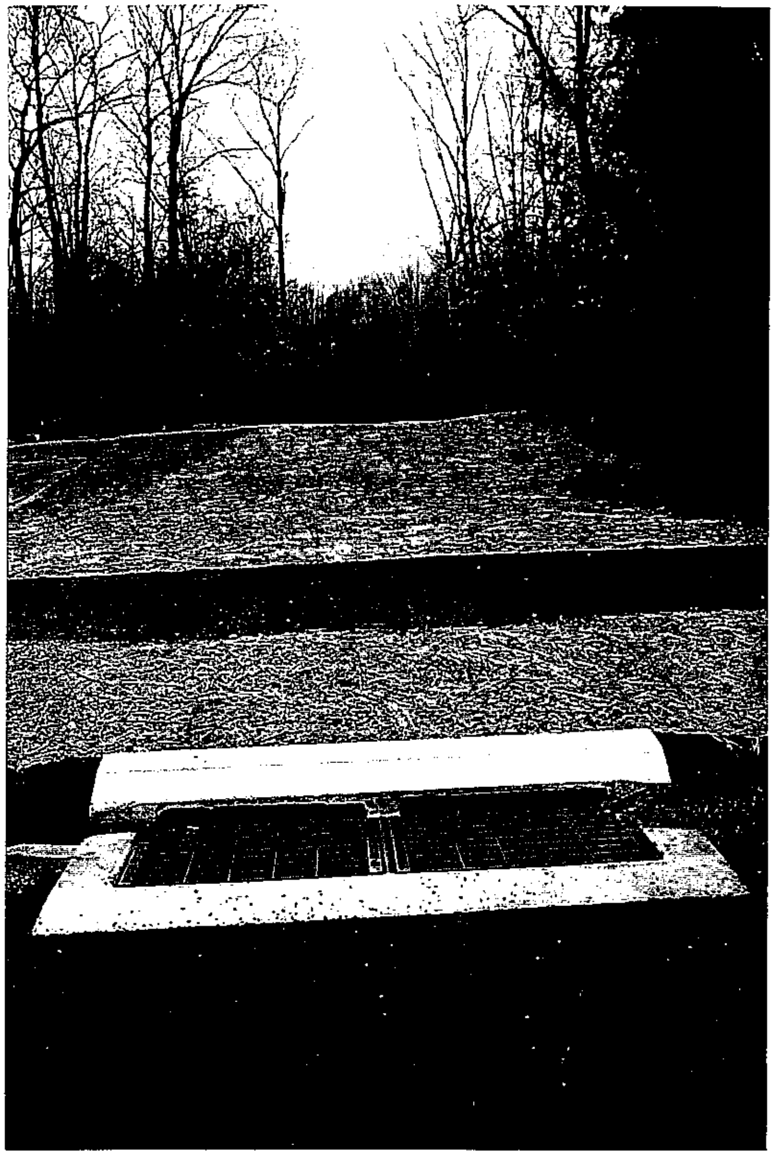
To investigate the correlation between storm flows and erosion more clearly, one needs to look at the extent and configuration of impervious surfaces because these are the primary source of the high powered flows which are so damaging. Storm flows do the vast majority of erosive work (Herbert Bormann, personal communication, 1996*a*). In addition, low permeability surfaces—such as lawns—contribute to these violent flows during large storms because significant amounts of rain water do not infiltrate through the ground. Instead it becomes overland flow and is added to the other overland flows associated with the impervious surfaces.

The total impervious surface for the total developed area in the six neighborhoods is estimated to be 11 acres and includes roofs, driveways, and road surfaces. The total low permeability surface area is estimated at 29 acres. (See Appendices A and B for more information.) This leaves roughly 6 acres of effectively permeable surfaces within the developed area. This means that 10 percent of the Pine Gutter Brook watershed is impervious and 38 percent is a combination of impervious and low permeability surfaces.

Regarding the configuration of storm water drainage, there are two outfalls that enter the brook from the north, two from the south and one from Laurel Hill Road where it crosses the brook. The Red Rock Road neighborhood (including Pine Hollow Road, Bear Path and most of Red Rock Road) drains into the lower northern outfall (the large system marking the upstream extent of our measurements). The segment of Red Rock Road between Laurel Hill Road and Pine Hollow Road drains into the upper northern storm water discharge. The Squire Hill Apartment area generally drains into the lower southern storm water discharge, although some of the area appears to contribute to the upper southern outfall. This outfall also discharges all of the storm water from the Richill Road neighborhood. Finally, the flow contributions from the areas of Crestwood Road, Laurel Hill Road, and the Pine View Apartments are discharged into the culvert through which Pine Gutter Brook flows as it crosses under Laurel Hill Road.

From this information, we can see the correlation between development, impervious surfaces, storm water drainage, and erosion. Our observations also revealed that there are multiple storm water discharges that concentrate high energy storm flows into the brook. These storm flows are largely responsible for the erosion we see. Since these structures are typical of modern suburban developments, we believe that more attention must be paid to the downstream end of such outfalls, which so often are invisible from the street (as is the case in Pine Gutter Brook). Without hiking down into its wooded ravine, the average person living in the area could easily have no idea of the environmental havoc being wreaked below. In addition, we now have human development-biophysical impact numbers that can be used to compare to other situations with similar topography and soils.

Pine Gutter Brook
Storm Water Drainage
Drain grating leading to outlet on Pine Hollow Road off Red Rock Road.



Pine Gutter Brook
Storm Water Outfall
Outfall draining Pine Hollow, Bear Path, and a portion of Red Rock Roads.

Pine Gutter Brook Restoration Project

A restoration project has been pursued at the mouth of Pine Gutter Brook in an attempt to reduce the amount of sediment flowing into Pisgah Brook. This project had been pursued by the town in an apparently good faith attempt to address the problem. However, the project has failed. Instead of capturing the sediment, the project has exposed almost an acre of earth, which has remained barren and vulnerable to erosion from the fall of 1995 through the winter and into the spring of 1996. A settling pond was dug, and a log dam was built to raise the water elevation enough to enable the stream to flow into the settling pond, but the two components were never connected. During the major April 15-16, 1996 storm event, the base of the dam was blown out by the high volume and force of sediment-laden water in the brook. This resulted in further erosion of the stream channel and exposed banks below the dam, causing further degradation of water quality in Pisgah Brook and the Supply Ponds. A further impact on the local environment resulted from the fact that in order to get to the site, a bulldozer graded a half-mile path through the woods and across a culverted wetland, exposing additional soil to further erosion. We were unable to clarify the cause of such blatant project failure, but we suspect that time pressures, weaknesses in contract requirements, inadequate site design, and lack of oversight by the town were all involved.

According to several local residents, there have been previous restoration efforts in the same location that have also failed (Chester Blomquist, Professor Herbert Bormann, and Professor William Burch, Jr., personal communications, 1996). In addition to exacerbating the problem, these efforts have cost the public in the range of $200,000 (Herbert Bormann, personal communication, 1996*a*). These failed efforts underscore the difficulty of identifying and building engineering solutions to prior degradation of natural systems, especially as related to hydrologic problems. The best intentions and engineering expertise are no substitute for the natural system. This point suggests that careful attention must be paid to maintaining the capacity of the natural system in the initial design and permitting process involved with new developments. It also raises questions concerning the social structure being used to defend the integrity of the commons. The developer responsible for the initial problem does not appear to bear any liability for damages. In

Pine Gutter Brook Restoration Project
Mouth of Pine Gutter Brook and Pisgah Brook

Pine Gutter Brook Restoration Project
Showing pond intended as sediment basin

Pine Gutter Brook Restoration Project
Showing undermined dam during this April 15-16 storm

Pine Gutter Brook Restoration Project
2500' access road into project site with visible erosion during April 15-16 storm

the case of Pine Gutter Brook, the public is paying twice—in lost environmental and recreational quality from a valued resource, and in footing the bill for failed restoration efforts.

Piscatello Drive and Richill Road Erosion

In order to gain a broader view of the development-erosion relationship, we looked for and found other examples in the watershed. Most notably, we discovered a case of deep gully erosion emanating from Piscatello Drive that has carried extensive amounts of soil about 700 feet into Pisgah Brook and its associated wetlands. Overland flows from the upstream developed areas has gouged a much deeper channel than would likely have occurred under natural conditions. There are portions of the gully that are much deeper than the height of an average person and with sectional areas that rival the worst of Pine Gutter Brook. All of this has been generated on a slope without any perennial stream. However, the elevation of the road and drainage source is 150 feet, while Pisgah Brook is at 60 feet. This 90-foot drop occurs over a distance of only 700 feet, or an average slope of 13 percent. This compares to a 6 percent drop for Pine Gutter Brook and partly explains the severity of erosion. What is remarkable about this situation, however, is that the only source of water is overland flow from a very small portion of the Piscatello Road development. Moreover, there is no storm drain, nor even curbs to direct flows. It does not appear that the impervious surfaces of the few homes in the area contribute any significant volume of water. Our observation is that the amount of flow is but a tiny fraction of what exists in Pine Gutter Brook.

The problem had been apparently caused unintentionally by the simple movement of approximately 10 to 15 feet of a natural berm between the road and the hillside slopes. This action made the ground level with the road and allowed storm water from the road to escape at this point. From the road one would have no way of knowing that a devastating problem had been created below.

Pine Gutter Brook indicates that a large part of the Pisgah Brook watershed is vulnerable to erosion. The Piscatello Road also highlights another vulnerability: very little storm water can cause massive damage. It also takes relatively little total drop in elevation to cause extensive damage. Steep slopes, erodible soils, and even limited flows of storm water appear to be highly